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Resin trees of Mount Gede Pangrango photo by Ricky Martin

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Title of the article should be written in compact, clear, and informative sentence, preferably not more than 20 words. Name of author(s) should be completely written. **Name and institution** address should also be completely written with street name and number (location), postal code, telephone number (O), facsimile number (O), and personal email address. For Indonesian universities, use local name. Manuscript written by a group, author for correspondence along with address is required. First page of the manuscript is used for writing above information.

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Saharjo BH, Nurhayati AD. 2006. Domination and composition structure change at hemic peat natural regeneration following burning; a case study in Pelalawan, Riau Province. Biodiversitas 7: 154-158.

Book:

Rai MK, Carpinella C. 2006. Naturally Occurring Bioactive Compounds. Elsevier, Amsterdam.

Chapter in book:

Webb CO, Cannon CH, Davies SJ. 2008. Ecological organization, biogeography, and the phylogenetic structure of rainforest tree communities. In: Carson W, Schnitzer S (eds) Tropical Forest Community Ecology. Wiley-Blackwell, New York.

Abstract:

Assaeed AM. 2007. Seed production and dispersal of *Rhazya stricta***.** 50th Annual Symposium of the International Association for Vegetation Science, Swansea, UK, 23-27 July 2007.

Proceeding:

Alikodra HS. 2000. Biodiversity for development of local autonomous government. In: Setyawan AD, Sutarno (eds.) Toward Mount Lawu National Park; Proceeding of National Seminary and Workshop on Biodiversity Conservation to Protect and Save Germplasm in Java Island. Universitas Sebelas Maret, Surakarta, 17-20 July 2000. [Indonesian]

Thesis, Dissertation:

Sugiyarto. 2004. Soil Macro-invertebrates Diversity and Inter-Cropping Plants Productivity in Agroforestry System based on Sengon. [Dissertation]. Universitas Brawijaya, Malang. [Indonesian]

Information from internet:

Balagadde FK, Song H, Ozaki J, Collins CH, Barnet M, Arnold FH, Quake SR, You L. 2008. A synthetic *Escherichia coli* predator-prey ecosystem. Mol Syst Biol 4: 187. www.molecularsystemsbiology.com. DOI:10.1038/msb.2008.24

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Assessment of Angiosperm taxa at Bharsar and its adjoining area of district Pauri Garhwal, Uttarakhand, India with emphasis on ethnomedicinal uses

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Abstract. *Bisht AS. 2017. Assessment of Angiosperm taxa at Bharsar and its adjoining area of district Pauri Garhwal, Uttarakhand, India with emphasis on ethnomedicinal uses. Asian J For 1: 1-17.* The Himalayas region becomes an enigma for various aspects including biological diversity. Bharsar region, district Pauri Garhwal, Uttarakhand, India is a biologically important region in the Himalaya, yet there is limited information on the flora diversity comprised in this region. This paper aimed to reveal the biological diversity of plants within Angiosperm in the Bharsar region. Botanical surveys were conducted in Bharsar and its adjoining area from December 2014 to December 2016. A total of 75 families and 274 species of Angiosperm plant were recorded during the study period with 237 species were dicotyledons (66 families), and 37 species of monocotyledons (9 families). Out of the 75 angiosperms families, Asteraceae contributed the highest with 13.14% (36 species), followed by Fabaceae 6.16% (17 species), Lamiaceae and Rosaceae both 5.43 % (15 species), Poaceae 4.71%, Ranunculaceae 4.35 % (12 species), Polygonaceae 4.04% (11 species). The people in this region use a variety of plant species for various purposes including medicine, food, fuel, and fodder. Bharsar happens to be one of the newly developed areas and experiences different types of biotic pressure of plant life which are especially accelerating with the process of developmental activities. This study serves as baseline information for future studies including those aiming to monitor the biodiversity in Bharsar region.

Keywords: Angiosperm, Bharsar, diversity, flora, Garhwal, Himalaya, medicinal plants

INTRODUCTION

The Himalayas is the pivotal source of attractions, curiosity, and challenge to human intellect through the ages. Amongst several aspects of the Himalayas, the vegetation provides an everlasting and interesting field of investigation. The diversity, copiousness, as well as uniqueness of the plant components in various habitats, retained sound and aesthetic environment of the Himalayas. However, in recent decades, excessive exploitation of vegetation, unplanned land use, natural disasters, and several developmental processes, have accelerated the deterioration of vegetation or loss of individual species. This situation is worsened since there is a limited detailed botanical record for several of the localities or regions. One of such botanical interests is located in a little-known region in the Bharsar in district Pauri, which sustains unique and rich genetic resources.

In view of the multiple stresses and depletion of genetic resources and habitat, today's foremost concern of the globe in general and Himalayas, in particular, is the conservation of biological diversity, for which detailed descriptions of plant genetic entities are essential. Keeping in view: (i) the diversity and richness of biological resources in vast and varied stretch of land; (ii) the lack of earlier record; (iii) the deterioration of mountain ecosystem; and (iv) present-day concern of biodiversity, an attempt is made to reveal the biological diversity of plant within Angiosperm in the Bharsar region of District Pauri Garhwal, Uttarakhand, India.

MATERIALS AND METHODS

Study area

The present study was carried out in the temperate regions of Bharsar area (Figure 1). Bharsar is situated about 57 km from the district headquarter, Pauri Garhwal on the Pauri- Thalisain-Ram Nagar National Highway 121. The district Pauri Garhwal is the most fascinating segment of the Himalaya, stretching from the Ram Ganga River that separates Pauri-Kumaon border in the East and to Ganga demarcating the Western border.

Soil

Soil texture, color, and nature represent wide range of variations, depending upon geology, altitude, slope aspects, climate, vegetation, and biological and chemical interactions of particular site. In general, the soil is deep clay-loam. The soil is slightly acidic and rich in potassium, medium in phosphorous and nitrogen contents, with the exception of some cultivated fields.

Climate

In general, the climate of Bharsar represents mild summer, higher precipitation, and prolonged cold winter season. The climatic factors, such as precipitation, temperature, relative humidity and wind, in association with elevation, slope aspects, drainage, vegetation, etc., are responsible for the micro-climate of this area. Generally, days in Bharsar are fairly warm followed by cool nights. The area receives adequate sunshine hours whereas the growing period is shorter due to long winter. The area also receives heavy precipitation during monsoon and occasional snowfall during winter season. The mean monthly weather data for one year is presented in Figure 2.

Data collection

The present investigation was a result of extensive and intensive field surveys, conducted from November 2013 to April 2016 and focused on an assessment of angiosperm diversity at the Bharsar and its adjoining areas of Pauri Garhwal. The specimens were collected by usual methods of collection, preservation, and maintenance of specimen in the herbarium with field notes of the collected specimens were identified with the help of recent and relevant floras i.e. Gaur (1999), Naithani (1985).

Information on medicinal properties of various plant species was gathered through personnel interviews with the local inhabitants and also cross-checked with various literature. Usually, the information was collected from the local 'vaidyas' or medicinal practitioners, however occasionally the information was also obtained from housewives, rural old folk, and grazers with long experience.

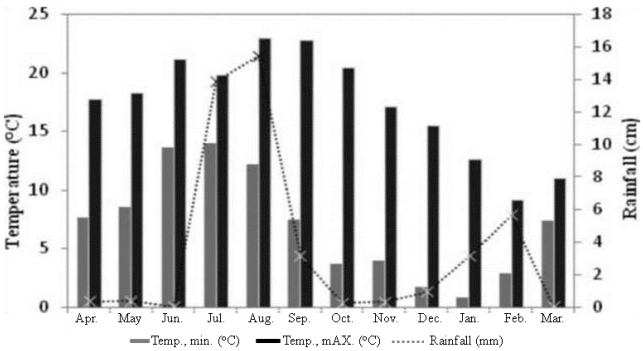

Figure 2. Temperature and rainfall in Bharsar, District of Pauri Garhwal, Uttarakhand, India

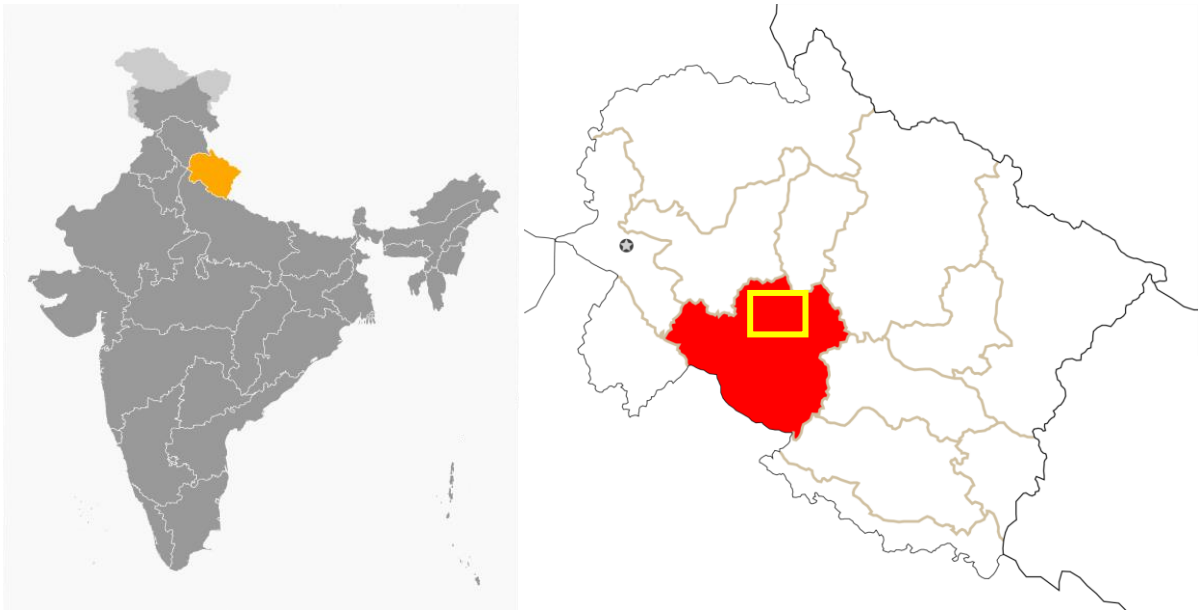

Figure 1. Study site in Bharsar, District of Pauri Garhwal, Uttarakhand, India

Table 1. The summary of families, genera and species of Angiosperms in Bharsar, District of Pauri Garhwal, Uttarakhand, India

Groups	Families		Genera		Species	
	Number	Percent	Number	Percent	Number	Percent
Dicotyledones	66	88.00	177	84.43	237	86.59
Monocotyledons	9	12.00	33	15.56	37	13.40
Total	75	100.0	212	100.00	274	100.00

RESULTS AND DISCUSSION

Results

In total, 274 species of 75 families of Angiosperm flora were collected during the study period in which 237 species were dicotyledons (66 families) and 37 species of monocotyledons (9 families). Out of the 75 families, Asteraceae contributed the highest share of 13.04% (36 species), followed by Fabaceae 6.16 % (17 species), Lamiaceae and Rosaceae both 5.43 % (15 species), Poaceae 4.71%, Ranunculaceae 4.35 % (12 species), Polygonaceae 4.04% (11 species) and other families make 56.84 % of total flora in study area during study period. The composition based on plant habitus is shown in Figure 3 and detailed statistics are presented in Tables 2 and 3.

The families were arranged according to the Cronquist system of classification (1981). The genera and species were arranged alphabetically. Ethnobotanical uses have also appended wherever applicable those plants are medicinally used.

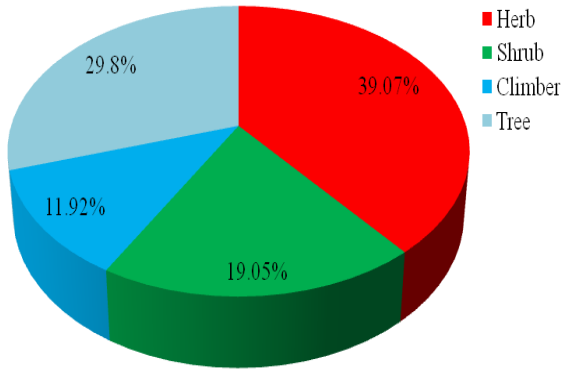

Figure 3. Composition of Angiosperm flora in study area in Bharsar, District of Pauri Garhwal, Uttarakhand, India based on habitus

Table 2. Contribution of family, genera, and species in study area in Bharsar, District of Pauri Garhwal, Uttarakhand, India

Family	Genera		Species	
	Number	Percent	Number	Percent
Acanthaceae	4	1.91	4	1.46
Amaranthaceae	3	1.44	3	1.10
Amaryllidaceae	1	0.48	1	0.37
Anacardiaceae	2	0.96	2	0.73
Apiaceae	4	1.91	4	1.46
Apocynaceae	1	0.48	1	0.37
Araceae	2	0.96	2	0.73
Araliaceae	1	0.48	1	0.37
Asteraceae	26	12.38	36	13.14
Balsaminaceae	1	0.48	1	0.37
Begoniaceae	1	0.48	1	0.37
Berberidaceae	1	0.48	2	0.73
Betulaceae	1	0.48	1	0.37
Brassicaceae	3	1.44	3	1.10
Cannabinaceae	1	0.48	1	0.37
Caryophyllaceae	3	1.44	4	1.46
Ceasalpiniaceae	1	0.48	1	0.37
Chenopodiaceae	1	0.48	1	0.37
Campanulaceae	2	0.96	2	0.73
Convolvulaceae	1	0.48	1	0.37
Corylaceae	1	0.48	1	0.37
Crassulaceae	2	0.96	2	0.73
Cucurbitaceae	4	1.91	4	1.46
Cyperaceae	4	1.91	6	2.19
Daphniphylaceae	1	0.48	1	0.37
Dioscoreaceae	1	0.48	2	0.73
Dipsacaceae	1	0.48	1	0.37
Ericaceae	5	2.38	3	1.10
Euphorbiaceae	3	1.43	3	1.10
Fabaceae	12	5.72	17	6.21
Fagaceae	1	0.48	4	1.46
Fumariaceae	1	0.48	2	0.73
Gentianaceae	3	1.43	8	2.92
Geraniaceae	1	0.48	2	0.73
Hippocastanaceae	1	0.48	1	0.37
Hypericaceae	1	0.48	3	1.10
Juglandaceae	1	0.48	1	0.37
Lamiaceae	13	6.19	15	5.48
Lauraceae	3	1.44	4	1.46
Liliaceae	3	1.43	3	1.10
Linaceae	1	0.48	1	0.37
Lythraceae	1	0.48	1	0.37
Malvaceae	1	0.48	1	0.37
Meliaceae	2	0.96	2	0.73
Mimosaceae	1	0.48	1	0.37
Moraceae	1	0.48	5	1.83
Myricaceae	1	0.48	1	0.37
Orchidaceae	6	2.86	6	2.19
Oxalidaceae	1	0.48	2	0.73
Papaveraceae	1	0.48	1	0.37
Plantaginaceae	1	0.48	2	0.73
Poaceae	12	5.72	13	4.75
Polygonaceae	7	3.34	11	4.02
Primulaceae	2	0.96	2	0.73
Ranunculaceae	4	1.91	12	4.38
Rhamnaceae	1	0.48	1	0.37
Rosaceae	11	5.24	15	5.48
Rubiaceae	3	1.43	6	2.19
Rutaceae	3	1.43	3	1.10
Sapotaceae	1	0.48	1	0.37
Saxifragaceae	4	1.91	4	1.46
Scrophulariaceae	6	2.86	6	2.19
Smilacaceae	2	0.96	2	0.73
Solanaceae	1	0.48	2	0.73
Symplocaceae	1	0.48	1	0.37
Theaceae	1	0.48	1	0.37
Thymelaeaceae	1	0.48	1	0.37
Tiliaceae	2	0.96	2	0.73
Ulmaceae	1	0.48	2	0.73
Urticaceae	3	1.44	3	1.10
Valerianaceae	1	0.48	2	0.73
Verbenaceae	2	0.96	2	0.73
Violaceae	1	0.48	3	1.10
Vitaceae	1	0.48	1	0.37
Zingiberaceae	2	0.96	2	0.73
Total	210	100	274	100

Table 3. List of taxa with ethnobotany notes in Bharsar, District of Pauri Garhwal, Uttarakhand, India

Botanical name	Local name	Habit	Ethnobotany
DICOTYLEDINEAE			
Lauraceae			
Cinnamomum tamala Buch. – Ham.	Dalchini, Tejpat.	Tree	Bark and dried leaves are used for flavoring tea and various food preparations; bark is chewed for dyspepsia and throat irritation
Neolitsea cuipala Buch. – Ham. ex D.Don.	Lampatiya	Tree	Twigs are used as fuel and leaves as fodder. Fruits paste with Camphor are applied on infested wounds of cattle. Wood is used for agricultural implements.
Neolitsea pallens D. Don.	Bilaru	Tree	Wood is used for construction of various articles. Oil extract from the fruits is used in scabies and eczema.
Persea odoratissima (Nees)	Kaula	Tree	Wood is for construction and furniture; plants are used for silkworm farming.
Ranunculaceae			
Anemone obtusiloba D. Don.	Kanchphool	Herb	Root decoction is given to cure diarrhea.
Anemone rivularis Buch – Ham.	Mirchilee	Herb	Paste of leaves is applied externally on forehead in headache. Leaf juice is applied to wound, sores, and earache in local therapy.
Anemone vitifolia Buch.-Ham. ex DC.	Mudeela	Herb	Roots and leaves paste are applied externally on ringworm and eczema in folk medicine and leaves used as fodder
Clematis barbellata Edgew.	Kanguli	Climber	Leaves are poisonous to cattle, leaf paste is externally applied for skin ailments.
Clematis gouriana Roxb. ex DC.	Kanguli	Climber	Leaves are poisonous to livestock, fiber is used for coarse ropes. The root decoction (about 15 ml) is used three times every day for three days in stomachache.
Clematis connata DC.	*Ghantiyali*	Climber	Leaves are used as fodder for goat and sheep.
Clematis montana Buch.-Ham. ex DC.	Kujju.	Climber	Leaves are browsed by sheep and goats. Leaf extract is given to cure diabetes and urinary troubles
Ranunculus diffusus DC.	Angasia – Jhar.	Herb	-
Rannunculus hirtellus Royle	Simariya	Herb	Plant paste is externally used on deteriorated wounds. Plant is browsed by goats.
Ranunculus laetus Wallich ex D.Don. in Royle	Dainya	Herb	
Thalictrum foliolosum DC.	Mamiri	Herb	Root is used in ophthalmia and also in colic and fever.
Thalictrum secundum Edgew.	Peelijari	Herb	Root is juice taken to relieve stomach disorders in folk medicine.
Berberidaceae			
Berberis aristata DC.	Kingore	Shrub	Juice from bark of stem or root often known as 'Rasaut' dropped in ophthalmia. Infusion of root is given in fever. Edible fruits, bark yields yellow dye.
Berberis asiatica Roxb. ex DC.	Kilmora	Shrub	Root decoction (about 20 ml.) is taken thrice a day in body inflammation and stomachache.
Papaveraceae			
Argemone mexicana Linn	Kanjilu	Herb	The seed emetic and narcotic are used as medicine; root decoction as wormicide; root chewed in leucorrhoea.
Fumariaceae			
Corydalis cashmeriana Royle	-	Herb	-
Corydalis cornuta Royle	Balsam jar	Herb	Aqueous paste of roots taken to reduce body swelling and inflammations root juice given in fever.
Daphniphylaceae			
Daphniphyllum himalense Benth.	Ratniyalu	Tree	Wood is used in agriculture implements and fuel.

Ulmaceae			
Celtis australis Linn.	Kharik	Tree	Edible fruits, leaves provide good fodder. Bark gives yellow dye, wood used for making small articles. It is an important tree of agroforestry.
Celtis eriocarpa Decne. in Jacq.	Kharik	Tree	Edible fruits, leaves as fodder, wood for fuel and making small articles, etc.
Cannabinaceae			
Cannabis sativa Linn.	Bhang	Herb	Bark – fiber used for making ropes, sacs, and rough clothes; stem as a fuel. Seed is used as condiment; seed – oil edible, besides, its leaves and flowers used as an intoxicating agent
Moraceae			
Ficus auriculata Lour.	Timla	Tree	Leaves are made into cups and plates; also provide good fodder for cattle; ripe fruit edible, unripe fruits made into vegetables. Plants are conserved for their religious significance and utilisations.
Ficus palmata Forsk.	Bedu	Tree	Leaves and twigs yield good fodder, fruits delicious in taste, often taken with salt or filled inside the bread, fruits medicinal for digestive disorders and useful plant of Agroforestry.
Ficus sarmentosa Buch. - Ham	Beduli	Shrub	Edible fruits; leaves provide good fodder.
Ficus subincisa Buch. – Ham.	Chachari	Tree	Leaves and branches are used as fodder; Edible fruits
Ficus religiosa Linn.	Peepal	Tree	Traditional use as in Temples and as fodder.
Urticaceae			
Urtica dioica Linn.	Kandali	Shrub	Stem yield strong – shining fiber, used for sacs, ropes, and mass; young branches and leaves are used as delicious pot herb; seed oil edible as well as medicine in sciatica, rheumatism and several skin ailments; hair – wash leaf extract believed to avoid baldness.
Elatostema sessile J. & G.Forster	Chaulu.	Herb	-
Girardinia diversifolia (Link.) Friis, Kew Bull.	Bhainsya kandali	Herb	-
Juglandaceae			
Juglans regia Linn.	Akhrot	Tree	Edible fruits and also provide oil, wood is hard, excellent for furniture, carved work, gunstocks, and veneers. Bark used as dye and as medicine, rind of fruits used to intoxicate fishes and for dyeing and tanning. Leaves mixed with stored grains as fungicide and insecticide and important tree of social forestry.
Myricaceae			
Myrica esculanta Buch.-Ham. ex D.Don.	Kaphal	Tree	Edible fruits, raw or made into refreshing drinks, bark is used to intoxicate fishes and yield yellow dye and wood is used as fuel and in agricultural implements.
Betulaceae			
Alnus nepalensis D.Don.	Utees	Tree	Wood is used for carpentry and construction; bark used is in local medicine; fast-growing trees used as soil binders.
Fagaceae			
Quercus floribunda Lindley ex Rehder.	Moru or Tilonj,	Tree	Wood is used as household articles and as fuel, leaves provide fodder, fruits eaten by wild animals.
Quercus glauca Thunb.	Harinj, Phaniyant	Tree	Wood is used as household articles and as fuel, leaves provide fodder.
Quercus leucotrichophora A. Camus in Riviera Sci.	Banj, Eng. White Oak.	Tree	Wood is used as fuel, rarely for agricultural implements; leaves as fodder. Leaves are used as fodder, gum of the tree medicinally is used for gonorrheal and digestive disorders. Fruits are eaten by monkeys and bears decomposed leaves used, as organic manure. It is also an important tree of social forestry.
Quercus semecarpifolia Smith	Khairu or Kharsu	Tree	Wood is used as fuel, rarely for agricultural implements; leaves as fodder, important tree for social forestry.
Corylaceae			
Carpinus viminea Lindley	Kathway, Chamkharik	Tree	Wood is used for furniture and articles of sports as well as weaving shuttle; leaves used as fodder.
Chenopodiaceae			
Chenopodium album Linn	Bathua	Herb	Leaves is used as pot– vegetable; bread prepared from the grinned grains.

Amaranthaceae			
Achyranthes bidentata Blume	Chicheree, Latjira	Herbs	Root infusion is taken in malarial fever. Leaf extract supposed to facilitate delivery, root powder used in making local beverages, plant decoction used in dropsy and bronchitis.
Alternanthera sessilis (Linn.) DC. in Cat.	Gudre-Saag	Herb	Occasionally leaves are used as vegetables during scarcity.
Cyathula tomentosa (Roth) Moq. in DC.	Lichkura	Herb	Leaf extract has emetic properties and given in snakebite, plant used as fodder.
Caryophyllaceae			
Arenaria serpyllifolia Linn.		Herb	
Stellaria media (Linn.)Vill.	Badyal	Herb	Plant is used as green vegetables, as well as fodder; plant paste is externally applied on burns, boils, and wounds.
Stellaria monosperma Buch. – Ham.	Badyalu	Herb	
Gypsophila cerastioides D.Don.	Bakarchee	Herb	Poultice of plant applied on boils and wounds.
Polygonaceae			
Bistorta amplexicaul D.Don.	Kutrya	Herb	Decoction of plant is said to cause abortion if taken orally. Leaf paste is applied on wounds and extracted to relive dysentery
Fagopyrum dibotrys Wallich ex Meisn.	Kanalya	Herb	Leaves occasionally are used as vegetables and leaf paste rubbed on insect bites.
Fallopia pterocarpa Wall.	-	Herb	-
Koenigia delicatula (Meisn) Hara.	-	Herb	-
Persicaria barbata (Linn.) Hara.	-	Herb	-
Persicaria capitata (Buch.-Ham. ex D.Don)	Kaflya	Herb	-
Polygonum emodi Meissn.	-	Herb	-
Polygonum plebeium R. Br.	Dondya	Herb	Plant is used for manure and root extract is applied on head to avoid baldness.
Polygonum recumbens. Royle	-	Herb	
Rumex hastatus D.Don.	Almoru	Herb	Sour leaves, made into sauce, leaf extract applied on cuts and wounds to check bleeding and also believed to relieve nettle sting inflammation.
Rumex nepalensis Spreng.	Almora	Herb	The sap of leaves and stems is applied on cuts for its astringent powder.
Theaceae			
Eurya acuminata DC	Deura	Tree	Wood is used as fuel and for agricultural implements. Green leaves and young twigs are lopped for fodder.
Hypericaceae			
Hypericum elodeoides Choisy in DC.	Basanti.	Herb	-
Hypericum oblongifolium Choisy	Chitroi	Herb	Leaves are lopped for fodder, roots yield yellow dye, decoction of leaves and stem given to facilitate delivery
Hypericum uralum Linn.	Bhyoul	Herb	Paste of leaves is applied on cuts to stop bleeding. Infusion of leaf given in malarial fever. Seed powder against food poisoning and as abortifacient.
Tiliaceae			
Grewia sapida Roxb. ex DC.	Bhimal	Shrub	The extraction of bark is given to pregnant women for smooth delivery. The extraction is also given in constipation.
Triumfetta rhomboidea Jacq.	Liswa Kura	Shrub	Root juice is applied on the cuts; hot infection of fruits and leaves is given to facilitate delivery.
Malvaceae			
Urena lobata Linn.	Chatkura	Shrub	Stem yields a coarse fiber, flower expectorant, root paste applied on body pain and rheumatism.
Violaceae			
Viola biflora J. Smith in Rees.	Banfsa	Herb	The whole plant either in the form of extract or powder is taken as diaphoretic, useful in skin and blood diseases, flowers and leaves boiled with tea, supposed to be good for fever and cough.
Viola tricolor Wallich in Roxb	Banfsa	Herb	Decoction of plants is useful in malarial fever, bronchitis and asthma, root used as an emetic, flower demulcent, sometimes eaten raw and leaf juice applied on cuts and wounds.
Viola pilosa Blume	Banafsa.	Herb	Fresh flower is boiled with tea to relieve cough and cold. Flowers are eaten raw: leaf paste applied on headache and jaundice.

