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Introduction

Moving on!

Dear Lyonia readers,

This will be my last issue of Lyonia to publish. After three years as Editor-in-Chief of Lyonia it is time for me to move on to new tasks.

In the last three years, Lyonia changed from an infrequently published in-house journal, to an internationally recognized online journal with multiple issues per year.

The quality of manuscripts submitted to Lyonia is excellent. Lyonia's focus on tropical ecology and sustainable development attracts a large number of contributions. The journal is read especially widely in the tropical countries of our world, with the highest percentage of its readers coming from Latin America.

There is always room for improvement however, and I hope that Lyonia is going to become even better under its new Editor-in-Chief. For now, Dr. Cliff Morden, Interim Director of Lyon Arboretum, will take over this position.

I wish to thank all members of the Editorial Board, all reviewers, and of course, all contributers, who have helped to make Lyonia a successful online journal in a very short time.

Regards,

Rainer Bussmann

Editorial Board

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Rainer Bussmann

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Editorial Board

What is Lyonia?

What is Lyonia?

Lyonia is an electronic, peer-reviewed, interdisciplinary journal devoted to the fast dissemination of current ecological research and its application in conservation, management, sustainable development and environmental education. Manuscript submission, peer-review and publication are entirely handled electronically. As articles are accepted they are automatically published as "volume in progress" and immediatelly available on the web. Every six months a Volume-in-Progress is declared a Published Volume and subscribers receive the table of Contents via e-mail.

Lyonia seeks articles from a wide field of disciplines (ecology, biology, anthropology, economics, law etc.) concerned with ecology, conservation, management, sustainable development and education in mountain and island environments with particular emphasis on montane forest of tropical regions.

In its research section Lyonia published peer-reviewed scientific papers that report original research on ecology, conservation and management, and particularly invites contributions that show new methodologies employing interdisciplinary and transdisciplinary approaches. The sustainable development and environmental education section contains reports on these activities.

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Phenology of species of moist deciduous forest sites of Similipal biosphere reserve

Phenology of species of moist deciduous forest sites of Similipal biosphere reserve

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Phenology of species of moist deciduous forest sites of Similipal biosphere reserve

Abstract

Vegetative and reproductive phenology of 57 overstorey and 33 understorey species was studied in a tropical moist deciduous forest of Similipal Biosphere Reserve (SBR) located in Orissa state in India. A prominent peak in leaf drop, leaf flush and flowering of overstorey species occurred in March, April and April to May, respectively. However the peak period of such phenological events in understorey species is slightly different than over storey species. The peak fruiting period of both overstorey and understorey species are same i.e. from May to June. The fruiting phenology follows closely the flowering phenology. Fruit fall culminates before or just at the beginning of the monsoon season and, thus, ensures availability of sufficient moisture to seeds for germination and seedling establishment. Leaf drop, leaf flush and flowering both in overstorey and under storey species have been triggered by changes in day length and temperature, which indirectly signifies that soil moisture availability may have shaped the phenological patterns of both overstorey and understorey species. The phenological information obtained both for overstorey and understorey species in the present study is mostly influenced by the seasons and would be useful for planning proper management strategies in Similipal biosphere reserve to sustain regeneration development .
Key words: Degree of disturbance, Fruiting, Flowering, Leaf flushing, Phenological activity, Seasonality.

Introduction

Phenology is the study of the timing of recurring biological events, among phases of the plant species, which provide a background for collecting and synthesizing detailed quantitative information on rhythms of plant communities. Tropical plants with their high level of species diversity display phenological events such as leaf drop, leaf flushing, flowering and fruiting, etc. in relation to time and space (Justiniano and Fredericksen, 2000; Singh and Singh, 1992). Study of such events is useful in evolving proper management strategy as well as better understanding of natural forest regeneration potential and community level interactions (Fox, 1976). Studies from different parts of the world have shown that climatic factors are mainly responsible for vegetative and reproductive phenology at both community and species level. But phenology of the tropical forest tree species is not well understood although water stress is most frequently cited as a primary factor responsible for the timing of phenological events (Singh and Singh, 1992). However , various phenological events are triggered by rainfall, water availability, temperature, photoperiods, duration of dry spell and change in day length (Bhat and Murali, 2001; Hamann, 2004; Sivaraj and Krishnamurthy, 2002).

The tropical forests have a distinctive array of species different from temperate and rain forests. It supports different varieties of overstorey and understorey plant species, which are major food resources for a variety of biota (Bhat and Murali, 2001). In India extensive reports are available on phenological studies of tropical tree species in forest ecosystems of Central Himalaya (Ralhan et al., 1985a, b; Sundriyal, 1990), northeastern India (Shukla and Ramakrishnan, 1982; Kikim and Yadav, 2001), Western Ghats (Bhat and Murali, 2001) and Eastern Ghats (Sivaraj and Krishnamurthy, 2002). However the phenological pattern of tree species of Similipal Biosphere Reserve(SBR), which is included under Eastern Ghats has not yet been worked out. Therefore the present study aims at analyzing the phenological pattern of tree species to understand their response to climatic factors and the periodicity of seasons.

Description of study sites

The study was conducted in northern tropical moist deciduous forests of Similipal in Mayurbhanj district of Orissa (210 28/ to 220 08/ N latitude and 860 04/ to 860 37/ E longitude). It is a tract of hilly terrain with gentle slopes and broad valleys at altitudes ranging from 80 to 869m. The soil of all the forest sites is reddish in colour and loam to sandy loam in texture. The soil is slightly acidic in nature with pH ranging from 5.23 to 6.52 and average monthly soil moisture content varies from 18.13 to 40.25 % (Fig.1).

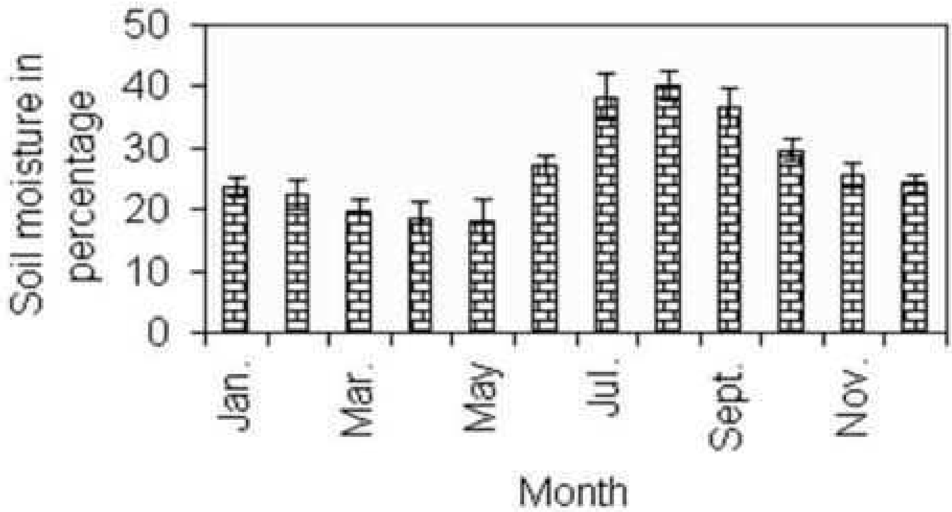

Fig. 1. Average monthly soil moisture content of Similipal biosphere reserve

Figure 1

The climate of the area is monsoonal and divisible into three seasons; summer (March-June), rainy (July- October) and winter (November-February). The climatic description is based on temperature and rainfall. The average annual rainfall varies from 28.11 to 395.96 mm, and is largely restricted to the period from July to October. Pre-monsoon showers are received during May and June. Post monsoon showers are received during November and December. The mean maximum temperature varies from 16.39 C (December) to 35.03 C (June) and mean minimum temperature from 5.7 C (January) to 21.57 C (June) (Fig.2). The natural vegetation is moist deciduous type (Champion and Seth, 1968) and is dominated by *Shorea robusta*, *Anogeissus latifolia*, *Buchnania lanzan*, *Dillenia pentagyna*, *Syzygium cumini* and *Terminalia alata*. Saxena and Brahmam (1989) have given details of the floristic of SBR. Table 1 summarizes the salient features of the study sites.

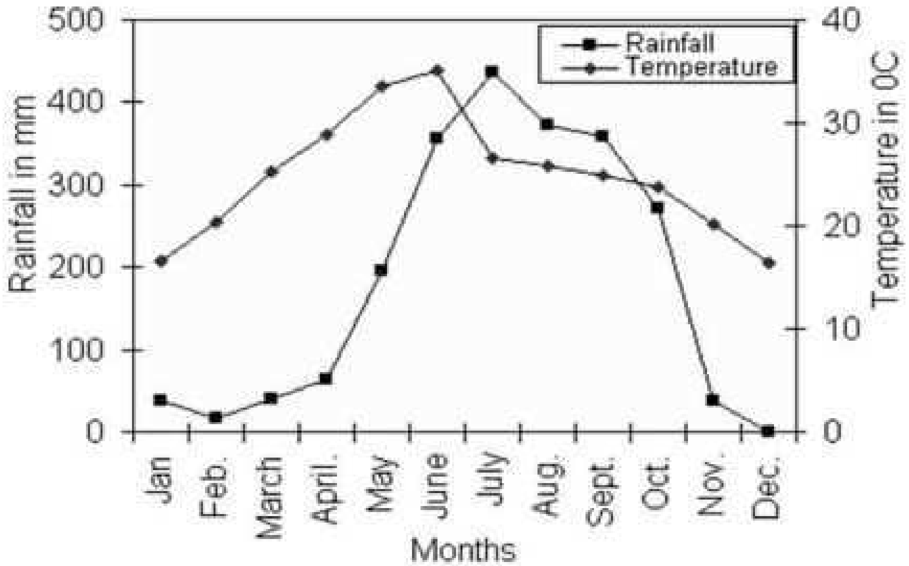

Fig.2. Rainfall and temperature data for the study period(2003-04)

Figure 2

Table 1: Characteristic features of study sites

Site	Elevation	Aspect	Density (Plants/ha)	Basal area (m2/ha)	Normal trees	Damaged trees	Total (Normal +Damaged)	D.I. (%)	L.I.
Podadiha	80	South-East	680	52.36	109	84	193	43.52	HB
Bangirposi	226	East	675	59.54	107	81	188	43.68	HB
Handipuhan	280	West	715	48.71	111	96	207	46.38	HB
Ghodabindha	557	West	650	49.13	105	82	187	43.85	HB
Chahala	774	North	875	88.59	168	29	197	14.72	NB
Nigirdha	830	North	985	85.07	190	38	228	16.67	NB
UBK*	824	South	970	84.86	186	36	222	16.22	NB
Jenabil	869	South	895	104.92	175	31	206	15.05	NB

L.I. - Level of Interference
D.I. (Disturbance Index) = Percentage of damaged individuals of the total number of woody individuals per 2000 m2 area.
*UBK- Upper Barakamda
HB- High biotic interference; NB- No biotic interference

Materials and Methods

Eight one-hectare permanent study plots were selected inside the Similipal Biosphere Reserve. Four of the eight one-hectare plots were situated in buffer zone while the other four were situated in the biotically undisturbed zone (core zone). All the overstorey and understorey woody plants having cbh (Circumference at breast height, 137cm) of > >31cm were enumerated in each study plot. The plants were identified following Saxena and Brahmam (1994-96) and Haines (1925). Phenological observations were made on 90 species from eight sites along biotically disturbed and undisturbed gradient, determined on the basis of protection afforded to each forest site, which is reflected through the tree density, basal area and disturbance index of each study site. Individuals of each of the 90 species were marked and tagged for each species. Whenever the required number of individuals was not available inside the permanent plot, additional individuals in adjacent area were also marked. Besides, observations on large populations by taking additional similar stands were also made to alleviate replication deficiency. If a given phenophase was observed in 5-10 percent individuals of a species, it was considered to have initiated. For each tagged tree, records were made on leaf drop, leaf flushing, flowering and fruiting. The duration of activity and phenological behaviour of tree species were determined following the method given by Opler et al. (1980).

The phytosociological characters such as density and basal area of individual species were quantified using standard quantitative methods (Muller-Dombois and Ellenberg, 1974). For measuring disturbance index, the physical condition of each individual tree present inside the 10 x 10 m2 quadrat was noted under normal and damaged categories. The trees involved under normal categories were the healthy individuals. The damaged category included the individuals that were partly broken at the top, partly dry or were green fallen. The individuals that were standing dead, dead cut stump and completely dry were also taken into consideration. Because such plants create problems in identification only numbering was done. All tree species were divided into two categories: (i) Overstorey species consists of canopy and subcanopy trees with a height of > > 10m and (ii) understorey species with < < 10m. Evergreen species continually produce at least small amount of new leaves throughout the year and do not show heavy leaf fall at a concentrated period whereas deciduous species has a marked leaf fall and leaf flushing at a concentrated period of the year.

Duration and pattern of activity

Both brief and extended activity was observed for the periodicity of leaf flushing, flowering and fruiting activity by individuals of a species population. Brief activity extends for 2 weeks or less while extended activity refers to periods more than 2 weeks. A more or less continuous flowering and fruiting activity throughout the year is referred to as continuous activity. The term seasonal and extended activity refers to flowering/fruiting occurs during a given period and extending into more than one period respectively. Marginal activity refers to species that have their activity occurring during transition period of seasonal changes. When some individuals of a tree species are in flowering/fruiting simultaneously is referred to as synchronous activity (S). The species showing flower/fruit development during a distinct period is known as asynchronous (A).

Fruit maturation activity

There are 2 categories of fruiting activity i.e. rapid and lengthy. Rapid (r) can be characterized as fruit maturation periods of 4 months or less following fertilization and those more than 4 months is termed as lengthy (L).

Results and Discussion

Out of 90 species, 52 were deciduous (32 overstoreys and 20 understoreys), 21 were semi-evergreen (17 overstoreys and 4 understoreys) and 17 were evergreen species (8 overstoreys and 9 understoreys). The forest does not maintain its green appearance throughout the year because majority of the species are deciduous in this forest. However in the wet months of July to October deciduousness of the forest is not so conspicuous due to reduced leaf fall in comparison to the drier and cool months. The general phenological stages of all species are presented in Table 2 (over storey species) and Table- 3 (under storey species). Their seasonal phenological behaviours have been discussed under leaf drop, leaf flushing, flowering and fruiting activities.

Table 2: Phenology of overstorey woody tree taxa of SBR

Name of the plant species	VT	Leaf drop	Leaf flushing	Flowering	Fruiting

Anogeissus latifolia	D	3 (r) A	4 (e)	6-9 (eA)	12-1, 3 (eRM)
Adina cordifolia	D	2-3 (r) A	4 (e)	6-7 (eA)	2-5 (eR)
Aegle marmelos	D	3-4 (r) A	5 (e)	3-4 (eA)	5-6 (eR)
Albizia procera	SE	5-6 (r) S	6(e)	8-9(eA)	12,1,2,3,4,5(eL)
Albizia marginata	E	1-2 (r) A	3(e)	5-6(eA)	10-4 (eL)
Albizia lebbeck	D	1 (r) A	4(e)	2-4(eS)	3-6(eR)
Alangium salvifoila	D	1-2 (r) A	3(e)	2-5(eS)	3-5(eR)
Anthocephalus cadamba	E	1-12/3-4*(l) S	-	5-7(eA)	8-10(eR)
Buchanania lanzan	D	12,1 (r) S	1(e)	2-3(eS)	3-4(eR)
Bridelia retusa	E	1-12/3-4*(l) S	-	8-10(eA)	11,12,1(eR)
Bombax ceiba	D	2-3 (r) A	4(e)	3-4(eS)	3-6(eR)
Baringtonia acutangula	SE	2-3 (r) A	4(e)	5(eA)	9(eR)
Croton roxburghii	D	1-2 (r) A	3(e)	1-2(eA)	3-4(eR)
Careya arborea	D	2-3 (r) S	3(e)	3-5 (eA)	7 (eR)
Cassia fistula	D	3-4 (r) S	4 (e)	5-8 (eA)	1-12/4* (eL)
Dalbergia sisoo	D	12,1,2,3 (l) A	4 (e)	3-4 (eA)	6-7 (eR)
Diospyros melanoxylon	D	1-2 (r) A	3 (e)	5 (eS)	5-7 (eR)
Dalbergia latifolia	D	4-6 (l) S	6 (e)	9 (eA)	1-2 (eR)
Dillenia pentagyna	D	2.5-5(l) S	5(e)	3-4 (eA)	5-6 (eR)
Diospyros embryopteris	E	1-12/3-4* (l) S	4 (e)	5 (eS)	3-6 (eR)
Diospyros malabarica	E	1-12/2-3* (l) S	4 (e)	3-4 (eA)	5 (eR)
Diospyros sylvatica	SE	3-4 (r) A	4 (e)	5 (eA)	1-3 (eR)
Diospyros Montana	D	1-2 (r) S	2 (e)	4-6 (eA)	12 (eR)
Ficus benghalensis	SE	3 (r) A	5-6 (e)	5-8 (eS)	4-6,12-2 (eRM)
Ficus hispida	SE	3 (r) A	4-5 (e)	1-12 (eS)	10-12 (eR)
Ficus microcarpa	SE	3 (r) S	3-4 (e)	-	10-4 (eL)
Ficus religiosa	D	12-2 (l) A	3-4 (e)	-	6-10 (eL)
Gmelina arborea	D	2-4 (l) S	4 (e)	2-4 (eA)	5-6 (eR)
Garuga pinnata	SE	1-2 (r) S	2-3 (e)	2-3 (eS)	3-5 (eR)

Kydia calycina	D	3 (r) S	3.5 (b)	9-11 (eA)	12-5 (eL)
Lannea corromandelica	D	3-4 (r) S	4 (e)	3-4 (eS)	-
Lagerostroemia parviflora	D	2-3 (r) S	3 (e)	4-5 (eA)	12-1 (eR)
Madhuca indica	D	3-4 (r) S	4 (e)	3-4 (eA)	6-7 (eR)
Mangifera indica	SE	4-5 (r) A	6 (e)	1-3 (eA)	5-6 (eR)
Mitragyna parviflora	SE	4-6 (l) S	4-6 (e)	5-6 (eA)	3-4,11 (eRM)
Melia dubia	D	3-4 (r) A	5 (e)	6 (eS)	6 (eR)
Miliusa velutina	D	4(r) A	5-6 (e)	5-6 (eS)	6-7 (eR)
Michelia champaca	SE	3-5 (l) S	3,10 (M)	4-5 (eA)	7 (eR)
Pterocarpus marsupium	SE	4-5 (r) S	5-6 (e)	10 (eA)	12-1 (eR)
Protium serratum	D	3-4 (r) S	4(e)	4 (eA)	5-8 (eR)
Phoebe wightii	SE	3 (r) A	4 (e)	4.5 (bS)	5-6 (eR)
Phoebe lanceolata	SE	2-3 (r) A	4(e)	4-5 (eS)	5-6 (eR)
Shorea robusta	D	3(r) A	4 (e)	3-4 (eA)	6-7 (eR)
Syzygium cumini	SE	2-3 (r) A	4 (e)	3-4 (eA)	5-7 (eR)
Syzygium cerasoides	SE	3-4 (r) S	4 (e)	5-6 (eA)	8 (eR)
Sterospermum suaveolens	D	3 (r) A	4 (e)	4-5 (eA)	9-2 (eL)
Schleichera oleosa	SE	3(r) A	4 (e)	3 (eA)	6 (eR)
Suregada angustifolia	E	1-12/1-2* (l) S	2 (e)	3-4 (eA)	-
Samanea saman	E	1-12 (l) S	-	3-4 (eA)	5-7 (eR)
Schrebra swietenoides	SE	2-3 (r) A	4-5 (e)	4-5 (eS)	5-6 (eR)
Terminalia alata	D	3-5(l) A	6-7 (e)	5-6 (eA)	7-10 (eR)
Terminalia chebula	D	2-3 (r) A	4 (e)	4-5 (eA)	11-2 (eR)
Terminalia bellirica	D	2-3 (r) A	4,10 (eM)	3-5 (eA)	1-2 (eR)
Trewia nudiflora	D	12,1-2 (l) A	3 (e)	1-3 (eA)	10-12 (eR)
Terminalia arjuna	D	3(r) A	4 (e)	4-7 (eS)	5-8 (eR)
Vitex leucoxylon	E	-	-	5-6, 10 (eAM)	2 (eR)
Xylia xylocarpa	D	4-5 (r) S	5 (e)	4-5 (eS)	2-4 (eR)

V[IMAGE] [IMAGE] T vegetation type; 1-12: January to December; r = rapid leaf drop < < 2 months; l = lengthy leaf drop > > 2 months; * = concentrated period of leaf drop; e = extended flowering/fruiting extending into more than one period; S (synchronous)= flowering/fruiting taking place simultaneously; A (a synchronous)= Flower/Fruit development during distinct period; D= deciduous; E= evergreen; SE= semi-evergreen; b= brief periods < < 2 weeks per episode; e= extended periods > > 2 weeks per episode; M= multiple events per year; R= rapid fruit maturation < > 4 months.