Cucurbitaceae			
Coccinia grandis (Linn.) Voigt.	Kaduri	Herb	Leaves and root juice are given in diabetes, leaves are also supposed to be antiseptic; fruit juice is given in gonorrhea.
Cucumis hardwickii Royle.	Elaroo	Herb	Decoction of root barks is given and fevers; seeds are given in suppressed urination.
Mukia maderaspatana Linn.	Ban kakari	Climber	Fruit and vegetable are given in malarial fever and urinary disorders; seed paste with warm is water given to relieve vomiting.
Solena amplexicaulis Lam.	Gawal Kakari	Herb	Root and seed are given in digestive troubles; seed mixed with leaf extract of Vasik, believed to cause abortion.
Begoniaceae			
Begonia picta Smith	Patharchatta	Herb	Decoction of plant in boiled is water given in colic and dyspepsia and young leaves occasionally cooked as vegetable.
Brassicaceae			
Barbarea vulgaris R.Br. in Aiton f.	-	Herb	-
Rorippa indica (Linn.) Hiern.	Piria	Herb	Plant juice is given in diarrhea and pastes applied on sprains.
Thlaspi arvense Linn.	Maula, Bulbulii	Herb	Leaves are used as green vegetables; poultice of leaves applied on cuts and wounds
Ericaceae			
Gaultheria nummularioides D.Don.	Bhwinla	Shrub	-
Lyonia ovalifolia (Wallich) Drude.	Anyar	Tree	Wood is used as fuel, young leaves poisonous to cattle, and seed paste applied on wounds and boils.
Rhododendron arboreum Smith.	Burans	Tree	Wood is used for fuel and charcoal, flowers eaten raw or made into sauce, jellies, jams or refreshing drinks, flowers and bark medicinally for digestive and respiratory disorders, and flowers useful in bee forage.
Sapotaceae			
Madhuca longifolia Koeing	Mahwa	Tree	Wood for various constructions flowers and Edible fruits, afresh or made into several preparations; useful in apiculture as bee – forage; seeds yield an oil, used for candle and soap manufacturing; flowers often used in local beverages.
Symplocaceae			
Symplocos ramosissima Wallich ex G.Don.	Lodh	Tree	Leaves are used a fodder; flowers visited by bees for nectar and pollen
Primulaceae			
Androsace lanuginosa Wallich in Roxb.	-	Herb	-
Primula denticulata Smith	Jalkutra, Eng. Primrose	Herb	Aqueous paste of flowers is used in the treatment of diabetes and urinary ailments and root paste applied to kill lice.
Crassulaceae			
Sedum rosulatum Edgew.	-	Herb	-
Saxifragaceae			
Astilbe rivularis. Buch. – Ham.	-	Shrub	Traditionally is used in workshop of deities. Powder is believed to be an abortifacient, leaves used as fodder.
Bergenia ciliata (Har) Sternb	Silpari, Pasanbhed.	Herb	The leaves and roots of plants are given to the patient of kidney stone. The folk belief is that if the patient takes it thrice a day i.e. morning, noon, evening he will get rid of stone very soon.
Parnassia nubicola Wallich ex Royle.	Phutkya.	Herb	Plant extract is taken to stimulate vomiting in case of food poisoning, paste from rootstock applied externally as an antidote to snakebite.
Saxifraga diversifolia Wallich ex Seringe in DC.	Silyans.	Herb	Root extract is used as vermifuge
Rosaceae			
Agrimonia pilosa Ledebour in Index Sem.	Lesukuria	Herb	Plant decoction is given in cough and diarrhea, root paste with mustard oil is applied around the belly in suppressed urination.
Cotoneaster microphyllus Wallich ex Lindley in Edgew.	Bugarchilla	Shrub	Branches are used for making baskets, ripe fruit edible, and fuel from wood. Leaf extract and fruits are given in diarrhea, root paste is applied on cuts and wounds and flowers useful in apiculture.

Fragaria nubicola Lindley ex Lacaita in J. Linn. Soc. Bot.	Gand-kaphal	Herb	Edible fruits, leaf juice is dropped for relieving earache and fruits are also used in local beverages.
Potentilla atrosanguinea Lod.	-	Herb	-
Potentilla fulgens Wallich ex Hook.	Bajardantu, Bajradanti	Herb	The paste of root is used for healing wounds. Edible fruits, plant juice applied to mouth in stomatitis and aphthae.
Potentilla gerardiana Lindl. ex Lehm.	-	Herb	Root paste is applied to wounds.
Potentilla nepalensis Hook.	-	Herb	-
Prinsepia utilis Royle	Bhainkal	Shrub	Seeds yield oil, used for edible purposes as well as medicinal in rheumatic pains. Root bark is used in diarrhea, flowers useful in apiculture as bee forage and sometimes plant used as biofence.
Prunus cerasoides D.Don.	Panyyan	Tree	Branches for walking sticks, bark in psych medicines, leaves as fodder and ripe Edible fruits, and the juice from the bark applied on body swelling and contusion, flower useful source of bee forage. Plant regarded as sacred, used in several rituals of locals.
Pyracantha crenulata (D.Don) M. Roemer.	Ghingaru	Shrub	Branches are used for walking sticks and tool handles, fruits are rarely edible, flowers are useful in apiculture as bee forage and plants act as soil binder.
Pyrus pashia Buch.-Ham. ex D.Don.	Malu or Mahel	Tree	Leaves and twig as fodder. Ripe Edible fruits are used in digestive disorders; wood made in to stick; flower use fuel in apiculture; believed to check soil erosion in landslide zones.
Rosa brunonii Lindley.	Kunja, Kujju	Shrub	Edible fruits, wood is used as an occasional fuel, flowers is useful in apiculture as bee forage and flower paste is applied on skin ailments.
Rubus ellipticus Smith in Rees.	Hinssar, Hisolu	Shrub	Edible fruits, root extract is used in local beverages as intoxicating ingredient, flowers are useful in apiculture as bee forage and plant act as soil binders.
Rubus foliosus D.Don.	Kala Hissar	Shrub	Young twigs and Edible fruits.
Rubus paniculatus. Smith	Kathula	Shrub	Fruit is edible; leaf paste is externally applied on skin ailments.
Spiraea bella Sims in Curtis	Kuji.	Shrub	Branches are used as brooms, seed paste applied to wash sores and wounds.
Mimosaceae			
Acacia dealbata Link.	Chikaka	Tree	-
Caesalpiniaceae			
Caesalpinia decapetala Roth.	Kingri	Shrub	Leaves are used as fodder of goat and sheep; leaves applied to burns; bark yield tannin, flowers useful of bee- forages.
Fabaceae			
Astragalus leucocephalus Graham ex Benth. in Royle	Rudravanti	Herb	Roots are used as blood purifiers and in skin diseases; plant infusion as tonic, leaves used as fodder.
Crotalaria albida Heyne ex Roth	Chunchuni	Herb	Roasted seed powder is taken as blood purifier and roots chewed in constipation.
Crotolaria medicaginea Lam.	Ban-Methi	Herb	Leaf juice is applied in scabies and urticaria.
Desmodium concinnum DC.	Sakina	Herb	-
Desmodium microphyllum (Thunb.) DC.	-	Shrub	-
Desmodium multiflorum DC.	-	Herb	Plants are browsed by cattle.
Dumasia villosa DC.	-	Herb	-
Eriosema himalaicum Ohashi.	Bhatiya	Shrub	The tuberous root is edible.
Erythrina arborescens Roxb	-	Tree	Leaflets are used for making plates and cups; bark is used in skin diseases; leaf extract is given in suppressed menses, and also for intestinal worms; an important tree of social forestry.
Erythrina suberosa Roxb.	Manura.	Tree	Wood soft, used for minor articles barks as an insecticide; leaf extracts in gonorrheal diseases. An important tree of social forestry
Flemingia strobilifera (Linn.) R.Br. in Aiton f.	Bari-Kapasi	Shrub	Plants are used as brooms. Leaves for treating hysteria and also used as fodder
Indigofera glandulosa Willd.		Herb	
Indigofera heterantha Wallich ex Brandis	Sakina	Shrub	Flowers are used as vegetable, leaves are lopped for fodder, twigs are made into baskets or containers. Leaf juice is taken in diarrhea, dysentery, and cough.

Lathyrus aphaca Linn.	Kurphali	Climber	As a weed of crop fields and used as fodder.
Piptanthus nepalensis (Hook.) D.Don in Sweet.	Chembera.	Shrub	Green pods are chewed raw, ripe seeds are cooked as vegetables and extract is used as galactagogue. Leaf juice is dropped in pussed ear.
Robinia pseudoacacia Roxb.	Black locust	Tree	It is one of the most important nitrogen-fixing Agroforestry trees.
Trifolium repens Linn.	Tpatiya	Herb	Leaf paste is used as an astringent; plant provides good fodder.
Lythraceae			
Woodfordia fruticosa (Linn.) Kurz in J. Asiat.	Dhaula	Shrub	Flowers yield dye for silk, leaves, and bark medicinal, as febrifuge, dried flower used as tonic particularly in hemorrhoids, flowers useful in apiculture as bee forage and also made into refreshing drink during summer and also good soil binder.
Thymelaeaceae			
Daphne papyracea Wallich ex Studel.	Vern. Satpura	Shrub	Ropes and sacs made from the stem fiber, in the past paper was manufactured from the stem and leaves, known as Satpura, especially used for religious purposes and leaf paste applied on eczema
Euphorbiaceae			
Euphobia royleana Boissier in DC.	Sulla	Shrub	Planted for hedges as well as to check soil erosion in the exposed slopes. Latex considered antiseptic and germicidal.
Phyllanthus amarus Schum& Thonn.	Bumianwala.	Herb	Herb as an astringent stomachache diuretic and febrifuge; leaves are said to bear antibacterial properties.
Sapium insigne (Royle) Benth. ex Trimen.	Khinna	Tree	Leaves and bark are used for intoxicating fishes, wood is used for making floats, cases, drums, toys, matchboxes, latex is regarded as poisonous, causes blisters.
Rhamnaceae			
Rhamnus purpureus Edgew. in Trans. Linn. Soc.	Gaunta	Shrub	Wood is used in agricultural implements, leaves are lopped for fodder and manure, flower is useful source of bee forage, barks extract with milk given in digestive disorders.
Vitaceae			
Ampelocissus divaricata Wallichx Lowson	Pan – laguli.	Shrub	Fruits and young leaves are edible; stem as fibers.
Linaceae			
Reinwardtia indica Dumortier	Phiunli	Herb	Petals are chewed as tongue wash, considered sacred, as indicator of spring season and flower useful in apiculture as a source of bee forage.
Hippocastanaceae			
Aesculus indica (Colebr. ex Cambess.) Hook. in Curtis	Pangar	Tree	Cream-colored wood is made into pots and vessels, fruits are given to cattle and goat, flour from seed mixed with wheat flour during famine, seed paste is applied in rheumatic pain, flowers are useful in apiculture as a source of bee forage, leaves as fodder and manure, and also important tree of social forestry.
Anacardiaceae			
Cotinus coggygria Scopoli.	Jal-Tungla	Shrub	Bark and leaves are used for tanning, leaves are used for cattle padding and flowers useful sources of bee forage.
Rhus parviflora Roxb.	Tungla	Tree	Edible fruits, leaves mixed with tobacco, sometimes during famine fruits ground and mixed with flour. Infusion of leaves given in cholera, flowers useful source of bee-forage in apiary and sometimes used as biofence
Meliaceae			
Melia azadirach Linn.	Dainkan.	Tree	Leaves fruits and seeds are useful in skin diseases as well as in rheumatic pains. Fruits and leaves as antiseptics, leaves as fodder; wood useful source of bee – forage in apiary.
Toona hexandra (Wallich ex Roxb.) M. Roemer	Tun	Tree	It is important tree for construction purposes, furniture, and other articles. Sulphur dye is obtained from the flowers, useful source of bee-forage and apiculture, and also important tree of social forestry.
Rutaceae			
Boenninghausenia albiflora (Hook.) Reichb. ex Meisn.	Pissumar	Herb	Leaf paste is applied on cuts and wounds, root powder is used as antiseptic and juice given in vomiting and dysentery.
Skimmia anquetilia. Taylar & Airy	Nair patti	Shrub	Leaves are chewed for cooling effects, as well as mixed with other ingredients to manufacture incense dhup.
Zanthoxylum aromatum DC.	Timroo	Tree	Leaves and fruits are chewed for mouth wash and tooth care. Walking sticks are made from the stem, sometimes kept in the house doors, believed to get rid of all evils, bark used for intoxicating the fishes and, flowers are important source of bee forage in apiary.

Oxalidaceae			
Oxalis corniculata Linn.	Bhilmori, Khati-Buti	Herb	Leaves are taken as salad or cooked as vegetables and leaf juice is dropped in cataract and conjunctivitis.
Oxalis dehradunensis Raizada in Suppl. Duthie's Fl. U. Gang.	Khatura	Herb	A fine paste of the top shoot along with a few fruits of black pepper is applied to boils, abscesses wound and weeping eczema, also relives in abscess of the breast.
Geraniaceae			
Geranium nepalense Sweet.	-	Herb	Plant infusion is used in fever and renal disorders; roots paste applied externally on itching and eczema; rot in tanning industry.
Geranium wallichianum D.Don ex Sweet.	Ratanjot	Herb	Root juice in diarrhea and ophthalmic, red dye obtained from the roots said to promote growth of hairs, as well as dye to woolen clothes.
Balsaminaceae			
Impatiens thomsonii Hook.	-	Herb	Seed edible powder of roasted seed with honey given to relieve cough and cold.
Araliaceae			
Hedera nepalensis K. Koch.	Laguli	Climber	Leaf and fruit paste are applied on ulcers and leaf juice given in dyspepsia.
Apiaceae			
Bupleurum hamiltonii Balakrishnan.	-	Herb	Roots are used in stomach and liver disorders and plant browsed by cattle.
Centilla asiatica Linn.	Brahmi	Herb	Plant juice or powder is used in the treatment of mental disorders and as a blood purifier; herb is regarded as a tonic and diuretic; leaf paste is applied for skin diseases including leprosy.
Pimpinella diversifolia DC.	Teroi, Phoree	Herb	Plant extract is given in digestive disorders and as well as in cold and cough.
Selinum candollii DC.	Bhutkeshi,	Herb	Root powder with honey is useful in cough and asthma and incense of root beneficial in hysteria.
Gentianaceae			
Gentiana aprica Decne.	Chirotu	Herb	Plant juice with flower decoction of Viola sp. is given in tea as a remedy of intermittent fever and headache.
Gentiana capitata Buch.-Ham. ex D.Don.		Herb	-
Gentiana pedicellata (D.Don.) Wallich ex Grisebach.	Chhoti buggi	Herb	-
Gentianella contorta Royle.	-	Herb	-
Swertia angustifolia Buch.-Ham. ex D.Don.	Chirata	Herb	Plant extract is used as a tonic and febrifuge and used as substitute for original 'Chiryata'.
Swertia cordata (D.Don.) C.B. Clarke in Hook. f.	Chratu	Herb	Plant is used as substitute for 'Chirayita'.
Swertia chirayita (Roxb.ex Fleming). Vern.	Chrayata	Herb	The plant is well known for Ayurvedic medicine "Chretta" which is used in blood diseases and as febrifuge.
Swertia paniculata Wall.	-	Herb	Plant is used as substitute of 'Chirayata'.
Apocynaceae			
Quirivella frutescens (Linn.) M.R. and S.M. Almeida,	Bel-kami	Shrub	Branches are made into baskets, leaf extract is supposed to be febrifuge and paste applied in leucoderma. Flowers are used as a source of bee-forage in apiary.
Solanaceae			
Solanum erianthum D.Don.	Akra	Shrub	Roots, leaves and fruits after heating are applied on wounds and burns, extract chiefly used in urinary troubles and skin diseases. Fruits occasionally eaten.

Verbenaceae			
Callicarpa macrophylla Vahl.	Daiya	Shrub	Edible fruits, useful in oral aphthae, leaves after heating are applied externally on rheumatic pain and flowers are used as a source of bee forage.
Caryopteris foetida (D.Don) Thellung.	Karwi	Shrub	Used as fodder, leaf juice applied on wounds and flowers as source of bee-forage
Lamiaceae			
Ajuga bracteosa Wallich ex Benth. in Wallich.	Neelkanthi	Herb	Leaf extract is used in malarial fever, bitter plant extract is used as a tonic, astringent, and febrifuge.
Clinopodium umbrosum (M. Bieb.) C. Koch in Linnaea.	-	Herb	Plant extracts are used as an astringent, carminative and as blood purifier, leaves infusion is used in gastric troubles and flowers as a source of bee-forage.
Leucas lanata Benth. in Wallich.	Bis-kapra.	Herb	Plant infusion is given with honey in the treatment of whooping cough and young shoots cooked as vegetable.
Micromeria biflora (Buch.-Ham. ex D.Don) Benth.	Gorakhopan	Herb	-
Micromeria capitellata Benth. in DC.	Van ajwain	Herb	Flavor of crushed leaves is inhaled in cold and sinusitis, extract of leaves with milk given in gastro-enteritis.
Nepeta ciliaris Wallich ex Benth. in Wallich.	Nueet	Herb	Decoction of leaves and seeds is taken in fever. Leaves also yield essential oil.
Origanum vulgare Linn.	Bantulsi	Herb	Plant extract is used in bronchitis, colic and diarrhea, leaves eaten as vegetable and flavoring agent, flowering branches hung on the houses to get rid of bad spirits.
Plectranthus mollis (Aiton) Sprengel		Herb	Flowers as a source of bee forage.
Pogostemon benghalense (Burm. f.) Kuntze	Kala-Basingu	Shrub	Leaf extract in water is given in colic and fever, flower important source of bee-forage and plant is a good soil binder.
Prunella vulgaris Linn.	Ust-khadus	Herb	Extract of the herb is used in gastric and breathing problems.
Rabdosia lophanthoides (Buch.-Ham. ex D.Don.) Hara.	-	Herb	-
Rabdosia rugosa (Wallich ex Benth.) Hara.	Chhenchneri	Shrub	Decoction of leaves is used in fever and flowers are important source of bee forage.
Salvia lanata Roxb.	Ghanyajhar	Herb	Leaf infusion is given in colic and diarrhea, flower paste used in cold and cough and flower as a source of bee-forage.
Scutellaria scandens Buch.-Ham ex D.Don.	Kutlaphul	Herb	Flowers as a source of bee forage.
Teucrium quadrifarium Buch.-Ham. ex D.Don.	Bilmga	Shrub	Root chewed for sore throat, infusion of leaves used as abortifacient.
Plantaginaceae			
Plantago erosa Wall.	-	Herb	-
Plantago depressa Willd.	Luhurya	Herb	Paste from leaves and seeds are applied on cuts wounds and piles; plant part tied around the belly of infant for good health
Scrophulariaceae			
Hemiphragma heterophyllum, Wall.	-	Herb	-
Mazus surculosus D.Don	-	Herb	-
Misopates orontium (Linn.) Rafinesque-Schmaltz,	Weasel's Snout	Herb	Plant is believed to be poisonous to cattle.
Pedicularis punctata Decne. in Jacquem.	-	Herb	-
Scrophularia himalensis Royle ex. Benth.	Sikula	Herb	Leaves are mixed with stored grains as an insecticide.

Acanthaceae			
Barleria cristata Linn.	Saundi, Kala-bansa	Shrub	Root decoction is used against bronchitis and pneumonia; leaves and root paste is applied on wound-swelling, root chips are added to local beverages, seeds are regarded as antidote to snake bite, flowers as a source of bee forage and plant act as soil binder.
Dicliptera bupleuroides Nees in Wallich.	Kulartore	Herb	The plant is used as fodder, leaf paste is applied on wounds to check bleeding, leaf juice useful in cough and gastroenteritis. Flowers as a source of bee-forage in apiary.
Lepidagathis incurva Buch.-Ham. ex D.Don.	-	Herb	-
Pteracanthus angustifrons (C.B. Clarke) Bremekamp.	Pathora	Shrub	-
Campanulaceae			
Cynanthus integer Wall.	-	Herb	-
Cynanthus lobatus	-	Herb	-
Rubiaceae			
Galium asperifolum Wallich in Roxb.	Liswa kuri	Herb	Plants paste is used fuel for skin ailments.
Galium aparine Linn.	Khuskusa, Kuri	Herb	Extract of leaves is used as astringent and plant paste applied on skin diseases.
Galium elegans Wallich in Roxb	Manjeethee	Herb	Plant extract is given in colic, dyspepsia and as well as in jaundice.
Leptodermis lanceolata Wall.	Padera	Shrub	Occasionally browsed by cattle; bark paste is externally applied in migraines; flowers as an important source of bee – forage in apiculture.
Rubia manjith Roxb. ex Fleming in Asiat. Res.	Majethi	Climber	Dye commercially known as Manjit, extracted from the root and stem, roots medicinal, as tonic and astringent, stem used as an antidote to snakebite and flower extract in bacillary dysentery.
Spermodictyon suoveolens Roxb.	Padera	Shrub	Root powder or extract is given in diarrhea and cholera. Leaves as fodder and are also used as insecticide for the stored grains and flowers as an important source of bee-forage.
Valerianaceae			
Valeriana hardwickii Wallich in Roxb.	Somaya	Herb	Root decoction is used in urinary disorders; paste is applied externally in joint pains. Dried roots are used as incense and insecticide.
Valeriana jatamansii Jones in Asiat. Res.	Balchari	Herb	Roots are used as an aphrodisiac and in mental disorders, as well as in local beverages to promote aroma. Dried roots are also used as an incense and insecticide
Dipsacaceae			
Morina longifola Wallich ex DC.	Biskandaru.	Herb	Root paste is applied externally on wounds dried roots burnt as incense; the aroma of the flower believed to cause unconsciousness
Asteraceae			
Ageratum conyzoides Linn.	Gundrya	Herb	Plants with the root of *Thallictrum foliosum* made into paste and applied on sores, cuts and various skin ailments.
Ainsliaea latifolia (D.Don) Schultz-Bipontinus in Jahresber	Kauru	Herb	Decoction of roots is given in colic
Anaphalis adnata Wallich.	Bugla	Herb	Paste of head and leaves is applied on cuts, wounds and boils, Fibers of leaves and stem used to lit the fire by friction of stones, locally known as Agela.
Anaphalis contorta (D.Don) Hook. F. in Fl. Brit. India	Bugla	Herb	Paste of heads and leaves is applied on cuts, wounds and boils. Smokes of plants are used as insect repellent.
Anaphalis triplinervis (Sims) C.B. Clarke in Comp. Indicae	Buglya	Herb	Leaf juice is dropped in laceration of toes during rainy season. Paste of heads and leaves is applied on cuts, wounds, and boils.
Artemisia capillaris Thunb.	Jhirun	Herb	Decoction of leaves is taken as a bitter tonic for worms and colic, twigs used as brooms.

Aster molliusculus (Lindley ex DC.)	-	Herb	-
Aster peduncularis Wallich ex Nees.	Phulyan	Herb	Extract of plant is believed to be useful to dissolve renal-calculi and root powder as stomachic.
Bidens pilosa Linn.	Kumra	Herb	Plant extract with honey used in cough and bronchitis, the vegetable of the herbs considered useful in leucoderma and plants browsed as fodder.
Cicerbita cyanea (D.Don) G. Beauv.	-	Herb	-
Cicerbita macrorhiza (Royle) G. Beauv.	-	Herb	-
Conyza japonica (Thunb.) Lessing ex DC.	-	Herb	-
Elephantopus scaber Linn.	Adhomukha	Herb	Root extract is used in intermittent fever and to stop vomiting and leaves as tonic of blood diseases.
Emilia sonchifolia (Linn.) DC. in Wight.	-	Herb	-
Erigeron sublyratus DC. in Wight.	Hirankuri, Dudhi.	Herb	Occasionally upper leaves are cooked as vegetable. Herbs are used as febrifuge and leaf juice used in eye inflammation and night blindness.
Eupatorium adenophorum Sprengel.	Kharna, Bakura	Shrub	An obnoxious introduced weed occupying large grassy localities reducing fodder produce. Crushed leaves are applied on wounds.
Gerbera gossypina (Royle) G. Beauv.	Kapasee	Herb	Leaf juice is applied on wounds and cuts and paste plastered on bone fracture. In old days, fiber was used to manufacture coarse cloth for sacs and mats and also used to burn fire.
Gnaphalium hypoleucum DC. in Wight.	Buglya	Herb	Plant extract is applied on cuts and wounds, plant juice is applied on breast and believed to increase lactation.
Gnaphalium pensylvanicum Willd.	-	Herb	-
Inula cappa (Buch.-Ham. ex D.Don.) DC.	Athhu, Tamagari	Shrub	Roots are given in suppressed urination.
Lactuca dissecta D.Don.	-	Herb	-
Myriactis nepalensis Lessing in Linnaea.	Bakura	Herb	Leaves and young shoots are occasionally used as vegetable
Pentanema indicum (Linn.) Ling in Acta Phyt.	-	Herb	-
Saussurea auriculata (Sprengel ex DC.) Schultz-Bipontinus in Linnaea,	Thimra, Nurya	Herb	Leaf paste of the plant along with the leaves of *Betula utilis* is used externally in venereal diseases.
Saussurea heteromalla (D.Don.) Hand.-Mazz.	Murang	Herb	Leaf paste with mustard oil is massaged on leucoderma and wounds and root extract is taken in fever and colic.
Senecio graciliflorus DC.	-	Herb	Plant paste is applied on insect bites and ringworm diseases; juice of head dropped in pussed ear; plant believed to be poisonous to cattle
Siegesbeckia orientalis Linn.	Liskura	Herb	Decoction of plant with rice waters is taken in diarrhea and bowel complaints.
Solidago virgaurea Linn.	Pinja-phool	Herb	Juice of leaves is given in kidney troubles, decoction of whole herb is used for treatment of asthma, rheumatism, and wounds and root chewed in throat irritation.
Sonchus asper (Linn.) Hill.	Pili-dudhi, Choplya		The plant is used as a tonic to purify blood and in hepatitis and leaf paste applied on wounds.
Sonchus brachyotus DC.	Karatu	Herb	Roots are used in folk medicine against cough and bronchitis. Young shoots and leaves are used as vegetable in famine.
Tagetes minuta Linn.	Jangli genda	Herb	-
Taraxacum officinale Weber in Wiggers	Kanphuliya	Herb	Root extract is used in the treatment of migraine, hepatitis, and headache. Young shoots and leaves are thoroughly boiled and cooked as vegetable.

MONOCOTYLEDONEAE			
Araceae			
Acorus calamus Linn.	Buch, gud buch	Herb	Soft drinks are made from rhizome; extract of rhizome is often used in gastric troubles of infants some times garland is tied around neck or belly to relieve jaundice; also used in bronchitis; rhizome paste used to kill lice.
Arisaema intermedium Blume.	Meen	Herb	Spadix is used in psychomedicine.
Cyperaceae			
Carex aristata Tilloch and Taylor.	-	Stolons	-
Cyperus niveus Retz.	Murya-ghas	Herb	-
Cyperus nutans Vahl in Enum.	-	Herb	
Cyperus rotundus Linn.	Motha	Herb	Dried underground parts used in perfumes and plant extract used as diaphoretic and astringent.
Kobresia laxa Nees in Wight, Contrib.		Herb	
Scirpus ternatanus Reinwardt ex Miq.		Herb	
Poaceae			
Apluda aristata Linn.	-	Herb	Used as fodder when young.
Brachiaria reptans (Linn.) Gardner and C.E. Hubbard in Hook.	-	Herb	-
Brachiaria villosa (Lam.) A. Camus in Lecomte.	Malchu	Herb	Used as fodder to milching animals.
Chrysopogon aciculatus (Retz.) Trinius.	Surwala or Lampa.	Herb	As fodder but sharp callus intermingled with the body of cattle.
Cynodon dactylon (Linn.) Persoon.	Dubla	Herb	Plant is believed pious and used in several religious ceremonies.
Dichanthium annulatum (Forsk.) Stapf in Prain	-	Herb	Excessively used as fodder.
Eragrostis nigra Nees. ex Steudel.	-	Herb	-
Eulalia trispicata (Schultes.) Henrard in Blumea.	-	Herb	-
Heteropogon contortus (Linn.) P. Beauv. ex Roemer & Schultes	Kumrya-ghas	Herb	Grass stored as fodder for the period of scarcity.
Poa annua L.	-	Herb	-
Saccharum filifolium Steudel.	-	Herb	-
Setaria viridis (Linn.) P. Beauv.	Birali-ghas		The grain edibles hay and green grass as fodder.
Sporobolus diander (Retz.) P. Beauv.	Sitya	Herb	Crushed leaves are applied on burns and pimples and good soil binder and also provide fodder.
Zingiberaceae			
Hedychium spicatum Buch.-Ham. ex J.E. Smith in Rees.	Kapoor Kachari	Herb	Boiled underground parts ate with salt, roasted powder of rhizome given in asthma, seeds believed to cause abortion and decoction of rhizome with sawdust of deodara taken in tuberculosis.
Roscoea purpurea J.E. Smith	Kakoli	Herb	Dried powder of leaves is used in wound and cuts of cattle; plant extract as a tonic.
Liliaceae			
Asparagus racemosus Willd	Satavari, Jhirni	Herb	Root aphrodisiac, antiseptic, refrigerant is often used with freshwater or milk. Root decoction with jaggery used an abortifacient.
Polygonatum cirrhifolium (Wallich) Royle.	Khakan Medha	Herb	Leaves are eaten as vegetable; root infusion with milk used as an aphrodisiac and blood purifier; paste in cut and wound.
Theropogon pallidus (Kunth) Maxim.	-	Herb	-

Smilaceae			
Smilax aspera Linn.	Kukurdara	Climber	Occasionally young leaves are cooked. Roots are diuretic and diaphoretic. Root paste with mustard oil massaged on rheumatic-arthritis and flowers as a source of bee-forage.
Dioscoreaceae			
Dioscorea belophylla (Prain) J.O.	Tairu	Climber	Tuber edible as well as medicinal much liked by wildlife.
Dioscorea bulbifera Linn.	Genthi	Climber	Tuber are cooked as vegetable. Dried tuber used as an antiseptic, applied on burns and wounds, flowers occasionally visited by bee
Orchidaceae			
Calanthe plantaginea Lindley.	-	Herb	-
Coelogyne cristata Lindley.	Gondya	Herb	Infusion of pseudobulbs given in constipation and also as an aphrodisiac
Dactylorhiza hatagirea (D. Don.) Soo Nom	Hattarjari	Herb	Used in Aphrodisiac and tonic.
Dandrobium monticola P.F.	-	Herb	-
Habenaria intermedia D.Don	-	Herb	-
Nervillia prainiana King and Pantling.	-	Herb	-

Discussion

The study area is rich in plant biodiversity corresponding to the climate and topography of the area. The area has temperate vegetation with altitudes ranging from 1500-2200 m asl. Different factors have influenced (lower or exceeded) the normal limit of vegetation type and flowering seasons. Natural vegetation in vicinity of towns and villages in the subtropical belt has been subjected to face more biotic disturbances as compared to the villages at high elevations. There is abundance of grasses and annuals during monsoon, whereas perennials, shrubs, and trees mostly bloom during spring and summer (Bisht and Sharma 2014).