Table-3: Phenology of understorey woody tree species of SBR

Name of the plant species	VT	Leaf drop	Leaf flushing	Flowering	Fruiting
Artocarpus lacucha	SE	3 (r) A	4 (e)	12,4 (eA)	5,10-11 (eRM)
Alangium salvifolium	D	10-11 (r) A	1-2 (e)	1-3,12 (eSM)	1-5 (eL)
Bauhinia malabarica	E	1-2 (r) A	3 (e)	3-6 (eS)	5-11 (eL)
Bauhinia purpurea	SE	4 (r) A	6 (e)	7-8 (eA)	10-11 (eR)
Bauhinia variegata	E	3 (r) A	4 (e)	2-3 (eA)	4-5 (eR)
Crateva religiosa	D	1-3 (r) S	3 (e)	3-4 (eA)	6 (eR)
Casearia graveolens	D	5-6 (r) S	6 (e)	5-6 (eS)	5-7 (eR)
Cartunaregum spinosa	D	3-4 (r) A	5 (e)	4-5 (eA)	9-12 (eR)
Chionanthus intermedius	D	3-4 (r) S	5 (e)	1-4 (eS)	3-5 (eR)
Casearia elliptica	D	2-4 (r) S	4 (e)	2-5 (eS)	4-5 (eR)
Cleistanthus collinus	D	3-4 (r) A	4 (e)	4-5,9 (eAM)	3-4 (eR)
Euonymus glaber	E	-	-	5 (eAS)	3-6 (eR)
Ficus glomerata	D	10-11 (r) A	12-1 (e)	4 (eS)	3-6 (eR)
Glochidion velutinum	D	3-4 (r) S	4-5 (e)	4-5 (eA)	6-8 (eR)
Glochidion lanceolarium	E	-	3 (e)	3-5 (eA)	9-1 (eL)
Gardenia latifolia	D	3-4 (r) A	5 (e)	4 (eA)	12-6 (eL)
Gardenia gummifera	D	4 (r) A	5 (e)	3-5 (eA)	6-8 (eR)
Homalium nepalens	D	3-4 (r) A	5 (e)	5-6 (eA)	-
Hymenodictyon excelsum	D	11-5 (l) S	5 (e)	8 (eA)	1 (eR)
Holarrhena antidysentrica	D	2-4 (l) S	4 (e)	5-7 (eA)	12-2 (eR)
Hyptianthera sticta	E	1-12 (l) S	-	4-8 (eA)	11-2 (eR)
Ixora parviflora	E	1-12 (l) S	-	3-5 (eS)	5-6 (eR)
Ligustrum gamblei	SE	-	-	6-8 (eA)	12-1 (eR)
Nyctanthes arbor-trstis	D	4-5 (r) S	5 (e)	9-11 (eA)	12-1 (eR)

Ochna obtusata	D	2-3 (r) A	4 (e)	3-5 (eA)	6-8 (eR)
Phyllanthus emblica	D	4 (r) A	5 (e)	9 (eS)	9 (eR)
Prunus ceylanica	SE	9-10 (r) A	11 (e)	8 (eA)	11-2 (eR)
Securinega virosa	D	3-4 (r) S	4 (e)	5-9 (eS)	5-9 (eL)
Symplocos cochinchinensis	E	1-12/5-6*(r) S	2-3 (e)	1-3 (eA)	4-6 (eR)
Wendlandia tinctoria	E	1-12/1-2* (r) S	3-4 (e)	9-10 (eA)	3-6 (eR)
Wendlandia exerta	E	1-12/2-3* (r) S	4-5 (e)	1-3 (eS)	3-4 (eR)
Ziziphus rugosa	D	1-3 (l) A	5 (e)	3-4 (eS)	4-5 (eR)
Ziziphus mauritiana	D	1-2 (r) A	4 (e)	2-3 (eA)	5-7 (eR)

V[IMAGE] [IMAGE] T vegetation type; 1-12: January to December; r = rapid leaf drop < < 2 months; l = lengthy leaf drop > > 2 months; * = Concentrated period of leaf drop; e = extended flowering/fruiting extending into more than one period; S (synchronous)= flowering/fruiting taking place simultaneously; A (a synchronous)= Flower/Fruit development during distinct period; D= deciduous; E= evergreen; SE= semi-evergreen; b= brief periods < < 2 weeks per episode; e= extended periods > > 2 weeks per episode; M= multiple events per year; R= rapid fruit maturation < > 4 months.

Leaf drop

Leaf drop may be total or partial depending upon the species. In some truly deciduous taxa, all or most of the old leaves got abscised before the arrival of new ones and the tree was bare for a period of weeks or to few months. Examples of this category are *Anogeissus latifolia*, *Adina cordifolia*, *Aegle marmelos*, *Albizia marginata*, *Bombax ceiba*, *Croton roxburghii*, *Diospyros melanoxylon*, etc. In other species such as *Ficus benghalensis*, *Albizia procera*, *Barringtonia acutangula*, *Diospyros sylvatica*, *Garuga pinnata*, *Ficus microcarpa*, *Mangifera indica* and *Mitragyna parviflora*, leaf fall and leaf flushing processes slightly over lapped in the same tree. In evergreens old leaves were abscised over a period of time throughout the year, thus, retaining a steady population of functional leaves all the time. Majority of the species start leaf shedding in dry months i.e. from January and extending up to May and being low in other months. The peak of leaf drop was recorded in February to March in overstorey species and March to April in understorey species (Fig.3). In overstorey species the leaf drop was significantly ($F = 23.906$, $P < < 0.001$) different among the seasons but insignificant between the sites. However, in understorey species the variation of leaf drop was significant both among the seasons and sites ($F = 29.835$, $P < < 0.001$; $F = 12.688$, $P < < 0.001$ for season and site, respectively). Such phenological leaf drop in overstorey species in relation to aspects was insignificant but significant ($F = 6.884$, $P < < 0.001$) in understorey species (Tables 4 and 5). Again the study reveals that site, season and category have no interactive significant effect on leaf drop, while site, season and the degree of disturbance among the study sites for both the layers have interactive effects on leaf drop which is statistically significant ($F = 4.104$, $P < < 0.05$) (Table-6). Arjunan and Ponnammal (1993) stated that leaf drop is delayed due to rain and high temperature and advanced due to drought and low temperature. In the present investigation it was observed that the leaf drop of overstorey and understorey species had negative significant correlation with rain fall ($r = -0.609$ and -0.610 for overstorey and understorey species, respectively at p < > flowering after leaf flushing > > flowering before leaf flushing> > flowering later after leaf flushing. For understorey species the order was: flowering and leaf flushing simultaneously > > flowering later after leaf flushing > > flowering after leaf flushing = flowering before leaf flushing. The synchronization of flowering with leaf flushing seems to be related to moisture, temperature and photoperiod (Bhooj and Ramkrishnan, 1981; Murali and Sukumar, 1994). Cool and dry winter period is responsible for maximum leaf drop whereas increase in temperature during warm and dry periods induces the leaf flushing and flowering in most of the species.

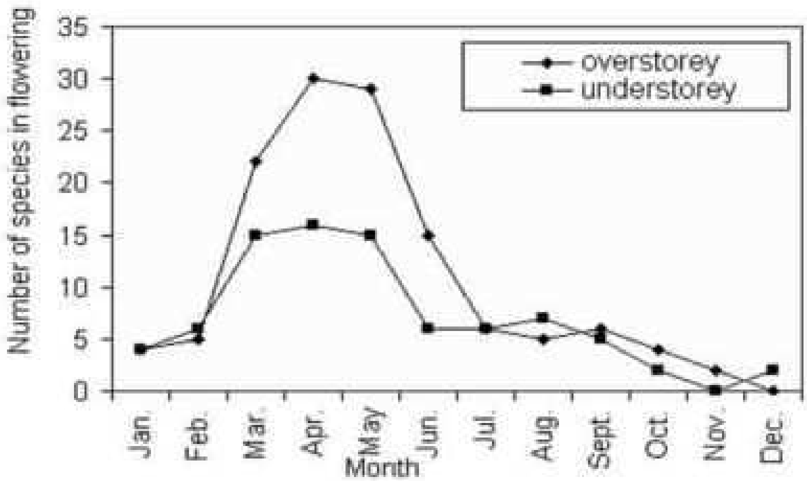

Fig 5. Number of overstorey and understorey species in flowering

Figure 5

Fruiting activity

Fruiting activity was observed throughout the year with approximately 1.5 times more activity around May and June than in December (Fig.6). The peak period of fruit maturity in the present study was observed during winter and summer. The fruit development period for different species of both layersvaries from 4 to 28 weeks. A majority of the species in both the categories showed rapid fruiting activity. Next to rapid fruiting activity a larger proportion of species recorded lengthy fruiting behaviour but only very few species had multiple fruiting behaviour (Table-2 and 3). Almost all tree species had phenological patterns that synchronized flowering and fruiting in the dry months i.e. April, May and June. Most of the species flowered at the beginning of April and fruited near the end of May and beginning of June, needing only a short time for the development of fruits. Rest of the species flowered during April and May, fruited during December, with a moderate amount of time required for fruit development. Flowering and fruiting at hottest summer i.e. April and May have selective advantage. It is more efficient to transfer assimilates directly into growing organs rather than having to store them and mobilize and translocate them latter (Wright and Schaik, 1994). We observed strong positive correlations ($r = 0.962$ and 0.963 at $P << 0.001$ for overstorey and understorey tree species, respectively) between the temperature of hottest months and the number of species fruited in the same period. This perhaps establishes that increased temperature favours formation of fruits in most of the overstorey and understorey species. Analysis of variance of fruiting activity between site, category and season was found significant ($F = 2.278$, 19.97 and 138.21 at $P << 0.05$, 0.001 and 0.001 for site, season and category, respectively). But such phenological parameter has no interactive effect between site, season and category. However, season, category and the degree of disturbance among the study sites have interactive significant effect ($F = 5.214$) at $P << 0.01$ (Table 6).

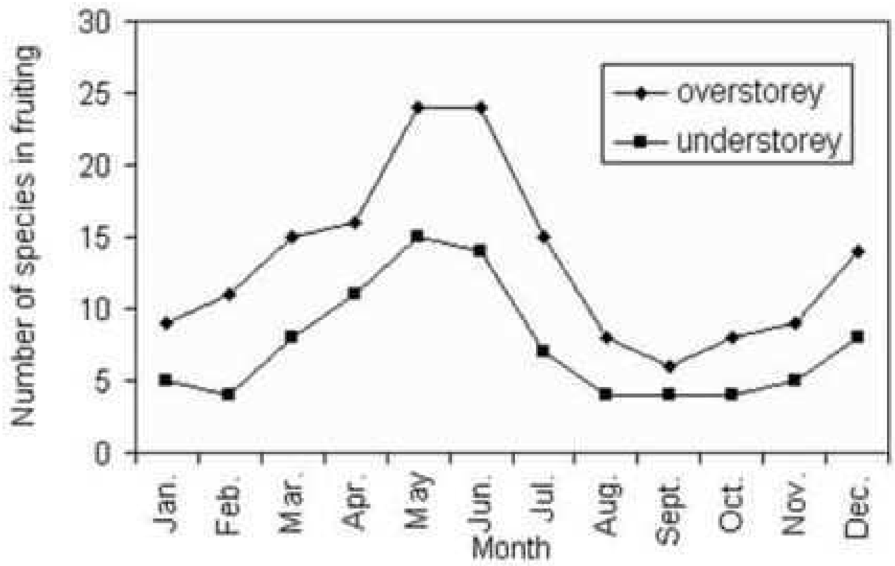

Fig 6. Number of overstorey and understorey species in fruiting

Figure 6

Table 6: Analysis of variance of different phenological conditions of overstorey and understorey woody tree species of SBR.

Phenological condition	F-value between parameters					
	Season	Site	Category	Disturbed and undisturbed	Season X Site X category	Season X Site X Disturbed and undisturbed
Leaf drop	22.383***	1.133 (NS)	19.509 ***	0.00069 (NS)	0.368 (NS)	4.104*
Leaf flush	14.68***	19.54***	3.29 (NS)	0.00048 (NS)	2.09 *	7.875 **
Flowering	96.69***	1.654 (NS)	81.021***	0.084 (NS)	2.189*	21.675***
Fruiting	19.97***	2.278*	138.21***	0.590 (NS)	1.354 (NS)	5.214**

***- Significant at P< < 0.001
**- Significant at P < < 0.01
*- Significant at P < < 0.05

In both the category of woody tree species ripening of fruits began in the later part of rainy season and continued upto end of cool and dry winter period. This is due to the difference in time taken for fruit maturation. Forty-seven out of 57 overstorey species showed extended and rapid fruiting activity, while only 7 and 3 species showed extended lengthy and extended rapid and multiple fruiting activity, respectively. Similarly out of 33 understorey species 27, 5 and one species showed extended rapid, extended lengthy and, extended and multiple fruiting activity, respectively. Similar observation has also been reported for tropical forests (Bullock and Solis Margallenus, 1990; Frankie et al., 1974) of Himalaya. It has also been reported that minimal pest pressure (Aide, 1988) and maximal activity of pollinating insects (Foster, 1996) may occur during dry season. Also fruit production at the end of dry season ensures that seedlings are not immediately exposed to water stress.

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Sequestration and storage capacity of carbon in the canopy oak trees and their epiphytes in a Neotropic Cloud Forest, Colombia

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Sequestration and storage capacity of carbon in the canopy oak trees and their epiphytes in a Neotropic Cloud Forest, Colombia

Abstract

For this project, the sequestration and storage capacity of carbon were quantified in canopy trees along with their epiphytes in a fragment of a cloud forest where oak trees - *Quercus humboldtii* - represent the largest part of the whole forest. It was found that each of the components of the epiphyte-host tree system shows different percentages of C concentration. In the case of Oak trees, it was found that the branches with diameters lower than 5 cm. have the largest capacity in capturing C (40.13%), followed by the wood contained in the trunk and in branches with diameters higher than 5 cm (38.75%) and fresh leaves and dead leaves show (35.95%) and (34.05%) of C retention respectively. In the case of epiphytes growing on these trees, it was discovered that the lichens and bryophytes yielded a 43% of C, being the component with more capacity of retention of C in the epiphyte - host tree system; the bromeliads had a capacity of 38.82% also presenting a bigger capacity of capture of C than that of the components of their host tree, excepting the upper branches. As for the C stored in the biomass it was found that in the four evaluated trees and their epiphytes, there was 32 066 kg in 0.0938 ha.
Key words: *Neotropic, Cloud Forest, Carbon sequestration, Canopy, Oaks, Epiphytes*

Resumen

Se cuantificó la capacidad de captura y almacenamiento de carbono en árboles de dosel y sus epífitas en un fragmento de bosque de niebla dominado por árboles de *Quercus humboldtii*. Se encontró que cada componente del sistema epífitas - hospederos presenta diferentes porcentajes de concentración de C, en el caso de los árboles de roble se obtuvo que las ramas con diámetros inferiores a 5 cm. son las que mayor capacidad de captura de C presentan (40.13%), seguido por la madera contenida en el tronco y en las ramas con diámetros mayores a 5 cm (38.75%), las hojas frescas (35.95%) y la hojarasca (34.05%). En el caso de las epífitas que crecen sobre estos árboles se encontró que los líquenes y briófitos con el 43 % son el componente que más capacidad de retención de C tuvieron en el sistema epífitas - hospederos; las bromelias tuvieron una capacidad de 38.82% presentando también una mayor capacidad de captura de C que la de los componentes de su hospedero, exceptuando las ramas superiores. En cuanto al C almacenado en la biomasa se encontró que en los cuatro árboles evaluados y sus epífitas, hubo 32 066 kg en 0.0938 ha
Palabras claves:*Neotrópico, Bosque de niebla, Captura de carbono, Dosel, Robles, Epífitas*

Introduction

Tropical forests and temperate zones sequester and store more carbon than any other terrestrial ecosystem does. In addition, these ecosystems contribute to the 90% of the annual flow of C between the atmosphere and the ground (Brown *et al.* 1993, Dixon *et al.* 1994). This fact has generated a special concern about the great importance of these forests as C stock places (Husch 2001), since they store big amounts of greenhouse gases, especially CO2 (Macera *et al.* 2000).

In the case of tropical forests, these have received special attention due to their wide covering on a great part of the terrestrial surface (Terborgh 1985), the rapid transformation rate into commercial plantations and pastures (Vitousek *et al*. 1987), and their contributions to the C cycles as well as their potential impacts in the global weather (Brown & Lugo 1982). In the last decades, the amount of C found in land vegetation has generated a special concern, so different conservation and reforestation strategies have being posed in order to face this situation (Macera *et al.* 2000).

Eleven percent of these tropical forests are represented by montane and submontane forests. They are spread all over America, Africa, Southwest of Asia, and Pacific islands (Doumenge *et al.* 1995). In America, Montane and submontane forests are located in Central America, the Caribbean (Labastille & Pool 1978) as well as in the tropical Andes in the northern part of South America (UNESCO 1981). In this continent, the biggest extension of montane forests is located in Peru, followed by Colombia, Bolivia, Ecuador, and Venezuela.

In Colombian submontane and montane forests, where generally a co-dominance is presented among several species, it can be found homogeneous woods dominated by Oaks - *Quercus humboldtii*- (Lozano & Torres 1974). These forests are located in the three Colombian mountain ranges, covering areas from 1 100m up to 3 450m high (Cavelier *et al.* 2001). In the past, these forests covered big areas of land. However, nowadays, the presence of the oak in Colombia is limited to discontinuous fragments that put it in certain threat degree (UNESCO 2001). So far, studies about the capacity of capturing carbon in canopy trees (*Q. humboldtii*) and their epiphytes had not been carried out. Therefore, the following article is an approach to know the role of the Oak trees as well as their epiphytes that they hold in the storing process of C; this with the purpose of showing one of the many environmental services that this ecosystem provides.

Materials and Methods

Study Area

The project was carried out in the Macanal Reserve located in the eastern Colombian Andean Mountain, in a town called Bojaca, located 27km far from Bogota. The study area is a montane cloud forest which is in a precipitous area with steep slopes, and it is located at 2700m above the sea level. The vegetation presents different levels of human intervention, and this is shown in the fragments of mature forests where mature Oak trees *(Q. humboldtii)* are the predominant species.

The climatology data of the area is registered by the Acapulco weather station of the "Instituto de Hidrología, Meteorología y Estudios Ambientales (IDEAM)". According to the 13 year-old data analysis (from 1990 to 2002), it has a precipitation with a bimodal behavior with an annual average of 61.5mm of rainfall; in which the most rainfall months that are March, April, and May in the first term of the year, and October and November in the second term. The average annual temperature is about 13º C, with the highest temperature on May with about 13.4º C and the minimum on July with about 12.6º C. The relative annual humidity average is about 91.9% for April, June, and July present the highest percentage with about 93%.

Methods

This study was carried out in an oak forest where neither wood mining, nor any other kind of forest profit have taken place. The methods used for measuring the tree volume were not destructive at all. In fact, in order to measure the trees and the epiphytes, five platforms were built over the upper surface of the four Canopy trees - *Q. humboldtii*- to an average height of 20m and 23m. By means of a simple rope technique and tree-climbing equipment, it was easy to have access to different parts of the four chosen trees such the trunk and the crown as well as to the platforms.

The approximate biomass of each evaluated tree was calculated from the tree volume and the wood density. For each tree, the trunk and the branches volume were calculated. For this, the length and the diameter of each trunk and branch were measured, and after that, we calculated the volume with the cylinder equation. In addition, the wood density was obtained from fragments of trunks and branches. For these samples, it was taken advantage of the natural falling of canopy oaks that were near the study area.

The biomass found in green leaves and upper branches of the crown was calculated from the gathering of six branches of different trees with approached dimensions of: 2m x 2m x 2m. All the leaves were taken off these branches in order to be dried and weighed. Subsequently, the number of branches that showed a covering of 2m x 2m x 2m was counted in each tree**.** With this, it was made an approximation of the number of branches and the quantity of biomass that these held.

The total biomass of bromeliads and organic matter placed on the bromeliads was evaluated in the selected trees taking into account the following parameters: 1) species, 2) number of individuals from each species in each host tree, 3) age class of the epiphytes. This was established from the gathering of 115 individuals that came in different sizes and the seven species that lived in the place. The diameter and the height were measured from these individuals, and then, leaves were taken off. Once the plant was stripped off, the bromeliad leaves were separated from the organic matter placed on the plant. Both samples were dried to a temperature of 70º C up to the point of obtaining a homogeneous drying to be weighted to obtain the biomass quantity after all. The analysis of bromeliads was carried out by visual estimation after having established the size.

Likewise, the biomass of lichens and bryophytes held in the crown tree was calculated from the selection of 32 branches of well-known volume with distinct diameters and located in different points of the crown of different trees. The lichens and bryophytes biomass held in the trunk was evaluated from six trunk parts of mature trees. All lichens and bryophytes were taken off to the 38 branches and

trunk fragments, so that they could be dried to a temperature of 70º C with the purpose of obtaining the biomass value. The total biomass of lichens and bryophytes was calculated starting from generalizating about the samples of the whole tree volume.
The capacity of carbon sequestration in each component was determined in the laboratory by means of oxidation by using a dicromato potassium solution mixed with sulphuric acid measured colorimetrically. To sum up, 36 tests were made that were distributed in the following way: six samples of wood taken from the trunk, six samples of branches, six samples of green leaves, six samples of dead leaves, six samples of non-vascular epiphytes which included lichens and bryophytes, and, six samples of bromeliads. The sample C content was carried out at the "Corpoica - Tibaitata" soils laboratory.

Results

The aerial biomass of oak trees and their epiphytes
The evaluated aerial biomass was made up by the trunks, branches and leaves of each tree studied besides all the group of epiphytes that they held. The selected trees presented an average height of 25m and 26m, coverings between 209m2 and 255m2, and diameters between 0.86m and 1.70m (Table 1). The biggest percentage of biomass was found in the wood contained in the trunk, and the branches with a diameter higher than 5cm, where values fluctuated between 15 000kg and 25 000kg (Table 2). The branches with a diameter lower than 5cm were the ones that less biomass presented with an average between 58% kg and 78kg. Finally, it was found that the biomass of the green leaves had an average between 20kg and 28kg (Table 3).
In the case of the epiphytes associated to the oak tree and to the organic matter placed on the bromeliads, it was found that the biggest biomass was provided by the lichens and bryophytes with values between 36kg and 63kg, continued by the bromeliads whose biomass fluctuated between 6kg and 39kg, and finally, the organic matter placed on the bromeliads with values between 4kg and 23kg, which was made up mostly by dead oak tree leaves (Table 2).

	Cover (m^2)	DBH (m)	Trunk height (m)	Crown height (m)	Total height (m)
Tree 1	253.98	0.99	5	21	26
Tree 2	209.3	0.86	5	20	25
Tree 3	241.5	0.73	5	21	26
Tree 4	233.91	1.70	7	18	25

Table 1.Sampled oak trees - *Quercus humboldtii*- characteristics

	Components per tree (kg)			(kg)	Epiphytes (kg)	
	Trunk wood and branches with diameters higher than 5 cm	Branches with diameters lower than 5 cm	Green Leaves	Organic matter placed on the simple bromeliads	Bromeliads	Lichens and bryophytes
Tree 1	24 626	70.48	24.84	22.5	39.2	62.67
Tree 2	19 299	60.06	21.17	5.44	10.8	52.55
Tree 3	15 897	58.22	20.52	4.75	6.8	38.1
Tree 4	22 246	77.22	27.22	10.07	15	36

Table 2.Oak tree biomass distribution in each one of its components and the epiphytes distribution that grow in the crown including the organic matter accumulated on it.

Sequestration and Storage Capacity of C

The capacity of sequestration of carbon fluctuated in the different components of the oak tree. The values were between 35.95% and 40.13 % (Table 3). The component with the biggest capacity of C capture was that of the branches with diameters lower than 5cm with 40.13%, continued by the wood contained in the trunk and in the branches with superior diameters to 5cm with 38.75%; then, the fresh leaves with 35.95%, and finally, the dead leaves produced by the tree with 34.05% (Table 3) On the other hand, in the epiphytes grown in the outer canopy it was found that the lichens and bryophytes presented 43% of C. These showed to be the component with the biggest C capacity of capturing inside the epiphytes epiphyte-host tree system. Bromeliads captured 38.82% showing a higher capacity of capture than of the components of their host tree, except by the superior branches. (Table 3)

			%	
	Component	(n)	X	SD
	Branches with diameter lower than 5 cm	6	40.13	7.71
Oak tree	Trunk wood and branches with diameters higher than 5 cm	6	38.75	4,43
	Green leaves	6	35.95	4,79
	Dead leaves	6	34.05	4.48
Epiphytes	Bromeliads	6	38.82	3.81
	Lichens and bryophytes	6	43	7.27

Table 3. C (%) capture capacity in oak trees (*Q. humboldtii*) as well as the epiphytes held on them. n = number of individuals; X = average value; SD = standard deviation.

As for the C stored in the biomass it was found that in the four evaluated trees and their epiphytes, there was 32 066kg in 0.0938ha - corresponding to the sum of the coverings of the four evaluated trees -. The biggest quantity of C was found in the trunk and the branches higher than 5cm with values between 6 161 and 9 543kg. On the other hand, the branches lower than 5cm captured between 23.36kg and 30.99kg. Finally, the green leaves captured between 7.38kg and 9.78kg. Concerning the epiphytes, the lichens, and the bryophytes, the values were between 15.65kg and 26.95kg. The bromeliads had between 2.6kg and 15.2kg while dead leaves had between 1.62kg and 7.66kg (Table 4).

	Components per tree (kg)			(kg)	Epiphytes (kg)	
	Trunk wood and branches with diameters higher than 5 cm	Branches with diameters lower Than 5 cm	Green leaves	Organic matter placed on the simple bromeliads	Bromeliads	Lichens and bryophytes
Tree 1	9 542.58	28.28	8.93	7.66	15.2	26.95
Tree 2	7 478.36	24.10	7.61	1.85	4.2	22.60
Tree 3	6 160.09	23.36	7.38	1.62	2.6	16.38
Tree 4	8 620.33	30.99	9.78	3.43	5.8	15.65

Table 4. Carbon content of tree stock in each component of the oak tree, their associated epiphytes and the intercepted organic matter.

Discussion

One of the main factors that is affecting the montane cloud forests is Global warming which is directly associated to the growing presence in the atmosphere of greenhouse gases and the destructive emissions of the ozone layer (Hamilton 2001). In addition, the deforestation processes have reduced the original montane woods coverage in South America, and in fact, they are considered along with the tropical dry woods, to be the most threatened ecosystems in the world (Cavalier *et al.* 2001). Concerning oak forests it has been estimated that it is necessary at least a period of 65 years to restore the structure and floral composition, without taking into account epiphytes, and at least 84 years to reach the structure of a mature oak forest (Kapelle 2001).

Some years ago, before knowing the importance of oak forest fragments as protectors of basins of great importance for the hydric system, regulators of the regional weather conditions, and their role in the cleaning of air among other environmental services, the oak tree was used for carpentry purposes as well as agricultural purposes. It also was used for doing posts, fences, house and railroad beams, floors, bodywork, fine joinery, and coal, amongst other uses (UNESCO 2001). These uses without appropriate handling generated alterations in the storage of C in oak forests. Deforestation as well as the incorrect use of soil have produced a reduction in the flow of the C and in their percentages of storing. This change is due to the lower biomass of pastures and certain crops (Macera *et al.* 2000)

In the oaks evaluated, it was found that the percentage of C in the biomass of the host trees and their epiphytes was, in all the cases, inferior to 50% indicated as value for defect for the IPCC (1996), and inferior to values reported in other studies where it has been registered that the content of C of the wood of conifers is between 50 and 53% while in the species of wide leaf varies from 47 to 50% (Ramírez *et al.* 1997). These differences are probably due to that it is a mature forest where the efficiency of fixation of C is smaller, contrary to what happens in the secondary forests that are composed of species of quick growth (Denslow 1980), and that these can have a bigger efficiency in the fixation of the C that the primary forests (Ortiz 1997).

In spite of the low values in the concentration of C in the canopy oak trees and in their epiphytes, the epiphyte - host tree system presented high values of biomass which makes that this system can retain a significant quantity of C. However, it should be kept in mind that this study had as objective the estimation of the biomass of huge trees; therefore, the data that was obtained is generalized only to mature individuals of oak, and not to big extensions of vegetable covering, since in the forests there is not a continuity of this type of trees neither of its epiphytes. As a result, an overestimation of the aerial biomass can be made and, consequently, content of C can be mistaken. Brown & Lugo (1982) affirm that the presence of trees with big diameters can have a great influence on the vegetable biomass as well as the quantity of C.

To calculate the percentage of the sequestration and storage capacity of C in a forest has become a tool to keep big extensions of vegetable covering, since the storage of C helps to mitigate the global warming (Husch 2001). To be able to know in a more precise way which is the quantity of C that can store a natural forest it becomes necessary to calculate not only the wooden quantity in living vegetation, but also the biomass of all those herbaceous forms of life that grow in the soil as well as on the trees, since these forms of life are abundant in the tropical forests. In the case of the epiphytes, these are an important component of the tropical forests since they contribute significantly with the total of the biomass (Ingram & Nadkarni 1993), the diversity of species (Gentry & Dobson 1987), and in the cycle of several nutrients (Nadkarni 1984) of these ecosystems.

The forests of *Quercus humboldtii* have several important elements to take into account inside projects that imply forests like places that sequester and stock C, and conservation. These are forests of wide distribution along the three Colombian mountain ranges whose conserved relicts harbor big mature trees with a high biomass that are also covered by a great epiphytes biomass that at the same time intercepts a part of the organic matter that falls. All this biomass accumulated in the epiphyte - host tree system makes these forests to be potential resource to storing significant quantities of gases of effect greenhouse effect and in particular CO2; obtaining one more environmental service from these ecosystems.

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Tree population structure, regeneration and expected future composition at different levels of *Lantana camara* L. invasion in the Vindhyan tropical dry deciduous forest of India

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Tree population structure, regeneration and expected future composition at different levels of *Lantana camara* L. invasion in the Vindhyan tropical dry deciduous forest of India

Abstract

This study deals with the differential response of *Lantana camara* L. (lantana) cover on the forest structure, regeneration and expected future compositional change of tree species in the Vindhyan dry deciduous tropical forest of India. A total of 90 quadrats, distributed over three sites, differing in lantana cover (low; 0-30%, medium; 31-60% and high; 61-100%), were used to enumerate the tree species. A total of 37 species with 14851 stems were enumerated from the three study sites, which were in gradient of lantana cover. Number of species varied from 21 to 30, while the number of individuals varied from 3408 to 7458 per site with former in high and later in low lantana cover. PCA ordination and Bray-Curtis cluster analysis revealed that the sites were not very unique with tree composition but showed marked uniqueness of sites in terms of seedling composition. The distinctness of species composition in the seedling stage is indicative of marked temporal dynamics, of this lantana invaded forest. The site wise regeneration analysis with the relative density of tree species at each life cycle stage (adult, sapling and seedling) showed that regeneration of species is poor at high-invaded site. The least invaded site indicated good regeneration with many new species emerging. Such differential change in vegetation composition at different lantana cover may be attributed to changed light and fire regime and also due to increased allelopathic suppression of tree seedlings. In conclusion lantana cover is suppressing regeneration and reducing availability of forest resources, which is of serious human concern.

Key words: Bray-Curtis analysis, future forest composition change, *Lantana camara* cover, PCA ordination and regeneration

Introduction

Invasive alien plants have become a serious threat to plant biodiversity in many parts of the world (Mack et al. 2000). These invasive species form very dense population, which affect the population dynamics of the persisting species (Mack et al. 2000). Land-use changes such as the replacement of natural ecosystems by agricultural systems clearly alter many ecosystem functions and may promote biological invasions (Hobbs, 2000). In India, tropical forests account for approximately 86% of the total forest land (Singh & Singh, 1988) and dry forests account for 38.2% of the total forest cover (MoEF, 1999). These forests are under immense pressure due to various human induced activities. The human population of the Sonebhadra district in the Vindhyan region increased from 683249 in 1981 to 930993 in 1991 and 1463468 in 2001 (about 36.25% increase in previous 10 years and 57.20% increase in later 10 years) (Rajya Niyojan Sansthan, 2000; Anonymous, 2003). These forests are also exposed to illegal sporadic tree felling, wide spread lopping of trees for timber resources and shrubs for fuel wood and leaf for fodder (Singh & Singh, 1989; Jha & Singh, 1990). This rapid modification of the habitat facilitated the invasion of *Lantana camara* (lantana) at an accelerated rate, which can affect species regeneration and subsequently leading to future compositional change of the forest. Although lantana may potentially have a devastating impact on the community structure and dynamics of forest ecosystems throughout the tropical world, there are very few studies that focus on how the cover of this species are actually affecting the tree species regeneration and future composition of the forest

Materials and Methods

Study area

The study area lies on the Vindhyan plateau in the Sonebhadra district of Uttar Pradesh (24º 13' to 24º19' N; 83º59' to 83º13') (Fig 1). The elevation above the mean sea level ranges between 315 and 485 m (Singh & Singh 1992). This area has been known as "Sonaghati" (golden valley) due to richness of its natural resources (Singh *et al*. 2002).

The climate is tropical with three seasons in a year, i.e. summer (March-mid June), rainy (mid June to September) and winter (October to February). October and March constitute the transition months between the rainy and winter seasons, and between winter and summer seasons, respectively. The average rainfall varies between 850 and 1300 mm. About 85% of the annual rainfall occurs during the rainy season from the southwest monsoon. The maximum monthly temperature varies between 20ºC in January to 46ºC in June, and the mean minimum monthly temperature between 12ºC in January to 31ºC in May.

Red coloured and fine textured sandstone (Dhandraul orthoquartzite) is the most important rock of the area. Sandstone is generally underlain by shale and limestone. The soils derived from these rocks are residual ultisols and are sandy-loam in texture (Raghubanshi 1992). These soils are part of the hyperthermic formation of typical plinthustults with ustorthents according to VII approximation of the USDA soil nomenclature (Singh *et al.* 2002). The potential natural vegetation of the region is tropical dry deciduous forest, which is locally dominated by species such as *Anogeissus latifolia, Boswellia serrata, Buchanania lanzan, Diospyros melanoxylon, Hardwickia binata, Lagerstroemia parviflora, Lannea cormendelica, Madhuca longifolia, Shorea robusta* and *Terminalia tomentosa*.

Methods

Reconnaissance survey of the entire region was made and three sites were selected at random, these sites had visually different levels of lantana invasion. At each site 30 quadrats each 10 x 10 m in size, were sampled randomly for vegetation analysis. A total of 90 quadrats, were sampled for vegetation analysis from the entire study area.

Lantana cover was estimated in each quadrat, using the Domin Krajina scale and was transformed into percentage cover for final analysis (Mueller-Dumbois and Ellenberg 1974). Later, each site was quantified into low (0% to 30%), medium (31% to 60%) and high (61% to 100%) invasion sites on the basis of percentage cover of lantana.

The diameter of each adult individual tree 9.6 cm diameter at breast height, dbh) was measured in each quadrat. In the centre of each 10 x 10 m quadrat, a 2 x 2 m area was marked for enumeration of saplings (individuals 3.2 cm to maximum 9.6 cm dbh) and established seedlings (individuals less than 3.2 cm diameter but 30 cm height) (Sagar and Singh 2004). Seedlings shorter than 30 cm height were considered ephemeral, and the established seedlings category represented 1 to 3 yr old individuals. Stem diameter of adult and sapling individuals was measured at 1.37 m from the ground and for seedlings it was measured at 10 cm above the ground (Sagar and Singh 2004). Thus, all individuals were enumerated and measured by species. Diversity indices were calculated using the following equations:

$$H' = \sum_{i=1}^{s} pi \ln pi \quad \text{(Shannon and Weaver, 1949)}$$

In the above equations, S = number of species, pi = proportion of individuals belonging to species i, H' = Shannon-Wiener index, ln = natural log (i.e. base 2.718). The relative density of each species was calculated from number of individual species to the percentage of the total number of individuals occurring in that respective class. To interpret the future trend in species composition of the different lantana invaded forest, the presence of number individual of different species in their tree, sapling and seedling layers were enumerated. Shannon-weiner diversity indices, Bray-Curtis cluster analysis and Principal component analysis was calculated using Biodiversity Pro version 2.0 (Mc Aleece, 1997)

Statistical Analysis

Multivariate analysis

This uses an inductive, non-experimental approach to generate rather than test hypothesis. Multivariate analysis methods follow one of two strategies, either ordination (e.g. principle component analysis, factor analysis, discriminant analysis), or clustering (e.g. cluster analysis) or hybrids of these. Two methods of multivariate analysis were utilized in an effort to ascertain patterns among tree species at different life cycle stages and lantana cover, namely PCA and cluster analysis.

Principal Component Analysis

This is a method of ordination widely used in many fields, in which axis or component are successively extracted from a matrix similarities. In PCA all individuals contribute equally to the component, avoiding dominance of outliers. Mathematically, PCA involves eigen analysis of a symmetric matrix to similarities to produce a series of eigen values and there corresponding eigen vectors (Marshall and Elliot, 1998). There are as many eigen values as there are rows (or columns) in the matrix and conceptually they can be considered to measure the strength (relative length) of an axis. Each eigen value has an associated eigen vector. An eigen value gives the length of an axis; the eigen vector determines its orientation in space.

Cluster analysis

Cluster analysis is a multivariate analysis technique and is not as much a typical statistical test as it is a collection of different algorithms that put objects into clusters. The clusters formed with this family of methods should be highly internally homogeneous (member are similar to one another) and highly externally heterogeneous (members are not like members of other cluster). Unlike many other statistical procedures, cluster analysis methods are mostly used when there are no prior hypotheses, but where research is still in an explanatory phase (Backer, 1994). In essence cluster analysis finds the most significant solution possible. Group member will share certain properties in common and it is hoped that the resultant classification will provide insight into the structure of the data. A dendrogram (tree like diagram) is produced, which summarises the process of clustering. Similar cases are joined by links whose position in the diagram is determined by the level of similarity between then cases (Aldenderfer and Blashfield, 1984).

Results and Discussion

Current status of the forest

A total of 37 species with 14851 stems was recorded from the three study sites, each 0.3 ha. Number of species and number of individual varied from 21 to 30 and 3408 to 7458 per site with former in high lantana cover and later in low lantana cover (Table 1 and 2). Total diversity increased with decreasing lantana cover. Maximum 26 species and 6825 individual seedlings was at low lantana cover and minimum 17 species and 2925 individuals of seedling was reported at high lantana cover site (Table 1 and 2). The PCA ordination of the three sites on the basis of relative density (Table 2) of species in the tree (adult), sapling and seedling population is illustrated in Figure 1. The PCA axis 1 and 2 accounted for 29.38 and 22.60% variation for tree species (Fig 1a), while it accounted 17.66 and 16.32% variation for sapling species (Fig 1b). On the other the seedling species showed 44.64 and 21.34 %variation for axis 1 and 2 respectively (Fig 1c). When all the stages were taken into consideration the PCA axis 1 accounted for 21.64% variation and axis 2 accounted for 12.7% variation (Fig 1d). Table 3 show the dominant and the co-dominant species in there various life cycle stages (tree, sapling and seedling) at different level of lantana cover, with the next top three subordinate species at low lantana cover includes *Acacia catechu*, *Buchanania lanzan* and *Briedelia retusa* / *Schrebera swietenioides*. At medium lantana cover *Anogeissus latifolia*, *Lagerstroemia parviflora* and *Terminalia tomentosa* form the subordinate species. And at high lantana cover *Madhuca longifolia*, *Terminalia tomentosa* and *Adina cordifolia* form the major subordinate species.

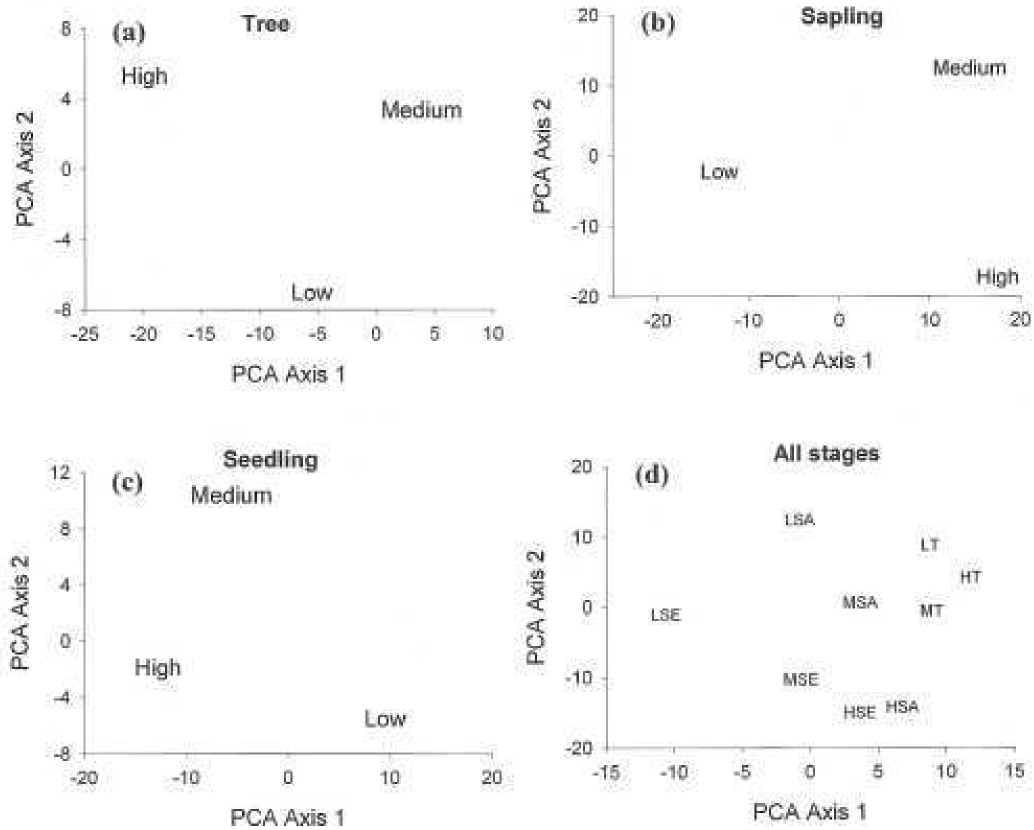


Figure 1: PCA ordination of lantana invaded {low (L), medium (M) and high (H) } sites (a) for adult tree species; T (b) for sapling; SA (c) for seedling; SE (d) all stages taken together.