The most attractive part of vegetation in the study area was the presence of numerous medicinal plant species, the fact is generally ignored by scientists. Each plant species has its own value in the form of fodder, and vegetables, flowers as bee forage, resin, tannin, gum, dye, ornamentation, psychomedicine, and medicines, etc. A total of 274 species, near about 47 species were also purely medicinal and used in the form of leaves, stem, bark, root, flowers, fruits, seeds, and whole plant. These plant species are used against dropsy, bronchitis, boils and wounds, insect and snake bite, relieve from suffering of nettle sting, malarial fever, facilitate delivery, body pain, rheumatism, fever, cold and cough, gonorrhea, colic and dyspepsia, diarrhea, digestive and respiratory disorders, diabetes and urinary ailments, relieving earache, body swelling and contusions, psych medicines, treatments of migraines, hepatitis and headache, dysentery, etc. by villagers and Vaishyas. Some important species include *Achyranthus bidentata, Agrimonia pilosa, Anaphalis contorta, A. triplinervis, Aster peduncularis, Anemone vitifolia, Argemone ochroleuca, Asparagus recemosus, Berberis aristata, Barleria cristata, Begonia picta, Bupleurum hamiltonii, Clematis buchananiana, Coccinia grandis, Coelogyne cristata, Cyathula tomentosa, Gerbera gossypina, Gnaphalium hypoleucum, Hedychium spicatum, Inula cappa, Jasminum humile, Leucus lanata, Saussurea heteromalla, Senecio graciliflorus, Siegesbeckia orientalis, Solidago virgaurea, Sonchus asper, Swertia cordata,* and *Taraxacum officinale*.

The extinction of these medicinal plants from their natural habitat is a matter of great concern but it has not attracted the attention of naturalists and environmentalists. This is probably because the medicinal wealth of this area is little known hence no agency or related departments care for the protection and management of these continuously declining species of drug importance. Changing atmospheric conditions and lack of knowledge, infectious nature of some dominating weeds e.g *Eupatorium adenophorum* and *Parthenium* sp. are among the other factors responsible for the extinction of these important medicinal plant species. (Bisht 2005; Bisht and Bhatt 2012). Due to lack of awareness about medicinal importance of these weeds they are discarded by the farmers. These weeds can become an additional source of income for the farmers, if they are made aware of the medicinal importance of these crop weeds (Bisht et al 1988).

The important medicinal plant species in Bharsar, a total of 34 medicinal plant species belonging to 32 genera and 25 families were collected and recorded for their use in various ailments. Most of the local people in the study area are poor and illiterate. On one hand, these people are out of the reach of modern medicines and on the other hand, the market prices of most available medicines are very expensive. As a result, these medicinal plants are used to cure following diseases, especially for abscess, asthma, abortion, cough, cold, smallpox, dysentery, diarrhea, diabetes, eczema, fever, itches, jaundice, menstrual disease, paralysis, piles, skin diseases, snake-bite, toothache, worm, wound and others.

The study reveals that local people still depend on a number of plants for their daily needs especially medicine. Among identified medicinal trees, most of them are commonly found near the villages surrounding, wasteland, and forest areas. Plants of scientific knowledge, which have been investigated pharmacologically and chemically, and their active principle are used in modern medicine or provide valuable leads for partial or total synthesis of new drugs(Dhar et al. 2002; Parkash et. al.2002).

Despite their significance to rural livelihoods, the abundance and diversity of understory medicinal plant species are threatened by changes in the structural attributes of the cover story in native old-growth forests as a result of degradation (Galliam 2007). Therefore, the present study adds new knowledge on ethnobotanical uses of Angiosperm plants from Bharsar and adjoining area of district Pauri Garhwal. People in this region are partially or completely dependent on forest resources for medicine, food, fuel, and fodder. A great deal of traditional knowledge of the use of various plant species is still intact with the indigenous people, and this fact is especially relevant with the mountainous areas such as the Himalayas due to less accessibility of terrain and comparatively slow rate of development (Farooquee et al. 2004).

Convention on Biological Diversity states that indigenous people play a vital role in environmental management and development through their traditional practices. It requires nation to protect the traditional knowledge and customary practices related to the use of biological diversity (Glowka et.al.1997).

REFERENCES

Atkinson ET. 1882. The Himalayan Gazetteer, Vol. 2 (reprint 1973), Cosmo Pub. Delhi..

Badoni AK. 1990. Remarks on the high-altitude medicinal plants of Garhwal Himalayas. J Himalayan Stud Reg Dev 13 &14: 37-45.

Bisht AS, Bhatt AB. 2012. A contribution of the medicinal plants of Sahastradhara, district Dehradun, Uttarakhand (with ethnobotanical Notes). J Drug Deliver Therapeut 2 (5): 114-120. DOI: DOI: 10.22270/jddt.v2i5.261.

Bisht AS, Sharma KD. 2014. Plants utilization by the communities of Bharsar and adjoining area of Pauri Garhwal District, Uttarakhand, India. Biodiversitas 15 (1) 94-100. DOI: 10.13057/biodiv/d150114..

Bisht AS. 2005. Ecological Studies of Some Important Medicinal Herbs; Their Multiplication and Conservation in Garhwal Himalaya, India, [Dissertation]. Garhwal University, Srinagar (Garhwal), Uttarakhand.

Bisht MK, Bhatt KC, Gaur RD. 1988. Folk medicines of Arakot valley in district Uttarkashi: an ethnological study. In Purshottam Kaushik (ed)

Indigenous Medicinal Plants. Today Tomorrow Printers and Publishers, New Delhi.

Burkill IH. 1965. Chapters on the History of Botany in India. BSI, Howrah.

Cronquist A. 1981. An integrated system of classification of flowering plants. Columbia University Press New York.

Dhar U, Manjkhola S, Joshi M. 2002. Current status and future strategy for development of medicinal plants sector in Uttaranchal, India. Curr Sci 83: 956-964.

Farooquee NA, Majila BS, Kala CP 2004. Indigenous knowledge systems and sustainable management of natural resources in a high-altitude society of Kamaun Himalaya, India. J Hum Ecol 16: 33-42. DOI: 10.1080/09709274.2004.11905713.

Gaur RD. 1999. Flora of the District Garhwal North West Himalaya (with ethnobotanical notes). Transmedia, Srinagar Garhwal, Uttaranchal, India.

Gilliam FS 2007. The ecological significance of the herbaceous layer in temperate forest ecosystems. Bioscience. 57:845-858. DOI: 10.1641/B571007.

Glowka L. 1997. A Guide to designing legal frameworks to determine access to genetic resources, the world conservation union, IUCN, Gland, Switzerland.

Naithani BD. 1985. Flora of Chamoli. 2 Vols. BSI, Calcutta.

Negi KS, Gaur RD, Tiwari JK.. 1999. Ethnobotanical notes on the flora of Har Ki Doon (District Uttarkashi. Garhwal Himalaya, U.P. India. Ethnobotany 5 (1&2): 73-81. DOI: 10.1080/21513732.2011.575385

Parakash V. 2002. Himalayan Medicinal Plants Potential and Prospect (eds.), GyanodayaPrakashan, Nanital.

Rao R R. 1994. Biodiversity in India (Floristic aspects) II. Bishen Singh & Mahendra Pal Singh, Dehra Dun.

Rao RR. 1994. Biodiversity in India (Floristic aspects) I. Bishen Singh & Mahendra Pal Singh, Dehra Dun.

Rawat DS, Bhandari BS, Gaur RD. 2001. Vegetation Wealth. In: Kandari OP, Gusain OP (eds.) Garhwal Himalaya Nature, Culture and Society. Transmedia House, Pub. Co., Srinagar, Garhwal.

Samant SS, Dhar U, LMS Palni,. 2001. Himalayan Medicinal Plants Potential and Prospects. Gyanodaya Prakashan, Nainital.

Samant SS, Dhar U, Palni LMS. 1998. Medicinal plants of Indian Himalaya: Diversity Distribution Potential value. Gyanodaya Prakashan, Nainital.

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Degradation level of mangrove forest and its reduction strategies in Tabongo Village, Boalemo District, Gorontalo Province, Indonesia

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Abstract. *Katili AS, Ibrahim M, Zakaria Z. 2017. Degradation level of mangrove forest and its reduction strategy in* Tabongo Village, *Boalemo District, Gorontalo Province, Indonesia. Asian J For 1: 18-22.* Mangrove forest ecosystem plays a vital role in delivering various ecosystem services. Yet, many mangrove forests are deforested and degraded including in Indonesia. This research aimed to assess the degradation level of mangrove forests in Tabongo Village, Dulupi Sub-district, Boalemo District, Gorontalo Province, Indonesia and to develop strategy to reduce such degradation. Explorative survey was conducted to collect data using Point Quarter Centered Meter (PQCM) method while the data analysis was done with quantitative descriptive analysis. The degradation level of mangrove forests was analyzed by standard criteria of mangrove degradation prescribed by the government regulation. Results showed that there were four species of mangroves in the studied area namely *Rhizophora apiculata* Blume, *Rhizophora mucronata* Lamk., *Ceriops tagal* (Perr) C.B.Rob, and *Bruguiera* which included in the Rhizophoraceae family. *Rhizophora apiculata* had the highest IVI value at the stage of tree and sapling, while *Rhizophora mucronata* Lamk had the highest IVI value at the stage of seedling. The mangroves in Tabongo can be classified as dwarf forest type which was a typical mangrove found in low edges. The mangrove condition in the coastal area of Tabongo was categorized as degraded (TNS_1 = 210). The conservation strategy that could be implemented to recover the quality of mangrove areas includes (i) the assessment of the importance of the mangrove areas with regard to their ecological and economic value, (ii) quality improvement of mangrove habitat, (iii) educational approach by making the mangrove areas as learning media and source, and (iv) empowerment of people living around the mangrove areas.

Keywords: Coverage value, degradation, density, mangrove forest

INTRODUCTION

Coastal areas consist of several ecosystems, such as mangrove forests, beach vegetation, coral reefs and seagrass beds, some of which may occur simultaneously and interrelated each other. These ecosystems deliver various ecosystem services in terms of provisioning, regulating, cultural and supporting services. One role played in supporting service is these ecosystems serve as an important habitat for biodiversity. For example, mangrove forests and coral reef ecosystems serve as the breeding and feeding grounds for various marine organisms, including fishes from larvae to adulthood (Onrizal et al. 2009, 2017; Utina 2012).

Mangrove forest is a coastal wetland ecosystem located in the intertidal zone of the transition between marine and terrestrial realms. It is commonly situated in estuaries, deltas, creeks, lagoons and swamps especially in tropical and subtropical areas. Some experts define the term "mangrove" differently, but principally it refers to the same thing, i.e., mangroves are plants in tidal areas and live as communities. Arief (2003) stated that mangroves are halophytic vegetation or plants that have high adaptability to salinity and must live in saline environmental conditions, thus called obligate halophyte plants. Whereas Noor (2012) added that mangroves can also include distinctive littoral plant formations in tropical and subtropical sheltered beaches.

As one of the natural resources in coastal areas, mangrove forest community has various benefits in terms of socio-economic and ecological aspects. In socio-economic, mangrove can produce timber and in some cases, mangrove forests are managed as recreation areas. Ecological functions include maintaining coastal stability, the habitat of birds and marine biotas (e.g., fish, shrimp), acting as genetic pools, and supporting the entire life system around it (Irwanto 2007).

Nowadays, there is an emerging concern that mangrove forests play a vital role in climate change mitigation. Ilmiliyana (2012) states that over the last decade CO_2 emissions increased from 1,400 million tons per year to 2,900 million tons per year. This increase of CO_2 in the atmosphere will trigger global climate change. According to Bismark et al. (2008), mangroves is the major absorber of carbon dioxide (CO_2) from the atmosphere. Donato et al. (2012) stated that mangroves are known to have high assimilation ability and C absorption rate. It is supported by research in 25 mangrove sites along the Indo-Pacific regions indicating that mangroves are one of the richest carbon forests in the tropics, containing about 1,023 Mg of carbon per hectare which is far high compared to the average carbon stock of other forest types in the world.

This certainly is related indirectly to the mangrove ecological function. Mangroves absorb some of the carbon in the form of CO_2 and use it for the process of photosynthesis, while others remain in the atmosphere.

Despite their importance, mangrove forests are often destructed as the population increases and the need for economic development. As a result, a large area of mangroves has been declining over time including in Indonesia (Onrizal 2010; Ilman et al. 2016). Yet, the destruction of mangrove forests is still continuing these days, especially in the fishery sector by clearing mangrove forests for pond development (Pramudji 2000).

One of mangrove areas in Indonesia is located in the coastal area of Dulupi Sub-district, Boalemo District, Gorontalo Province. The mangrove ecosystem in this area continues to be under pressure due to various human activities including fish aquacultures, settlements and agriculture. These activities result in the deforestation and degradation of mangrove forests in Dulupi. One of the causes of mangrove loss was vegetation clearing to establish hatchery areas. In addition to deforestation, degradation occurs due to intensive utilization of mangrove wood for fuel and building materials. This study is aimed to assess the vegetation condition of mangrove forests in Dulupi Sub-district, Boalemo District, Gorontalo Province to provide insight on the degradation level of the forest. We expect the results of this study can be used as a baseline for future studies and monitoring to develop management and conservation strategies of the mangrove forest.

MATERIALS AND METHODS

The study was located in Tabongo Village, Dulupi Sub-district, Boalemo District, Gorontalo Province, Indonesia (Figure 1). Tabongo Village has 178.67 ha mangrove area. Based on the report of environmental status of Gorontalo Province, in 2013 the degraded mangrove area in Dulupi Sub-district was 13.05 Ha, with 9.52 Ha of the degraded mangrove was located in Dulupi Village and 3.53 Ha in Tabongo Village.

Explorative survey method was used in this study. Data were collected in the form of primary data and secondary data. The primary data collection was done by identifying all mangrove species in the research site and measuring the mangrove density level using the Point-Centered Quarter Method (Figure 2), based on Dahdouh-Guebas and Koedam (2006). Importance Value Indices (IVI), Species Coverage (Ci), and Relative of Species Coverage (RCi) were calculated for each stage of mangrove trees. The degradation level was assessed using the standard criteria of mangrove degradation prescribed by the Indonesian Ministry of Forestry (2005).

RESULTS AND DISCUSSION

Results

There were four species of mangrove found at the research location in Tabongo Village, Dulupi Sub-district, namely *Rhizophora apiculata* Blume, *Rhizophora mucronata* Lamk., *Ceriops tagal* (Perr) C.B.Rob, and *Bruguiera gymnorrhiza*. All of them were found in stages of tree, sapling, and seedling.

Importance Value Index (IVI)

At tree stage, *Rhizophora apiculata* had the highest IVI value (49.55%) compared to all species, followed by *Bruguiera gymnorrhiza* (49.16%) and *Rhizophora mucronata* Lamk (48.048%). *Ceriops tagal* had the lowest IVI with 46.88%.

The floristic composition based on IVI at sapling stage is similar to tree stage, where *Rhizophora apiculata* also had the highest IVI value (50.88%), followed by *Bruguiera gymnorrhiza* (50.47%) and *Rhizophora mucronata* (49.87%). Ceriops tagal was also recorded as the lowest IVI (49.84%). At the seedling stage, *Rhizophora mucronata* was recorded as species with the highest IVI (81.30%), followed by *Rhizophora apiculata* (73.65%) and *Bruguiera gymnorrhiza* (70.74%). Similar to tree and sapling stage, *Ceriops tagal* had also the lowest IVI (69.99%). Based on this result, the mangrove community in this area is typical of *Rhizophora apiculata-Rhizophora mucronata* vegetation.

Rhizophora apiculata and *R. mucronata* are known as the most important and widespread species of mangrove plants (Noor et al. 1999, Onrizal and Mansor 2016; Onrizal et al. 2017). The dominance of these two mangrove species can cover up to 90% of the vegetation growing in one location, and the optimal growth occurs in deeply flooded areas, as well as on humus-rich soil, and they also bloom throughout the year. The research conducted by Soeroyo and Achmad (2002) showed that species in Rhizophoraceae family dominated the front zone of mangrove forest in the region of Sulawesi. This is in line with the results of this research which found that these two species were the main vegetation in the mangroves in Dulupi Sub-district.

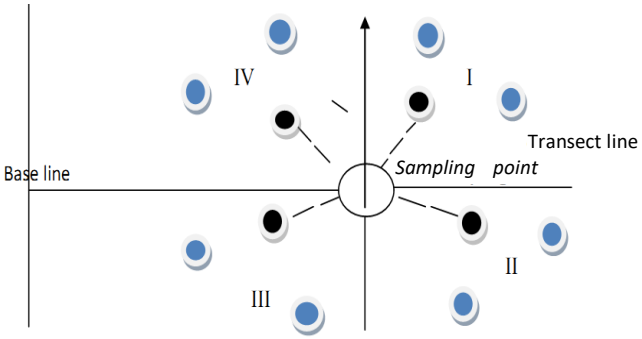

Figure 2. Point-centered quarter meter (PCQM) method used in this study

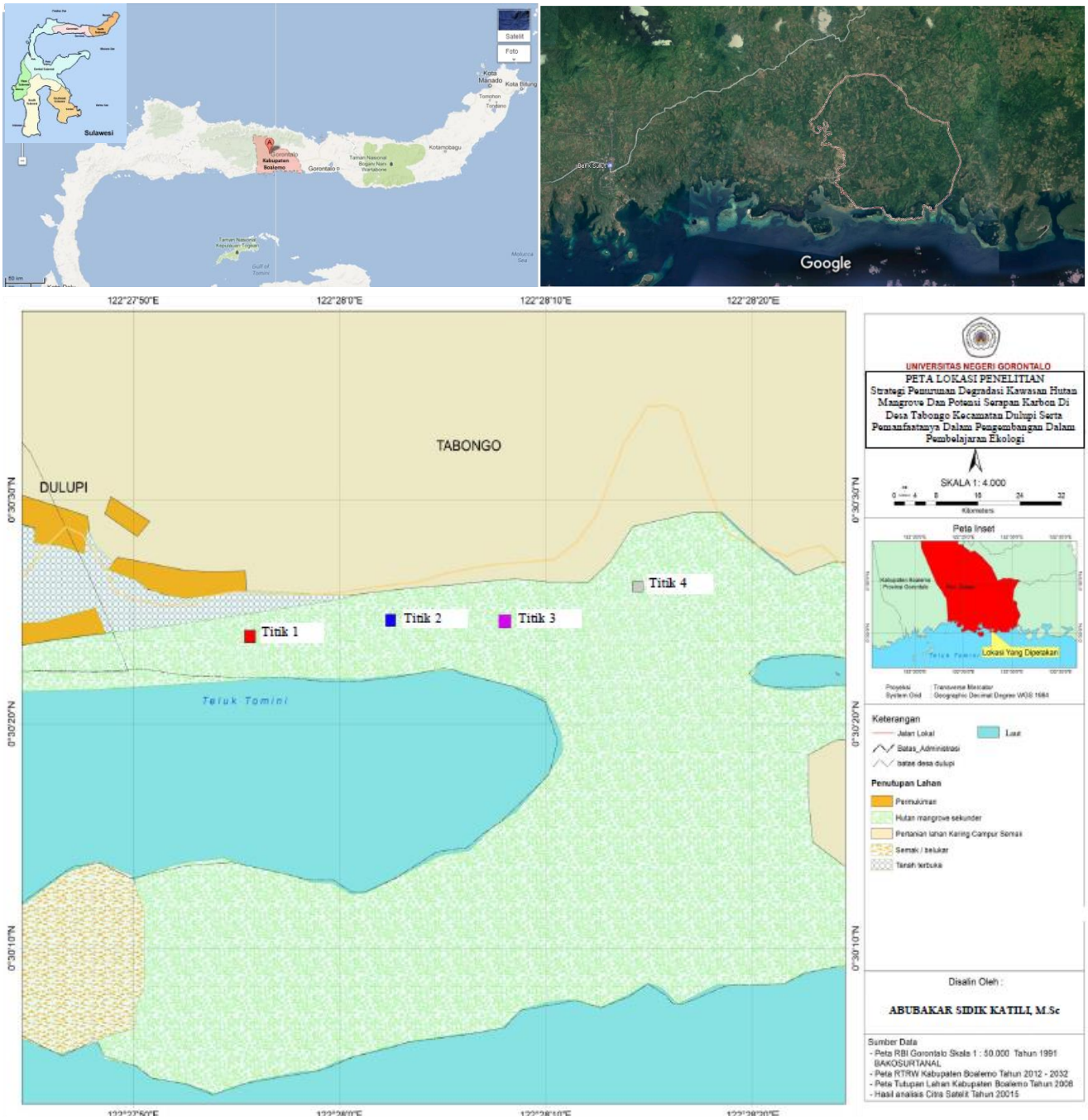

Figure 1. Research site in Tabongo Village, Boalemo District, Gorontalo Province, Indonesia

Degradation level of mangrove

Based on the calculation in tree and sapling stage, the mangrove condition at the studied area was categorized as degraded (TNS_1 = 210). However, based on land survey criteria it was categorized as not degraded (TNS_2= 330). According to MoF (2005), the mangrove condition in the coastal area of Tabongo Village was categorized as good-very dense due to its density of >1,500 trees/ha for the sapling stage, while that for tree stage was 767.45/ha which was categorized as degraded-sparse due to its density of < 1000 trees/ha. Based on the relative coverage values of each mangrove species, the condition was in the degraded criteria due to the coverage value of < 50%/ha.

Discussion

The mangrove coverage at the research site showed significant degradation. This condition might be influenced by various human activities, such as the development of ponds for fish hatcheries, expansion of settlements, and timber cutting of mangroves for buildings and firewood. The degradation of mangrove coverage can cause mangrove litter production to decline and bring a negative impact on nutrient cycles in the region. According to Supriharyono (2007) the fertility of mangrove soils is affected by the decomposition of mangrove leaf litter and the level of sedimentation that occurred. This means that the lack of mangrove coverage also causes the sedimentation process of materials containing nutrients carried by the river flow to become less. While mangrove roots can retain the materials that enter the mangrove forest, the reduction in mangrove coverage causes less and even loss of mangrove roots, causing rich-nutrient materials in mangrove will be lowered.

The condition of mangrove forest in Tabongo Village, Boalemo was seriously damaged at the tree level. The same condition was also seen at the sapling level. Given the facts and conditions of existing mangrove area of Tabongo Village, Boalemo it can be predicted that after a period of time the ideal condition of mangroves in this area will continue to decrease significantly. Mitra (2013) stated that mangrove forests have immense ecological value. These forests protect and stabilize the coastal zone, fertilize the coastal waters with nutrients, yield commercial forest products, support coastal fisheries and provide a surprising genetic reservoir that are the sources of several bioactive substances and extracts having high medicinal values. Mitra (2013) said that these roles are influenced by three main factors, namely levels of water turbidity, tidal mixing, and the physical and structural complexity of the habitat.

Based on the results of this study, mitigation strategies to counterforce deforestation and degradation of mangrove forest in Tabongo Village is needed. This should be done by combining the ecological functions (conservation of mangrove forest) with the socio-economic interests of the people around the mangrove area. Thus, the strategies applied would be able to overcome the socio-economic problems of the surrounding community. One way of such strategies is by maintaining the natural conditions of mangroves and making its ecosystem as a buffer zone, while still involving the people around mangrove areas. Other ways to recover mangrove degradation can be done by growing mangrove seedlings and replanting them on the damaged area; introduction of various species of mangrove and its use through learning activities in schools around the mangrove area; and also more sustainable hatcheries management while considering the suitability of environmental factors such as the type of substrate and salinity.

In conclusion, mangrove vegetation in Tabongo was the type of *Rhizophora apiculata-Rhizophora mucronata* and dwarf forest type generally. This type was classified as a typical mangrove found in low edges. The mangrove in this area was in degraded condition. As such, mitigation strategies are required to restore the quality of the mangrove areas, including (i) the assessment of the importance of the mangrove areas with regard to their ecological and economic value, (ii) improving quality of mangrove habitat, (iii) educational approach by making the mangrove areas as learning media and source, and (iv) empowerment of people living in the mangrove areas.

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REFERENCES

Arief A. 2003. Mangrove Functions and benefits. Kanisius. Jogjakarta. [Indonesian]

Bismark M, Subiandono E, Heriyanto NM. 2008. Diversity and Potential Types Carbon Content of Mangrove Forests in Subelen Siberut River, West Sumatera. Center of Forests Research and Conservation, Bogor. [Indonesian]

Dahdouh-Guebas F, Koedam N. 2006. Empirical estimate of the reliability of the use of the Point-Centred Quarter Method (PCQM): Solutions to ambiguous field situations and description of the PCQM+ protocol. For Ecol Manag 228 (1): 1-18. DOI: 10.1016/j.foreco.2005.10.076.

Donato CD, Kauffman JB, Murdiyarso D, Kurnianto S, Stidham M, Kanninen M. 2012. Mangrove is one of the Richest Forests of Carbon in the Tropics. Cifor, Bogor. [Indonesian]

Giri C, Ochieng E, Tieszen LL, Zhu Z, Singh A, Loveland T, Duke N. 2011. Status and distribution of mangrove forests of the world using earth observation satellite data. Global Ecol Biogeogr 20 (1): 154-159. DOI: 10.1111/j.1466-8238.2010.00584.x.

Ilmiliyana A, Muryono M, Purnobasuki H. 2012. Estimation of Carbon Stok on *Rhizophora stylosa* stands at Camplong beach, Sampang-Madura. Department of Biology, Mathematics and Natural Science Faculty, Sepuluh November Technology Institute, Surabaya. [Indonesian]

Irwanto. 2007. Analysis of vegetation for management of protect area Marsegu Island, West Seram district. Maluku. Gadja Madah University. Yogyakarta. [Indonesian].

Environmental status report of Gorontalo Province, 2013. [Indonesian].

MoF. 2005. Pedoman Inventarisasi dan Identifikasi Lahan Kritis Mangrove. MoF, Jakarta. [Indonesian]

Mitra A. 2013. Sensitivity of Mangrove Ecosystem to Changing Climate. Springer, New Delhi.