***Lantana* cover**	**Adult**	**Sapling**	**Seedling**	**Total**
Low (0%-30%),	158	475	6825	7458
Medium (31%-60%)	135	625	3225	3985
High (61%-100%)	83	400	2925	3408
Total				14851

Table 1: Summary of stem inventory in different stages at different lantana cover class.

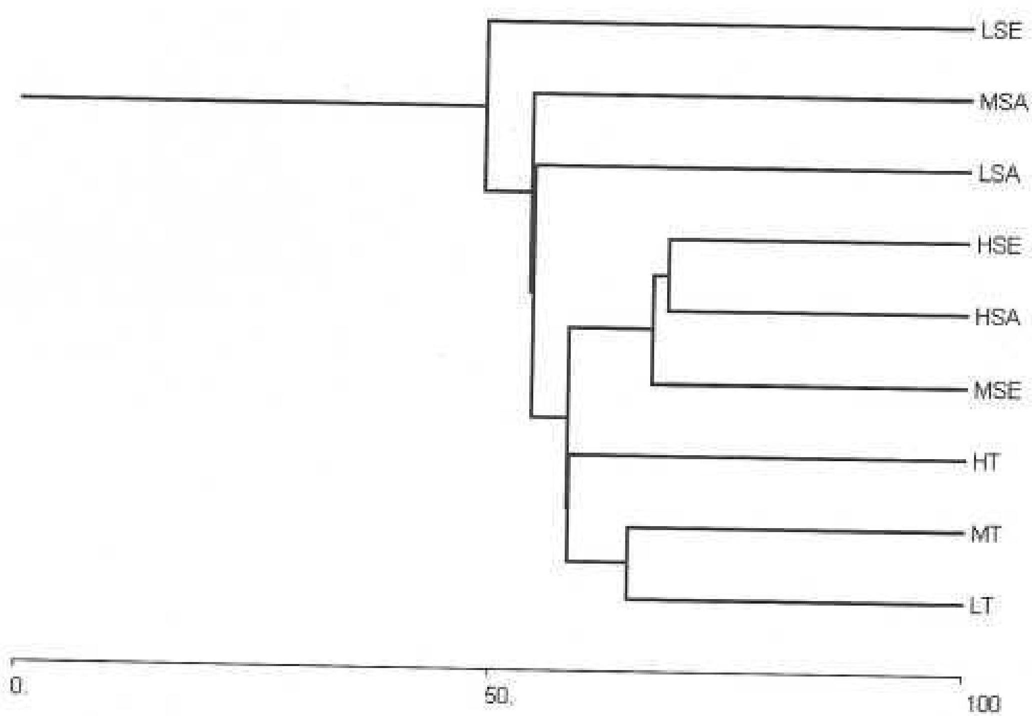
Species/ adult	Low (0-30%)			Medium (31-60%)			High (61-100%)		
	RD A	RD SA	RD SE	RD A	RD SA	RD SE	RD A	RD SA	RD SE
Acacia auriculiformis				0.74					
Acacia catechu	7.59	5.26	1.10	14.07	12.00	1.55			
Adina cordifolia			1.10				4.82		
Antidesma ghaesmbilla			0.37						
Anogeissus latifolia	1.90	5.26	2.20	11.11	4.00	3.10		12.50	10.26
Azadricta indica									0.85
Bauhinia racemosa			2.20						
Boswellia serrata	1.90		5.86	0.74					
Briedelia retusa	5.70	21.05	11.72	0.74					0.85
Buchanania lanzan	6.33		0.73	3.70	4.00	0.78	3.61		
Cassia fistula				0.74					
Carissa spinarum								6.25	2.56
Casearia elliptica									5.13
Diospyros melanoxylon	3.80	5.26	9.16	6.67	8.00	34.11	2.41	25.00	32.48
Elaeodendron glaucum	1.27			1.48			1.20		
Emblica officinalis	3.80	5.26	0.73	0.74					0.85
Eriolena quinquelaris			1.83	0.74					
Flacourtia indica			3.66	1.48		6.20			0.85
Gardenia latifolia	0.63	5.26	1.83	0.74		0.78			
Grewia serrulata			4.03						
Hardwickia binata	3.16			2.22	4.00				
Hollarhena antidysenterica			15.38	0.74		4.65			6.84
Hymenodictyon excelsum			1.47			0.78			
Lagerstroemia parviflora	2.53		0.73	10.37	4.00	3.10	1.20	12.50	2.56
Lannea coromandelica	10.76	5.26		2.22	8.00	0.78	20.48	6.25	2.56
Madhuca longifolia							14.46		0.85
Miliusa tomentosa	1.90	5.26	2.56	2.22	16.00	13.95	1.20		
Mitragyna parviflora			0.37						
Pterocarpus marsupium			0.37						
Schrebera swietenioides	5.70					0.78			0.85
Semecarpus anacordium	1.27	5.26	4.40		4.00	1.55			0.85
Shorea robusta	32.91	15.79	9.52	28.89	8.00	13.95	37.35	18.75	23.08
Soymida febrifuga	2.53	5.26	0.37	0.74		2.33			
Sterculia urens	1.27	10.53	1.47			1.55			
Sikti (unidentified)									1.71
Terminalia tomentosa	5.06	5.26	15.75	8.89	28.00	8.53	13.25	18.75	6.84
Zizyphus nummularis			1.10			1.55			
Total species	19	13	26	21	11	18	10	7	17
Shannon H' Log Base 10.	1.052	1.045	1.172	1.015	0.935	0.952	0.762	0.799	0.909

Table 2: Relative density of tree species in different stages, total species and Shannon diversity at different lantana cover class. (RDA: Relative density adults, RDSA: Relative density sapling, RDSE: Relative density seedling)

Lantana cover	Stages	Dominant	Co-dominant
Low (0%-30%),	Adult	*Shorea robusta*	*Lannea coromandelica*
	Sapling	*Briedelia retusa*	*Shorea robusta*
	Seedling	*Terminalia tomentosa*	*Hollarhena antidysenterica*
Medium (31%-60%)	Adult	*Shorea robusta*	*Acacia catechu*
	Sapling	*Terminalia tomentosa*	*Miliusa tomentosa*
	Seedling	*Diospyros melanoxylon*	*Shorea robusta/ Miliusa tomentosa*
High (61%-100%)	Adult	*Shorea robusta*	*Lannea coromandelica*
	Sapling	*Diospyros melanoxylon*	*Shorearobusta/Terminalia tomentosa*
	Seedling	*Diospyros melanoxylon*	*Shorea robusta*

Table3: Dominant and Co-dominant species in different stages at different lantana cover class.

In the present study, cluster analysis was performed based on relative density of species in their different life cycle stages (tree, sapling and seedling) at low, medium and high lantana cover together, to see the differences in vegetation composition (Fig 2).



% Similarity

Figure 2: Bray-Curtis Cluster Analysis (Single link) at low (L), medium (M) and high (H) lantana cover for tree (T), Sapling (SA) and seedling (SE).

Species diversity

Shannon-Wiener diversity index also decreased with increasing lantana cover. Figure 3 shows K-dominance of species rank plot. The bottom curve (LSE) represented the highest diversity, while the uppermost curve (HSA) represented the lowest diversity. The diversity of different sites was compared using *K*-dominance plot, in which percentage cumulative importance value is plotted against log species rank (Platt et al 1984). Platt et al (1984) advocated that diversity could only be unambiguously assessed when the *K*-dominance curves from the sites to be compared do not overlap. In this situation the lowest curve will represent the most diverse site and the upper most curve will represent least diverse site. In the situation where the curves intersect each other, the sites cannot be discriminated among themselves on the basis of life cycle stages. Figure 3 shows that maximum diversity was observed for seedlings at low lantana cover. Seedling and sapling at high lantana cover cannot be distinguished and are least diverse. The species composition pattern observed through both the analysis has shown that the three sites almost similar in tree vegetation composition, revealing that the invader is least affecting the tree composition (Fig 1d and 2). But on the other, seedling composition at the least invaded site differ highly in species composition. Probably as the least invaded site has the highest number of species and also accounted for maximum variation of PCA 1 axis i.e. 44.64%.

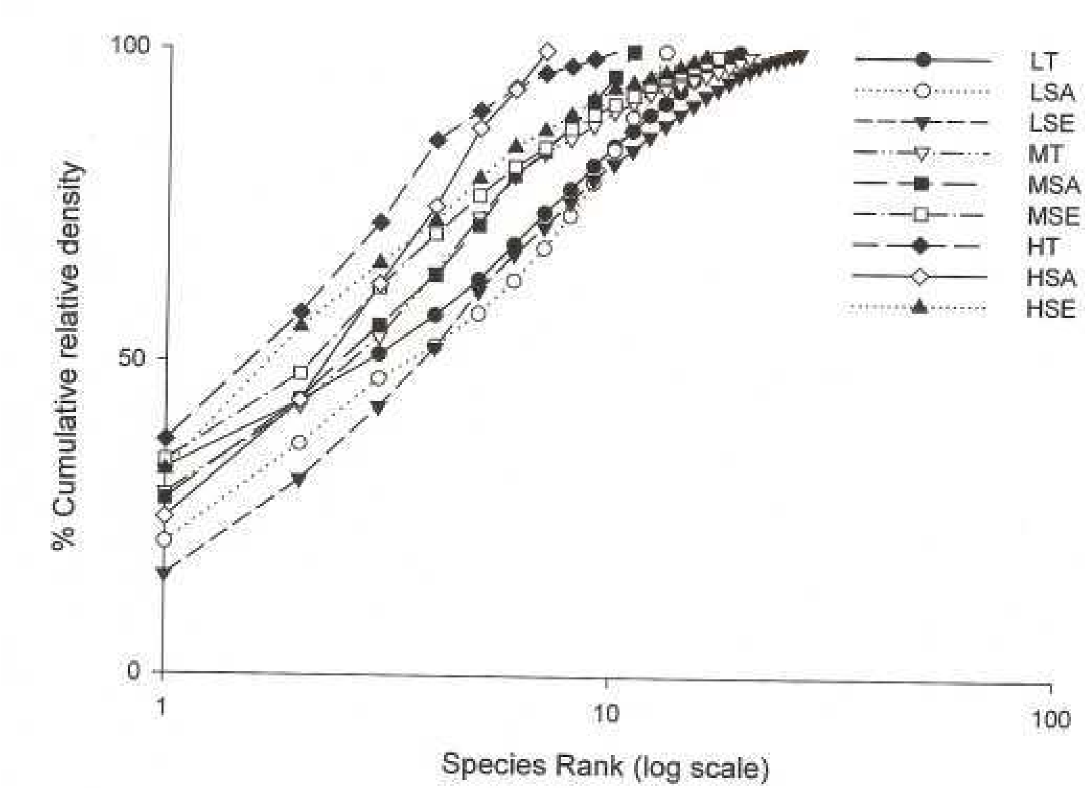


Figure 3: The K-dominance plot when percent cumulative relative density is plotted against log of species rank for each class (for abbreviations see fig 2).

Regeneration status

The regeneration potential of the low lantana cover site is better as many new seedlings are emerging (*Antidesma ghaesmbilla*, *Bauhinia racemosa*, *Eriolena quinquelaris*, *Flacourtia indica*, *Grewia serrulata*, *Hymenodictyon excelsum*, *Mitragyna parviflora* and *Pterocarpus marsupium*) (Fig 4a:iii). The regeneration potential of the *Emblica officinalis*, *Gardenia latifolia*, *Lannea coromandelica*, *Soymida febrifuga* and *Sterculia urens* seems to be well recently but now they seem to disappear (Fig 4a:ii).

The regeneration potential of the medium lantana cover site does not seem to be good as only few seedling species are emerging (*Hymenodictyon excelsum*, *Schrebera swietenioides*, *Sterculia urens* and *Zizyphus nummularis*) (Fig 4b:iii). The regeneration potential of *Acacia catechu*, *Anogeissus latifolia*, *Buchanania lanzan*, *Hardwickia binata*, *Lannea coromandelica*, *Miliusa tomentosa* and *Terminalia tomentosa* seemed to be well recently but now they also seem to decline (Fig 4b:ii).

The regeneration of seedlings at high lantana cover site showed only few new species (*Anogeissus latifolia*, *Briedelia retusa*, *Casearia elliptica*, *Emblica officinalis*, *Flacourtia indica*, *Hollarhena antidysenterica*, *Schrebera swietenioides*, *Semecarpus anacardium* and Sikti etc (Fig 4c:iii). The regeneration of *Lagerstroemia parviflora*, *Lannea coromandelica*, and *Terminalia tomentosa* seem to be better recently but now it is declining (Fig 4c:ii).

Future composition

In the low lantana invaded forest *Shorea robusta* will remain as the dominant species but later it may be replaced by *Bauhinia racemosa*, *Diospyros melanoxylon*, *Hollarhena antidysenterica* and *Terminalia tomentosa* species either (Ref fig 4a).

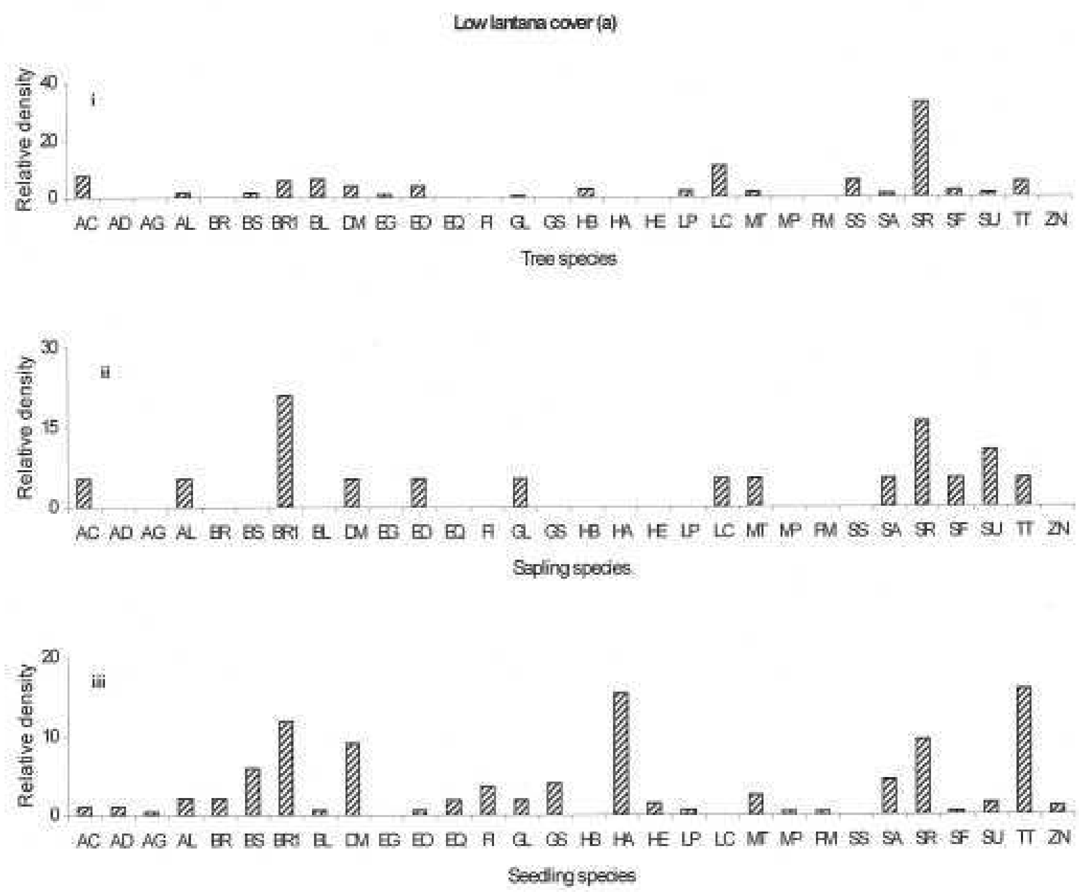


Figure 4a: Relative density of different species in tree, sapling and seedling stages, at different lantana cover {low (a), medium (b) and high (c)}. *Acacia auriculiformis* =AA, *Acacia catechu* =AC, *Adina cordifolia* =AD, *Antidesma ghaesmbilla* =AG, *Anogeissus latifolia* =AL, *Azadricta indica* =AI, *Bauhinia racemosa* =BR, *Boswellia serrata* =BS, *Briedelia retusa* =BR1, *Buchanania lanzan* =BL, *Cassia fistula* =CF, *Carissa spinarum* =CS, *Casearia elliptica* =CE, *Diospyros melanoxylon* =DM, *Elaeodendron glaucum* =EG, *Emblica officinalis* =EO, *Eriolena quinquelaris* =EQ, *Flacourtia indica* =FI, *Gardenia latifolia* =GL, *Grewia serrulata* =GS, *Hardwickia binata* =HB, *Hollarhena antidysenterica* =HA, *Hymenodictyon* excelsum =HE, *Lagerstroemia parviflora* =LP, *Lannea coromandelica* =LC, *Madhuca longifolia* =ML, *Miliusa tomentosa* =MT, *Mitragyna parviflora* =MP, *Pterocarpus marsupium* =PM, *Schrebera swietenioides* =SS, Semecarpus anacardium =SA, *Shorea robusta* =SR, *Soymida febrifuga* =SF, *Sterculia urens* =SU, Sikti (unidentified) =S, *Terminalia tomentosa* =TT, *Zizyphus nummularis* =ZN.

In the medium lantana invaded forest *Shorea robusta* may remain as the dominant species but the co-dominant species *Acacia catechu* may be replaced by *Terminalia tomentosa* in future. The decline in species at the seedling and sapling stages may be attributed to lantana cover (Ref fig 4b).

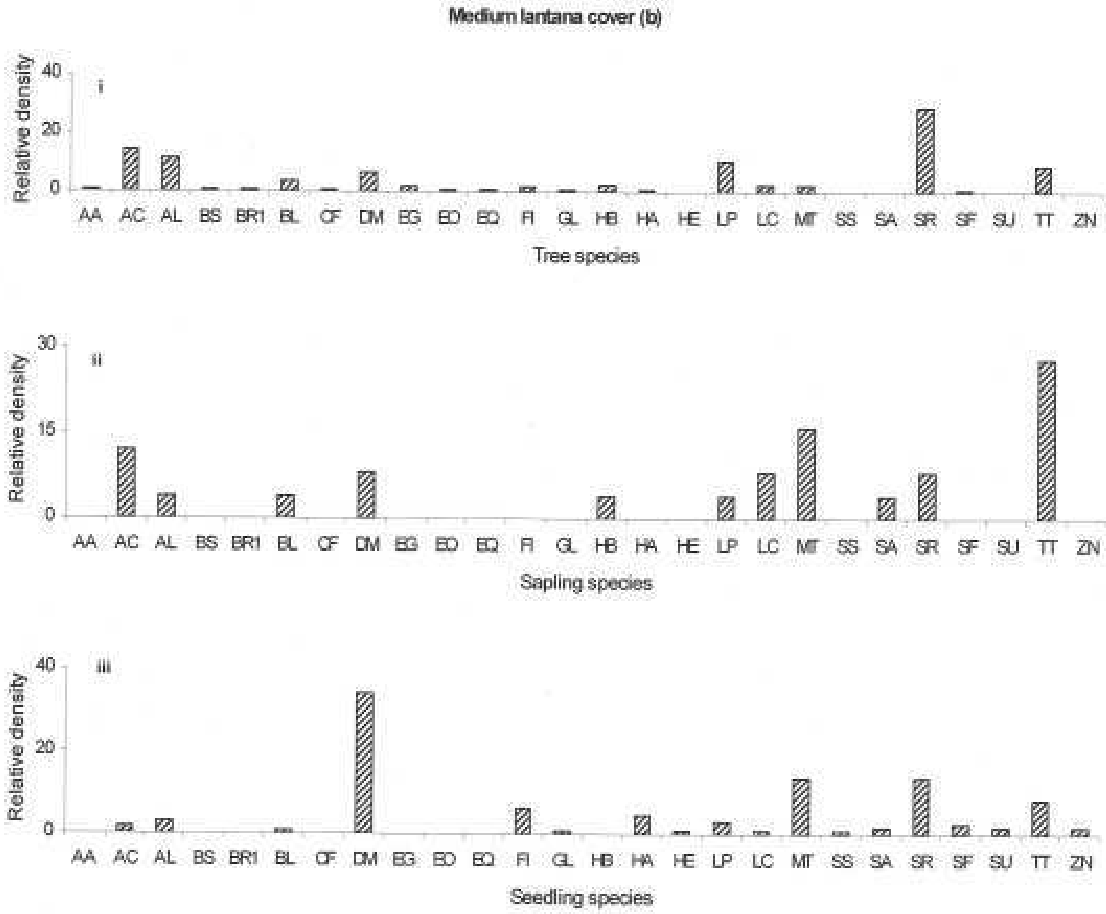


Figure 4b: Relative density of different species in tree, sapling and seedling stages, at different lantana cover {low (a), medium (b) and high (c)}. *Acacia auriculiformis* =AA, *Acacia catechu* =AC, *Adina cordifolia* =AD, *Antidesma ghaesmbilla* =AG, *Anogeissus latifolia* =AL, *Azadricta indica* =AI, *Bauhinia racemosa* =BR, *Boswellia serrata* =BS, *Briedelia retusa* =BR1, *Buchanania lanzan* =BL, *Cassia fistula* =CF, *Carissa spinarum* =CS, *Casearia elliptica* =CE, *Diospyros melanoxylon* =DM, *Elaeodendron glaucum* =EG, *Emblica officinalis* =EO, *Eriolena quinquelaris* =EQ, *Flacourtia indica* =FI, *Gardenia latifolia* =GL, *Grewia serrulata* =GS, *Hardwickia binata* =HB, *Hollarhena antidysenterica* =HA, *Hymenodictyon* excelsum =HE, *Lagerstroemia parviflora* =LP, *Lannea coromandelica* =LC, *Madhuca longifolia* =ML, *Miliusa tomentosa* =MT, *Mitragyna parviflora* =MP, *Pterocarpus marsupium* =PM, *Schrebera swietenioides* =SS, Semecarpus anacardium =SA, *Shorea robusta* =SR, *Soymida febrifuga* =SF, *Sterculia urens* =SU, Sikti (unidentified) =S, *Terminalia tomentosa* =TT, *Zizyphus nummularis* =ZN.

At highly invaded lantana sites *Shorea robusta* may remain as the dominant species in the future but the co-dominant species *Diospyros melanoxylon*, *Terminalia tomentosa*, *Anogeissus latifolia* and *Lagerstroemia parviflora* may replace *Lannea coromandelica* (Ref fig 4c). The decline of *Diospyros melanoxylon* at the tree stage may be attributed to its heavy exploitation. According to Spurr and Barnes (1980) heavy exploitation of a single species can cause the entire structure of the community to change. But here at the high-invaded site lantana cover could be responsible for forest compositional change.

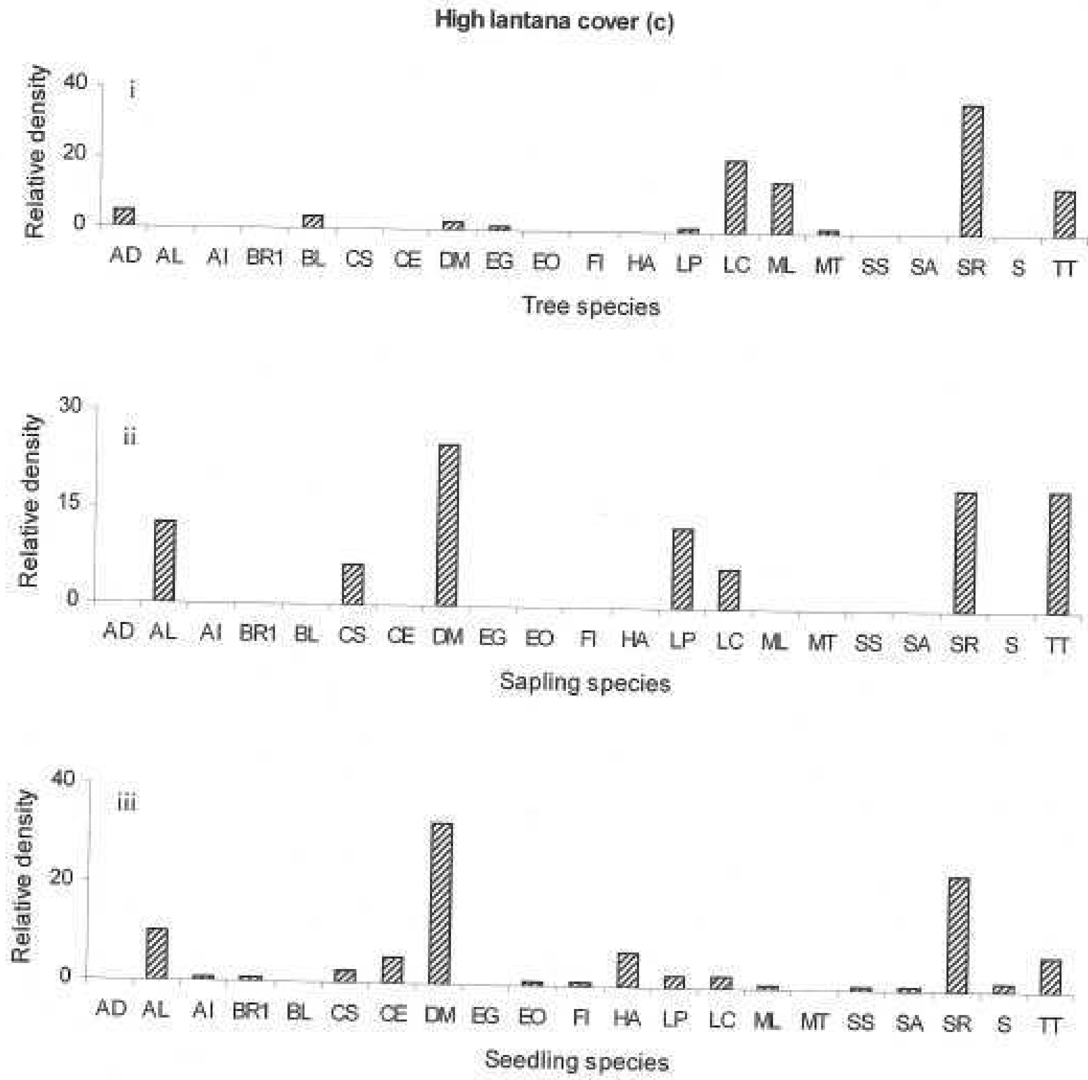


Figure 4c: Relative density of different species in tree, sapling and seedling stages, at different lantana cover {low (a), medium (b) and high (c)}. *Acacia auriculiformis* =AA, *Acacia catechu* =AC, *Adina cordifolia* =AD, *Antidesma ghaesmbilla* =AG, *Anogeissus latifolia* =AL, *Azadricta indica* =AI, *Bauhinia racemosa* =BR, *Boswellia serrata* =BS, *Briedelia retusa* =BR1, *Buchanania lanzan* =BL, *Cassia fistula* =CF, *Carissa spinarum* =CS, *Casearia elliptica* =CE, *Diospyros melanoxylon* =DM, *Elaeodendron glaucum* =EG, *Emblica officinalis* =EO, *Eriolena quinquelaris* =EQ, *Flacourtia indica* =FI, *Gardenia latifolia* =GL, *Grewia serrulata* =GS, *Hardwickia binata* =HB, *Hollarhena antidysenterica* =HA, *Hymenodictyon* excelsum =HE, *Lagerstroemia parviflora* =LP, *Lannea coromandelica* =LC, *Madhuca longifolia* =ML, *Miliusa tomentosa* =MT, *Mitragyna parviflora* =MP, *Pterocarpus marsupium* =PM, *Schrebera swietenioides* =SS, Semecarpus anacardium =SA, *Shorea robusta* =SR, *Soymida febrifuga* =SF, *Sterculia urens* =SU, Sikti (unidentified) =S, *Terminalia tomentosa* =TT, *Zizyphus nummularis* =ZN.

Lantana cover and mortality

The differential response of species at different lantana cover may be attributed to differed fire, light and allelopathic interaction within the community.

Fire

Although lantana burns readily during hot, dry conditions, even when green (Gujral & Vasudevan, 1983), moderate and low intensity fire may promote the persistence and spread of lantana thickets rather reducing them. However, on the other, such conditions increase seedling mortality of tree species. As the depth of heat penetration can be expected to affect regeneration of buried propagules and young seedlings (Moore and Wein 1977). Further, lantana invasion promotes fire due to its self-perpetuating fire cycle (Hiremath and Sundaram, 2005), which may ultimately culminate into mortality of seedlings.

Light

Light limitation is the mechanism by which undisturbed vegetation limits the invasion of lantana. Light has long been recognized as an important plant resource (Maximov 1929; Blankenship 2002) that may interact with other plant resources to affect plant performance (Cole 2003). Below certain thresholds, however, light limitation alone can prevent seedling survival regardless of other resource levels (Tilman 1982). It is likely that shrubs influence the distribution and abundance of tree species seedling by reducing the amount of light that reaches the forest floor, and this is probably the mechanism responsible for the decline in tree seedlings beneath lantana canopies (Gyan P Sharma pers. obs.). However, the dense cover created by vertical stratification of lantana may reduce the intensity or duration of light and thus prevent the establishment of other tree species seedlings. Low light has been shown to affect the distribution of other herbaceous species in understory habitats (Sharma et al. 2005), and this may have important management implications for biological invasions and maintenance of biological diversity.

Allelopathy

Lantana due to its strong allelopathic properties has the potential to interrupt regeneration process of other species by decreasing germination, reducing early growth rates and selectively increasing mortality of other plant species. These result in a reduction of seedling diversity (Loyn and French 1991; Gentle and Duggin 1998). Subsequently results in marked changes in the structural and floristic composition of natural communities. Therefore, as the density of lantana in forests increases, species richness decreases (Fensham *et al.*, 1994), which is consistent with the findings reported here. In most cases, the native species outperformed the alien under conditions of reduced light (Daehler, 2003), increased fire and allelopathy.

In conclusion we may say that lantana suppress the regeneration of other vegetation. Thus in the near future it will reduce the availability of forest products that people derive from the forest. This is a serious concern for biodiversity conservation and human society.

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Vegetation zonation and nomenclature of African Mountains - An overview

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Vegetation zonation and nomenclature of African Mountains - An overview

Abstract

This review provides an overview on the vegetation zonation of a large part of the mountain systems of the African continent. The Atlas and Jebel Marra are discussed as examples for the dry North African Mountains. The Drakensberg range is shown as representative of the mountain systems of Southern Africa. The main focus of the review falls on the Afrotropical mountains: Mt. Kenya, Aberdares, Kilimanjaro, Mt. Meru, Mt. Elgon, Mt. Cameroon, Mt. Ruwenzori, Virunga, Simien Mts., Bale Mts. and Imatong. A new nomenclature for the vegetation belts of Afrotropical Mountains is proposed.

Key words: Africa, mountain vegetation, vegetation belts, nomenclature, Mt. Kenya, Aberdares, Kilimanjaro, Mt. Meru, Mt. Elgon, Mt. Cameroon, Mt. Ruwenzori, Virunga, Simien Mts., Bale Mts., Imatong, Atlas, Jebel Marra, Drakensberg

Geology, landforms and soil conditions

Africa is an old continent. Nowhere else is so much of the surface covered by basement rocks, and the larger part of the geology of Africa is indeed the geology of pre-cambrian material (Petters 1991). Large areas, so called cratons, have remained essentially unchanged since the early Proterozoic (~ 2000 Mio BP). The mobile belts, i.e. the huge basins and swells between these cratons, are composed of equally old rocks, but have been subject to deformation and partly to metamorphoses, mainly in the Pan-African orogenesis (700 - 500 Mio years BP). Today, relief differences are relatively small in these areas, so the continent can be described as a large, uneven plateau, which is tilted to the northwest. Extensive erosion surfaces covered by ancient, heavily leached soils are more widespread in Africa than on any other continent, and the huge relatively flat Savannahs are well known. Inselbergs are very characteristic remnants of the older surfaces in these plains, but far too low to merit treatment here.

Equally well known as the flat surfaces are, however, some much more recent geological features, namely the huge, isolated volcanoes of the tropical part of the country, and the high fault mountains in the Atlas region and in South Africa. In these three regions, true high-altitude environments are found, with several ranges reaching well above 4000 m. These are almost exclusively located in the tropical parts, with Mt. Kilimanjaro (5985 m), Mt. Kenya (5198 m) and Ruwenzori (5109 m) being the highest sites. Several other mountains reach above the treeline, with the most extensive areas being in Ethiopia. However, the High Atlas in Morocco is also high enough to support truly alpine vegetation (4165 m).

Morocco occupies an intermediate position between the tectonic domains of southern Europe and Africa. The evolution is complex, and the atlas region was formed in several successive uplifting events. The south-westernmost part, the Anti-Atlas contains Precambrian material, but was largely formed in the late Proterozoic. Uplift occurred in Hercynian times in close correspondence to some mountains in Europe, and again mainly in late Cretaceous tectonic movements that formed the several chains of the High Atlas and the Saharan Atlas. The northern Riff and the Tell Atlas in northern Algeria are the southernmost outposts of the Alpine orogen, but recent Tertiary uplift affected also the older ranges, notably the Saharan Atlas. Most of the material is acidic, but several ranges display calcareous rocks, like the central High Atlas, part of the Saharan Atlas and the Rif. Only the High Atlas reaches above 3000 m, while the neighboring ranges hardly climb above 2000 m.

The central Saharan mountains Hoggar and Tibesti rest on the relatively stable West African craton. Part of the Tibesti is of ancient, Proterozoic origin, but there has been extensive recent volcanism. Both ranges are part of a chain of volcanoes of Cenozoic age that extends southwards to the central African Mt. Cameroon and eastwards to the East African Rift Valley System.

Mt. Cameroon is a huge single structure of largely Tertiary origin, but has been active ever since with more than 10 major events in the 20th century, some as recent as 1982 and 2000 (Ndam et al. 2001). The series of volcanoes starting at Mt. Cameroon has been described to continue up to the Jebel Marra in central Sudan. This is a massif rather than a single volcano, which has been active from the Miocene to the early Holocene (Miehe 1988). Lavas are predominantly basaltic in all these ranges.

Further eastwards, the huge volcanic plateau of Ethiopia rests on ancient material, but was largely formed in the tectonic processes during the formation of the East African Rift Valley system. The EARS is the prime example for a continental rift, and its huge structure extends over more than 6000 km from northern Mozambique along all of eastern Africa and through the Red Sea. Rifting started in the Cretaceous but has intensified in the Tertiary, and is most likely a consequence of tensional forces driving the two escarpments apart. Volcanism has been intensive and complex, following the two main branches, the Albertine Rift in the west, and the Gregory Rift in the east (Schlüter 1997).

The Ethiopian Rift is an extension of the latter, mainly formed by basaltic magmas in the Oligocene to Miocene, and reaching above 4000 m at several sites, notably in Simen Mts. in the northern part of Ethiopia and the Bale Mts. in the southwestern. Relatively deep and dry basins from the isolated volcanoes in east Africa proper separate this group of well-connected ranges.

Most of these are relatively young and of Pliocene to Quaternary age. This refers to mountains such as the Aberdares, which were formed from 3 Mio. BP onwards; Mt. Kenya was formed between 2-3 Mio. years BP (Heinrichs 2001); Mt. Kilimanjaro is even younger at 1-2 and Mt. Meru appears to be of similar age as are the Aberdare Mts. Lavas on the huge shields are predominantly alkaline or basaltic, but intermediate lavas formed several strato-vulcanoes.

The mineral composition is similar for Mt. Elgon, which is however an exception with respect to its age. Mt. Elgon lies at the border of Uganda and Kenya, and is thus not strictly located in the Rift Valley. Here volcanism commenced some 20 Mio years ago and lasted for about 10 Mio years. The neighboring Cherangani range is an ancient block of largely metamorphic rocks, but has been lifted to its present height in the Miocene. These two ranges have been high mountains, long before their neighbors in the eastern part of Africa, and also those in central Africa had attained high altitudes. The Ruwenzori is a huge pre-Cambrian block, but has been lifted to alpine heights later than 2 Mio years BP. The Kahuzi-Biéga west of Lake Kivu has apparently experienced a similar evolution (Fischer 1996). The other high mountains along the Albertine Rift Valley are exclusively of volcanic origin, with volcanism commencing as early as some 13 Mio years BP in the Virungas. However, most of the activity occurred in the last 2 Mio. years and continued to the present, as was so strikingly demonstrated at the city of Goma, which was largely destroyed during a catastrophic lava outpour in 2001.

These young mountains are in striking contrast to the truly ancient Eastern Arc Mountains in Tanzania and northern Kenya. They are composed of granulite gneiss complexes and have been mountains during for over 25 Mio years. However, they barely reach 3000 m and lack an alpine belt typical for the other mountains discussed here.

Faulting during the formation of the Rift Valley has formed much of the present tropical part of African. Beyond Mozambique, mountains in the southernmost part of the continent are fault mountains like the northwestern Atlas system

The lower slopes of the volcanic ranges have been subject to intensive weathering and leaching, resulting in deep reddish soil profiles, mainly Acri- and Nitisols, occasionally Ferralsols. The dominant soil type of the upper montane belt are however well developed Andosols. The Andosols have moderately acidic soil pH values, and are exceedingly fertile and explain the intensive agriculture on the tropical mountains. The alpine regions are partly covered by Andosols, notably on the younger volcanoes, partly by various weakly developed soils on glacial deposits such as Regosols and Rankers. Very widespread are various Histosols that result from slow decomposition of organic matter due to coldness and stagnant water. They are characterized by low pH values (under 4 to 5.5) and generally low nutrient availability.

Altitudinal belts in the African mountain regions

Vegetation belts in the North African Mountains

Atlas

With respect to their geologic origin, mountains in northwest Africa are closely related to European mountains like the Alps. Correspondingly, climate, flora and vegetation display strong similarities to Mediterranean mountains like the Sierra Nevada in Spain, and mediate to the arid sites of central northern Africa.

There are three principal complexes, namely the High Atlas and its neighbors Anti-Atlas and Central Atlas; the Rif and Tell Atlas in northern Morocco and Algeria; and the Saharan Atlas in Algeria and Tunisia. These display large-scale climatic gradients, with conditions getting progressively drier with distance to the coast, so the Rif and Tell Atlas get most precipitation with annual totals above 750 mm in the northern foot zone. In the Moroccan Atlas, conditions get drier from west to east. These differences among ranges are small in comparison to the large differences between the northern and the south (-eastern) slopes within the mountain ranges. The northern lowlands receive well above 300 mm, while the southern slopes border the Saharan basin, where precipitation quickly drops to less than 100 mm in the lowlands (Weischet & Endlicher 2000).

Montane regions clearly receive more than lowlands with a precipitation maximum at 2000 - 3000 m elevation. This is around 750 mm in the High Atlas, and above 500 mm in all regions except for parts of the Saharan Atlas. The Rif and the Tell Atlas receive annual totals of above 1000 mm, which rise occasionally up to 2000 mm. Rainfalls occur almost exclusively in winter, so the summit regions are at least seasonally covered by snow, which might last until the following year in moist conditions. Thus, moisture availability and the usual altitudinal temperature lapse rate control most of the vegetation patterns, but these are modified by edaphic components. Like in the Alps, calcareous and acidic bedrocks intersect, so vicariating plant communities are found depending on the geological background. This analogy is however limited, since the extremely harsh climatic conditions with a pronounced seasonality and the general dryness of the summit region induce excessive weathering. Thus the uppermost regions are covered with scree, which move in the frequent freeze-thaw cycles. Soils are weakly developed and conditions resemble those of dry ranges in the Sahara or even Central Asia, with an open and rather sparse vegetation cover completely different from the Alps.

Human impact has been tremendous in the entire region. Agriculture and livestock keeping were introduced some 5000 BP, and, like the entire Mediterranean region, most of the natural vegetation has been replaced by various secondary plant communities, rendering inferences of the potential character of the landscapes often different.

The Moroccan Atlas

Botanical exploration the area started equally late as in the seemingly much more remote tropical parts of Africa and started in the 1870's. It has however been intense and the general patterns are known since the middle of the last century (Rauh 1952). The High Atlas displays the typical situation. The northern foot zones are covered by open shrublands with *Zizyphus* ssp., *Lotus* and notably *Acacia gummifera* up to 900 m, where the dwarf palm *Chamaerops humilis* demarcates the transition to forest vegetation. *Tetraclinis articulata* forests are the natural community up to 1400 m, from where they are replaced by various communities dominated by *Quercus ilex*. Stands are dense and relatively shady with few companions as *Cistus laurifolius* on acidic, and *Buxus sempervirens* on calcareous bedrocks. Much of these forests have been replaced by various scrub communities with *Pistacia lentiscus* and *Juniperus phoenicea* in the lower regions, and by *J. thurifera* in the upper montane belt. Impressive Cedar (*Cedrus atlantica*) stands built a special forest community restricted to the moistest parts of the Atlas, but are more extensive in the Rif and in the Tell Atlas. Above 2800 m, *J. thurifera* forests dominate up to the treeline in some 3100 m. Unlike in other areas of Africa, progressively diminishing and finally shrubby growth of the dominant species do apparently not characterize the treeline ecotone. Instead, Junipers retain their single-stemmed growth up to the treeline, with stands opening progressively and distance between trees increasing.