Noor YR, Khazali M, Suryadiputra INN. 2012. Guidance introduction of mangrove in Indonesia. PHKA/WI-IP, Bogor.[Indonesian]

Onrizal. 2010. Change of mangrove forest coverage in east coastal area North Sumatra period 1977-2006. Jurnal Biologi Indonesia 6 (2): 163-172. DOI: 10.14203/jbi.v6i2.3154. [Indonesian]

Onrizal, Ahmad AG, Mansor M. 2017. Assessment of Natural Regeneration of Mangrove Species at Tsunami Affected Areas in Indonesia and Malaysia. IOP Conference Series: Materials Science and Engineering 180 (1): 012045. DOI: 10.1088/1757-899X/180/1/012045.

Onrizal, Kusmana C, Mansor M. 2009. The effect of tsunami in 2004 on mangrove forests, Nias Island, Indonesia. Wetland Sci 7 (2): 130-134.

Pramudji. 2000. The mangrove forest in Indonesia: The role of mangrove, problems, and management. Oseana 25 (1): 12-20. [Indonesian]

Utina R. 2012. Ecological Intelligence in Local Wisdom of Bajo Community Torosiaje Village Gorontalo Province. Proceedings of the 21st National Conference And Seminar of Indonesia's Center for Environmental Studies September 2012. Mataram. [Indonesian]

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Non-timber forest products extraction activities of traditional communities in the upstream Mamberamo Basin of West Papua, Indonesia

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Abstract. *Rahawarin YY. 2017. Non-timber forest product extraction activities of traditional communities in the upstream Mamberamo Basin of West Papua, Indonesia. Asian J For 1: 23-26.* Forest provides a variety of resources that benefit traditional communities, including indigenous communities in Papua. The aim of this study was to investigate the utilization of non-timber forest products (NTFPs) by local communities in the upstream part of Mamberamo Basin, West Papua, Indonesia. Field surveys, direct observation and semi-structural interviews were conducted to generate data. The results showed that the local communities in the upstream part of Mamberamo Basin extract several non-timber forest products over the course of their generations to fulfill basic daily necessities and to generate cash incomes. Sago palm (*Metoxylon sagu*) was among the most important non-timber forest products which are used as a staple food, while hunting freshwater crocodiles (*Crocodylus porossus*) for its skin and collecting agarwood (*Gyrinops* sp.) were the primary activities to generate cash incomes. These activities have lasted for generations, so people called them traditional conservation. They are believed to be done on a sustainable basis to keep the availability of non-timber forest products to fulfill the daily needs over generations.

Keywords: Non-timber forest products, local communities, upstream part, Mamberamo Basin, traditional conservation

INTRODUCTION

Forest ecosystem is a life-supporting system that provides a wide range of ecosystem services, especially for the surrounding communities. The components of forest ecosystem, such as wild animals, plants, water, and soil, support a better socio-economic condition for the society (Rahawarin 2010a, 2010b). Tropical forest is very rich in flora and fauna, which can be utilized to fulfill human needs, such as timber and non-timber products (NTFPs) for the present and next generations (Masripatin 2007).

Papua is located in the eastern part of Indonesia with an area of over 421,981 km^2. The vast area of Papua stretches over various types of ecosystems, from coastal to mountain ecosystems, including tropical rainforest with its rich biodiversity elements which serve as the source of livelihoods of traditional communities (Beno et al. 2009). Petocz (1987) and Conservation International (1999) reported that there are about 20,000-25,000 species of plants, 200,000 species of insects and invertebrates, 330 species of reptiles and amphibians, 650 bird species, and 164 mammals in the land of Papua.

Indigenous communities in Papua are highly dependent on forest resources. The utilization of forest products by local communities in Papua is not limited solely to the flora, but also to the fauna through traditional hunting. Pattiselanno (2003) claimed that hunting of some wild animals in the tropical rainforest in Papua gives a significant contribution to the communities, not only to provide protein but also to generate income for traditional households.

However, wild animal hunting warrants investigation since this practice is not necessarily sustainable in the long run. Studies by Robinson and Redford (1994) and Robinson and Bodmer (1999) showed that hunting in several tropical rainforests was not sustainable and wild animals will be very vulnerable to over-exploitation which can lead to extinction.

Departed from such issue, it is important to investigate the sustainability of forest resources in Papua in relation to the extraction activities, not only on animals but also on other components. Therefore this research was conducted to study the utilization of non-timber forest products (NTFPs) by local communities in the upstream part of Mamberamo Basin, West Papua, Indonesia.

MATERIALS AND METHODS

This study was conducted at the upstream part of Mamberamo River, administratively located in Bernakamp, Taive, and Dabra Districts of Mamberamo Raya Regency, West Papua. In general, the location is characterized by a rigged area dominated by mountains and small rivers flowing to the sea (Figure 1).

Field surveys, direct observation and interviews were applied in this study. Through field survey and observation, primary data of flora and fauna were taken. Socio-

economic and cultural data were also gathered through oral interviews by asking the communities using key questionnaires. Sampling plots were made in the forests to collect data on the diversity and distribution of the flora, while for the fauna, enumeration technique was carried out which was based on the preliminary information given by the communities. The surrounding forests belonging to the Tabruta Tribe were surveyed based on their daily activities in the forests. Several tools were used in data collection including manual diameter tape, Haga altimeter, binocular camera, documentation tools, and stationery.

Secondary data on biophysical conditions of the surrounding forests in which extraction activities were carried out by the communities were collected through literature research of documents from relevant stakeholders. The data were analyzed descriptively.

RESULTS AND DISCUSSIONS

Distribution of Non-Timber Forest Products

The main distribution of Non-Timber Forest Products (NTFPs) is located upstream of Mamberamo Basin. This area consists of various landscapes, including lowland forest, swamp forest, and man-made agricultural lands (Figure 1). Based on a report published by the Agricultural Service of Mamberamo Raya District (2012), the total area is about 317,353 Ha which is dominated by lowland forest (96.68%) from the Plateau of Taribu Mountain at Taria Village, Bernakamp village to the Rotia Mountain in the Dabra area. Swamp forest (2.64%) is distributed in the Mamberamo Basin along the tributaries which flow to the northern part which form many small lakes. These areas are used for farming *Mozambique tilapia (Oreochromis mossambic*us), common carp (*Cyprinus carpio*), and freshwater crocodiles (*Crocodylus porosus*). There are around 20-25 lakes regularly used to fulfill the household needs. The total area intended for fish and crocodile farming is about 1-2 Ha. In addition, the swamp forest around the upstream of the river are planned for cultivation of sago (*Metroxylon sagu* Rottb.), and a handful of areas is allocated for hunting wild boar (*Sus scrofa*). The locations for sago are quite limited which are around the lowland forest.

Figure 1. A. The vegetation condition of Taribu Mountain; B. The landscape of Rotia Mountain; C-D. The lowland tropical forest viewed from the upstream of Mamberamo river, West Papua, Indonesia

The percentage of NTFPs from agriculture sector is only 0.58%, mainly used as the source of carbohydrates, vegetables and protein, including protein from animals. The total cultivating area for each household is approximately around 0.25-0.5 ha.

The previous studies by Allen et. al. (2002) and Binur and Ohee (2010) reported that there were 22 species of NTFPs found the upstream of Mamberamo River (Table 1). Based on the interviews in this study, the communities consider NTFPs commodities as the primary source to generate household income, namely the extraction of agarwood and crocodile skin for accessories. Other products also generate income, but are less significant, such as the yields from gardening, hunting and fishing.

Utilization of Non-Timber Forest Products

The communities who live upstream of the Mamberamo River extract the NTFPs based on their traditional ways and beliefs. For example, agarwood from the lowland forest is extracted using traditional ax or blade by cutting the tree and taking out the resin then sold it. There are no specific skills needed for the management and processing.

Sago as the major source of staple food for the traditional communities is extracted using simple traditional methods by cutting down the tree using an ax, rinsing with water to disentangle the starch and sago residue, and packing the starch with a traditional bag made from sago leaves. Besides the starch, the midribs of Sago plants are used to make roofs of the traditional houses around the Mamberamo River. Those processes are managed in the traditional way without formal education. Instead, the information is just passed from generation to generation within the communities.

Crocodiles hunting activities are carried out by setting the fishing equipment or catching them directly from rivers, usually in the evening. The animals are then transported to the house in order to take out the skin. The young crocodile's meat is cooked or grilled for consumption. The skin is preserved by pouring it with salt then covering it with a plastic bag.

Generally, the upstream communities in Mamberamo do not work as fishermen to get cash income, but they do fishing only to fulfill their daily needs (Polhemus and Richards 2001). Other NTFPs intentionally planted in the surrounding area are *Areca catechu*, taro and cassava for consumption.

Table 1. List of Non-Timber Forest Products utilized by indigenous communities in the upstream river of Mamberamo, West Papua, Indonesia

Name of species		Parts of plants	Purposes
English name	**Scientific name**		
Agarwood	*Gyrinops* sp.	Resin and tree bark	The resin is traded whereas the tree bark is used for walls of houses.
Betel palm	*Areca catechu*	Fruits	Chewed in *pinang-sirih* activities either for self-consumption or for sale.
Cananga	*Cananga odorata*	Stems and bark fiber	Stems are used for construction materials and bark fiber for material and traditional bag (*noken*).
Crocodile	*Crocodylus porosus*	Meat and scale, skin	Meat is eaten and skin is sold.
Dammar	*Vatica rassak*	Sap	Used to make candles for light.
Figs	*Ficus* sp.	Tree bark and fiber bark	Tree bark is used for covering the food whereas the bark fiber is made into traditional bag and clothes.
Fijian longan	*Pometia pinnata*	Fruits	Used as edible fruit
Common carp	*Cyprinus carpio*	Meat	Meat is eaten and sold.
Guava	*Syzygium* sp.	Fruits	Used as edible fruit.
Masohi	*Cryptocarya* sp.	Bark	The bark is sold.
Melinjo	*Gnetum gnemon*	Bark fiber, leaves and fruits	Leaves and fruits are edible. Bark fiber is made into *noken*.
Mozambique tilapia	*Oreochromis mossambicus*	Meat	Meat is eaten and sold.
Orchid	*Dendrobium* sp.	All parts of the plant	Used as decorative plant
Palm	*Orania* sp.	All parts of plant	Leaves and midribs are used for construction materials, whereas stems are used to make bows and arrows.
Palm	*Hydriastele* sp.	Stems and all parts plant	Steams are used for construction and hand-made crafts. Palm is used for home decoration.
Palm	*Linospadix* sp.	Leaves	Leaves are used for construction.
Rattan	*Korthalsia zippeli*	Stems	Stems are used for materials and construction, i.e., chairs, tables, and fences.
Red fruit	*Pandanus* sp.	Fruits and leaves	Fruits are edible and leaves are used for housing floor materials.
Sago	*Metroxylon* sp.	Sago starch, leaves, stems midribs and trunks	Sago starch is commonly used as a staple food and sold; leaves and midribs are used for construction materials; steams are applied for media, sago caterpillar for food protein.
Stinging tree	*Laportea indica*	Leaves	Used as traditional medicine.
Wild boar	*Sus scrofa*	Meat and teeth	Meat is eaten and sold, while teeth are used for accessories/souvenirs.
Yellow fruit moonseed	*Arcangelisia* sp.	Stems	Used as traditional medicine

Traditional conservation of NTFPs

With regard to the availability of NTFPs, conservation and preservation actions are required. There are a number of solutions in order to keep the benefit of NTFPs while maintaining future availability for generations to come. It is clear that the utilization of NTFPs for self-consumption and small-scale commercial activities are managed in a sustainable way by considering the natural capacity. However, extensive activities and cultivation are mandated to do in the communities to reduce the over-exploitation in the natural habitat. Land is continuously managed for growing some edible crops and domesticated animals. For example, during dry season when level of water in the river is reduced, the communities tend to alter their daily activities into the swamp forests and rivers. On the other hand, during rainy season the communities are focused on the high land to extract NTFPs.

The communities believe that by managing the forest and nature in a sustainable way, they will continuously get benefits from them. Such beliefs that traditional communities carry have been made into some traditional regulations and customs. For example, every hunting activity should get permission from the traditional leader. Sumule (1995) and Pattiselano (2006) reported that some areas in Papua belong to certain ethnic groups or clans; therefore, besides requesting the permit, they also should share some of their hunting product with the communal landholders.

REFERENCES

Allen G, Ohee H, Boli P, Bawole R, Warpur M. 2002. Fishes of the Yongsu and Dabra areas, Papua, Indonesia. In: Richards SJ, Suryadi S (eds.). A Biodiversity Assessment of Yongsu – Cyclops Mountains and the Southern Mamberamo Basin, Papua, Indonesia. RAP Bulletin of Biological Assessment No 25., Washington DC.

Beno M, Ohee H. 2009. Traditional Conservation Knowledge of Endemic Birds for the Community at Soaib Village in Kemtuk District, Jayapura. J Papua Biol 1 (1): 15-20.

Binur R, Ohee HL. 2010. The diversity of freshwater fishes in Haya, Mamberamo-Papua. Jurnal Natural 9 (1). DOI: 10.30862/jn.v9i1.319

Chahya DN. 2000. Teknologi Berburu Rusa (*Cervus timorensis*) dan Kasuari (*Casuarius* sp.) Secara Tradisional Pada Masyarakat Suku Marind dan Kanuum di Kawasan Taman Nasional Wasur Kabupaten Merauke. [Skripsi]. Fakultas Kehutanan, Universitas Negeri Papua, Manokwari. [Indonesian]

CI. 1999. Lokakarya Penentuan Prioritas Konservasi Keanekaragaman Hayati di Irian Jaya. [Laporan Akhir]. Conservation International, Jakarta. [Indonesian]

Dinas Pertanian Kabupaten Mamberamo Raya. 2012. Data Base Pembangunan Pertanian Kabupaten Mamberamo Raya. Kerjasama Pemerintah Kabupaten Mamberamo Raya dan Universitas Negeri Papua, Manokwari. [Indonesian]

Pattiselanno F. 2003. The Wildlife value: example from West Papua, Indonesia. Tigerpaper 30 (1): 27-29.

Pattiselanno F. 2006. The wildlife hunting in Papua. Biota 11: 59-61.

Petocz RG. 1994. Konservasi Sumberdaya Alam dan Pembangunan di Irian Jaya. Graffitti Press, Jakarta. [Indonesian]

Polhemus DA, Richards SJ. 2002. Ulasan Geografis Pegunungan Cyclops dan Daerah Aliran Sungai Mamberamo. In: Richards SJ, Suryadi S (eds.). A Biodiversity Assessment of Yongsu – Cyclops Mountains and the Southern Mamberamo Basin, Papua, Indonesia. RAP Bulletin of Biological Assessment No 25., Washington DC.

Rahawarin Y. 2010a. Forest land use by the community in Sorong National Tourism Park at Sorong City, West Papua Province. Biodiversitas 11 (4): 222-227. DOI: 10.13057/biodiv/d110410.

Rahawarin Y. 2010b. Strategi pengelolaan hutan tropika sebagai komponen penyimpan karbon. Agripura 6 (1): 798-806. [Indonesian]

Robinson JG, Redford KH. 1994. Measuring the sustainability of hunting tropical forests. Oryx 28: 249-256. DOI: 10.1017/S0030605300028647.

Robinson JG, Bodmer RE. 1999. Towards wildlife management in tropical forest. J Wildlife Manag 63: 1-13. DOI: 10.2307/3802482.

Sumuel AI. 1995. The technology adoption behavior of the indigenous people of Irian Jaya: A case study of the Arfak Tribal. Faculty of Agriculture, Universitas Cenderawasih, Manokwari.

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Diversity and of tree species in tropical forests of Northcentral Eastern Ghats, India

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Abstract. *Premavani D, Naidu MT, Kumar OA, Venkaiah M. 2017. Diversity and distribution of tree species in tropical forests of Northcentral Eastern Ghats, India. Asian J For 1: 27-32.* Tropical forests are among the most biodiversity rich ecosystems in the world, yet they are understudied. The diversity and stand structure of tree species were studied in three 1-ha sites of tropical deciduous forests in the northcentral Eastern Ghats of India. The phytosociological data from forest sites were analyzed quantitatively to determine the species diversity, richness, basal area and stand density. A total of 1,507 individuals of 104 plant taxa, pertaining to 82 genera under 41 families were enumerated at ≥15 cm gbh (girth at breast height) using belt transects (5 m × 1000 m). Tree stand density varied from 371-660 individuals per ha while average basal area ranged from 14.54 – 46.51 m^2 ha^{-1}. Shannon-Weiner Index (H') ranged from 0.97-0.98, evenness index ranged from 0.70-0.79 and Margalef richness index ranged from 10.54 – 10.82. The most dominant families were Rubiaceae, Euphorbiaceae, Fabaceae, Moraceae, and Verbenaceae. Our results suggest further development of forest management and biodiversity conservation in Eastern Ghats region.

Keywords: Diversity, species richness, stand structure, conservation, tropical forests, Eastern Ghats

INTRODUCTION

Tropical forests are the most species-diverse terrestrial ecosystems on the planet which comprise many endemic species (Sathish et al. 2013). Tropical forests cover only 7% of the earth's land surface, but harbor more than half of the world's species (Wilson 1988). They provide many ecosystem services, such as carbon sequestration, storing water, preventing soil erosion, and habitat for plants and animals (Anbarashan and Parthasarathy 2013).

In recent years, tropical forests are under great anthropogenic pressures and require management intervention to maintain the overall biodiversity, productivity and sustainability (Dash et al. 2009; Naidu and Kumar 2015). The first step toward the conservation and sustainable management of tropical forests is the availability of data on plant species diversity and the forest community structure. This information is important to serve as the baseline information for monitoring the changes that occurred in a tropical forest, especially because of the impacts of human activities.

Quantitative inventories in tropical forests have been concentrated on tree species than the other life forms since tree species diversity is an important part of an ecosystem (Mani and Parthasarathy 2006; Reddy et al. 2011). Trees form the major structural and functional basis of tropical forest ecosystems and can serve as robust indicators of changes and stresses at the landscape scale (Sahu et al. 2012a). The composition and structure of tree vegetation in tropical regions over small geographic scales often have been correlated with changes in topography and soil characteristics (Svenning 1999; Webb and Peart 2000).

Quantitative plant diversity inventories of Indian tropical forests are available from various forests of Eastern Ghats (Kadavul and Parthasarathy 1999a, b; Jayakumar et al. 2002; Natarajan et al. 2004; Reddy et al. 2008; Reddy et al. 2011; Sahu et al. 2012a, b; Premavani et al. 2014). Nonetheless, these kinds of studies are scarce in Andhra Pradesh, which covers a major part of the Eastern Ghats. In view of these conditions, we evaluated the diversity and distribution of tree species in a section of north-central Eastern Ghats, as part of East Godavari District in Andhra Pradesh, aiming to provide fundamental data for appropriate management strategies which will help to improve the ecosystem conservation status.

MATERIALS AND METHODS

Study area

The present study was carried out in three forest stands located in East Godavari District, Andhra Pradesh, India. The stands were located 245 km away from south-west direction of Visakhapatnam. They include Maredumilli (MM: 17°35′18.66″N 81°43′18.66″E), Rajavommangi (RV: 17°33′35.61″N 82°13′50.44″E) and Rayapalli (RP: 17°34′15.53″N 82°01′08.42″E) (Figure 1). These forests are classified as Southern moist deciduous and dry deciduous forests (Champion and Seth 1968). The hill range consists mainly of charnokites and kondalites and varied crystalline metamorphic rocks (Subrahmanyam 1982). Soil of the study sites is black, loamy and lateritic. Lateritic soils are abundant in the deciduous forests of the area (Naidu et al. 2014).

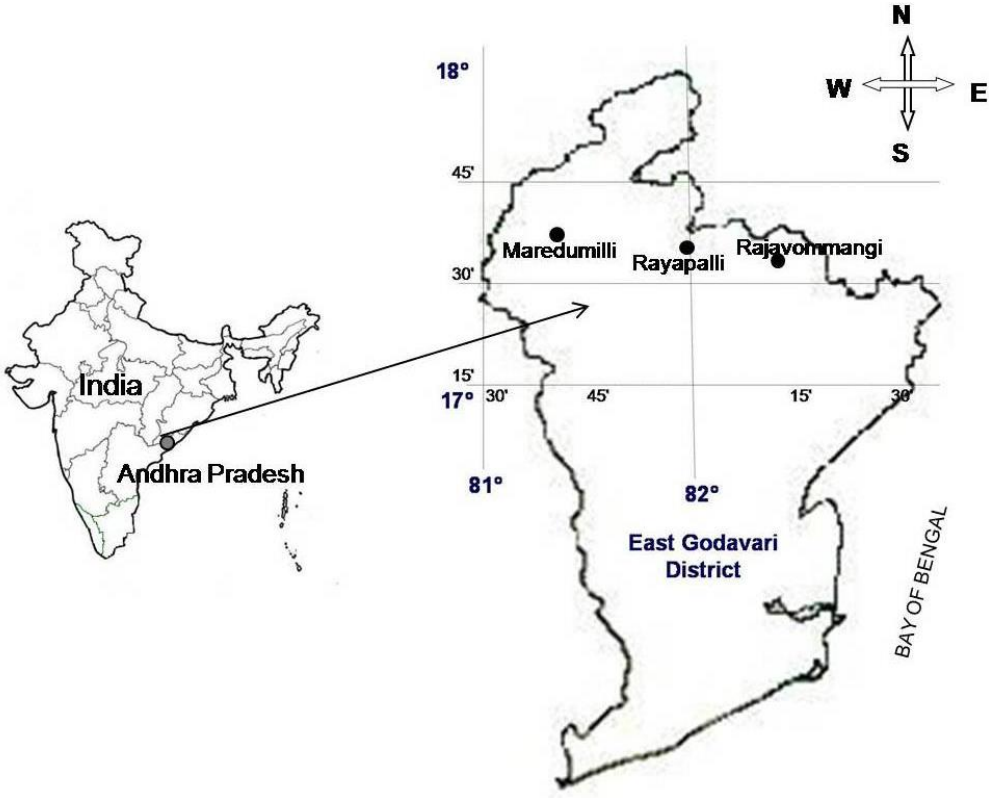

Figure 1. Map showing three study sites in East Godavari District of Andhra Pradesh, India. Note: MM = Maredumilli, RP = Rayapalli, RV = Rajavommangi

The annual precipitation is 1300 mm and the temperature rises from 28^0 to 46^0C in the summer while in the winter it ranges from 13^0 to 27^0C (Public Works Department/PWD data). The were anthropogenic activities noted such as intentional forest fire, timber cutting, lopping, grazing, and fuelwood and medicinal plant collection. Invasion of exotic species was also observed.

Sampling methods

The study was carried out during 2009-2011 as part of a national-level project. Two belt transects with size of 5 × 1,000 m were established. Depending on the shape of the forest stand, these transects were sub-divided into five lines with size 5 × 200 m and care was taken to cover landscape heterogeneity and was given by their locality name which was used for further analytical use. All individual trees covered in the quadrats were measured at girth at breast height (GBH) ≥ 15 cm. Voucher specimens were collected, processed and identified by following Gamble and Fischer (1915-1935) and Rao et al. (1999) and stored in the Botany Department Herbarium (BDH), Department of Botany, Andhra University, Visakhapatnam, for reference.

Data analysis

Vegetation data were quantitatively analyzed for basal area, relative density (RD), frequency (RF) and dominance (RDom). The Importance Value Index (IVI) of tree species was determined (Curtis and McIntosh 1950). The collected data were also used to compute community indices, namely Species diversity (H') which was calculated using the Shannon-Weiner Index (Shannon and Weiner 1963) as follow:

$$H' = -\Sigma (Pi)/ In (Pi),$$

Where, Pi =ni/N, ni= number of all individuals of one species, N=he total number of individuals of all species, and In=Logarithm.

Species dominance (Cd) was calculated following Gini-Simpson (Simpson 1949) as follow:

$$Cd = \Sigma (ni/N)^2,$$

Where, ni and N are the same as those of Shannon-Weiner index. Evenness refers to the degree of relative dominance of each species in that area. It was calculated according to Pielou (1966) as:

$$Evenness\ (e) = H'/\log S$$

Where, H'= Shannon index, S = number of species. Species richness was determined by Margalef index (Margalef 1968) as:

$$d = S_1/\log N$$

Where, S is the number of species and N is the number of individuals.

RESULTS AND DISCUSSION

Species richness and diversity

A total of 1,507 individual trees with gbh ≥ 15cm were recorded, consisting of 104 species of 82 genera and 41 families. Of these, 71 species of 61 genera and 33 families occurred in MM, 66 species of 60 genera and 33 families occurred in RV and 65 species of 56 genera and 30 families occurred in RP sites. Stem density varied in the three study sites with 660 in MM, 476 in RV and 371 individuals in RP (Table 1). Rubiaceae was the dominant family with eight species, followed by Euphorbiaceae (6 spp.) and 5 species of each by Anacardiaceae, Apocynaceae, Caesalpiniaceae, Combretaceae, Flacourtiaceae, Mimosaceae, Moraceae, Papilionaceae, Rutaceae, Sterculiaceae and Verbenaceae while three families Annonaceae, Ebenaceae and Sapotaceae were represented by three species each, eight families had two species each and 16 families were represented by only single species. The diversity values 3.9, 3.86, and 3.94 for the sites MM, RV, and RP, respectively. The Simpson index was 0.97, 0.97, and 0.98, respectively, Evenness index of tree communities at MM, RV, and RP, represented 0.70, 0.72, and 0.79, respectively. The Margalef richness index was 10.78, 10.54, and 10.82 for the sites MM, RV, and RP, respectively (Table 1).

Table 1. Number of taxa, diversity indices and structural characteristics of 3 1-ha sites in the northcentral Eastern Ghats, India.

Variable	MM	RV	RP
Latitude	17° 35' 37.01"	17° 33' 35.61"	17° 34' 15.53"
Longitude	81° 43' 18.66"	82° 13' 50.44"	81° 01' 08.42"
Elevation (m)	654	310	307
No. of species	71	66	65
No. of genera	61	60	56
No. of families	33	33	30
Density	660	476	371
Basal area	46.51 m^2 ha^{-1}	27.47 m^2 ha^{-1}	14.54 m^2 ha^{-1}
Shannon_H	3.9	3.86	3.94
Simpson_1-D	0.97	0.97	0.98
Evenness_e	0.70	0.72	0.79
Margalef	10.78	10.54	10.82

Density and basal cover

The average tree density was 502 individuals ha^{-1} with a range of 371 (Site RP) to 660 individuals ha^{-1} (MM). Site wise tree species densities were shown as *Xylia xylocarpa* (36 individuals) followed by *Terminalia alata* (29 individuals) and *Lannea coromandelica* (27 individuals) in MM; *Cleistanthus collinus* (36 individuals), *Anogeissus latifolia* (32 individuals) and *Xylia xylocarpa* (27 individuals) in RV; *Chloroxylon swietenia* (20 individuals), *Lannea coromandelica* (19 individuals) and *Dalbergia paniculata* (18 individuals) in RP. The sum of total tree basal area of three sites was 88.52 m^2 ha^{-1} with a range from 14.54 m^2 ha^{-1} (RP) to 46.51 m^2 ha^{-1} (MM).

A comparison was made to see the relative distribution of the total number of individuals and their basal area in each diameter class. The girth (GBH) class-wise tree density followed to girth class intervals were found more for 31-60 cm and 61-90 cm. In most of the individuals with 52.7% fall in 31 to 90 gbh. The basal area of these classes showed 2.44 and 8.81 m^2 ha^{-1}. The highest basal area contributed in >120 cm girth class about 31.08 m^2 ha^{-1} (Figure 2.A). In Site RV, girth classes decreased from the smallest to largest trees in context to their stem density except for <30 girth class. The girth class 61-90 cm contributed 26% of stem density. The distribution of basal area in different girth intervals i.e more than 120 cm and 91-120 cm contributed about 15.01 m^2ha^{-1} and 7.05 m^2 ha^{-1}, respectively (Figure 2.B). In site RV, stem density decreased consistently with increase in girth class of tree species beyond 31-60 girth class. The distribution of basal area across different girth intervals i.e >120 cm and 91-120 cm contributed 6.21 m^2 ha^{-1} and 3.74 m^2 ha^{-1} respectively (Figure 2.C).