Thorny cushion plants characterize the lower alpine region up to 3600 m. Cushions grow 0.5 to 1.0 m in height and have thick, often several meters long root. The dominant species are the widespread *Alyssum spinosum*, *Bupleurum spinosum*, joint by the flat thorny cushions of *Arenaria pungens* in upper elevations. In contrast, *Erinacea pungens* and *Vellea mairei* are restricted to calcareous bedrocks. Cushions prefer weakly inclined to level slopes where they can built almost closed stands, but have also benefited from anthropo-zoogenic human impact on the upper montane Juniper forest, where they from secondary stands on disturbed sites.

Moist sites in the lower alpine zone near small brooks are the habitat of communities called "Pozzines". These are meadows, physiognomically similar to alpine meadows in Europe, and thus colorfully flowering in summer. However, they are of very limited spatial extent, and are restricted to soils with impeded drainage over acidic bedrocks.

Substrate movement in the upper alpine region becomes increasingly strong above 3300 to 3600. The cushions become more and more restricted to the few level sites, and plants truly adapted to scree slopes and rock crevices take over. Again, we find vicariant taxa on acidic and calcareous substrates, like *Viola dyris* var. *orientalis* on calcareous rocks and *Viola dyris* var. *typica* on acidic bedrocks. The latter is an endemic taxon of the Atlas, other examples are *Linaria lurida*, *L. heterophylla* ssp. *galioides*and *Vicia glauca* var. *rerayenssis*, all growing on scree slopes. The relative importance of endemic species increases with altitude in the Atlas, and is around 30% in the lower alpine zone, while it reaches some 75% in the upper alpine and summit regions. There is no truly nival belt and plants occur up to the summit region.

The zonation on the southern slopes is somewhat different because of the greater aridity. The foot zone is covered by succulent *Euphorbia*species or open shrublands like on the northern slopes up to 1500. *Juniperus phoenicea* partly replaces *Tetraclinis articulata* and the belt of *Quercus ilex* forests is smaller and widely replaced by open Juniper scrub. *Cedrus* forests are entirely absent. The timberline is formed by *J. thurifera* as on the northern slopes, and the alpine vegetation is similar as well.

The Rif and the Tell Atlas

The Rif reaches barely 2500 m and the Tell Atlas is even lower, but affinities to the Moroccan Atlas are strong in the montane belt (Knapp 1973), so the description is kept short. The most widespread montane forest communities are also built by *Quercus ilex*, which forms dense and rather shady stands. *Quercus suber* forms extensive forests at the relatively moist coast of Algeria and Tunisia up to some 1000 m asl., but small stands of the Oak are also found in Morocco. Like *Quercus coccifera*, it has rather high moisture demands and is restricted to the coastal regions below 1200 m. Much of the areas have been cleared for agriculture, especially *Olea europea* plantations. The olive forms (semi-)natural stands with *Pistacia lentiscus* in drier parts of the lowlands, which might however be secondary in nature. Aleppo Pine (*Pinus halepenis*), often mixed with *Quercus ilex*, dominates much of the lower montane zone at 500 - 1500 m in the Rif and Tell Atlas, but is also occasionally found in the Moroccan Atlas. *Cedrus atlantica* forest is common in the moister ranges above 1500 m. However, the moistest sites there are covered by deciduous oak forests (e.g. *Q. faginea*) and coniferous forests with *Abies maroccana* and *A. numidica*. *Juniperus phoenicea* forests in the drier parts of the montane belt have suffered heavily from anthropo-zoogenic disturbance but occur up to 2400 m under natural conditions. Replacement communities include mixed scrub with various Cistaceae, Fabaceae and Ericaceae species in the lower montane belt, and shrublands with the dwarf palm *Chamaerops humilis* and *Rosmarinus officinalis* in the montane belt.

There is no truly alpine vegetation in the Rif and in the Tell Atlas simply because the ranges are too low.

The Saharan Atlas in northern Algeria

The Saharan Atlas forms a second chain leeward of the Tell Atlas and is thus relatively dry. Much of the natural vegetation has been replaced by widespread steppes with *Stipa tenacissima*, that is an important species of secondary grasslands in the western Mediterranean region. It is accompanied by *Lygeum spartum* or *Artemisia herbae-alba*, mostly on dense or compacted soils. The natural montane vegetation closely resembles the situation in the Moroccan Atlas described above, notably in the western part of the country near the inter-state boundary. Communities with higher moisture demands are almost exclusively absent, and forest with *Quercus ilex* and occasionally *Pinus halepensis* would be the zonal vegetation of much of the northern slopes. The southern slopes are influenced by the arid Saharan climate and dry vegetation types with succulents climb up well into the montane belt. Where the mountains are high enough, alpine vegetation types occur, which are also similar to the High Atlas. Thorny cushions are relatively common, as are scree communities, but communities of moist rock crevices are impoverished and Pozzines are entirely absent. The alpine vegetation shows the typical differentiation of vicariating species depending on the presence of acidic or calcareous bedrocks as was described for the High Atlas.

Dry mountains in central Sudan - the Jebel Marra

The Jebel Marra is a highly isolated volcanic massif in the center of Africa, more than 1500 km away from the nearest coast and more than 1000 km distant to the next mountain, with the Simen Mts. in northern Ethiopia being the most "closely" related range. The Jebel Marra emerges from a pedi-plain in 1000-1200 m, with a semi-arid climate with down to 280 mm of annual precipitation (Miehe 1988). The mountain slopes receive more rain, and the southwestern side is clearly moister than the eastern. The belt of maximum precipitation is situated at around 2000 m asl., where totals can be as high as 1800 mm in extreme years, but 800 mm appear to reflect the average conditions better. For the summit region (max. 2976 m Times Atlas 3071) 600 mm have been estimated.

The vegetation shows correspondingly clear altitudinal gradients. Drought deciduous woodlands cover the piedmont and *Acacia* scrub, interspersed with lowland gallery forests along watercourses and in moist ravines and valleys, mainly in the southwest. These can be regarded as remote outposts of tropical evergreen forest. Typical species include evergreen *Ficus ingens*, *F. thonningii*, *F. sur*, *Syzygium guineense* and *Trema orientalis*, indicating affinities to tropical montane forest described below..

The dominant vegetation type in the submontane belt are, however, communities with *Combretum molle* and *Boswellia papyrifera*, which are replaced by wooded grasslands with *Entada abyssinica* and *Acacia albida* as a transitional belt to the montane communities.

The transition from these submontane lowlands to the montane, sparsely wooded grasslands occurs at some 2000 m. The principal tree species is *Olea laperrinei*, which forms riverine forests above 1900 m with *Ficus palmata*. The olive is also found in the Saharan mountains and indicates the relationships to Hoggar and Tibesti. However, the dominant vegetation are grasslands with *Andropogon-Hyparrhenia*, and *Themeda triandra-Conyza hochstetteri*. Scattered trees of *O. laperrinei* can be found on scree slopes and in the grasslands, indicating that at least part of these grasslands are suitable for tree growth. The upper montane grasslands above 2800 m are composed of *Pentaschistis* species and *Festuca abyssinica*. Occasionally, remnants of ericaceous vegetation, notably *E. arborea*, occur in the upper montane region. Ericaceous vegetation dominates the timberline ecotone in much of tropical Africa, but the Jebel Marra is not high enough for a true alpine belt.

Thus, with respect to the temperature and moisture availability most of the montane belt should be suitable for dry afromontane forests dominated by *O. laperrinei*, which have presumably been cleared by large-scale woodcutting, grazing and fire. This would clearly indicate parallels to the tropical mountains described in the following chapter.

Vegetation belts in the tropical African mountain regions

Mount Kenya - A typical example for the altitudinal zonation of tropical African mountain vegetation

Mt. Kenya (Figure 1 a & b) is intermediate among the mountains in tropical Africa in terms of geographical position and climate. Research there has started early in the last century, so the available data are relatively comprehensive. Hence, we will discuss the vegetation zonation of Mt. Kenya in some detail, while descriptions for the other mountains are kept shorter and focus on the differences to the typical situation in central Kenya.

Mount Kenya, located about 180 km north of Nairobi on the eastern side of the Great Rift Valley, is a widely isolated volcano. The base diameter is about 120 km; the northern foothills reach the equator. With its main peaks Batian (5198 m) and Nelion (5188 m), Mt. Kenya is, after Kilimanjaro (Kibo 5899 m), the second highest mountain in Africa. It is broadly cone-shaped with deeply incised, in the upper parts U-shaped valleys, indicating extensive former glaciations. Most parts of Mt. Kenya are still covered with forests up to approximately 3400 m in the South and 3000 m in the North, where a sharp boundary separates the forest from the lower alpine zone. Shape and location of the upper treeline has been severely influenced by fires. The present lower timberline is a result of extensive forest clearance and agriculture with cultivation reaching up to 1800 m on the southern, up to 2400 m on the eastern and western, and nearly up to 2900 m on the northern slopes. Without human impact, the mountain would be almost completely surrounded by dense forests.

As an important water catchment, Mt. Kenya contributes mainly to the Ewaso Nyiro and Tana River drainage systems, and is therefore of outmost importance for the water supply of about 50 % of the Kenyan population. Moreover, since other power stations did not fulfill the expectations hydropower from these rivers continues to generate more than half of the country's production of electrical energy (Berger 1985; Decurtins 1985, 1992; Leibundgut 1986). Densely populated farming areas surround the whole mountain, and large parts of the forest suffered heavily from encroachment in the last decades. The vertical zonation of the mountain has already been described in the early 20th century (Engler 1895; Allaud & Jeannel 1914), but the first comprehensive accounts are from the 1950s (Hedberg 1951).

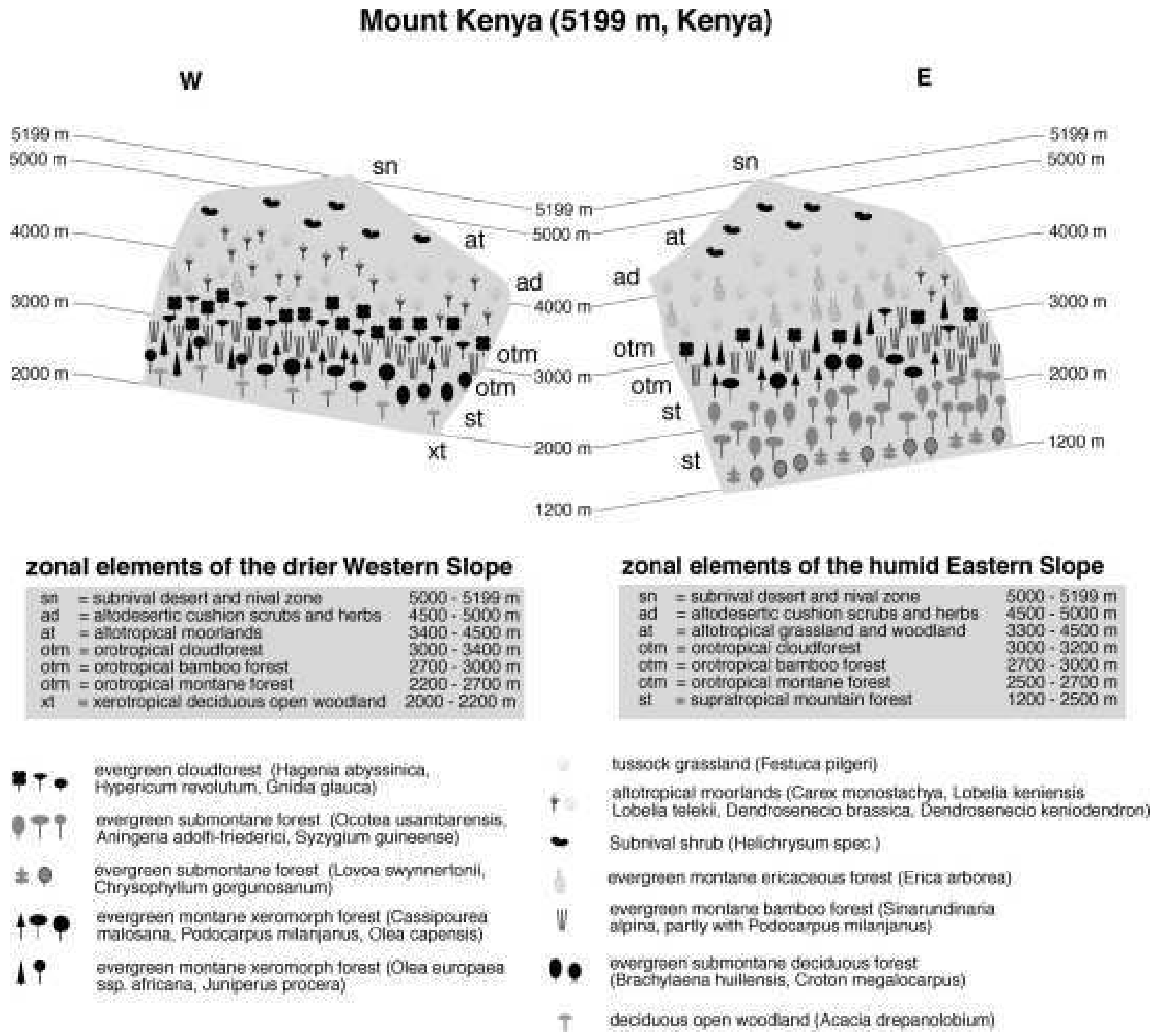

Fig. 1a. Vegetation zonation on Mt. Kenya, West-East Transect

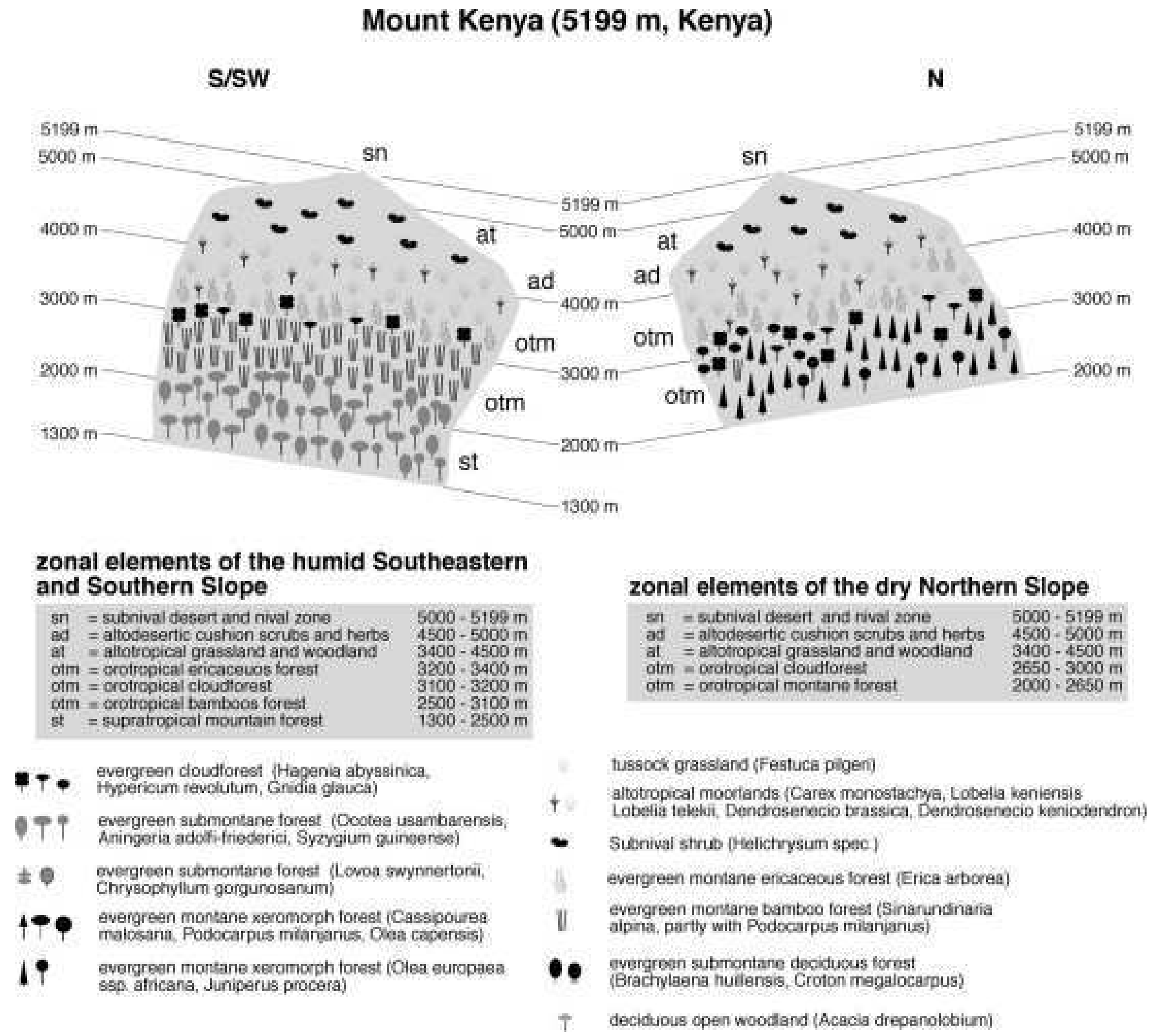

Fig. 1b. Vegetation zonation on Mt. Kenya, North-South Transect

Supratropical evergreen montane forests

The lowermost areas on the eastern and northeastern slopes from 1200-1500 m are covered with evergreen mountain forests, which closely resemble forest types of central and western tropical Africa. *Newtonia buchananii, Lovoa swynnertonii* and *Chrysophyllum gorungosanum*are prominent tree species. These have survived only in comparatively small remnants, while the principal forest formation are typical Camphor forests, with *Ocotea usambarensis, Aningeria adolfi-friederici* and *Syzygium guineensis* being the most important canopy species. These evergreen submontane forests (Bussmann 1994, 2001, Bussmann & Beck 1995a,b, 1999) are two-storied, with huge specimens of the African Camphor tree, *Ocotea usambarensis* in the upper canopy, and *Xymalos monospora*, *Lasianthus kilimandscharicus*, *Pauridiantha holstii* and *Psychotria orophila* in the lower tree layer and the often-dense shrub stratum. Further characteristic species in the upper tree layer are *Strombosia scheffleri* and *Apodytes dimidiata* in the upper tree layer, while *Tabernaemontana stapfiana*, *Ochna insculpta*, *Macaranga kilimandscharica* and *Peddiea fischeri* form low trees and shrubs. *Asplenium sandersonii*, *A. elliottii* and *Panicum calvum* occur in the herb layer, together with *Piper capense*, *Oplismenus hirtellus*, *Plectranthus luteus*, *Begonia meyeri-johannis* and the ferns *Dryopteris kilemensis* and *Blotiella stipitata*. *Cyphostemma kilimandscharicum* is a common climber, and abundant fern epiphytes include *Elaphoglossum lastii*, *Trichomanes borbonica*, *Asplenium theciferum* and *Oleandra distenta*.

On the lowermost eastern slopes of Mt. Kenya, forests with only one closed tree layer are found, dominated by *Newtonia buchananii* and many, often very tall palms (*Phoenix reclinata*), which give these areas an appearance like an Andean cloud forest. Once, these forests covered large tracts of land especially on the eastern slopes of Mt. Kenya, and formed the lowermost submontane forest belt in transition to the savannah lowlands, but these forests have long ago been cleared for cultivation.

On the western side of Mt. Kenya, evergreen submontane semi-deciduous forests, where drought resistant species like Calodendron capense or Croton megalocarpus are common, follow woodlands dominated by Acacia drepanolobium from 2000-2300 m.

On the northern part of Mt. Kenya, the woodlands lead directly into very drought-resistant xeromorphic forests, which are almost entirely dominated by Pencil Cedar (*Juniperus procera*) and Wild Olive (*Olea europaea* subsp. *africana*). A Bamboo belt is absent there, and even the narrow cloud forest belt is heavily interspersed with Cedar. Several authors mentioned a so-called "forest gap" on the drier northern slopes of the mountain (e.g. Hutchins 1909; White 1950). Whether this gap is natural or man made has been a matter of debate. According to the statements of long-term residents of the area, clearing the forest for farming purposes has widened the gap. In the late 1970’s, the Kenyan government for farmland excised some areas of the Mt. Kenya Forest Reserve. In many smallholder fields (shambas) of this area, forest trees or remnants of trees are still present, indicating clearly the former extension of the forest belt. Climatic conditions are less probable to be responsible for the gap since in an even drier area exactly north of the gap on Mount Kenya, the Ngare Ndare forest with extensive stands of *Juniperus procera* is found. Therefore, there are no reasons to assume a natural reason for the existence of the forest gap. Most probably, a formerly closed forest belt must be concluded.

Riverine forests and a variety of very different forests can be also found, indicating affinities to the mountain forest communities of Central and Western Africa. *Lovoa swynnertonii*, a very tall and dominant canopy tree is a typical species, growing together with the shrubs *Rawsonia lucida*, and with *Heinsenia diervilleoides* and *Rinorea convallarioides.* In many places *Uvariodendron anisatum*, with its beautiful and very fragrant white leaves, grows abundantly in the lower tree stratum and in the shrub layer.