The average tree height was 18.2 m with ranges from 2 to 21 m. Tree height distribution intervals showed that most of trees in the study area were between 5 and 15 m in height (Figure 3). This pattern is common for all three sites. The forests in the study sites can be considered for having two defined strata. The first is between 5 and 10 m which comprises the majority of individuals. The second stratum consists of individuals with 11-15 m high canopy. Very few species reached heights greater than 15 m.

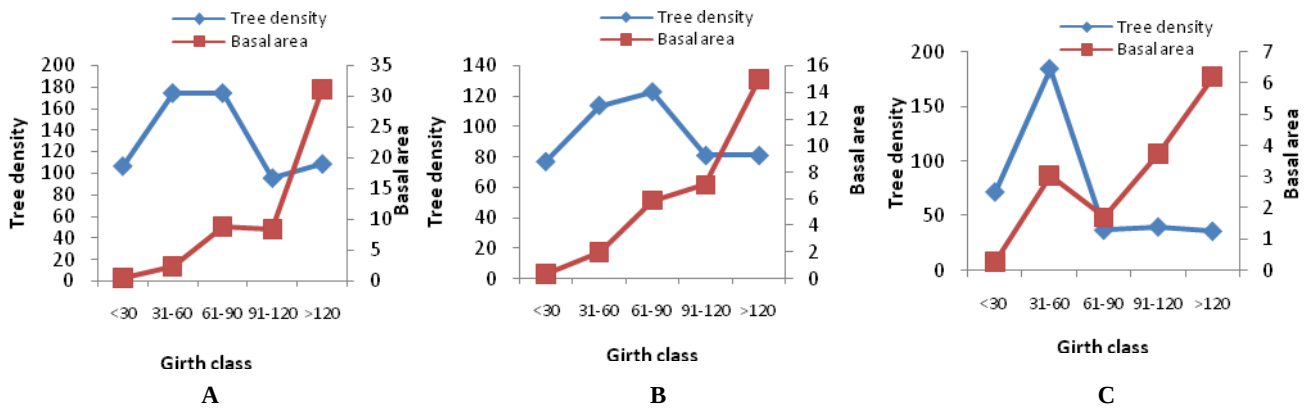

Figure 2.A-C. Contribution of tree species, stands density and basal area based on girth class distribution in northcentral Eastern Ghats, India

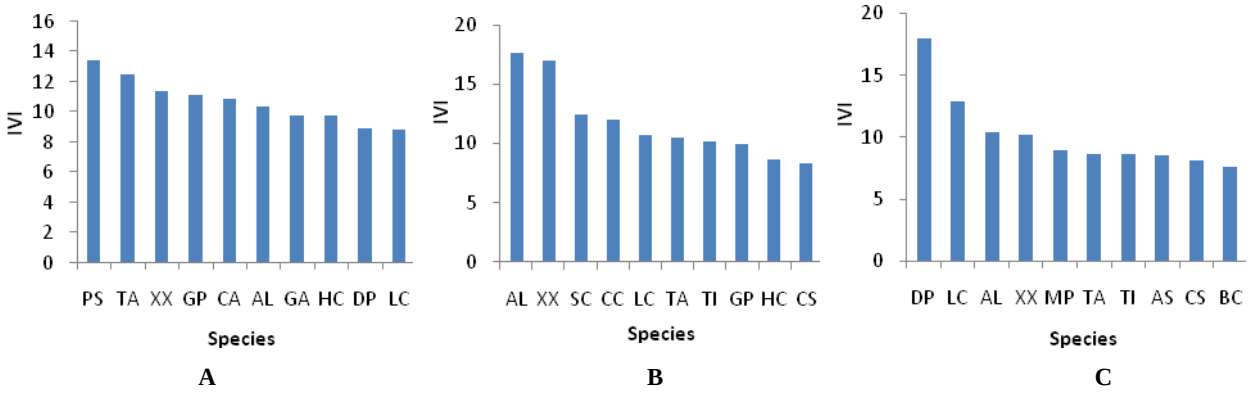

Figure 4.A-C. Top ten IVI of tree species in northcentral Eastern Ghats. Abbreviations used (a-c). PS = *Protium serratum*; TA = *Terminalia alata*; XX = *Xylia xylocarpa*; GP = *Garuga pinnata*; CA = *Careya arborea*; AS = *Alangium salvifolium*; GA = *Gmelina asiatica*; HC = *Haldinia cordifolia*; DP = *Dalbergia paniculata*; LC = *Lannea coromandelica*; SC = *Syzygium cumini*; CC = *Cleistanthus collinus*; TI = *Tamarindus indica*; CS = *Chlooxylon swietenia*; *Mitragyna parvifolia*; AL = *Anogeissus latifolia*.

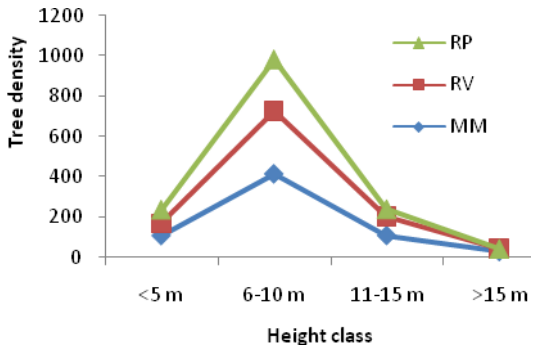

Figure 3. Distribution of individuals per height classes in northcentral Eastern Ghats, India

Important Value Index (IVI)

Top ten species accounted for 36% of IVI in MM with *Protium serratum* as the most dominant species with IVI of 13.5%. The co-dominant species were *Terminalia alata*, *Xylia xylocarpa*, *Garuga pinnata*, *Careya arborea* and *Anogeissus latifolia* (Figure 4.A). In RV, top ten species accounted for 39% with *Anogeissus latifolia* as the most dominant species with IVI of 17.67%. The co-dominant species included *X. xylocarpa*, *Syzygium cumini*, *Cleistanthus collinus*, *Lannea coromandelica*, *Terminalia alata* and *Tamarindus indica* (Figure 4.B). In RP, top ten species accounted for 34%, and *Dalbergia paniculata* was the most dominant species with IVI 17.89%. The co-dominant species were *L. coromandelica*, *A. latifolia*, *X. xylocarpa* and *Mitragyna parviflora* (Figure 4.C).

Discussion

The present study can be compared with a large number of similar forest sites studied in India and elsewhere in the tropics. Tree species richness varied in different stands with total of 104 species of 41 families were recorded from 3 ha^{-1} sites, resulting in species richness ranging from 65-71 ha^{-1} with mean value of 67 ha^{-1} recorded. The mean value of 67 species ha^{-1} recorded in the present study is higher than that of 31 species ha^{-1} in dry deciduous forests in western India (Kumar et al. 2010), 9 to 41 species ha^{-1} in Bannerghatta National Park (Gopalakrishna et al. 2015), 32 to 48 species ha^{-1} in natural forests of Barak valley (Nandy and Das 2013) and 64 species ha^{-1} in tropical dry deciduous forests of Eastern Ghats, Southern Andhra Pradesh (Reddy et al. 2008). Species number per ha found in the present study is smaller when compared to results of lowland moist deciduous forests in northeast India which have 105 species ha^{-1} (Majumdar et al. 2012), 150 species ha^{-1} in Indonesia (Whitemore 1990), 223 and 214 species ha^{-1} in Malaysia (Proctor et al. 1983), 223 species ha^{-1} (Parthasarathy and Sethi 1997). The species richness ranged between 65 and 71 per hectare is well within the range reported for tropical forests in Eastern Ghats, i.e. from low value of 22-29 species ha^{-1} in Niyamgiri hill range of Eastern Ghats (Sahu et al. 2012b) to a high value of 52-110 species ha^{-1} in Eastern Ghats of northern Andhra Pradesh.

Rubiaceae, Euphorbiaceae, and Papilionaceae were the dominant families in the present study area. There are similar dominant families to be recorded from Eastern Ghats of northern Andhra Pradesh (Reddy et al. 2011), Shervarayan hills (Kadavul and Parthasarathy 1999a), and Warangal region along Godavari valley (Raju et al. 2014). Leguminosae is the dominant family in many Indian deciduous forests, whereas Lauraceae, Meliaceae, Combretaceae, Rubiaceae, Euphorbiaceae and Moraceae, etc. are dominant elsewhere in other areas of India (Sukumar et al. 1992; Shankar 2001). But in tropics, Fabaceae is the most speciose family in Neotropical deciduous forests (Gentry 1995; Martin et al. 1997; Steege et al. 2000). For instance, *Protium serratum* and *Terminalia alata* were dominant in MM; *Anogeissus latifolia* and *X. xylocarpa* in RV and *Dalbergia paniculata* and *Lannea coromandelica* in RP. Reddy et al. (2011) reported *Xylia xylocarpa* and *Pterocarpus marsupium* were dominant species in Eastern Ghats of northern Andhra Pradesh; *Albizia amara* and *Euphorbia antiquorum* were dominant species in tropical forests of southern Eastern Ghats (Pragasan and Parthasarathy 2010); *Microtropis*

discolor and *Camella caudata* were the dominant trees in Jaintia hills of north east India (Upadhaya et al. 2003).

A total of 1,507 individual trees with the average stand density of 504 individuals ha^{-1} in the present study exists well within the range of 276-905 individuals ha^{-1} reported for trees ≥15 cm gbh in other tropical forests (Sahu et al. 2012a; Bhadra et al. 2010; Kumar et al. 2010; Sahu et al. 2007) and are close to the value reported by Jha and Singh (1990) for dry tropical forest of Vindhyan region of India. The basal area is an important aspect of studying forest vegetation and structure (Williams-Linera 1990). The mean basal area was 29 m^2 ha^{-1} for the study sites, ranging from 14.54 to 46.51 m^2 ha^{-1}. It is close to that of other tropical forests, such as dry evergreen (32.8 m^2 ha^{-1}) forests of Puthupet, south India (Parthasarathy and Sethi 1997), tropical forests of Eastern Ghats of northern Andhra Pradesh (Reddy et al. 2011), fan-palm dominated forests of east coast (25.3-48.6 m^2 ha^{-1}) in Malaysia (Nizam et al. 2013) but when compared to tropical rain forest in Amazonia (Campbell et al. 1992) lower in value (78 m^2 ha^{-1}).

With respect to girth class wise distribution, tree density decreased with increasing tree size classes, except in lower size class. This agrees with the studies from Malayagiri and Niyamgiri hill ranges of Eastern Ghats (Sahu et al. 2012a, 2012b). The mean tree height was 18.2 m, ranging from 2 to 21 m. The distribution of tree height class showed that individuals were between 5 and 15 m, this is in conformity with the findings for the Malayagiri hill ranges of Eastern Ghats (Sahu et al. 2012a) and dry tropical forests of Peru (Palomino and Alvarez 2005).

Species diversity depends upon adaptation of species and increases with stability of community. The Shannon – Weiner (H') index for all three sites varied from 3.86 to 3.94, which falls within the range of 0.67-4.86 reported by earlier works in tropical forests (Sundarapandian et al. 2000; Dash et al. 2009; Kumar et al. 2010; Sahu et al. 2012a). These values indicate that the present tropical deciduous forest is in a species diverse system. The concentration of dominance (Simpson's index) in the present study is within the reported range 0.21-1.0 for tropical forests by several studies (Kumar et al. 2010; Visalakshi 1995; Sahu et al. 2012c). The evenness index values fall within the range between 0.64-1.34 in other forests (Lalfakwma et al. 2009; Sahu et al. 2012a). The Margalef richness index is also within the range of 4.54-23.41 for other tropical forests (Mishra et al. 2005; Kumar et al. 2010).

In conclusion, forests are a rich repository of India's biodiversity but widespread habitat destruction is threatening its status. Plant diversity in tropical forests was mostly associated with forest structure and species composition. Quantitative inventory of tree species diversity revealed a considerable variation in the composition of dominant species and stood density between forest areas and calculations of IVI which have helped in understanding the ecological significance of species, from different communities. However, the present study clearly shows the fact that the tree diversity in tropical forests of Eastern Ghats varies in species richness and structure among study sites, mainly due to variation in physical heterogeneity and habitat disturbance. Our results highlight the necessity of preparing a comprehensive management plan to conserve the ecosystem of the north-central Eastern Ghats for its rich biodiversity. The present study further helps policymakers to formulate policies to conserve the natural forest ecosystems and as well for the proper utilization of natural resources.

REFERENCES

Anbarashan M, Parthasarathy N. 2013. Tree diversity of tropical dry evergreen forests dominated by single or mixed species on the Coromandel Coast of India. Trop Ecol 54 (2):179-190.

Bhadra AK, Dhal NK, Rout NC, Reddy VR. 2010. Phytosociology of the tree community of Gandhamaran hill ranges. Indian For 136 (5): 610-620.

Campbell DG, Stone JL, Rosas AJr. 1992. A comparison of the phytosociology and dynamics of three flood plain (Vazae) forests of known ages, Rio, Jurua, Western Brazilian Amazon. Bot J Linn Soc 108: 213-237. DOI: 10.1111/j.1095-8339.1992.tb00240.x

Champion HG, Seth SK. 1968. A Revised Survey of the Forest Types of India. Government of India Publications, New Delhi, India.

Chittibabu CV, Parthasarathy N. 2000. Attenuated tree species diversity in human-impacted tropical evergreen forest at Varagalair, Anamalais, Western Ghats, India. Biodiver Conserv 9: 1493-1519.

Curtis JT, McIntosh RP. 1950. The interrelations of certain analytic and synthetic phytosociological characters. Ecology 31: 434-455. DOI: 10.2307/1931497

Dash PK, Mohapatra PP, Rao YG. 2009. Diversity and distribution pattern of tree species in Niyamgiri hill ranges, Orissa, India. Indian For 135 (7): 927-942.

Gamble JS, Fischer CEC. 1915-1935. Flora of the Presidency of Madras, (3 vols.). (Rep.ed. 1957). Adlard and Son Ltd., London.

Gentry AH. 1995. Diversity and floristic composition of Neotropical dry forests. In: Bullock SH, Mooney HA, Mdina E. (eds). Seasonally dry tropical forests. Cambridge University Press, Cambridge.

Gopalakrishna SP, Kaonga ML, Somashekar RK, Suresh HS and Suresh R. 2015. Tree diversity in the tropical dry forest of Bannerghatta National Park in Eastern Ghats, Southern India. Eur J Ecol 1 (2): 12-27. DOI: 10.1515/eje-2015-0013

Jayakumar S, Arockiasamy DI, Britto SJ. 2002. Conserving forests in the Eastern Ghats through remote sensing and GIS: A case study in Kolli hills. Curr Sci 82: 1259-1267.

Jha CS, Singh JS. 1990. Composition and dynamics of dry tropical forest in relation to soil texture. Journal of Vege Sci 1: 609-614. DOI: 10.2307/3235566

Kadavul K, Parthasarathy N. 1999b. Structure and composition of woody species in tropical semi-evergreen forest of Kalrayan hills, Eastern Ghats, India. Trop Ecol 40: 247-260.

Kumar JIN, Kumar RN, Bhoi RK and Sajish PR. 2010. Tree species diversity and soil nutrient status in three sites of tropical dry deciduous forest of western India. Trop Ecol51 (2): 273-279.

Lalfakwma, Sahoo UK, Roy S, Vanlalhriatpuia K and Vavalalhluna PC. 2009. Community composition and tree population structure in undisturbed and disturbed tropical semi-evergreen forest stands of North-East India. Appl Ecol Envi Res 7: 303-318.

Majumdar K, Shankar U, Dutta BK. 2012. Tree species diversity and stand structure along major community types in lowland primary and secondary moist deciduous forests in Tripura, Northeast India. JFore Res23 (4): 553-568. DOI: 10.1007/s11676-012-0295-8

Mani S, Parthasarathy N. 2006. Tree diversity and stand structure in inland and coastal tropical dry evergreen forests of peninsular India. Curr Sci 90: 1238-1246.

Margalef R. 1968. Perspectives in Ecological Theory. University of Chicago Press, Chicago. pp: 111.

Martin ME, Aber JD. 1997. High spectral resolution remote sensing of forest canopy lignin, nitrogen and ecosystem processes. Ecol Appli 7: 431-443. DOI: 10.1890/1051-0761(1997)007[0431:HSRRSO]2.0.CO;2

Meng J, Lu Y, Lei X, Liu G. 2011. Structure and floristics of tropical forests and their implications for restoration of degraded forests of China's Hainan Island. Trop Ecol52 (2): 177-191.

Mishra BP, Tripati OP, Laloo RC. 2005. Community characteristics of a climax subtropical humid forest of Meghalaya and population structure of ten important tree species. Trop Ecol 46 (2): 241-251.

Naidu MT, Kumar OA, Venkaiah M. 2014. Taxonomic diversity of lianas in tropical forests of northern Eastern Ghats of Andhra Pradesh, India. Not Sci Biol 6 (1): 59-65. DOI: 10.15835/nsb.6.1.9193

Naidu MT, Kumar OA. 2015. Tree species diversity in the Eastern Ghats of northern Andhra Pradesh. J Thre Taxa 7 (8): 7443-7459. DOI: 10.11609/JoTT.o3764.7443-59

Nandy S and Das AK. 2013. Comparing tree diversity and population structure between a traditional agroforestry system and natural forests of Barak Valley, Northeast India. Intl J Biod Scie Eco Syst Man 9: 104-113. DOI: 10.1080/21513732.2012.748691

Natarajan D, Britto SJ, Balagaru B, Nagamurugan N, Soosairaj S and Arockiasamy DI. 2004. Identification of Conservation priority sites using remote sensing and GIS – A case study from Chitteri hills, Eastern Ghats, Tamil Nadu. Curr Sci 86: 1316-1323.

Nizam MS, Jeffri AR, Latiff A. 2013. Structure of tree communities and their association with soil properties in two fan-palm dominated forests of east coast Peninsular Malaysia. Trop Ecol 54: 213-226.

Palomino LR, Alvarez SIP. 2005. Tree community patterns in seasonally dry tropical forests in the Cerros de Amotape Cordillera, Tumbes, Peru. For Ecol Manag 209: 261-272. DOI: 10.1016/j.foreco.2005.02.003

Parthasarathy N, Sethi P. 1997. Tree and liana species diversity and population structure in a tropical dry evergreen forest in south India. Trop Ecol 38: 19-30.

Pielou EC. 1966. The measurement of diversity in different types of biological collections. J Theo Biol 13: 131-144. DOI: 10.1016/0022-5193(66)90013-0

Pragasan LA, Parthasarathy N. 2010. Landscape-level tree diversity assessment in tropical forests of southern Eastern Ghats, India. Flora 205: 728-737. DOI: 10.1016/j.flora.2010.04.011

Premavani D, Naidu MT, Venkaiah M. 2014. Tree species diversity and population structure in the tropical forests of north-central Eastern Ghats, India. Not Sci Biol 6 (4): 448-453. DOI: DOI: 10.15835/nsb.6.4.9382

Proctor J, Anderson JM, Chai P, Vallack HW. 1983. Ecological studies in four contrasting lowland rain forests in Gunug Mulu National Park, Sarawak. I-Forest environment structure and floristics. J Ecol 71: 237-360. DOI: 10.2307/2259975

Rao RS, Sudhakar S, Venkanna P. 1999. Flora of East Godavari District, Andhra Pradesh, India. INTACH, A.P. State Chapter, Hyderabad.

Raju VS, Krishna PG, Suthari S. 2014. Environmental assessment of climate of a habitat through floristic life-form spectra, a case study of Warangal north forest division, Telangana, India. J Nat Sci 2 (1): 77-93.

Reddy CS, Babar S, Amarnath G, Pattanaik C. 2011. Structure and floristic composition of tree stand in tropical forest in the Eastern Ghats of northern Andhra Pradesh, India. J For Res 22 (4): 491-500. DOI: 10.1007/s11676-011-0193-5

Reddy CS, Shilpa B, Giriraj A, Reddy KN and Rao KT. 2008. Structure and floristic composition of tree diversity in tropical dry deciduous forest of Eastern Ghats, Southern Andhra Pradesh, India. Asian J Sci Res 1 (1): 57-64. DOI: 10.3923/ajsr.2008.57.64

Sahu SC, Dhal NK, Dutt B. 2012c. Environmental implications of biological spectrum vis-à-vis tree species diversity in two protected forests (PFs) of Gandhamaran hill ranges, Eastern Ghats, India. Environmentalist 32: 420-432. DOI: 10.1007/s10669-012-9405-6

Sahu SC, Dhal NK, Mohanty RC. 2012a. Tree species diversity, distribution and population structure in a tropical dry deciduous forest of Malayagiri hill ranges, Eastern Ghats, India. Trop Ecol 53 (2): 163-168.

Sahu SC, Dhal NK, Reddy CS, Pattanaik C and Brahmam M. 2007. Phytosociological study of tropical dry deciduous forest of Boudh district, Orissa, India. Res J For 1: 66-72.

Sahu, SC, Dhal NK, Lal B, Mohanty RC. 2012b. Differences in tree species diversity and soil nutrient status in a tropical sacred forest ecosystem on Niyamgiri hill range, Eastern Ghats, India. J Mou Sci 9: 492-500. DOI: 10.1007/s11629-012-2302-0

Sathish BN, Viswanath S, Kushalappa CG, Jagadish MR and Ganeshaiah KN. 2013. Comparative assessment of floristic structure, diversity and regeneration status of tropical rain forests of Western Ghats of Karnataka, India. J Appl Nat Sci 5 (1): 157-164.

Shankar, U. 2001. A case of high tree diversity in a sal (*Shorea robusta*)-dominated lowland forest of Eastern Himalaya: floristic composition, regeneration and conservation. Curr Sci81: 776-786.

Shannon CE, Weiner W. 1963. The Mathematical Theory of Communication. University of Illinois Press. Urbana, U.S.A.

Simpson EH. 1949. Measurement of diversity. Nature163: 688.

Singh JS. 2002. The biodiversity crisis: a multifaceted review. Curr Sci 82: 638-647.

Steege HT, Sabatier D, Castellanos H, Van Andel T, Duivenvoorden J, de Oliviera AA, Ek R, Lilwah R, Maas P and Mori S. 2000. An analysis of the floristic composition and diversity of Amazonian forests including those of the Guiana Shield. J Trop Ecol 16: 801-828. DOI: 10.1017/S0266467400001735

Subrahmanyam VP. 1982. Eastern Ghats region, vegetation and climatic aspects. Proceedings of the seminar on resources, documentation, and environment on the Eastern Ghats. 26pp.

Sukumar R, Dattaraja HS, Suresh HS, John R, Joshi NV. 1992. Long-term monitoring of vegetation in a tropical deciduous forest in Madumalai, southern India. Curr Sci 62: 608-616.

Sundarapandian SM, Swamy PS. 2000. Forest ecosystem structure and composition along an altitudinal gradient in the Western Ghats, South India. J Trop For Sci 12: 104-123.

Svenning JC. 1999. Microhabitat specialization in a species-rich palm community in Amazonian Ecuador. J Ecol 87:55-65.

Upadhaya K, Pandey HN, Law PS, Tripathi RS. 2003. Tree diversity in sacred groves of Jaintia hills in Meghalaya, northeast India. Biodiver Conserv 12: 583-597. DOI: 10.1023/A:1022401012824

Visalaksi N. 1995. Vegetation analysis of two tropical dry evergreen forests in south India. Trop Ecol 36: 117-127.

Webb CO, Peart DR. 2000. Habitat associations of trees and seedlings in a Bornean rain forest. J Ecol 88: 464-478. DOI: 10.1046/j.1365-2745.2000.00462.x

Whitmore TC. 1990. An introduction to tropical rain forests. Oxford University Press, Oxford.

Williams-Linera G. 1990 Vegetation structure and environmental conditions of forest edges in Panama. J Ecol 78: 356-373. DOI: 10.2307/2261117

Wilson EO. 1988. The current state of biological diversity. In: Wilson EO. (ed.). Biodiversity. The National Academic Press, Washington, DC.

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Morphological characteristics and physical environment of *Terminalia catappa* in East Kalimantan, Indonesia

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Abstract. Marjenah, Putri NP. *2017. Morphological characteristics and physical environment of* Terminalia catappa *in East Kalimantan, Indonesia. Asian J For 1: 33-39.* Tropical almond (*Terminalia catappa*) is a large tree and is widely distributed throughout the tropics, especially in coastal environments. This plant has the potentials to be developed intensively as forestry commodity since the timber can be made into a useful and decorative general-purpose hardwood and is well suited for conversion into furniture and interior building timbers. Yet, there is limited knowledge on its ecological performance regarding the environments where it grows. Therefore, this research aimed to determine the growth of *T. catappa* in varying altitudinal ranges in three locations in East Kalimantan, Indonesia and to investigate the relationship among morphological characteristics and environmental factors. The results of statistical analysis showed that differences in altitudinal ranges had no significant effects on the growth of stem diameter, angle of branching, and width of canopy closure. Meanwhile, the analysis on stem height and radius of canopy showed highly significant differences. The exploration and characterization of *T. catappa* plants are still needed to reveal the potentials of its germplasm to be developed as forestry plants and not only for ornamental purposes.

Keywords: tropical almond, morphological characteristics, physical environment, flowering and fruiting,

INTRODUCTION

Tropical almond (*Terminalia catappa* L.) is a large tree and is widely distributed throughout the tropics especially in coastal areas. *T. catappa* belongs to the family Combretaceae (Combretum family) and is locally called 'Abrofonkate" (Whiteman's peanut). The tree is tolerant to strong winds, salt exposure, and moderately high salinity in the root zone. It grows principally in freely drained and well-aerated sandy soils.

The species has traditionally been very important for coastal communities, providing a wide range of non-wood products and services. It has a spreading, fibrous root system and plays a vital role in coastline stabilization. It is widely planted throughout the tropics, especially along sandy seashores for shade and ornamental purposes (Akpakpan and Akpabio 2012). The timber makes a useful and decorative general-purpose hardwood and is well suited for conversion into furniture and interior building timbers. The nuts are edible and fruits are produced from tree about 3 years of age, and the nutritious, tasty seed kernels may be eaten immediately after extraction (Thomson and Evans 2006). Its fruits and seeds have also medicinal properties

T. catappa is slightly deciduous during dry season, and in some environments may lose its leaves twice a year (Thomson and Evans 2006). Raju et al. (2012) recorded information that *T. catappa* changes foliage twice a year, once during February-March and the second during June-August, each time with the shedding leaves and new foliage puts forth.

It is a perennial tree reaching a height of 15-25 m and about 9 m in width of its symmetrical canopy. The leaves are arranged in close spirals. The leaf blade is simple broadly obovate, the leaf top is round and obtuse, gradually oval to a narrowing substrate base. The leaves change their color from green to red, yellow or gold and copper brown during the dry season and then they fell off. The greenish-yellow leaves are clustered in axillary spikes, small, and inconspicuous.

The plant forms layers of canopy and branches which bear clusters of fruits. It usually commences flowering within 2-3 years of out planting but this may vary with site and genotype (Oboh, et al. 2008). The fruits which consist of the epicarp, fleshy mesocarp, stony mesocarp, and fibrous endocarp enclosing the seed, and kernel are ovoid in shape, laterally compressed with various sizes and colors at maturity (Thomson and Evans 2006). The *T. catappa* tree has a conservative estimated yield of 75 kg of fruits per year, which has long been wasted in the field (Apata 2011).

The *T. catappa* tree produces fruits that pulp is fibrous, sweet, and edible when ripe. The fruit is widely eaten by children as forage snack with the nuts and seeds often discarded (Henn et al. 2014). In the Bahamas, children seek out the trees with the most palatable fruits and these are the ones with the most colorful skin and with reddish or pink tones extending through the flesh corky surface of the "nut" (Morton 1985).

The altitudinal distribution of plant species over the earth's surface could be described as phytogeography, which tends to reflect the dynamic trend of species richness and diversity. Such trend of amplitude does imply biological barrier that creates biotic difference on the natural biota with variation in the morpho-anatomical structures in relation to agro-climatic and environmental influences that dictate such macrophytic amplitude (Edwins-Wosu, et al. 2013). Variation in species richness in relation to species-latitude and species-area relationship with elevation has been known for over a century.