Pure Camphor forests are found mainly on the very wet southeastern and southern slopes of Mt. Kenya on altitudes between 1550-2550 m. They grow on humic Niti- and Acrisols and receive an annual rainfall of 1500-2500 mm. Moist forests in the lower and middle submontane region of southeastern Mt. Kenya are dominated by the evergreen species *Syzygium guineense* (Myrtaceae) and *Aningeria adolfi-friederici* (Sapotaceae), reaching a height of up to 50 m. Furthermore, the shrubs *Drypetes gerrardii* (Euphorbiaceae) and *Allophyllus cuneatus* (Sapindaceae), as well as the lianas *Adenia gummifera* (Passifloraceae) and *Jaundea pinnata* (*Connaraceae*) are characteristic species. The number of epiphytic mosses is limited, but a wide variety of epiphyllous and epiphytic liverworts and lichens occur.

Most stands suffered from heavy exploitation, and have been replaced by secondary vegetation types, leaving untouched evergreen forests only in steep ravines or in remote areas, which are difficult to access. *Macaranga kilimandscharica* dominates the canopy of these secondary forests, and often forms dense pure stands. It is a very fast growing species suppressing the regeneration of other trees.

Orotropical montane forest - Evergreen broad-leaved and evergreen xeromorphic montane forests

The cedar forests (*Juniperus procera*) grow on humic Acrisols (Speck 1986) at rainfall totals between 700 and 1500 mm. They represent the typical vegetation of the altitudinal range between 2500 and 2950 m of the drier exposures (Bussmann 1994, 2001, Bussmann & Beck 1995a, 1999).

Evergreen-broadleaved forests cover the moister southern and southeastern slopes, at lower altitudes between 2150-2650 m. *Juniperus procera* itself is rare or completely absent, due to heavy logging and suppressed regeneration in the closed stands. The dominant tree species in these two-storied stands are *Cassipourea malosana* (Rhizophoraceae) and *Olea capensis* subsp. *hochstetteri*, the East African Olive; both forming the upper canopy. *Lepidotrichilia volkensii* in the lower tree and shrub strata, and *Ilex mitis*, the African Holly are further important woody species.

Cedar forest, in contrast, is rather open and one or two-storied, with *J. procera* growing about 50 m tall under favorable conditions. Other important tree species, mainly of the lower canopy, are the Wild Olive (*Olea europaea* subsp. *africana*) and *Podocarpus latifolius*. Mosaics of dense grass layers with *Stipa dregeana* and *Brachypodium flexum*, interspersed with herbs (*Sanicula elata*, *Isoglossa gregorii* and *Achyranthes aspera*), and low shrubs (e. g. *Berberis holstii*) are also characteristic of these open cedar forests.

Orotropical Bamboo forest

Dense forests dominated by the African Bamboo (*Sinarundinaria alpina*) which are found on various East African mountains, constitute a very distinct formation (Bussmann 1994, 1997, Bussmann & Beck 1995a, 1999, Bussmann 2001, Bytebier & Bussmann, 2000). *Sinarundinaria alpina* is the overwhelmingly dominant species in all strata, but *Impatiens hoehnelii*, *Pseudocarum eminii* as well as *Selaginella kraussiana, Cyperus dereilema*, and *Anthriscus sylvestris* are common companions. Bamboo forests are restricted to a relatively narrow ecological range, mainly depending on soil temperatures of 10-15 °C and the presence of very deep volcanic soils, namely humic Andosols. On Mt. Kenya, they are found in an almost closed belt around the entire mountain, interrupted only on the dry northern slopes. Stands are somewhat more extensive on the very wet southern parts.

On steep slopes of the western, northwestern and eastern side of Mt. Kenya, in areas with lower rainfall and higher soil temperatures, often huge individual trees protrude from the dense Bamboo layer in some 10-15 m height. The dominant species of the tree stratum is always *Podocarpus latifolius*, which is also common in the surrounding montane forest. Towards the hygric limits of the Bamboo, mainly on the dry northwestern parts of the mountain, *Juniperus procera* and *Olea europaea* su*bsp. africana* are found as characteristic members of the tree stratum. Trails and heavily trampled resting places of big game occur everywhere in these forests, and seem to facilitate regeneration of trees in the otherwise extremely shady stands of *Sinarundinaria alpina*.

Orotropical cloud forest

Two forest types, namely tall and malacophyllous forest with Hagenia abyssinica occupy this vegetation zone, and lower stands built by various species with sclerophyllous, "ericoid" leaves. The so called "ericaceous belt" forms the transitions zone towards truly afroalpine vegetation within the timberline ecotone. In contrast, the malacophyllous forests extend from 2900 to 3300 m a.s.l., where low clouds and mist are frequent. The dominant tree is the Kosso tree, *Hagenia abyssinica* (Rosaceae), often accompanied by the Giant St. John's Worth, *Hypericum revolutum*. *Bothriocline fusca* is a common shrub, while *Polygonum afromontanum*, *Stephania abyssinica*, *Cinereria deltoidea* and *Carduus afromontanus* are common herbs. Pure *Hagenia-Hypericum* forests with a low, dense shrub layer of *Hypericum* are characteristic for the wetter southeastern to western slopes of Mt. Kenya. Here, important herbaceous companions are *Luzula johnstonii*, the large *Lobelia bambuseti, Rubus frieseorum*, *Agrostis schimperiana*, *Poa schimperiana*, *Helictotrichon milanjeanum*, and one of the few succulents, *Uebelinia rotundifolia*.

In the drier northern part of Mt. Kenya, the *Hagenia*-dominated forests are replaced by mixed forests with *Podocarpus gracilior* and broad-leaved species, clearly differentiated by the high frequency of *Juniperus procera*, *Olea europaea*, *Nuxia congesta* and especially *Rapanea melanophloeos*. *Hagenia abyssinica* is only a co-dominant canopy species and *Hypericum revolutum* is mostly absent.

From some 3300 m upwards, *open ericaceous communities gradually replace Hagenia forests*. They grow at the upper limit of forests, but the timberline has been lowered by several hundred meters due to fires and undulates now at 3100 to 3300 m. True *Erica excelsa* forests are poorly developed on Mt. Kenya, and most often the ericaceous belt is formed by remnant stands of ericaceous scrub with *Erica trimera* (formerly *Philippia*, Oliver 1987), *E. arborea*, *Conyza vernonioides*, and the astonishingly "ericoid" Asteraceae *Stoebe kilimandscharica* (Rehder et al. 1988). The latter, together with *Protea kilimanscharica*often indicates regular disturbance by high altitude fires. Fires are usually discontinuous, so the scrub is interspersed with various grassland types that are already afroalpine. Thus, ericaceous and afroalpine communities generally form patchy mosaics and transition communities rather than clear altitudinal belts.

Altotropical grasslands and moorlands

In tropical Africa, the altitudinal belt above the timberline has been termed "afroalpine" (Hauman 1955). Communities intersect with ericaceous vegetation, and are mainly dominated by tussock grasses and stands of Giant Rosette Plants. Fortunately, a vegetation map is available, so the spatial distribution of communities is well known (Rehder et al. 1988; Beck et al. 1990). "Open Moorlands" are particularly extensive on the western slopes of Mt. Kenya at altitudes from 3400-3800 m, often found at clearings of ericaceous vegetation. The dominant species are grasses, namely the large sedge *Carex monostachya*, interspersed with tussocks of *Festuca pilgeri* in drier places. Most characteristic are the large, cabbage-like ground rosettes of *Dendrosenecio brassica* and *Lobelia keniensis*. The Giant Rosette "tree" *Dendrosenecio johnstonii* subsp. *battiscombei* is common in the lower moorlands as well as in remnant ericaceous stands.

The "Upper Moorland Zone", extending from about 3800 m upwards as high as 4550 m comprises two very characteristic vegetation units. Where moisture availability is sufficient, "Upper

Alpine Wetlands" are formed by *Dendrosenecio brassica* and *Lobelia deckenii* ssp. *keniensis*. In contrast to lower altitudes, sclerophyllous dwarf shrubs like Alchemilla johnstonii, Alchemilla argyrophylla subsp. argyrophylla and Helichrysum brownei often replace grasses. Sedges are less important than in the lower moorlands.

The typical plant community above 4300 m is the "Dendrosenecio woodland", in which *D. brassica* is replaced by the Giant Groundsel, *Dendrosenecio keniodendron,* growing together with *Lobelia telekii*. From 4500 m onwards, the Giant Groundsels recede, and an open layer of *Festuca pilgeri,* interspersed with *Lobelia telekii, Festuca abyssinica, Carduus chamaecephalus*and *Senecio keniophytum* extends to the subnival zone. Occasional specimens of vascular plants where found up to the summit region in above 5000 m (Rehder et al. 1988). In contrast to the situation on Kilimanjaro, where low precipitation creates a real alpine desert, closed vegetation on Mt. Kenya is more limited due to freezing and continuous solifluction, although moisture availability probably has some influence (Beck 1994).

Mt. Kenya’s neighbors: Mt. Kilimanjaro, Mt. Meru, Aberdare Mts. and Mt. Elgon

Although they are separated by hundreds of kilometers of lowlands, the neighboring mountains show a vegetation zonation very similar to Mt. Kenya. These striking similarities have long been known to phytogeographers (Hedberg 1951; Hedberg 1964), and have let to the general classification scheme that provided the base for the previous chapter. The vegetation belts are very distinct, as are differences between sides of the mountains, where drought-resistant forest types on their northern escarpments replace very humid elements on their southern and southwestern slopes.

Exposure differences are particularly pronounced on Mt. Kilimanjaro (Figure 2). The southern slopes are unusually moist with an annual precipitation of around 900 mm in the southern foothills, around 2000 mm at 1500 m asl. and well above 3000 mm between 2000 and 2300 m. The summit region is, in sharp contrast, an alpine desert with well below 200 mm annual precipitation (Hemp 2002). Although no exact measurements are available, the northern slopes are clearly drier as indicated on the available vegetation map and the accompanying descriptions (Hemp 2001). Below 1000 m dry savannah surrounds the entire mountain, but on the northern slopes savannahs with *Acacia drepanolobium* and forest plantations climb above 2000 m altitude, followed by a small belt of xeromorphic forests with Cedar and Olive up to 2800 m.

In the moist south between 1000 - 1800 m, evergreen submontane deciduous forests has largely been replaced by dense agriculture. Remnants of the lowermost submontane forests are characterized by *Olea europaea* and at drier sites by *O. capensis*, but from 1700 m upwards, lower montane evergreen Camphor forests and other broadleaved forests dominated by Cassipourea malosana replace these. In proper montane forests above 2000 m *Podocarpus latifolius* becomes increasingly common. The most striking feature of these forests is the abundance of epiphytes, in particular Hymenophyllaceae and other fern groups, which give the stands the appearance of a true elfin forest. On all sides of Kilimanjaro, dense *Erica excelsa* forests occupies the belt between 2700-3100 m (South) and 2800-3400m (North). Lower down, in the central montane belt, such forests form replacement communities at disturbed sites (Hemp & Beck 2001). Cloud forests with *Hagenia abyssinica* and *Hypericum revolutum* are restricted to special sites such as boulder streams and moist valleys. Above 3100 m, *Erica* forests are gradually replaced by ericaceous scrub mixed with altotropical moorlands, where subspecies of *Dendrosenecio johnstonii* and*Lobelia deckenii* grow as vicariant taxa to Mt. Kenya (Knox 1993). Above 3900 m, subnival *Helichrysum* scrub takes over up to some 4600 m, where it becomes to dry for growth of vascular plants. The summit region is truly nival and devote of vegetation.

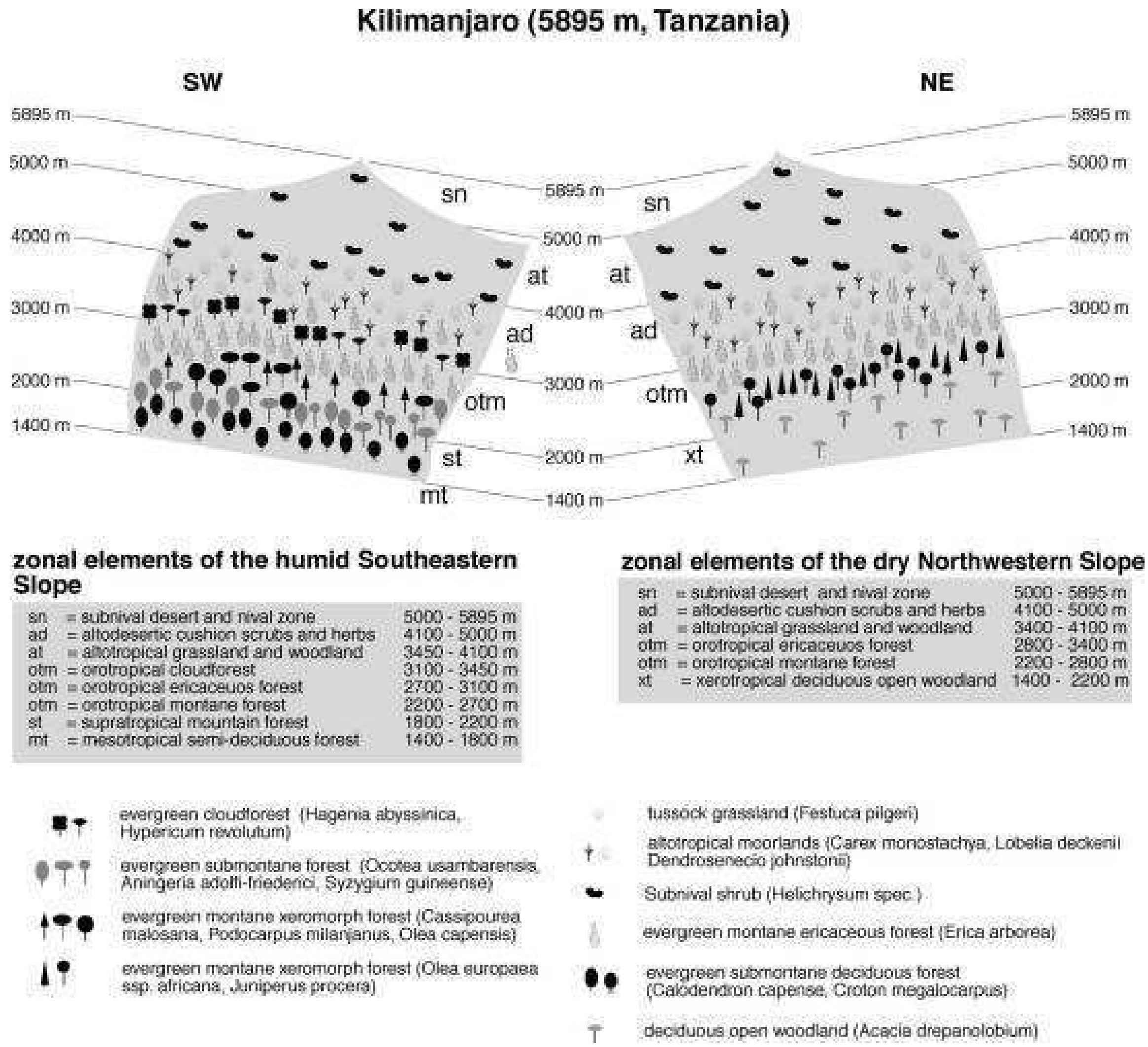

Fig. 2. Vegetation zonation on Mt. Kilimanjaro

The northern flanks of the neighboring Mt. Meru (Figure 3) are covered by deciduous open woodlands, which are followed by a small band of cloud forest with *Hagenia abyssinica, Hypericum revolutum* and *Gnidia glauca* between 2500-3000 m (Hedberg 1955; Hedberg 1964?). Higher up, these are replaced by evergreen ericaceous scrub up to 3700 m, which forms the transition to altotropical moorlands, where *Carex monostachya, Lobelia deckenii* and *Dendrosenecio johnstonii*dominate. On the southern slopes of this mountain, however, evergreen montane xeromorphic forest with *Podocarpus latifolius, Cassipourea malosana* and *Olea capensis* grows at altitudes from 1700-2300 m. These merge gradually into a distinct Bamboo belt that is replaced by typical cloud forest at 2550-2700 m. The zonation of the uppermost regions shows the same features as the northern escarpment.

The Aberdare Mts. form the next neighboring mountain range west of Mt. Kenya. Climate and vegetation were comprehensively described by Schmitt 1991, who also provides a vegetation map. Climatic conditions are similar to Mt. Kenya, with highest precipitation in the southeast and a maximum in the montane belt of around 2200 mm. The vegetation zonation is also largely similar, with *Cassipurea malosana* and *Olea capensis* in the supratropical mountain forest. Above 2500 to 2700 m, forests with Cedar, *Podocarpus latifolius* and riverine forests with *Afrocrania volkensii* dominate. An almost closed belt of Bamboo, from which specimens of P. latifolius and Nuxia congesta emerge, follows these. Above 2900 m cloud forests with *Hagenia abyssinica*, *Hypericum revolutum* and *Rapanea melanophloeos* take over. *Erica excelsa* becomes important towards the upper limit of montane forests on the main plateau in some 3100 m altitude. Thus, most of the upper region of the Aberdare Mts. is well in the altitudinal range of ericaceous forests and scrub, so that grasslands are largely secondary and promoted by fires as well as grazing by wild ungulates. The vegetation gives a very patchy impression, and altitudinal belts can hardly be inferred except towards the summits from 3600 m upwards. Ericaceous vegetation includes well-developed cloud forest of *E. excelsa*, and scrub with *E. trimera*, *Stoebe kilimanscharica* and *Cliffortia nitidula*. The altotropical grasslands are dominated by *Festuca pilgeri*, *Koeleria capensis*, the C4 grass *Andropogon lima*, and at moist sites sedges (*Carex monostachya*, *Cyperus kerstenii*). Again, vicariant subspecies of the *Dendrosenecio johnstonii* and of the *Lobelia deckenii* groups grow in the afroalpine zone.

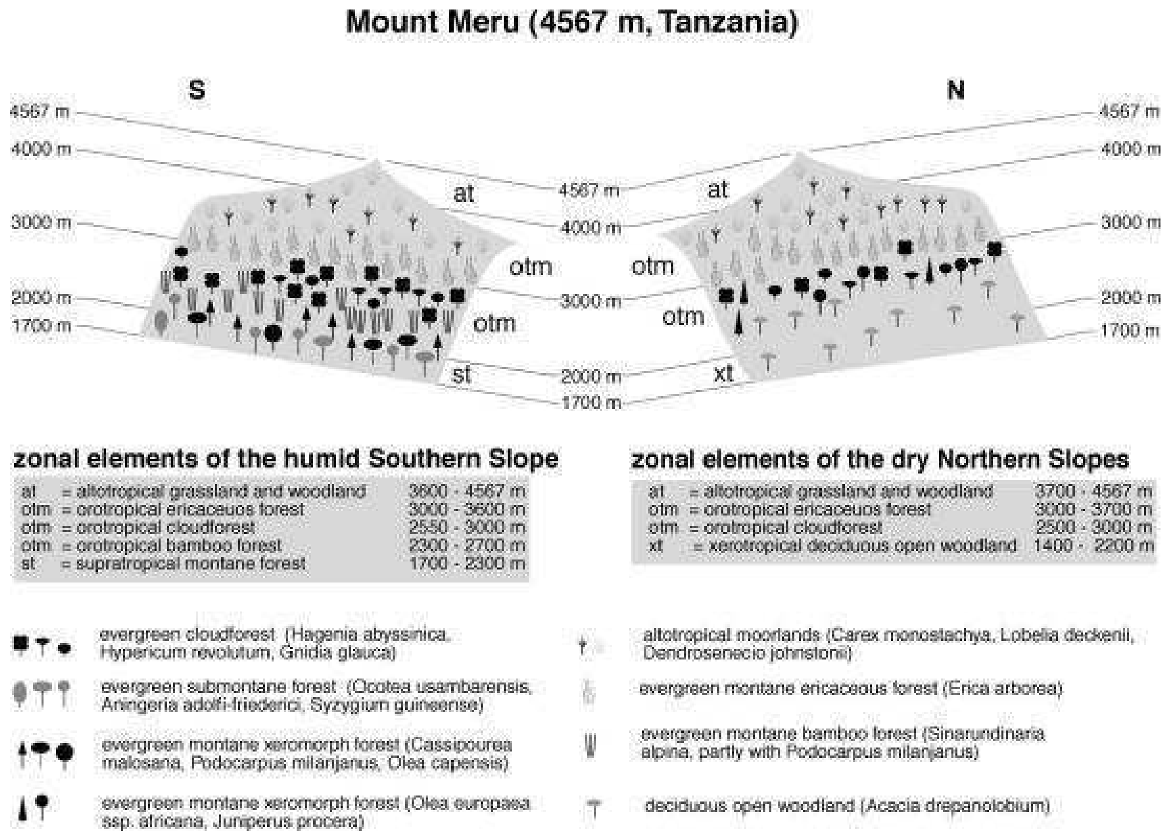

Fig. 3. Vegetation zonation on Mt. Meru

Near the boundary to Uganda, Mt. Elgon and the Cherangani Mts. form the easternmost part of these semi-humid mountain ranges. The Cheranganis are heavily cultivated and grazed on all elevations, so there is hardly any natural montane forest left. With some 3600 m altitude they are not high enough for extensive natural grasslands, so much of the present altotropical grasslands appear to be secondary (Mabberley 1975).