Several studies have found a decreasing trend in species richness with increasing elevation, whereas others found a hump-shaped relationship between species richness and elevation. This argument is further supported by the fact that landscapes are never static, and their elements are in permanent temporal and spatial flux. The elevation gradient in species richness pattern is commonly explained by similar factors such as climatic, productivity, and other energy-related factors (Wosu, et al. 2013).

In spite of the information on the phytogeographical trend of *T. catappa*, data on its ecological amplitude or diversity distribution are either not available or scanty. In light of this inadequacy, the objectives of this research were: (i) to determine the growth of *T. catappa* in varying altitudinal ranges, (ii) to investigate the relationship among morphological characteristics and environmental factors.

MATERIALS AND METHODS

Study period and area

This study was conducted from January to May 2017 in three locations in East Kalimantan Province, namely Balikpapan City, Samarinda City, and Kutai Kartanegara District to represent habitats with varying altitudes and environmental conditions.

One hundred and eighteen trees of *T. catappa* were randomly selected from the three locations. The trees selected as the research objects are trees that grow solitary planted on the roadside as shade plants because in East Kalimantan there is no stand of *T. catappa* that is planted as manmade forest.

Sampling procedure

At the sampling locations (Samarinda, Tenggarong, Balikpapan) 118 trees of *T. catappa* were determined as research objects. The sampling stages are as follows: (i) Determining the elevation of the site, measured as meter above sea level (m asl); (ii) Determining the sampled tree, measured as tree with minimum 10 cm in diameter at a height of 1.3 m from the ground; (iii) Measuring the width of the crown of the sampled tree which covers projections according to each of the four main points to the compass (North, South, East, and West); (iv) Observing the color of leaves; (v) Measuring length, width of leaves, petiole and leaf area.

Data collection

Morphological characteristics

Tree data were collected including location, height, diameter at breast height, canopy shape/width of header. Leaves data included leaf area, length, and width of leaves, leaf color (old, young), leaf texture, petiole angle, primary branch angle. Data of fruit were fruit shape, old fruit color, tip/base of fruit, diameter and length of fruit stalk (cm), period of flowering/fruit, length/width/circumference of fruit, fruit weight. Length and width of leaf measurements were taken using metric rule, leaf area using a square centimeter unit while weights were determined using a weighing balance.

Physical environmental characteristics

Observations/measurements of temperature and humidity of air in the field/under the canopy were done once in each sample tree using thermohydrometer; Measurement of light intensity is performed on every tree sample using Illuminometer. In each sample tree, we measured altitude of place and position, slope of land, and soil pH.

The altitudinal ranges where the *T. catappa* grew were grouped into 9 groups of elevation, namely: 0-10 m asl; 11-20 m asl; 21-30 m asl; 31-40 m asl; 41-50 m asl; 51-60 m asl; 61-70 m asl; 71-80 m above sea level; And 81 -> 90 m asl (Table 1).

Data analysis

All the data were presented as mean ± SD (standard deviation). Statistical comparisons were performed using Analysis of Variance (ANOVA with differences were considered significant at $p<0.05$.

RESULTS AND DISCUSSION

The research on *T. catappa* trees in the three locations obtained 118 trees occurred on the elevation from 0 to 90 m asl. The distribution of the sampled trees based on altitudinal ranges is presented in Table 1.

Table 1. The distribution of the sampled trees based on elevation (m asl)

Elevation (m asl)	Number of trees
0-10	17
11-20	30
21-30	20
31-40	15
41-50	4
51-60	15
61-70	5
71-80	5
81- > 90	7
Total	118

Variations in a plant can be observed from various aspects. One is a morphological feature that is easily observed by naked eye or is called macromorphologically. Macromorphological characters as taxonomic evidence have advantages. Although there are other taxonomic evidence, such as micromorphology, anatomy, biochemistry, etc., but they are generally uneven and completed for the taxon group, moreover they are not as detailed as they are, and also their numbers are inadequate, so their uses to construct a classification system are generally less efficient because they are difficult to coordinate. Therefore, for everyday purposes, the criteria of morphological characters continue to be the main focus of determination activities, the establishment, and the preparation of a practical classification system (Setyawan 1999). The variation of the morphological characteristics of *T. catappa* trees is shown in Table 2.

Results showed that there was a large variation in most of the characters examined. Leaf length ranged from 19.5 to 42.5 cm with a mean value of 29.7 cm, which is larger than that in South Western Nigeria with 8.58 cm to 17.3 cm with a mean 14.2 cm (Oboh, et al. 2008). The leaves of tropical almond tree are quite big. Usually, they are thick and leathery with an ovoid shape and glossy dark green color. Before shedding its leaves to survive the dry season, the Tropical almond tree will retract the valuable green pigmentation, leaving the leaves pinkish-reddish or yellow-brown (Figure 1).

Traditionally, only the fallen leaves of *T. catappa* are boiled or brewed as a drink (tea). These leaves have been used in folk medicine as an antidiarrheal and antipyretic in India, Philippines, and Malaysia. In Taiwan, it has been used to prevent liver tumors and to treat hepatitis (dos-Santos, et al. 2016)

Shedding of the leaves takes place twice a year, first on January/February/March and second, on July/August/ September. Such 'autumn leaves' are very rare in the tropics. After the crown is bare, all the twigs develop new leaves and the tree is fresh green. The tree then flowers after the new leaves have developed. According to Hayward (1990) about the flushing mark during flowering, especially from October to January, it is claimed that the reddish change and leaf-shedding was driven by drizzling rain due to relative humidity, although this relationship is not measured. *T. catappa* leaf color changes were identified during research activity and it is shown in Figure 2.

Along with the appearance of new leaves, generative shoots are also beginning to come out. Many tiny white flowers emerge on long spikes. The Almond tree produces drupe fruits, just like the true almond and many other famous plants, e.g. mango, date, and coffee. A drupe is a fruit characterized by having an outer fleshy part that wraps a shell inside containing a seed. In drupes, the hard shell, commonly referred to as pit, develops from the ovary wall of the flower. *Terminalia catappa* is andromonoecious and its inflorescences bear bisexual flowers at the bottom and staminate ones above. Three types of inflorescence occur and this classification is based on their length. Of all the three types of inflorescence, 30% bear only male flowers whereas the rest bears both bisexual and male flowers (Raju 2012).

Table 2. Range of variation in morphological characteristics of *Terminalia catappa* L. observed in this study.

Characters	Range	Mean ± SD
Leaf length (cm)	19.5-42.5	29.7 ± 5.4
Leaf width(cm)	10.3-21.0	16.1 ± 3.0
Leaf area (cm^2)	149.0-508.0	311.8 ± 105.5
Petiole length (cm)	1.0-3.5	1.9 ± 0.6
Fruit length (cm)	4.46-6.71	5.8 ± 0.6
Fruit width (cm)	3.32-4.19	3.9 ± 0.3
Fruit circumference 1 (cm)	10.65-15.50	14.0 ± 1.38
Fruit circumference 2 (cm)	9.8-12.55	11.0 ± 0.65
Fresh fruit weight (g)	16.43-30.55	25.0 ± 4.29
Dry seed weight (g)	5.06-7.33	6.0 ± 0.76
Number of fruit/kg	33-64	43 ± 9
Stem diameter (cm)	18.2-61.4	33.9 ± 11.7
Branching angle (^{O})	20-85	61 ± 20
Total height (m)	6.9-23.8	14.0 ± 5.0
Bole height (m)	1.1-6.6	3.0 ± 1.0
Canopy height (m)	2.7-21.3	11.0 ± 4.0
Canopy radius (m)	4.7-11.3	7.6 ± 1.5
Crown cover area (m^2)	67.9-397.6	188.1 ± 70.6

A B C

Figure 1. Phase of leaf color change (Photograph by Marjenah 2017). A. 7.5 GY 4/5: Dull green, B. 7.5 YR 7/8: Dull yellowish-orange, C. 7.5 RP 4/10: Strong red-purple

Figure 2. *Terminalia catappa* leaf color change identified during this research (Photograph by Marjenah 2017)

Figure 4. *Terminalia catappa* (Tropical almond tree) planted on the beach in Balikpapan, East Kalimantan, Indonesia (Photograph by Marjenah 2017)

The fruit is 4.46 to 6.71 cm length, 3.32 to 4.19 cm width, ellipsoid, more pointed at the apex than at the base, slightly flattened, with a prominent base around both sides and at the tip, whereby this form contributes to its ability to float in a long distance in the sea. A seed will be found inside the fruit and a fully ripe seed is edible. It tastes similar to almond, hence it is named like that. The seed is ready to eat when the fruit turns red. Just like many other fruits and berries, the almond tree fruit is green at first, then yellow, and finally red when ripe (Figure 3).

Table 3 shows the morphological variation of *T. catappa* plants based on the elevation of the growing site. From the result of statistical analysis of *T. catappa* morphological characteristics at various elevations, it is known that the growth of stem diameter, angle of branching, and width of canopy closure showed no significant results. Meanwhile, the analysis on stem height and radius of canopy showed highly significant results.

The effect of plant canopy on the microclimate is, directly and indirectly, related to the existence of crowns and stems. Branches and leaves reflect the sunray and absorb some of the solar radiation during the day, allowing less energy to reach the ground below the canopy (Arx 2012).

The trees that grew solitary in the open area (Figure 4) produce more seeds than those that grew in shaded areas. This extraordinary capacity to produce more beans is likely due to the availability of large amount of carbohydrates as a result of the high photosynthetic activity in the open area. The crops may be affected by environmental factors and this may limit the use of morphological characters especially since they tend to carry over the effect of climatic factors.

Elevation is one of the most influential factors on crop growth and yield. There is a close relationship between elevation and climate especially air temperature. The lower elevation the higher the air temperature. High or low air temperature is closely related to the irradiation conditions in the area. Light intensity acceptance as a growth factor is strongly influenced by this competition. The reduction of light intensity is usually followed by a decrease in the number of branches of the plant. Because of low light intensity, the plant grows higher, since the results of Photosynthesis used for establishment of branches are only in small amount, consequently, the number of branches is small too. Increasing light intensity will increase the process of photosynthesis in plants, because sunlight is a source of energy for photosynthesis.

Leaf area is the morphological characteristic commonly used to determine the development of the canopy. Leaf canopy structure, especially of leaf angle, is relative to vertical line. Plants with horizontal leaves proceed 30-40% of the light coming through each unit of index of leaf area, while the upright leaves can proceed 45-65% of the light. With leaves that are perpendicular to sunlight on bright sunlight, the growth rate of the crop will be theoretically enhanced by the spreading of the more evenly distributed light in the canopy with upright leaves (Goldsworthy and Fisher 1992).

The physical environmental variables based on elevation is shown in Table 4. Physical environment characteristics observed were light intensity, air temperature, relative humidity, soil temperature and pH.

Statistical analysis of physical environment characteristics of *T. catappa* trees based on elevation shows that the light intensity and relative humidity are not significant. On the other hand, air temperature, soil temperature, and pH are highly significant.

The average air temperature at the low elevation site was 29.8 ± 1.06ºC while in higher elevation areas (> 90 m asl) was 28 ± 1.4ºC. According to Ewusie (1990), air temperature decreased to follow altitude on high mountains. In the tropics, the average temperature decreases about 0.4ºC for every 100 m increase. The occurrence of decreased air temperature is related to escalation of elevation. The temperature difference is assumed that there are also differences in growth and phenological characteristics.

Groundwater and enough nutrients will cause an increase in metabolic activity of the plant. This will support the growth of the plant, so that the crop yield or quantity will increase. The process of photosynthesis, respiration, and transpiration will also increase (if there were no limiting factors) at higher temperatures. The air temperature will drop at a higher altitude.

Figure 3. Flower and fruit of tropical almond in Tenggarong, Kutai Kartanegara district, East Kalimantan, Indonesia (Photograph by Marjenah 2017)

Table 3. Morphological characteristics of *Terminalia* trees based on altitudinal ranges

Elevation (m asl)	Number of trees	Diameter (cm) range average	Angle of branching (º) range average	Height (m) range average	Radius of canopy (m) range average	Wide of canopy closure (m^2) range average
0-10	17	17.9-50.3	30-84	6.9-22.9	3.3-8.0	8.7-202.3
		30.5 ± 9.95	58.4 ± 19.70	15.7 ± 4.53	5.7 ± 1.43	80.1 ± 69.90
11-20	30	20.8-50.9	26-86	8.9-26.2	2.7-8.7	5.8-261.6
		30.7 ± 9.58	54.6 ± 19.78	16.8 ± 5.16	5.4 ± 1.95	102.8 ± 86.5
21-30	20	12.8-52.7	25-87	7.7-22.1	3.1-8.8	7.5-244.0
		26.7 ± 11.33	57.9 ± 23.01	13.8 ± 3.97	5.3 ± 1.63	78.3 ± 69.55
31-40	15	16.2-58.6	30-85	6.4-27.1	3.7-8.5	10.6-227.0
		30.3 ± 12.22	54.0 ± 18.42	16.1 ± 5.63	6.0 ± 1.65	104.7 ± 80.36
41-50	4	20.2-48.4	30-90	12.2-15.8	4.6-7.3	16.8-82.5
		28.6 ± 13.3	47.5 ± 28.7	14.3 ± 1.5	6.0 ± 1.3	44.6 ± 27.5
51-60	15	12.2-56.8	36.0-85.0	8.6-23.8	3.2-9.5	8.2-285.0
		32.3 ± 13.0	58.0 ± 16.5	15.9 ± 4.6	7.0 ± 2.0	159.5 ± 93.8
61-70	5	21.8-31.2	30-40	13.3-16.7	3.5-6.6	37.9-134.8
		25.6 ± 3.5	34.8 ± 4.1	14.8 ± 1.4	5.3 ± 1.3	91.1 ± 40.0
71-80	5	19.2-48.8	30-85	9.3-23.7	6.2-7.9	120.8-193.6
		31.0 ± 11.1	63.2 ± 26.2	15.4 ± 5.3	7.1 ± 0.8	158.4 ± 34.3
81-> 90	7	21.1-54.0	36-83	7.9-24.3	3.6-14.0	3.6-14.0
		32.9 ± 13.4	63.2 ± 23.1	14.7 ± 6.4	7.4 ± 4.1	203.7 ± 186.4
Fcal		1.25	0.10	8.48	10.91	0.002
Ftab(0.05)		2.45				
Ftab(0.01)		3.49				
Significance		ns	ns	**	**	ns

Table 4. Physical environment variables of *Terminalia catappa* growing site

Elevation (m asl)	Number of trees	Light intensity (%) range average	Air temperature (^{O}C) range average	Relative humidity (%) range average	Soil temperature (^{O}C) range average	pH Range average
0-10	17	12-53.2	28.8-31.4	72-95	26-28	6-9
		27.5 ± 10.38	29.8 ± 1.06	80.8 ± 12.1	27.2 ± 0.6	7.5 ± 1.5
11-20	30	26.8-59.1	28.9-34.1	81-90	27-31	5-10
		44 ± 14	29.7 ± 2.6	85.5 ± 14.4	27.9 ± 1.4	7 ± 2
21-30	20	14.8-39.2	26-35.1	76-90	27-28	5-10
		29 ± 7.2	28.3 ± 2.7	83 ± 9.9	27.3 ± 0.5	6.8 ± 1.5
31-40	15	12.2-70.9	26-33.1	74-82	26-32	5-12
		35.75 ± 20.1	28.8 ± 2.7	79.6 ± 3.3	27.7 ± 2	7.3 ± 2.4
41-50	4	12.1-38.9	28.1-30.7	72-79	27-28	6-8
		22.8 ± 11.8	29.1 ± 1.4	74.3 ± 4.0	27.3 ± 0.6	7 ± 0.8
51-60	15	11.5-40.8	26-31.6	76-92	27-31	4-11
		28.9 ± 9.2	28.8 ± 2.6	82 ± 7.7	28.2 ± 1.2	6.6 ± 2.6
61-70	5	18.7-23.8	27-31.6	71-90	26-28	4-9
		20.5 ± 2.3	28.8 ± 2.5	81 ± 9.5	26.8 ± 1.0	6 ± 2.4
71-80	5	18.3-30.6	27-29.5	71-86	26-29	5-8
		23.5 ± 5.2	28.6 ± 1.1	77.2-6.4	27.6 ± 1.3	6 ± 1.4
81-> 90	7	13.0-49.5	26-29	75-90	28-29	5-10
		30.0 ± 15.2	28 ± 1.4	80.6 ± 5.8	28.8 ± 0.5	7.5 ± 2.4
Fcal		0.14	21.86	0.72	20.90	23.37
Ftab(0.05)				2.45		
Ftab(0.01)				3.49		
Significance		ns	**	ns	**	**

The crops may be affected by environmental factors and this may limit the use of morphological characters especially since they tend to carry over the effect of climatic factors. Weather conditions affect seed production by influencing the formation of flower buds and existing flowers. High temperatures, sufficient light, and groundwater cause photosynthesis and accumulation of high carbohydrates and it is good for many seed productions. The long rainy season during the flowering season may decrease the production of seeds by inhibiting the spread of pollen, resulting in less pollination. Cloudy weather can cause falling on young fruits, as it reduces the activity of photosynthesis and lowers the supply of carbohydrates. Wetlands facilitate the absorption of nitrogen and other nutrients.

Soil temperature and pH are closely related to the growth of plant roots. Soil temperature greatly affects the ability of water absorption by plant roots. The absorption of water by the roots will increase as the soil temperature increases. Water absorption on tropical plants occurs at a temperature of 5-70 degrees Celcius. The distinction appears because of the ability of plant adaptation. Extremely high temperatures will lead to disruption of plants' physiological activity, e.g., stopping of photosynthesis, respiration, and enzymatic activity; so, the plants will require no water. Low soil temperatures will decrease the rate of roots water absorption, due to reduced transpiration, drastic soil temperature changes inflict water viscosity in cell membranes, therefore, it affects the physiological activity of root cells.

Soil pH in research area ranged from 4.0 to 12.0. According to Gardner (1991), soil pH beyond the 5.0-8.0 range potentially had a direct effect in preventing root growth. In such a range, as it is found in most field conditions, the influence is usually indirect. Soil pH of less than 6.0 increases Al, Mg, and Fe, which can be toxic, and can reduce root growth.

In conclusion, there is a difference in the characteristics of *T. catappa* plants due to differences in altitude and the size of photosynthetic parts of plants. The findings of this study imply that exploration and characterization of *T. catappa* plants are still needed to reveal the potential of its germplasm as well as the development of cultivation technology and the further processing of its production. The economic benefits of *T. catappa* trees are still unknown by the community, but the ecological benefit is known, e.g., as a shade plant. The fruits that are yellow to reddish when ripe are important for researcher to identify their specific functions. Therefore, ecological characterization, physiology, morphology, and even molecular of *T. catappa* plant is very necessary, especially since in Indonesia generally, and East Kalimantan especially, *T. catappa* is only planted as shade plants on the edge of the road. *T. catappa* has not been utilized as a forestry plant.

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REFERENCES

Akpakpan AE, Akpabio UD. 2012. Evaluation of proximate composition, mineral element and anti-nutrient in almond (*Terminalia catappa*) seeds. Res J Appl Sci 7 (9-12): 489-493. DOI: 10.3923/rjasci.2012.489.493

Apata DF. 2011. Effect of *Terminalia catappa* Fruit Meal Fermented by *Aspergillus niger* as Replacement of Maize on Growth Performance, Nutrient Digestibility, and Serum Biochemical Profile of Broiler Chickens. Department of Animal Production, University of Ilorin, Ilorin, Nigeria.

Arx GV, Dobbertin M, Rebetez M. 2012. Spatio-temporal effects of forest canopy on understory microclimate in a long-term experiment in Switzerland. Agric For Meteor 166-167 (2012): 144- 155. DOI: 10.1016/j.agrformet.2012.07.018

Dos-Santos OV, Lorenzo ND, Da Silva Lannes SC. 2016. Chemical, morphological, and thermogravimetric of *Terminalia catappa* Linn. Food Sci Technol Campinas 36 (1): 115-158. DOI: 10.1590/1678-457X.0090

Edwin-Wosu NL, Omara-Achong T, Nyannannyo BL. 2013. Ecogeographical amplitude and habitat of two species of Genus *Terminalia* (Combretaceae) in the Central Niger Delta Areas in Rivers State. J Appl Sci Environ Manag 17 (1): 75-80.

Goldsworthy PR, Fisher NM. 1992. The Physiology of Tropical Field Crops. (In Bahasa Indonesia. Translator: Tohari). Gadjah Mada University Press. Yogyakarta.

Hayward DF. 1990. The phenology and economic potential of *Terminalia catappa* L. in South-Central Ghana. Vegetatio 90: 125-131.

Henn JJ, McCoy MB, Vaughan CS. 2014. Beach almond (*Terminalia catappa*, Combretaceae) seed production and predation by Scarlet Macaws (*Ara macao*) and Variegated Squirrels (*Sciurus variegatoides*). Rev Biol Trop (Int J Trop Biol) 62 (3): 929-938. DOI: 10.15517/rbt.v62i3.14060

Morton JF. 1985. Indian Almond (*Terminalia catappa*) Salt-Tolerant, Useful, Tropical Tree with "Nut" Worthy of Improvement. Econ Bot 39 (2): 101-112. DOI: 10.1007/BF02907830

Oboh B, Ogunkanmi B, Olasan L. 2008. Phenotype diversity in *Terminalia catappa* from South Western Nigeria. Pakistan J Biol Sci 11 (1) 135-138. DOI: 10.3923/pjbs.2008.135.138

Raju AJS, Lakshmi PV, Ramana KV. 2012. Reproductive ecology of *Terminalia pallida* Brandis (Combretaceae), an endemic and medicinal tree species of India. Curr Sci 102 (6):-.

Setyawan AD. 1999. Status of the *Alpinia* genus taxonomy based on morphological characteristics, anatomy, and chemical essential oil content. BioSMART 1 (1): 31-40. [Indonesian]

Thomson LAJ, Evans B. 2006. *Terminalia catappa*. Species Profiles for Pacific Island Agroforestry. www.traditionaltree.org

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Vegetative structure, floristic composition and natural regeneration of a species in Ylat Forest, Meket Woreda, Northeastern Ethiopia

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Abstract. *Tegegne S, Workineh B. 2017. Vegetative structure, floristic composition and natural regeneration of a species in* Ylat Forest *in Meket Woreda,* Northeastern *Ethiopia. Asian J For 1: 40-53.* The high level of biodiversity comprised in natural forests in Ethiopia is threatened by various anthropogenic factors. Therefore, efforts to reveal biodiversity information are urgently required before such forests are gone. This study aimed to examine taxonomic richness, floristic composition and structure, and natural regeneration of vegetation in natural forest of Ylat in Meket Woreda, Northeastern Ethiopia. A systematic sampling design was used in this study to gather vegetation information. For each of the sampling sites, five transect lines totaling fifty-four primary plots with 400 m2 (20m × 20m) each were laid out to gather information on woody species along 200m line transects. A total of 60 vascular plant species belong to 41 families and 56 genera were identified of which 13 species (21.67%) were trees, 31 species (51.67%) bushes, 6 species (10%) climbers and 10 species (16.66) of herbs. Of all the families of woody plants, Lamiaceae was the family with the largest contribution of species (8.33%), followed by Fabaceae, Rosaceae, Solanaceae and Euphorbiaceae with 3 species (5%), then Sapindaceae, Aloaceae, Ranunculaceae, Poaceae, Oleaceae, Polygonaceae and Cucurbitaceae contains 2 species each (3.33%). A total of 2652 woody plant species individuals (1227.77 individual/ha) were found of with the most abundant was *Myrsine africana* with 405 individuals, while *Millettia ferruginea* had the lowest with 19 individuals. The total basal area was 1 m2 /ha and frequency of woody species was 258. The overall Shannon-Wiener diversity and evenness indices of woody species was 2.94 and 0.84, respectively, both are classified as high in diversity and distribution. The woody plant species having the highest importance value index (IVI) were *Erica arborea* (36.31%) followed by *Allophylus abyssinicus* (28.65) whereas *Hagenia abyssinica*, *Myrica salicifolia*, *Euphorbia tirucalli*, *Calpurnia aurea* were the lowest IVI and should be given conservation priority. Finally, this study showed that the population structure of most woody plant species in Ylat Timberland was in a great state of regeneration recruitment level.

Keywords: Floristic composition, vegetation structure, regeneration status, Ylat Forest

INTRODUCTION

Ethiopia is considered as one of the top twenty-five richest countries in the world in terms of biodiversity (WCMC 1994). Around 6000 species of higher plants are estimated, of which about 10% are endemic (Ensermu and Sebsebe 2014). At the level of Africa, Anon (1997a, b) states that Ethiopia has the fifth largest flora. The very heterogeneous flora and high endemism are considered to be caused by the diversity in climate, vegetation and terrain. A report from Kelbessa et al. (1992) indicated that six endangered endemic plant species are found in Ethiopia especially in the Ogaden region only, which is floristically the richest in endemism in Ethiopia.

Vegetation is defined as an assemblage of plants growing together in a particular location and characterized either by its component species or by the combination of structural and functional characters that determine the appearance or physiognomy of vegetation (Goldsmith et al. 1986). In some definitions, vegetation is referred exclusively to as a system of largely spontaneously growing plants, meaning that not all growing plants form vegetation. For instance, a sown cornfield or flower bed in a garden forms no vegetation, but the weeds surrounding such plants do form vegetation. A pine plantation will turn into vegetation after a few years of spontaneous growth of the pine trees. The complexities of vegetation arise from the great variation in altitude, temperature, humidity and rainfall (Woldu 1999).

The vegetation of Ethiopia is complicated. There is a variation from region to region; some regions of the country including in southern and southwestern parts of the countries are relatively richer in biodiversity than the other parts of the countries. Vegetation types in Ethiopia are also highly diverse, including Afroalphine and Sub Afroalphine, Dry evergreen montane forest and grassland, Moist evergreen montane forest, Evergreen scrub, Combretum Terminalia (broad-leaved) deciduous woodland, Acacia-Commiphora (small-leaved) deciduous woodland, Lowland semi-evergreen forest, The desert and semi-desert scrubland, and Riparian and swamp vegetation (Friis and Demissew 2001).

Ethiopia is also a very important center of crop genetic diversity and for this reason, it is one of the twelve Vavilovian centers (Vavilov 1951; Harlan 1969). It has a very high genetic diversity in four of the world's widely grown food crops (i.e., wheat, barley, sorghum and peas), in three of the world's most important industrial crops (i.e., linseed, cotton, castor bean), in the world's most important cash crop (coffee), and in food crops of regional and local importance (i.e., teff, finger millet, nug, sesame, enset) (EPA 1997).

However, the vegetation resources, including forests are being devastated at an alarming rate, due to a number of causes. The primary causes for the devastation of natural forests are agriculture (the expansion and the conversion of natural vegetation to farmland) and overexploitation for various purposes such as fuelwood, cultivation purpose, charcoal production, construction material and timber, uncontrolled utilization of natural founts (over-consumption). Additionally, forest fires, land degradation, habitat loss, drying of water bodies, soil erosion and fragmentation, invasive species, and wetland destruction (drying of water bodies) lead to the decline of forest and forest resources. All are accelerated by rapid human population growth which is at a rate of about 3%/yr. Bad management of stakeholders such as Zone, Woreda and Kebele rural and agricultural organizations also leads to the decline of natural high forests. If this situation continues unchecked, the natural forest will be gone in a few decades.

Deforestation and land degradation lead to ecological and socio-economic crises in Ethiopia (Lisanework 1987). The current rate of deforestation is 15000-20000 hectares per year (EFAP 1994). In case of the above factors, Ethiopia‘s forest area reduced from 16% in the 1950s and to 3.1% by 1982 (UNEP 1992). According to Yirdaw (1996), the annual loss of the highland montane forest areas of Ethiopia has been estimated between 160,000 and 200,000 ha.

Because of the rapid deforestation, forests plant and animal species that are important both at national and global levels are in the state of endangered now. This is mainly attributed to lack of proper conservation strategies and practices of forest and forest resources (Kelbessa et al. 1992). As the plant and animal species are lost from the area, the indigenous knowledge and associated practices will also be obscured and finally will be gone forever. Consequently, the danger certainly poses a major threat to the well-being of the population that depends on the biological resources of this ecosystem (Beyene 2010).

Most of the remaining natural forests in Ethiopia are found in the southern and south-western parts of the country, and the forests have virtually disappeared from the rest of the country except a few scattered and relatively small areas of forest cover that remained in the northern, central and eastern parts of the country (Gebre Egziabher 1986). Generally, the remaining forests are only small remnant patches mostly confined to inaccessible areas (e.g., mountain tops and steep slopes) and sacred places (e.g., churches, monasteries, and mosques) (Wassie et al. 2002). With the prevailing alarming rate of deforestation and other factors described above, the remaining natural forests could disappear within a few decades, unless appropriate and immediate measures are taken (Zegeye et al. 2010).

In Ethiopia, many ecosystems or habitats being important for biodiversity conservation are excluded from the country’s system of protected areas. Hillman (1993) described that some protected areas at different levels have been built by the government with a total extent of 193,600 Km^2 of land. The Wildlife Conservation Areas are divided into two main categories, namely Principal Wildlife Conservation Areas, which include nine National Parks and four Wildlife Sanctuaries, and Secondary Wildlife Conservation Areas (WCA) comprising eight Wildlife Reserves and eighteen Controlled Hunting Areas (CHA). But up to now, there is no formal protected area that has been built to conserve an ecosystem or habitat important for plant species although Ethiopia has high plant diversity (Tadesse 1991).

Various studies have been conducted in different parts of Ethiopia on the themes of population dynamics and regeneration ecology of forests (Demissew 1988; Alelign et al. 2007; Beyene 2010; Getaneh 2012). The outcomes of these works give relevant information on the rejuvenation status of numerous trees and bush species which are very important to perform suitable conservation and management measures. But up to now, there is no study carried out on the floristic composition and vegetative structure of Ylat Forest found in Amhara region North Wollo Zone Meket Woreda.

The objectives of this research were (i) to document the floristic composition of woody plant species of Ylat Forest, Meket Woreda, Northeastern Ethiopia, (ii) to describe the vegetative structure of the forest, and (iii) to evaluate the natural regeneration status of woody plant species of the forest.

MATERIALS AND METHODS

Description of the study area

Location and geographical features of the district

The study was carried out in October 2008 in the Ylat Forest in Meket Woreda, border of Boya and Kolla Boya Kebele. Meket Woreda is one of the twelve districts of North Wollo Zone Amhara regional state located at a distance of about 657 km from Addis Ababa, North East Ethiopia (Meket Woreda Communication Office) (Figure 1).

As the information gained from Meket Woreda Agricultural and Rural Office, the capital of the district is Filakit (found at 11º 35' 55" -12º 2' 30" N and 38º 32' 35" - 39º16'40" E) located on the main highway about 137 km west from Woldiya, the capital of North Wollo zone. The district is bordered on the North by Bugna, on the East by Gubalafto and Gidan, on the West by Gaynt and on the South by Wadla Woreda. The ranges altitude of the study area is 1699-3502 meters above sea level having 47 kebeles in which out of those 6 are urban kebeles.

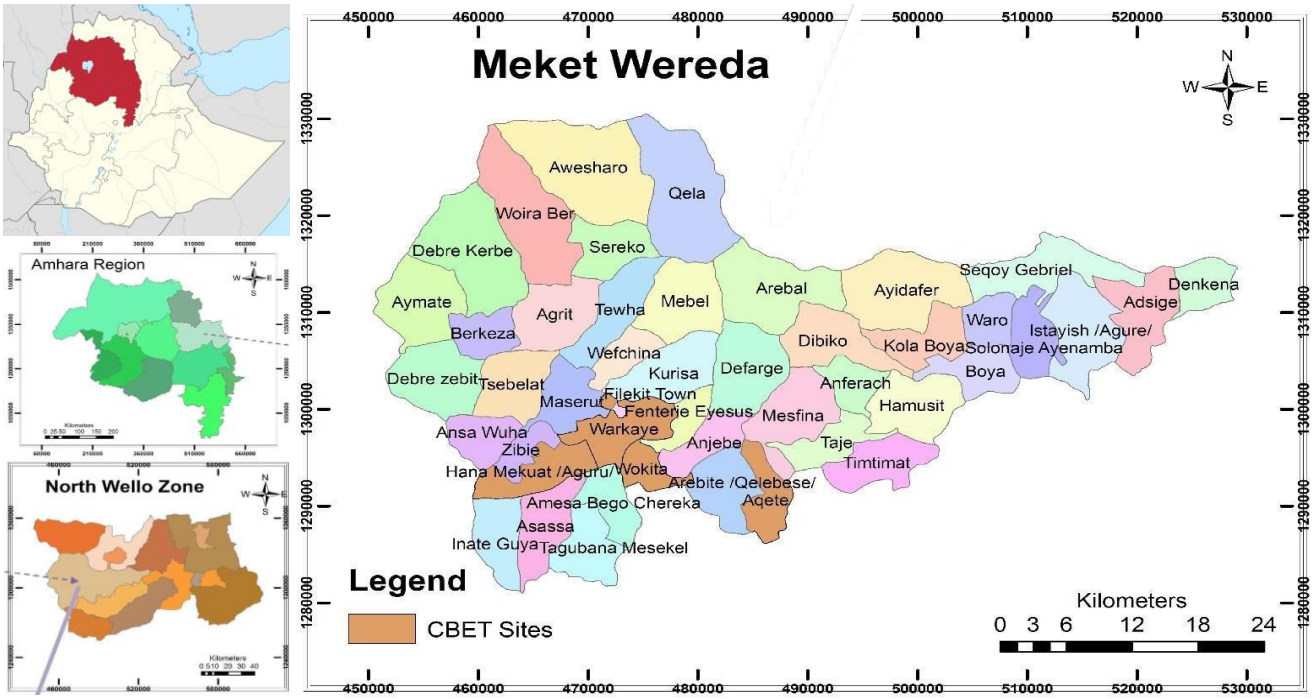

Figure 1. Map of the study area in Ylat Forest, Meket Woreda, North Wello, Amhara, Northeastern Ethiopia

Climate

The data from the head of the Meket Woreda Agricultural Office Ato Anteneh Alemie show that the study area is generally characterized by diverse agro-climatic zones; most of which are the "Kolla" and "Woyna dega" climates that are comparable to cold arid and warm to cool Sub-humid (semi-cold, semi hot-arid) climatic types respectively.

The mean minimum and maximum temperatures are 18 and 27.8ºc. In the district area, low temperature is recorded during July to 15 October, but sometimes in January, and is recorded when rain falls during autumn season. The high temperature is recorded from 15 February to 15June. The mean annual rainfall ranges from 900mm-1400mm. High rainfall is from June to August and low rainfall is during autumn season from March to May.

Topography and soil

The study area is generally characterized by rough topography. It consists of mountains and gorges. The district falls at an altitudinal range of 1699-3502 m.a.s.l. The major soil type and their spatial coverage in the district are Camisol (58.03%). Other soil types are also found in the study area including Litosol (12%), Roaksol (15.47%), Ntosol (6.12%) and Vertisol (15.47%).

Vegetation

The vegetation type of the Ylat Forest is indicated by patches of scattered plants like *Acacia albida*, *Dodonaea angustifolia*, *Bersama abyssinica*, *Mayte*nus *arbustifolia*, *Croton macrostachyus*, *Olea europaea*, *Myrsine africana*, *Juniperus procera*, and *Myrica salicifolia*. Previously, the forest-covered an area of about 102 km^2, but the forest had been declining due to various reasons such as agriculture expansion and cultivation, fuelwood, timber production, etc. Nowadays, the Ylat Forest is protected and it is the only forest conserved in the Meket Woreda.

Human population and social condition

According to the data obtained from Woreda information office, the total population of the observed district Meket Woreda was 273,000, among those 137,256 were males and 134,744 were females. All people in this area speak Amharic language (100%) and they belong to Amhara ethnic group. The two common religions embraced by these people are Orthodox (94.35%), Islam (4.95%), and 0.7% people embrace other types of religion.

The livelihood of the local people is predominantly based on subsistence agriculture. Agriculture activity is characterized by mixed cropping practices with the main principal crops of bean, pea, maize, teff, sorghum, barley, wheat and nug, and the cash crops including lentil and garlic (Meket Woreda Agricultural and Rural Development Office).

Wildlife

The information from kebele agricultural officer describes that the study area is generally poor in wildlife due to deforestation and high human interference. However, different kinds of wild animals are found, such as mammals (e.g., apes, monkeys, antelopes, common fox, leopards, rabbit, Ethiopian tiger, and hyena) and birds (e.g., jigra).

Methodology for data collection

Preliminary survey

To obtain vegetation patterns of the study area and to identify representative sampling sites about the forest, preliminary survey of Ylat Forest was conducted in October 2008. According to Panwar and Bhardwaji (2005), it is important to know the size of the vegetation as well as the number of plots to be laid out per hectare before data collection. In this case, 20 m x 20 m (400 m^2) plots were laid on the study area to collect the vegetation data. The data were collected from November to December 2008.

Sampling design (vegetation data collection)

A systematic sampling design was employed to collect vegetation data using line transect method described by Bullock (1996). In this method, parallel line transects were laid across the forests in west-east direction determined using compass. For each of the sampling sites, five transect lines each having 54 main plots were used to sample vegetation data. The first sampling point was established systematically which is 200 m away from each other. Plots having equal sizes of 20 m x 20 m (400 m^2) were laid out to collect the data on woody species. The distance between main plots was 200 m along each of the transect lines. The plot was made by using two measuring tapes bisecting at right angles in each center locating the four corners of the plot, and the square plot was fenced with a rope made from sack. The latitude, longitude and altitude were taken from the center of each main plot using a GPS (Global Positioning System). In each quadrat, all woody plant species with a DBH of ≥ 2.5 cm were measured and recorded.

In each quadrat, all the plant species were recorded. Data on Diameter at Breast Height (DBH) / Diameter at Shrub Height (DSH) of the trees or shrubs, number of stems, coverage of each tree/shrub and coverage of herbaceous composition were collected from total of 54 quadrats of 20 x 20m (400m^2). Diameters at Breast Height (DBH) ≥ 2.5 cm of trees and shrubs were measured by using diameter tape following the methods described by Cunningham (2001). Individuals of trees and shrubs with DBH < 2.5cm were counted as seedlings. New woody plant species occurring outside the sampling plots (quadrats) were also recorded to prepare a complete checklist of plants in the area. Diameter was measured for all individual trees and shrubs having DBH (Diameter at Breast Height) using a conventional tape-meter. Diameter of small and big trees was measured by using a caliper and diameter tape, respectively.

Specimens of all plant species were collected, stored and identified at the National Herbarium using Flora of Ethiopia and Eritrea.

Methods of data analysis

Structural data analysis

Density, frequency, diameter at breast height (DBH), dominance, importance value index (IVI) and basal area were analyzed to describe vegetation structure in all 54 sample plots.

Density is defined as the number of plants of a certain species per unit area. It is closely related to abundance but more useful in estimating the importance of a species. The counting is usually done in small plots placed several times into vegetation communities under study and the sum of individuals per species is calculated in terms of species density per convenient area unit such as a hectare (Mueller - Dombois and Ellenberg 1974).

$$D = \frac{\text{Number of above-ground stems of a species countered}}{\text{Sampled area in hectare(ha)}}$$

The relative density of the species is calculated by using the following formula.

$$RD = \frac{\text{Number of individual tree species}}{\text{Total number of individuals}} \times 100$$

Frequency is defined as the chance of finding a species in a particular study sample. According to Goldsmith et al. (1986), frequency is obtained by using quadrants and expressed as the number of quadrants occupied by a given species per number thrown or more often, as percentage. Higher frequency means higher importance of the plant in the community.

$$F = \frac{\text{Number of plots in which species occurred}}{\text{Total number of plots}} \times 100$$

The importance of a species within the frequency can be obtained by comparing the frequency of occurrences to the entire tree species present, and it is called the relative frequency and the formula is as follows:

$$RF = \frac{\text{Frequency of one species}}{\text{Total frequency}} \times 100$$

Dominance is the degree of coverage of species as an expression of the space at ground level (Mueller-Dombois and Ellenberg 1974). Dominance is measured in terms of cover or basal area. It is the mean basal area per tree times the number of tree species.

$$\text{Basal area} = \sum \pi (d/2)^2$$

Where:
d is diameter at breast-height and $\pi = 3.14$

Diameter at Breast Height (DBH) is carried out at about 1.3 m height from the ground using a measuring tape. It is easy, quick, inexpensive and relatively accurate. There is a direct relationship between DBH and basal area (Beyene 2010). Basal area is the area outline of a plant near ground surface. It is the cross-sectional area of tree stems at DBH.

Relative dominance is the ratio of dominance of individual tree species per dominance of all tree species. It will be calculated by the following formula:

$$RDO = \frac{\text{Dominance of individual tree species}}{\text{Dominance of all species}} \times 100$$

Importance Value Index (IVI) is used to calculate the significance of a plant species. In calculating this index, the percentage values of the relative frequency, relative density and relative dominance are summed up together and this value is designated as the Importance Value Index or IVI of the species (Kent and Coker 1992). As Lamprecht (1989) indicates that, it is useful to compare the ecological significance of species.

IVI = Relative density + Relative frequency + Relative dominance

Plant diversity analysis of plant species

The diversity of woody species (species richness and evenness) are determined using the Shannon-Wiener Diversity Index (H') and Evenness or Equitability Index (E) (Krebs 1999 and Barnes et al. (1998). Especially for Shannon-Wiener Diversity Index (H'), in addition to counting for species richness and evenness, it is not affected by sample size and it used to measure the degree of uncertainty, i.e., if the diversity is high in a given habitat, the certainty of observing a particular species is low (Kent and Coker 1992; Krebs 1999). Shannon-Wiener Equitability index (H') (the relative equitability or evenness) of the species in each cluster was calculated using Microsoft Excel. The species evenness that measures the equity of species in a samples area is represented by 0 and 1, which are equally abundant (Whittaker 1972). As Molles (2007) described that, it can be zero which is the value for a community with a single species and takes a maximum value of lnS for a given number of species (S), when the same number of individuals represents all species also increases as species richness and evenness increases.

Both the Shannon-Wiener Diversity Index (H') and Evenness or Equitability Index (E) are expressed as follows,

$$H' = \sum_{i=1}^{s} Pi \ln pi$$

Where,

H' is the Shannon-Wiener Diversity Index,

$\sum$ is sum of species from species 1 to species S,

Pi is the proportion of individual's abundance of the i^{th} species, S is number of species encountered

ln is natural logarithm in base e.

$$J = \frac{H'}{H'max} \times 100$$

Where:

H' max= ln S

H' is Shannon diversity index

lnS is the natural logarithm of the total number of species in each community

S is number of species in each community

RESULTS AND DISCUSSION

Floristic composition

In this study, 60 species of vascular plants representing 56 genera and 41 families were identified and recorded (Table S1). Out of the 60 identified plant species, 51.67% (31 species) were shrubs, 21.67% (13 species) were trees, 10% (6 species) were lianas and 16.66% (10 species) were herbs (Figure 2).

Out of the total families, 8.33% were Lamiaceae, 5% were Fabaceae, Rosaceae, Solanaceae, and Euphorbiaceae and 3.33% were Sapindaceae, Aloaceae, Ranunculaceae, Poaceae, Oleaceae, Polygonaceae, and Cucurbitaceae (Table 1).

Woody species

A total of 31 species belonging to 23 families and 31 genera with ≥ 2.5cm DBH of woody species individuals were recorded from 54 sample plots (2.16 ha). The highest number of species were Rosaceae, Solanaceae, Lamiaceae, and Fabaceae, followed by Euphorbiaceae and Sapindaceae. In total, 1227.77 individuals of woody plant species were recorded with *M. africana* as the highest of all woody species with 15.27% (Table S2).

Myrsine africana, Erica arborea and *Dodonaea angustifolia* were the dominant species consecutively. *M. salicifolia, Dombeya torrida, Capparis tomentosa, Millettia ferruginea* and *Euphorbia tirucalli were* some of the rare species within the plot. *E. arborea* and *Allophyllus abyssinicus* were the most common (most frequent) species in the sample plots in Ylat Forest.

Vegetation structure

Woody species density and DBH (Diameter at Breast Height)

The numbers of individuals which have DBH ≥ 2.5cm were 1227.77. *Myrsine aficana* had 15.27% of the total density followed by *E. arborea* (14.4%) and *Dodonaea angustifolia* (6.79%) (Table S2). These three woody species were the most dominant species. The least abundant species recorded were *M. salicifolia* (0.72%), *Dombeya torrida* (0.75%), *Capparis tomentosa,* and *Euphorbia trucalli* (0.9%) and *M. ferruginea* (1.02%). The mean density of woody species of the study vegetation was higher than Achera forest (1034.17 individuals per hectare) (Getaneh 2012).

Table 2 shows that 97.15% of woody species individuals were in ≤ 10cm DBH classes and about 2.85% were within 10 < 20cm DBH classes. An increase in DBH causes significant decrease in number of individuals. The Ylat Forest is composed of high proportion of small-sized woody species. *Opuntia ficus-indica* was the largest woody species with an average DBH 65.08 cm (Table 3 and Table S3).

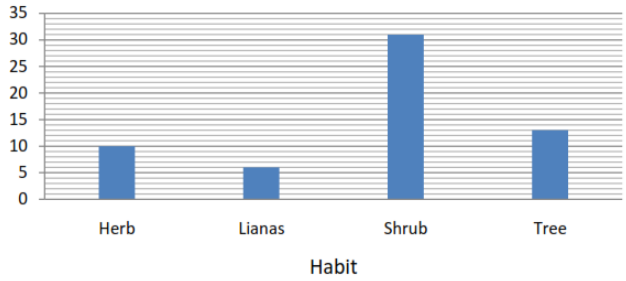

Figure 2. The plant habit (growth forms) in Ylat Forest, Meket Woreda, Northeastern Ethiopia. Note: Herbaceous includes herbs and grasses while woody species includes lianas, shrubs and trees

Table 1. Plant families with their genera and species distribution in Ylat Forest, Meket Woreda, Northeastern Ethiopia

Family	No. of Genera	% of Genera	No. of Species	% of Species
Lamiaceae	2	3.57	5	8.33
Fabaceae	3	5.36	3	5
Rosaceae	3	5.36	3	5
Euphorbiaceae	3	5.36	3	5
Solanaceae	3	5.36	3	5
Aloaceae	1	1.79	2	3.33
Ranunculaceae	2	3.57	2	3.33
Sapindaceae	2	3.57	2	3.33
Poaceae	2	3.57	2	3.33
Cucurbitaceae	2	3.57	2	3.33
Polygonaceae	2	3.57	2	3.33
Oleaceae	2	3.57	2	3.33
Acanthaceae	1	1.79	1	1.67
Loganiaceae	1	1.79	1	1.67
Capparidaceae	1	1.79	1	1.67
Apocynaceae	1	1.79	1	1.67
Sterculiaceae	1	1.79	1	1.67
Flacourtiaceae	1	1.79	1	1.67
Ericaceae	1	1.79	1	1.67
Myricaceae	1	1.79	1	1.67
Eubenaceae	1	1.79	1	1.67
Melianthaceae	1	1.79	1	1.67
Apiaceae	1	1.79	1	1.67
Balsamaminaceae	1	1.79	1	1.67
Cupressaceae	1	1.79	1	1.67
Malvaceae	1	1.79	1	1.67
Celasteraceae	1	1.79	1	1.67
Myrsinaceae	1	1.79	1	1.67
Asparagaceae	1	1.79	1	1.67
Convolvulaceae	1	1.79	1	1.67
Cactaceae	1	1.79	1	1.67
Santalaceae	1	1.79	1	1.67
Phytolaccaceae	1	1.79	1	1.67
Anacardiaceae	1	1.79	1	1.67
Salicaceae	1	1.79	1	1.67
Urticaceae	1	1.79	1	1.67
Scophulariaceae	1	1.79	1	1.67
Asteraceae	1	1.79	1	1.67
Guttiferaceae	1	1.79	1	1.67
Geraniaceae	1	1.79	1	1.67
Myrtaceae	1	1.79	1	1.67
Total	56	100	60	100

Table 2. Distribution of woody species in DBH classes

DBH (cm)	Density/ha	%
≤10	1192.77	97.15
10<20	35	2.85
20<30	0	0
30<40	0	0
>40	0	0

Table 3. Dominant woody species with their percentage basal area of Ylat Forest, Meket Woreda, Northeastern Ethiopia

Species	Density	Average DBH (cm)	BA/ha	Percentage
Opuntia ficus-indica	16.2	65.08	0.154	15.465
Acacia albida	60.65	64.09	0.149	14.98
Juniperus procera	59.26	62.23	0.141	14.14
Allophylus abyssincus	69.44	55.11	0.11	11
Erica arborea	176.39	49.97	0.091	9.12

Basal area

The total basal area of woody species was 1 m^2/ha (Table S4). *Opuntia ficus- indica* (15.465%), *Acacia albida* (14.98%) and *J. procera* (14.14%) were some of the highest basal area woody species. According to Dawins (1959; cited in Lamprecht 1989) the normal area of virgin tropical forest in Africa is 23-37m^2/ha. Based on the report, the basal area of Ylat Forest is low indicating the woody species are thin and scattered.

Opuntia ficus-indica has low density but highest basal area because of its high value of DBH while *E. arborea* has high density but low value of basal area because of its low value of DBH.

Frequency

The most frequent woody species in Ylat Forest were *E. arborea (*12.79%), *Allophylus abyssinicus (*12.02%) and *M. africana (*10.857%). The less frequent woody species were *E. tirucalli, Opuntia ficus-indica, Hagenia abyssinica, M. salicifolia* and *Withania semnifera* (Table S2).

Frequency indicates an approximate homogeneity and heterogeneity of species. Lamprecht (1989) pointed out that the high value in higher frequency and low value in lower frequency classes indicate constant or similar species composition whereas high value in lower frequency classes and low values in higher frequency indicates high degree of floristic heterogeneity. For convenience, the Ylat Forest woody species had been classified into four frequency classes (Table 4).

In the table, the result showed that there was high value in lower frequency classes and low values in higher frequency. This indicated that Ylat Forest had heterogeneous species composition. A similar result was also gotten from South Wollo zone, Yogof forest (Mohammed and Abraha 2013).

Table 4. Classification of Ylat Forest woody species, Meket Woreda, Northeastern Ethiopia

	Class frequency	Species frequency
A	31-40	2
B	21-30	3
C	11-20	6
D	1-10	22

Table 5. IVI of woody species of Ylat Forest, Meket Woreda, Northeastern Ethiopia

Scientific name	IVI
Erica arborea	36.31
Allophylus abyssinicus	28.65
Myrsine africana	27.61
Juniperus procera	27.49
Acacia albida	24.57
Eucalyptus globulus	20.02
Euclea racemosa subsp. *schimperi*	20.02
Opuntia ficus- indica	17.175
Dodonaea angustifolia	13.05
Hypericum revolutum	13.02
Discopodium penninervium	12.69
Otostegia tomentosa	7.14
Olea europaea subsp. *cuspidata*	6.82
Rhus retinorrhoea	6.19
Prunus Africana	4.71
Croton macrostachyus	4.23
Clerodendrum alatum	4.07
Salix subserrata	4.04
Capparis tomentosa	3.87
Carissa spinarum	3.52
Rosa abyssinica	3.52
Dombeya torrida	3.5
Withania somnifera	3.49
Clerodendrum myricoides	3.27
Dovyalis abyssinica	3.06
Osyris quadripartita	2.96
Millettia ferruginea	2.82
Calpurnia aurea	2.69
Hagenia abyssinica	1.74
Euphorbia tirucalli	1.5
Myrica salicifilia	1.285

Importance value index

McIntosh (1967) pointed out Important Value Index gives a more realistic figure of dominance from the structure standpoints. Lamprecht (1989) also noted that the IVI is useful to compare the ecological significance of species.

The result of IVI showed that *E. arborea* (12.09%), *A. abyssinicus* (9.59%), *M. africana* (9.2%), *J. procera* (9.17%), and Acacia *albida* (8.19) were plant species with the highest importance value index, while *M. salicifolia* (0.43%), *E. tirucalli* (0.5%), *H. abyssinica* (0.58%), *Calpurnia aurea* (0.9%) and *M. ferruginea* (0.96%) were species with the lowest importance value index.

The five most dominant woody species of Ylat Forest had 48.24% of the total importance value index (Table S5 and Table 5). Those dominant species were *E. arborea*, *A. abyssinicus*, *J. procera*, *M. africana* and *Acacia albida*. This result shows that much of IVI was attributed to few species. About 57.57% of woody species had IVI value less than 5 indicating the requirement for conservation management.

Species population structure

Dissimilar scheme of species population structure can indicate variation in population dynamics. The schemes are based on various size classes (DBH) and density. On the other hand, the variation could arise from inherent characters, interventions of human and livestock.

The six most significant values of woody species representing 33 species in Ylat Forest whose IVI value > 18 are illustrated in Figure 3. The population structure of *E. arborea*, *A. abyssinicus*, *J. procera*, *M. africana*, *Acacia albida*, and *Eucalyptus globulus* shows an inverted J curve population high number of individuals in the first DBH class by a progressive decrease in the number of individuals with increasing DBH. This scheme indicates good rejuvenation and recruitment. This successful regeneration might be associated with its environmental adaptation. As diameter increases, the density of this species also increases.

Regeneration status of the Ylat Forest

The counting of the composition and the density of seedlings and saplings of woody species were done in Ylat Forest. The number and type of seedlings and saplings in any vegetation cover shows the regeneration status of that vegetation cover. Accordingly, a total of 1339.83 seedlings/ha, 1319.45 saplings/ha and 1227.77 mature individuals/ha were recorded. From the analysis of seedlings and saplings data, the density of tree was 604.74/ha and shrub seedlings were 735.09/ha. Similarly, the densities of trees and shrub species saplings were 627.32/ha and 692.13/ha respectively (Figure 4).

The ratio of seedlings to mature individuals of woody species in Ylat Forest was 1.09:1, the ratio of seedlings to saplings was 1.02:1 and sapling to mature individuals was 1.07:1. This result shows the presence of more seedlings than saplings and saplings than mature woody species, which indicates successful regeneration of forest species.

The woody species in the study area were categorized into two groups based on the number of seedlings and saplings encountered during the study (Table 6). From this study, *E. arborea*, *J. procera*, *M. africana* and *Acacia albida* had highest number of saplings/ha. *E. arborea*, *M. africana*, *Dodonaea angustifolia* and *Discopodium penninervium* had the highest number of seedlings/ha in the study area (Table S6). The composition, distribution and density of seedlings and saplings indicate the future status of the vegetation cover. Woody species in category "B" needs priority of conservation.

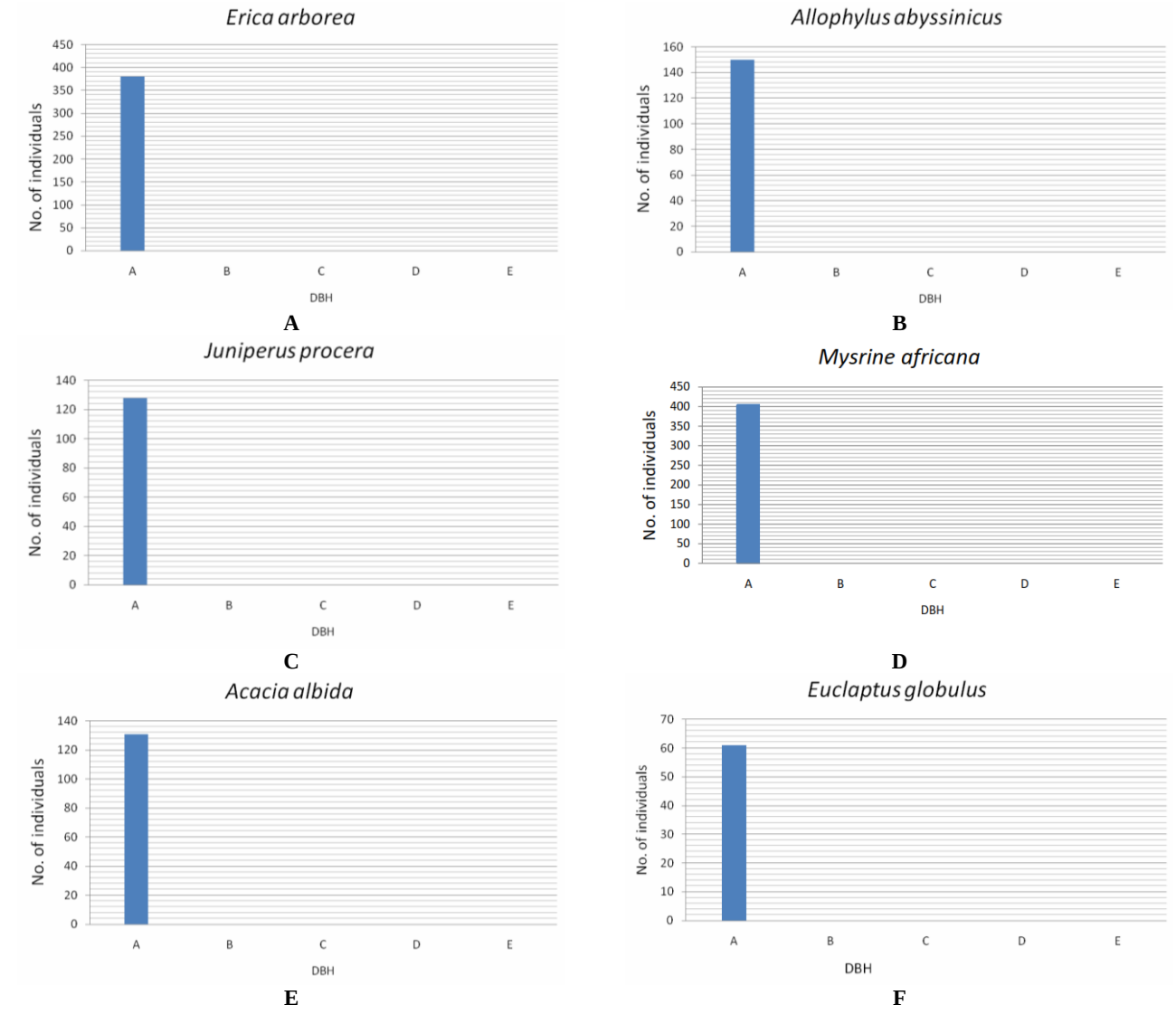

Figure 3. Population structure of six most important woody species in Ylat Forest, Meket Woreda, Northeastern Ethiopia. DBH A: 2.5-10cm, B: 10.1-20cm, C: 20.1-30cm, D: 30.1- 40cm, E: > 40cm

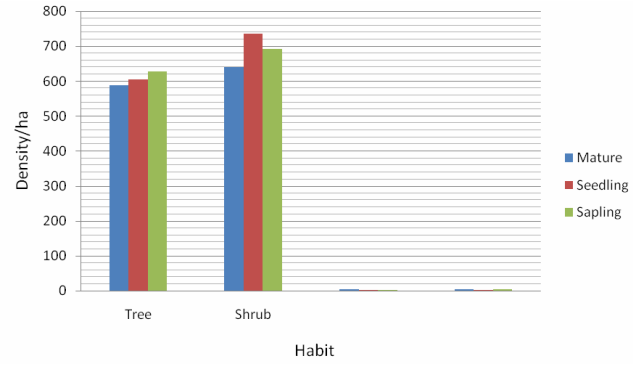

Figure 4. Seedling and sapling distribution of woody species of Ylat Forest, Meket Woreda, Northeastern Ethiopia

Species diversity and evenness

The diversity and evenness of woody species in Ylat Forest are relatively high. It is indicated by the Shannon-Wiener diversity index of 2.94 and evenness index of 0.84. According to Kent and Coker (1992), Shannon-Wiener index value varies between 1.5 and 3.5 and to exceed 4 is rare. Thus, the result of the present study showed that the Ylat Forest has a balanced species distribution, indicated by the relatively high value of Shannon-Wiener diversity index (H'=2.94), which is more diverse than of Menagesha Suba State forest (H'=2.57) (Beche 2011).

Table 6. The regeneration status of different woody plant species in Ylat Forest, Meket Woreda, Northeastern Ethiopia

Group	Species
A	*Acacia albida*
	Allophylus abyssinicus
	Calpurnia aurea
	Capparis tomentosa
	Carrisa spinarum
	Clerodendrum alatum
	Clerodendrum myricoides
	Croton macrostachus
	Discopodium penninervium
	Dodonaea angustifolia
	Dovyalis abyssinica
	Erica arborea
	Eucalyptus globulus
	Euclea racemosa subsp. *schimperi*
	Euphorbia tirucalli
	Hagenia abyssinica
	Hypericum revolutum
	Juniperus procera
	Millettia ferruginea
	Myrica salicifolia
	Myrsine africana
	Olea europaea subsp. *cuspidata*
	Opuntia ficus-indica
	Osyris quadripartita
	Prunus africana
	Rhus retinorrhoea
	Rosa abyssinica
	Salix subserata
	Withania somnifera
B	*Dombeya torrida*
	Otostegia tomentosa

Note: Group "A" = species with ≥ 1 seedlings and saplings and Group "B" =species no seedlings and saplings at all.

The presence of higher species diversity was indicated by the analysis of floristic composition, vegetative structure and regeneration data on Ylat Forest between altitudinal gradients of 1699-3502 m. The counting activity found a total of 60 species belonging to 41 families and 56 genera. The collection activity in Ylat Forest yielded 1227.77 individual ha^{-1} woody plant species. And it is also found that there was high value of woody plant species in first frequency classes, low value in the next frequency classes, a simple decline in the last frequency class. Therefore, this indicated that the Ylat Forest had heterogeneous species composition. From the overall distribution DBH classes, in Ylat Forest, high contribution of woody plant species in the lower Diameter Basal Height classes and lower plant contribution in the higher classes or as the DBH class size increases, the number of individuals gradually decrease which stimulates an ordinary inverted J-shaped distribution. It brings to an indication that small-sized individuals dominate the forest and allegedly due to selective cutting of large tree individuals for agriculture (farm implements), charcoal production and building houses (construction purpose). Yet, the forest remains in the status of good regeneration with high recruitment potential. The data analysis on the structure of woody plant species of Ylat Forest revealed that the density of seedling (1339.83 individual ha^{-1}) and sapling (1319.45 individual ha^{-1}) were relatively higher than the value on the mature (1227.77 individual ha^{-1}). Although, the seedling and sapling individuals died before reaching maturity due to the different factors, but this still brought up a good status of the vegetation cover in the future and a priority for conservation should be given.

REFERENCES

Wassie A. 2002. Opportunities, Constraints and Prospects of the Ethiopian Orthodox Tewahido churches in Conserving Forest Resources: The case of churches in South Gonder, Northern Ethiopia. [Thesis]. Swedish University of Agricultural Sciences.

Alelign A, Teketay D, Yemshaw Y, Edwards S. 2007. Diversity and Status of Regeneration of Woody Plant Species on the Penisuila: Diversity and Status of Regeneration of Woody Plant Species on the Penisuila of Zegie, Northeastern Ethiopia. [Thesis]. Addis Ababa University, Addis Ababa.

Anonymous.1997a National conservation strategy phase I report. Ethiopian Environmental Authority, Addis Ababa, Ethiopia.

Anonymous. 1997b. Conservation strategy of Ethiopia. Environmental Protection Authority Addis Ababa, Ethiopia.

Barnes BV, Zak DR, Denton, SR, Spurr SH. 1998. Forest Ecology. 4th ed. John Wiley and Sons, New York.

Bullock J. 1996. Plants. In: Sutherland WJ (ed.). Ecological Census Techniques: A Handbook. Cambridge University Press, Cambridge.

Cunningham AB. 2001. Applied Ethnobotany: People, Wild Plant Use and Conservation. Earthscan, London.

Beche D. 2011. Floristic composition, diversity and structure of woody plant species in Menagesha Suba State Forest, Central Ethiopia. MSc. Thesis Addis Ababa, Ethiopia.

Kelbessa E, Demissew S, Woldu Z, Edwards S. 1992. The status of some plants in parts of tropical Africa. In: Edwards S, Zemede A (ed). Some Threatened Endemic Plants of Ethiopia. East and Central Africa: NAPRECA, No.2. Botany 2000, Addis Ababa, Ethiopia.

EPA [Environmental Protection Authority]. 1997. Conservation strategy of Ethiopia. Environmental Protection Authority, Addis Ababa.

EFAP [Ethiopian Forestry Action Program]. 1994. Ethiopian Forestry Action Program (EFAP). Ethiopian Forestry Action Program, Addis Ababa, Ethiopia.

Gebre-Egziabher TB. 1986. Ethiopian vegetation - Past, present and future trends', SINET: Ethiopian J Sci 9 (suppl): 3-13.

Yirdaw E. 1996. Deforestation and Forest Plantations in Ethiopia. In: Palo PM, Mery G (eds.) Sustainable Forestry Challenges for Developing countries. Kluwer, Dordrecht.

Friis I, Demissew S. 2001. Vegetation maps of Ethiopia and Eritrea. A review of existing maps and the need for a new map for the Flora of Ethiopia and Eritrea. Kongelige Danske Videnskabelige Selskabs Biologiske Skrifter 54: 399-439.

Goldsmith FB, Harrison CM, Morton AJ. 1986. Description and analysis of vegetation. In: Moore PD, Chapman SB. (eds.), Methods in Plant Ecology. 2nd ed. Alden Press, Osney.

Getaneh H. 2012. Floristic Composition, Structure and Regeneration Status of Woody Plant Species of Achera Forest, North West Ethiopia. Bahir Dar, Ethiopia.

Hillman JC.. 1993. Ethiopia: Compendium of Wildlife Conservation Information. The Wildlife Conservation Society International, New York

Kent M, Coker P. 1992. Vegetation Description and Analysis. Belhaven Press, London.

Krebs, C.J. 1999. Ecological Methodology. Harper and Row, New York.

Lamprecht H. 1989. Silvi culture in the tropics-tropical forest ecosystem and their tree species possibilities and methods for their long term utilization, verlagsyesells chaft mbh pustach1164. Federal Republic of Germany, Bonn.

Molles JrMC. 2007. Ecology Concepts and Applications. McGraw-Hill, Inc., New York.

McIntosh RP. 1967. An index of diversity and the relation of certain concepts to diversity. Ecology 48: 392-404. DOI: 10.2307/1932674

Tadesse M. 1991. A survey of the evergreen forests of Ethiopia. NAPRECA Monograph Series No. *2*: 1-18.

Mueller-Dombois, D. and Ellenberg, H. 1974. Aims and methods of vegetation Ecology. John Wiley & Sons, London.

Lisanework N. 1987. An ecological study of the vegetation of Harenna forest. [Thesis]. Addis Ababa University, Ethiopia.

Panwar P, Bhardwaji SD. 2005. Hand Book of practical forestry. Agro bios, Jodhpur,

Demissew S. 1988. The floristic composition of the Menagesha State Forest ana the need to conserve such Forests in Ethiopia. Mountain Res Dev 8 (2/3): 243-24. DOI: 10.2307/3673454

Beyene S. 2010. Floristic composition and structure of Yangudirassa national park vegetation, Northeastern Ethiopia. [Thesis]. Addis Ababa University, Ethiopia.

Muhammed S, Abraha B. 2013. Floristic composition and structure of Yegof Mountain Forest, south Wollo, Ethiopia. Woldia University and Bahir Dar University, Ethiopia

UNEP. 1992. World Atlas of Desertification. United Nations Environmental Program. London.

Vavilov NI. 1951. The Origin, Variation, Immunity and Breeding of Cultivated Plants. Ronald Press, New York.

WCMC. 1994. Priorities for conserving global species richness and endemism. World Conservation Press, Cambridge.

Whittaker RH. 1972. Evolution and measurement of species diversity. Taxon 21: 213- 225. DOI: 10.2307/1218190

Woldu Z. 1999. Forests in the vegetation types of Ethiopia and their status geographical context. In: Edwards S, Demissie A, Bekele T, Haase G (eds.), Forest Genetic Resource Conservation: Principles, Strategies and Processing of the National Forest Genetic Resources Conservation Strategy Development Workshop, 21-22 June 1999; Institute of Biodiversity Conservation and Research (IBCR) and the German Technical Co-operation (GTZ); Addis Ababa, Ethiopia.

Zegeye H. 2010. Environmental and Socio-Economic Implications of *Eucalyptus* in Ethiopia. In: Gil L, Tadesse W, Tolosana E, López R. (eds.). Proceedings of the Conference on Eucalyptus Species Management, History, Status and Trends in Ethiopia, Adis Ababa, Ethiopia, September 15th-17th, 2010.

Table S1. Plant species, family and growth habits recorded from Ylat Forest, Meket Woreda, Northeastern Ethiopia

Scientific name	Family	Habit
Acacia albida Del.	Fabaceae	Tree
Acanthus sennii Chiov.	Acanthaceae	Shrub
Allophylus abyssinicus (Hochst.) Radlk.	Sapindaceae	Tree
Aloe berhana Reynolds	Aloaceae	Herb
Aloe pulcherrima Gilbret and Sebsebe	Aloaceae	Shrub
Anthoxanthum aethopicum I. Hedberg	Poaceae	Herb
Asparagus africanus Lam.	Asparagaceae	Shrub
Bersama abyssinica Fresen.	Melianthaceae	Shrub
Buddleja polystachya Fresen.	Loganiaceae	Shrub
Calpurnia aurea (Ait.) Benth.	Fabaceae	Shrub
Capparis tomentosa Lam	Capparidaceae	Shrub
Carissa spinarum L.	Apocynaceae	Shrub
Clematis simensis Fresen.	Ranunculaceae	Lianas
Clerodendrun alatum Gürke	Lamiaceae	Shrub
Clerodendrum myricoides (Hochst.) Vatke	Lamiaceae	Shrub
Clutia abyssinica Jaub. & Spach.	Euphorbiaceae	Shrub
Croton macrostachyus Del.	Euphorbiaceae	Tree
Cucumis ficifolius A.Rich.	Cucurbitaceae	Herb
Discopodium penninervium Hochst.	Solanaceae	Shrub
Dodonaea angustifolia L.f.	Sapindaceae	Shrub
Dombeya torrida (J.F.Gmel.) P. Bamps	Sterculiaceae	Tree
Dovyalis abyssinica (A.Rich.) Warb.	Flacourtiaceae	Shrub
Erica arborea L.	Ericaceae	Shrub
Euclaptus globulus Labill	Myrtaceae	Tree
Euclea racemosa Murr. Subsp. *schimperi* (A.DC.) White	Eubenaceae	Shrub
Euphorbia tirucalli L.	Euphorbiaceae	Tree
Ferula communis L.	Apiaceae	Herb
Geranium arabicum Forssk.	Geraniaceae	Herb
Hagenia abyssinica (Brace) J.F. Gmel.	Rosaceae	Tree
Hibiscus crassinervius Hochst. ex A. Rich	Malvaceae	Shrub
Hypericum revolutum Vahl	Guttiferaceae	Tree
Hyparrhenia variabilis Stapf	Poaceae	Herb
Impatiens rothii Hook.f.	Balsaminaceae	Herb
Inula confertiflora A. Rich.	Asteraceae	Shrub
Ipomoea tenuirostris Choisy	Convolvulaceae	Lianas
Jasminum grandiflorum L.	Oleaceae	Lianas
Juniperus procera Hochst.ex Endl.	Cupressaceae	Tree
Maytenus arbitufolia (A. Rich) Wilczek	Celastraceae	Shrub
Millettia ferruginea (Hochst.) Bak.	Fabaceae	Shrub
Myrica salicifolia A. Rich.	Myricaceae	Shrub
Myrsine africana L.	Myrsinaceae	Tree
Olea europaea L. subsp. *cuspidata* (Wall. ex G.Don) Cif.	Oleaceae	Tree
Opuntia ficus-indica (L) Miller	Cactaceae	Shrub
Osyris quadripartita Decn.	Santalaceae	Tree`
Otostegia integrifolia Benth.	Lamiaceae	Shrub
Otostegia tomentosa A. Rich.	Lamiaceae	Shrub
Otostegia tomentosa A. Rich subsp ambigens (Chiov.) Sebald	Lamiaceae	Shrub
Phytolacca dodecandra L He rit.	Phytolaccaeae	Lianas
Prunus africana (Hook. f.) Kalkm.	Rosaceae	Tree
Rhus retinorrhoea Oliv.	Anacardiaceae	Shrub
Rosa abyssinica Lindley	Rosaceae	Shrub
Rumex nepalensis Spreng.	Polygonaceae	Herb
Rumex nervosus Vahl	Polygonaceae	Shrub
Salix subserrata Willd.	Salicaceae	Shrub
Solanum marginatum L.f.	Solanaceae	Shrub
Thalictrum rhynchocarpum Dill. & A. Rich.	Ranunculaceae	Herb
Urera hypselodendron (A. Rich) Wedd.	Urticaceae	Lianas
Verbasicum sinaiticum Benth.	Scrophulariaceae	Herb
Withania somnifera (L.) Dunal	Solanaceae	Shrub
Zehnera scabra (Linn. f.) Sond.	Cucurbitaceae	Lianas

Table S2. Woody species, number of stems, density and frequency of Ylat Forest, Meket Woreda, Northeastern Ethiopia

Scientific name	No. of stems	Density	Density/ha (%)	r. density	Freq.	r. freq (%)
Acacia albida	131	60.65	4.94	4.94	12	4.65
Allophylus abyssinicus	150	69.44	5.65	5.65	31	12
Calpurnia aurea	35	16.2	1.32	1.32	3	1.16
Capparis tomentosa	24	11.11	0.9	0.9	2	0.78
Carissa spinarum	48	22.22	1.81	1.81	3	1.16
Clerodendrum alatum	66	30.56	2.49	2.49	2	0.78
Clerodendrum myricoides	45	20.83	1.69	1.69	2	0.78
Croton macrostachyus	30	13.89	1.13	1.13	2	0.78
Discopodium penninervium	144	66.67	5.43	5.43	12	4.65
Dodonaea angustifolia	180	83.33	6.79	6.79	10	3.89
Dombeya torrida	20	9.26	0.75	0.75	6	2.33
Dovyalis abyssinica	34	15.741	1.28	1.28	3	1.16
Erica arborea	381	176.39	14.4	14.4	33	12.79
Eucalyptus globulus	61	28.24	2.3	2.3	25	9.7
Euclea racemosa subsp. *schimperi*	51	23.61	1.92	1.92	2	0.78
Euphorbia tirucalli	24	11.11	0.9	0.9	1	0.39
Hagenia abyssinica	28	12.963	1.06	1.06	1	0.39
Hypericum revolutum	141	65.28	5.32	5.32	9	3.49
Juniperus procera	128	59.26	4.83	4.83	22	8.52
Milettia ferruginea	27	12.5	1.02	1.02	4	1.55
Myrica salicifolia	19	8.796	0.72	0.72	1	0.39
Myrsine africana	405	187.5	15.27	15.27	28	10.85
Olea europaea subsp. *cuspidata*	44	20.37	1.66	1.66	13	4.04
Opuntia ficus-indica	35	16.2	1.32	1.32	1	0.39
Osyris quadripartita	47	21.76	1.77	1.77	2	0.78
Otostegia tomentosa	96	44.44	3.62	3.62	8	3.1
Prunus africana	37	17.3	1.41	1.41	5	1.93
Rhus retinorrhoea	89	41.204	3.36	3.36	6	2.3
Rosa abyssinica	42	19.44	1.58	1.58	4	1.55
Salix subserrata	57	26.39	2.15	2.15	4	1.55
Withania somnifera	33	15.28	1.24	1.24	1	0.39
Total	2652	1227.77	100		100	258

Table S3. DBH range of woody species of Ylat Forest, Meket Woreda, Northeastern Ethiopia

Scientific name	Diameter at Breast Height (cm)			
	1-10	11-20	21-30	>40
Acacia albida	131	0	0	0
Allophylus abyssinicus	150	0	0	0
Calpurnia aurea	35	0	0	0
Capparis tomentosa	24	0	0	0
Carissa spinarum	48	0	0	0
Clerodendrum alatum	66	0	0	0
Clerodendrum myricoides	45	0	0	0
Croton macrostachyus	30	0	0	0
Discopodium penninervium	144	0	0	0
Dodonaea angustifolia	180	0	0	0
Dombeya torrida	20	0	0	0
Dovyalis abyssinica	34	0	0	0
Erica arborea	381	0	0	0
Eucalyptus globulus	61	0	0	0
Euclea racemosa subsp. *schimperi*	51	0	0	0
Euphorbia tirucalli	24	0	0	0
Hagenia abyssinica	28	0	0	0
Hypericum revolutum	141	0	0	0
Juniperus procera	128	0	0	0

Millettia ferroginia	27	0	0	0
Myrica salicifolia	19	0	0	0
Myrsine africana	405	0	0	0
Olea europaea subsp. *cuspidata*	44	0	0	0
Opuntia ficus-indica	0	35	0	0
Osyris quadripartita	47	0	0	0
Otostegia tomentosa	96	0	0	0
Prunus africana	37	0	0	0
Rhus retinorrhoea	89	0	0	0
Rosa abyssinica	42	0	0	0
Salix subserrata	57	0	0	0
Withania somnifera	33	0	0	0
Total	2617	35	0	0

Table S5. Importance Value Index (IVI) of each woody species of Ylat Forest, Meket Woreda, Northeastern Ethiopia resulted from the sum of relative density, relative frequency and relative dominance

Scientific name	**r. density**	**r. freq**	**r. dom**	**IVI**
Acacia albida	4.94	4.65	14.98	24.57
Allophylus abyssinicus	5.65	12	11	28.65
Calpurnia aurea	1.32	1.16	0.21	2.69
Capparis tomentosa	0.9	0.78	2.19	3.87
Carissa spinarum	1.81	1.16	0.55	3.52
Clerodendrum alatum	2.49	0.78	0.8	4.07
Clerodendrum myricoides	1.69	0.78	0.42	3.27
Croton macrostachyus	1.13	0.78	2.32	4.23
Discopodium penninervium	5.43	4.65	2.61	12.69
Dodonaea angustifolia	6.79	3.89	2.37	13.05
Dombeya torrida	0.75	2.33	0.417	3.5
Dovyalis abyssinica	1.28	1.16	0.617	3.06
Erica arborea	14.4	12.79	9.12	36.31
Eucalyptus globulus	2.3	9.7	8.02	20.02
Euclea racemosa subsp.. *schimperi*	1.92	0.78	1.53	4.23
Euphorbia tirucalli	0.9	0.39	0.21	1.5
Hagenia abyssinica	1.06	0.39	0.29	1.74
Hypericum revolutum	5.32	3.49	4.21	13.02
Juniperus procera	4.83	8.52	14.14	27.49
Milltettia ferruginea	1.02	1.55	0.25	2.82
Myrica salicifolia	0.72	0.39	0.175	1.285
Myrsine africina	15.27	10.85	1.49	27.61
Olea europaea subsp. *cuspidata*	1.66	4.04	1.12	6.82
Opuntia ficus-indica	1.32	0.39	15.465	17.175
Osyris quadripartita	1.77	0.78	0.41	2.96
Otostegia tomentosa	3.62	3.1	0.42	7.14
Prunus africana	1.41	1.93	1.37	4.71
Rhus retinorrhoea	3.36	2.3	0.53	6.19
Rosa abyssinica	1.58	1.55	0.39	3.52
Salix subserrata	2.15	1.55	0.34	4.04
Withania somnifera	1.24	0.39	1.86	3.49
Total	100	100	100	300

Table S4. Basal Area (BA) and dominance of woody species in Ylat Forest, Meket Woreda, Northeastern Ethiopia

Scientific name	BA	BA/ha	BA%	Mean BA	total no.	Dominancy	r. dominancy
Acacia albida	0.322	0.1491	14.98	0.002458	131	0.322	14.98
Allophylus abyssinicus	0.2384	0.1104	11	0.001589	150	0.2384	11
Calpurnia aurea	0.0045	0.002083	0.21	0.00012857	35	0.0045	0.21
Capparis tomentosa	0.04712	0.0218	2.19	0.0001963	24	0.04712	2.19
Carissa spinarum	0.011934	0.005525	0.55	0.00024862	48	0.011934	0.55
Clerodendrum alatum	0.0172	0.007963	0.8	0.0002606	66	0.0172	0.8
Clerodendrum myricoides	0.00894	0.0041375	0.42	0.000199	45	0.00894	0.42
Croton macrostachyus	0.0499	0.0231	2.32	0.001663	30	0.0499	2.32
Discopodium penninervium	0.05621	0.02602	2.61	0.0003903	144	0.05621	2.61
Dodonaea angustifolia	0.051	0.02361	2.37	0.000283	180	0.051	2.37
Dombeya torrida	0.00897	0.00415	0.417	0.0305	20	0.00897	0.417
Dovyalis abyssinica	0.013267	0.006142	0.617	0.0003902	34	0.013267	0.617
Erica arborea	0.1961	0.091	9.12	0.000515	381	0.1961	9.12
Eucalyptus globulus	0.1724	0.0798	8.02	0.00283	61	0.1724	8.02
Euclea racemosa subsp. *schimperi*	0.033	0.01528	1.53	0.000647	51	0.033	1.53
Euphorbia tirucalli	0.0046	0.00212	0.21	0.00019166	24	0.0046	0.21
Hagenia abyssinica	0.0062	0.00285	0.29	0.0002214	28	0.0062	0.29
Hypericum revolutum	0.09054	0.042	4.21	0.000642	141	0.09054	4.21
Juniperus procera	0.304	0.141	14.14	0.002375	128	0.304	14.14
Millettia ferroginia	0.0054	0.002481	0.25	0.0002	27	0.0054	0.25
Myrica salicifolia	0.00377	0.00175	0.175	0.0001984	19	0.00377	0.175
Mysrine africina	0.032	0.0148	1.49	0.000079	405	0.032	1.49
Olea europaea subsp. cuspidata	0.024	0.012	1.12	0.000535	44	0.024	1.12
Opuntia ficus-indica	0.3325	0.15394	15.465	0.0095	35	0.3325	15.465
Osyris quadripartita	0.0089	0.004157	0.41	0.0001911	47	0.0089	0.41
Otostegia tomentosa	0.009122	0.004223	0.42	0.000095	96	0.009122	0.42
Prunus africana	0.0294	0.0136	1.37	0.000795	37	0.0294	1.37
Rhus retinorrhoea	0.01145	0.0053	0.53	0.00012865	89	0.01145	0.53
Rosa abyssinica	0.00834	0.00386	0.39	0.0001985	42	0.00834	0.39
Salix subserrata	0.00722	0.003343	0.34	0.000127	57	0.00722	0.34
Withania somnifera	0.04	0.02016	1.86	0.00133	33	0.04	1.86
Total	2.15	1	100		0.0587	2652	2.15

Table S6. The regeneration status of woody plant species in Ylat Forest, Meket Woreda, Northeastern Ethiopia

Scientific name	**Seedlings/ha**	**Saplings/ ha**
Acacia albida	66.203	67.13
Allophylus abyssinicus	49.17	27.315
Calpurnia aurea	28.241	35.19
Capparis tomentosa	32.41	50.463
Carissa spinarum	17.593	58.33
Clerodendrum alatum	30.55	27.3
Clerodendrum myricoides	29.17	28.704
Croton macrostachyus	31.02	34.26
Discopodium penninervium	73.61	14.352
Dodonaea angustifolia	75.463	60.65
Dombeya torrida	0	0
Dovyalis abyssinica	45.83	43.52
Erica arborea	185.65	157.41
Eucalyptus globulus	30.0926	25
Euclea racemosa subsp. *schimperi*	13.426	18.06
Euphorbia tirucalli	63.89	65.74
Hagenia abyssinica	30.093	31.944
Hypericum revolutum	47.69	57.87
Juniperus procera	53.24	75.93
Millettia ferruginea	12.5	9.722
Myrica salicifolia	43.43	61.574
Myrsine africina	79.17	71.2963
Olea europaea subsp. *cuspidata*	43.06	42.13
Opuntia ficus-indica	68.06	61.57
Osyris quadripartita	34.26	37.5
Otostegia tomentosa	0	0
Prunus africana	44.44	40.741
Rhus retinorrhoea	46.759	45.37
Rosa abyssinica	18.98	19.91
Salix subserrata	24.074	22.685
Withania somnifera	21.76	27.78
Total	1339.83	1319.45