In contrast, Mt. Elgon is the largest solitary volcano with a full set of altitudinal belts comparable to Mt. Kenya (Wesche 2002, vegetation maps provided by van Heist 1994a; van Heist 1994b; Neville & Wesche in press). The western and southwestern slopes are clearly moister than the eastern part of the mountain, with a maximum of precipitation between 2300 and 2700 m asl. (1500-2000 mm on the western slopes, 1200-1500 on the eastern). Hardly any natural vegetation has survived the intense agriculture below 2200 - 2500 m, but higher up, large supratropical forests with scattered Camphor, *Aningeria adolfi-friederici*, *Podocarpus latifolius* and riverine *Afrocrania* forests survived. The eastern side is covered by dry orotropical forest with *P. gracilior*, *Olea capensis* and scattered Cedars. The Bamboo belt is almost closed except in the northernmost part. Cloud forests with Kosso and tree heather have mainly survived in the western part. Above the present timberline, mosaics of ericaceous vegetation with *E. trimera* and *Stoebe kilimandscharica*, *Helichrysum* and *Alchemilla*dwarf scrub and altotropical *Festuca pilgeri* grassland form the vegetation up to some 3700 m. Above this, afroalpine grasslands, *Helichrysum* scrub and *Dendrosencio* woodlands extend up to the summits. Mt. Elgon carries a separate species within the *Dendrosenecio johnstonii* complex, with one subspecies occurring up to 4000 and a second one between 4000 and 4300 m, resembling *D. keniodendron* on Mt. Kenya.

The interlacustrine highlands: Ruwenzori, Virunga Volcanoes and Kahuzi-Biéga

The mountains at the western branch of the Rift Valley form a separate group due to their perhumid rather than semi-humid climate. They border the huge rainforests of the Congo basin, so their lower slopes are covered by luxurious tropical evergreen forest with a high richness in species. Comprehensive vegetation surveys have been produced for Kahuzi-Biéga (Fischer 1996, including land cover map), the eastern half of the Ruwenzori range (Schmitt 1992; Osmaston 1996, land cover map by van Heist 1999, glaciological map by Osmaston & Kaser 2001), and for parts of the Virunga Mts. ((Snowden 1933; Biedinger 1995; Karlowski 1995).

Although the eastern side is generally drier, the vegetation of Ruwenzori (Figure 4), as of Mt. Cameroon, shows no clear distinction between the humid Western and drier Eastern side of the mountain, whereas on the Virunga Volcanoes (Figures 5 and 6) exposition differences are pronounced. The evergreen submontane forest belt of Ruwenzori stretches from 1000-1600 m. Common and typical tree species are *Ocotea usambarensis, Aningeria adolfi-friederici* and *Syzygium guineense*. On Muhavura and Karisimbi, submontane forest occupies both western and eastern slopes from 1300 to 2000 m. At altitudes between 2000-2300 m evergreen supratropical mountain forests with *Olea capensis, Cassipourea malosana* and *Podocarpus latifolius* replace lowland species in all three regions. In striking contrast to East Africa, no Cedar (*Juniperus procera*) can be found on any mountain in central Africa. Bamboo (*Sinarundinaria alpina*), mostly in stands interspersed with *P. latifolius*, is a prominent feature on Ruwenzori (from 2300 - 3000 m) and on the Virungas (2400-2600 m on Karisimbi, and stretching up as high as 2900 m on western Muhavura).

On Ruwenzori, evergreen *Erica* forest follows immediately after the Bamboo belt and forms extensive stands at 3000-3900 m. The situation on the Virunga Volcanoes is different. On Western Karisimbi (Figure 5), a small fringe of evergreen cloud forest with *Hagenia abyssinica* and *Hypericum revolutum* separates Bamboo and ericaceous belt between 2600-2700 m, from which ericaceous forests can be found up to 3800 m. The cloud forest belt is better developed on the humid eastern slope, where it extends from 2600-3500 m, followed by ericaceous scrub up to 3800 m. The drier Muhavura (Figure 6) shows an exactly inverted cloud forest distribution: on the more humid western slope, *Hagenia* prevails from 2900-3300 m, followed by the ericaceous vegetation up to 3700 m, whereas on the dry eastern escarpment the cloud forest zone is completely replaced by afroalpine grassland ***(***Karlowski 1995***).***

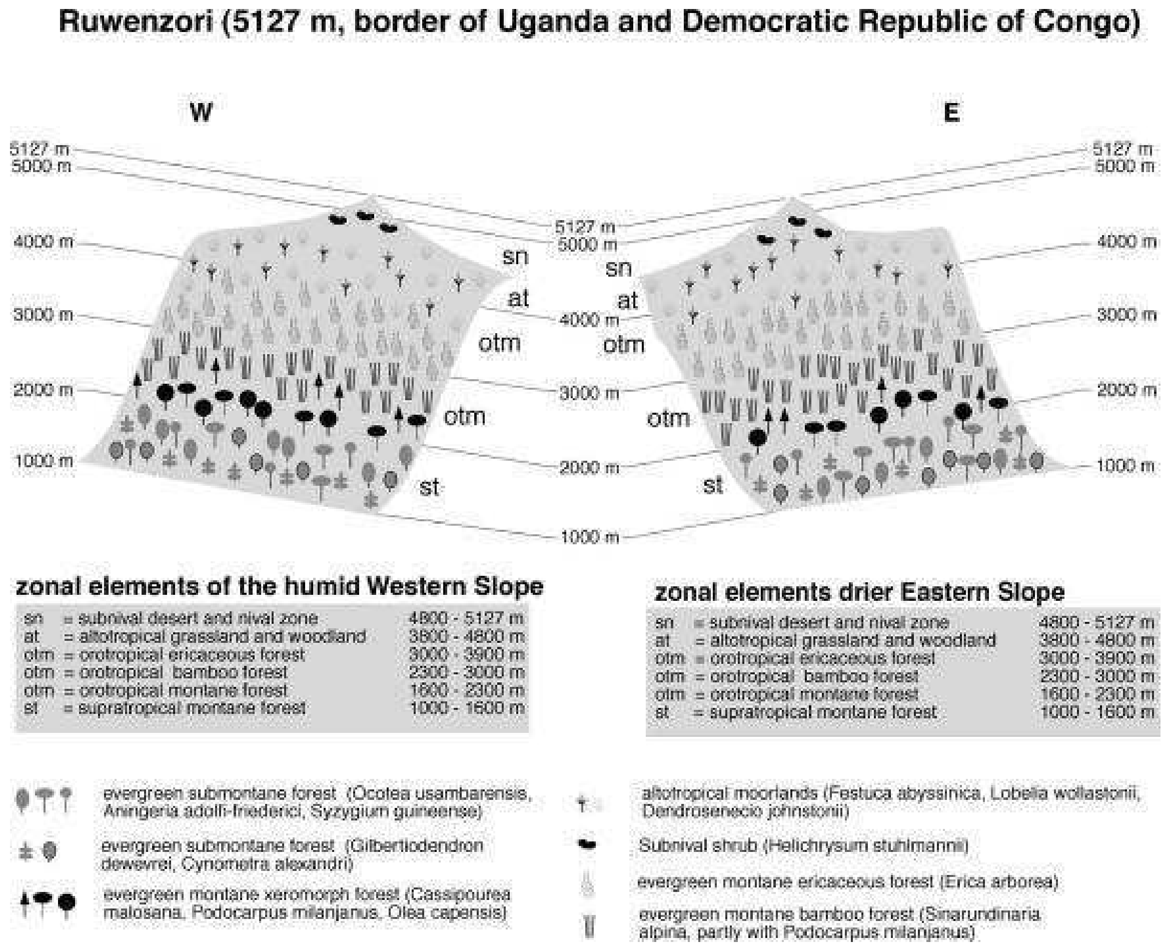

Fig. 4. Vegetation zonation on Mt. Ruwenzori

Extensive altotropical moorlands always occupy the alpine zone of the Central African Mountains. Tussocks of *Festuca abyssinica* and *Carex runssoroensis,* as well as the giant rosette plants *Lobelia wollastonii* and *Dendrosenecio johnstonii* occur on all three mountains, whereas *Lobelia stuhlmannii* grows only on the Virungas. Due to its much higher elevation, upper alpine dwarf scrub is only found on the uppermost parts of Ruwenzori, where *Helichrysum stuhlmanii* forms isolated thickets. The Kahuzi-Biéga range is not high enough for a true afroalpine zone, so the summit region is covered by ericaceous scrub and *Deschampsia flexuosa* grassland. The latter indicates the regular presence of fires.

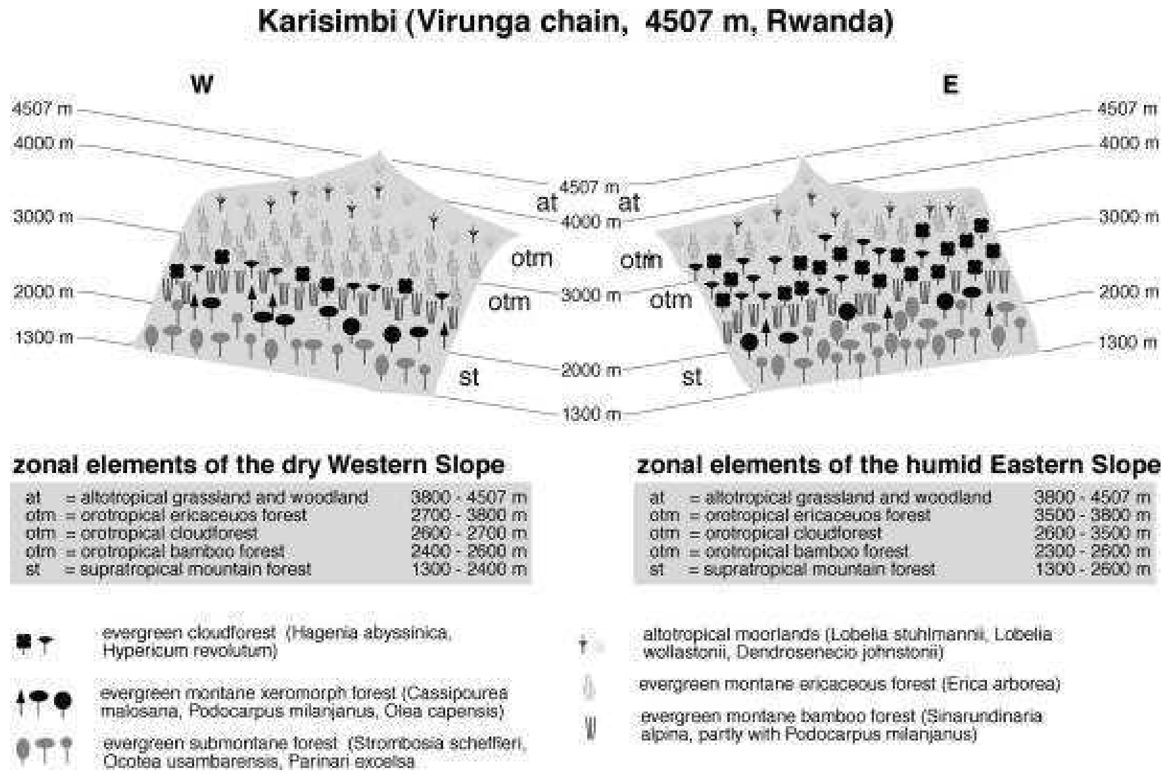

Fig. 5. Vegetation zonation on Mt. Karisimbi, Virunga Volcanoes

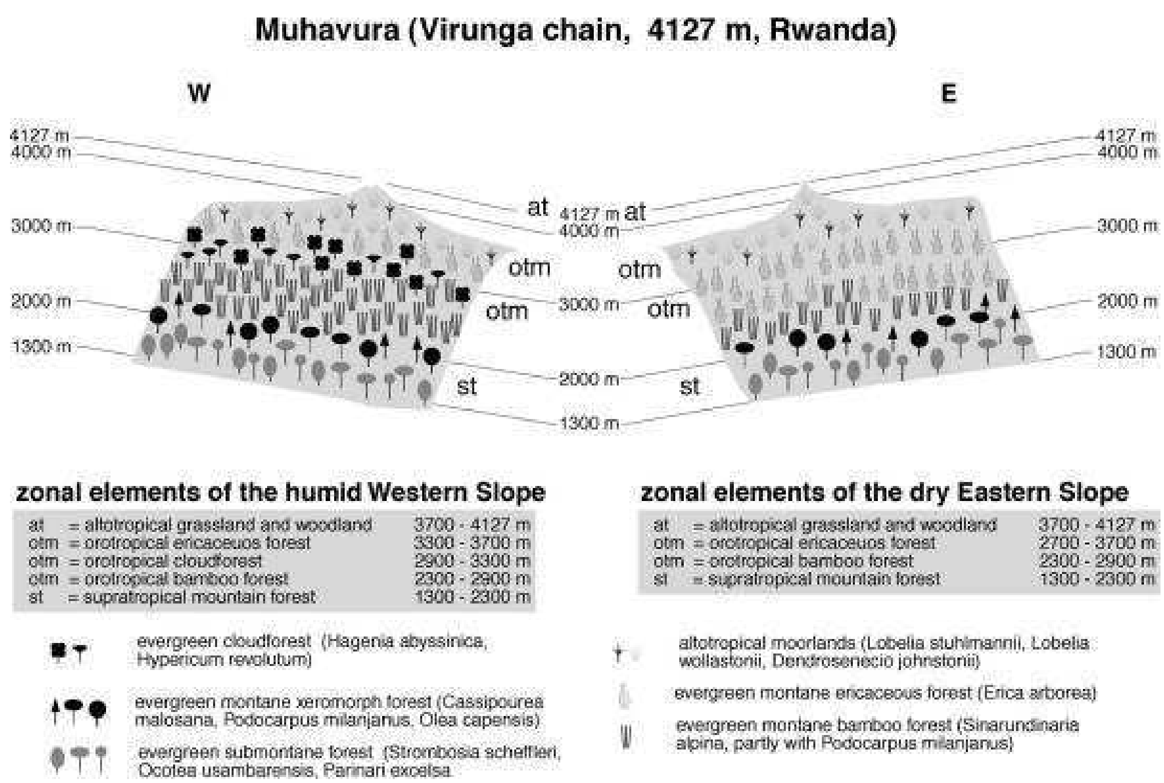

Fig. 6. Vegetation zonation on Mt. Muhavura, Virunga Volcanoes

The westernmost outpost - Mt. Cameroon

The highlands in Cameroon form a widely isolated archipelago in western central Africa. The highest peak is Mt. Cameroon (4095 m, Figure 7), an active volcano that had its most recent eruption in 1982. The climate is extraordinary moist, with up to 10000 mm annual precipitation in the foot zone and below 2000 mm in the summit region (Cable & Cheek 1998, including vegetation map). Mean air temperature is around 20°C at 900 m and estimated to be around 4° in the summit region. Snow is rare, even on top of Mt. Kilimanjaro. Soils in the mountains are mostly young and therefore fertile, so large areas have been cleared for agriculture. About a third of Mt. Cameroon is now under legal protection, and here natural vegetation has survived partly down to the sea level (Cable & Cheek 1998). The small remnants of lowland forests are rich in various species, and have the highest number of endemics of all vegetation belts (29 vs. 49 for the entire range). Pluviotropical evergreen rain forest dominate the larger part of these altitudes, with tree species like *Schefflera mannii* or *Syzygium guineense* frequently found in the canopy, and *Allophyllus bullatus* forming a second layer. These forests merge gradually into submontane evergreen forest from 800 m upwards. Species composition, however, changes only slightly, being characterized by *Syzygium staudtii*,*Schefflera abyssinica*, and still *Allophyllus bullatus*(Richards 1963; Hall 1973). From 2000-2600 m orotropical cloud forest is the dominant forest type with species found on all tropical African mountains like *Nuxia congesta*, *Prunus africana*,*Xymalos monospora*, and *Hypericum revolutum*. These form the evergreen cloud forest, together with *Rapanea neurophylla*. Bamboo is completely absent from Mt. Cameroon, but occurs other ranges in western central Africa. *Hagenia abyssinica* does also not occur on Mt. Cameroon, although all other species show clear relationships to the *Hagenia*-dominated upper montane forests common in other areas of sub-Saharan Africa. At all altitudes, large parts of the forests have been replaced by grasslands due to high volcanic activity and thus frequent fires. For the same reason, scrub and thickets are frequently found all over the mountain, with Marantaceae dominating below 2000 m and ericaceous species like *Erica mannii*, *Agauria salicifolia* and *Myrica arborea* forming a patchy ericaceous belt towards the timberline ecotone. Dense altotropical tussock grasslands reach up to 3400 m, where large Poaceae as *Andropogon* sp.*, Festuca abyssinica, Deschampsia mildbreadii* and *Loudetia camerunensis* dominate, interspersed with small tree islands (Photo). True giant rosette plants, *Dendrosenecio* or *Lobelia* species are absent from Mt. Cameroon, though *Crassocephalum mannii* and *Lobelia columnaris* show resemblances to this growth form. From 3400 m upwards to the summit region, vegetation cover becomes more open and impoverished in species (Maitland 1932). There are no clear vegetation differences with regard to slope exposition.

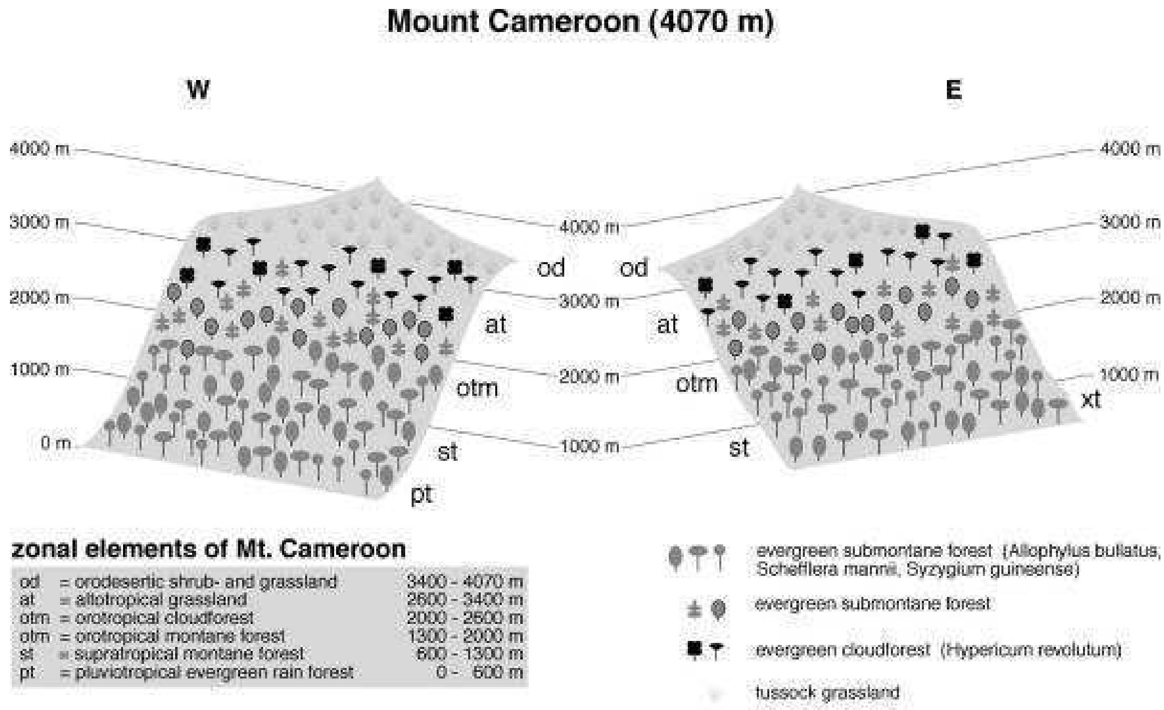

Fig. 7. Vegetation zonation on Mt. Cameroon

The Sudano-Ethiopian Mountains: Imatong, Simien, Bale

In striking contrast to the mountains in the strictly tropical part Africa, the Sudano-Ethiopian mountains emerge from dry vegetation and semi-arid surroundings. Thus, the mountains of southern Sudan and Ethiopia are characterized by steep climatic gradients and correspondingly, by clear altitudinal changes in the vegetation zonation. All ranges are widely isolated from the eastern African mountains, with the Imatong Mts. in southern Sudan being the least distant.

Their foot zone receives some 800 mm, while at 1900 m asl. some 2200 mm have been recorded; the highest figure in Sudan. The lower slopes of the Imatong Mts. (Figure 8) are covered with lush evergreen submontane forest, where *Ocotea usambarensis, Olea welwitschii* and*Chrysophyllum fulvum* are common species (Jackson 1956). Above 2000 m, these forests merge into evergreen montane xeromorphic forest with *Podocarpus latifolius* and *Olea capensis*. Above 2600 m, a mixture of evergreen Bamboo and evergreen cloud forests with Hagenia abyssinica replaces these. The highest zones, above 3000 m, are covered with dense thickets formed by *Erica arborea* and*Myrica salicifolia* up to the summit region.

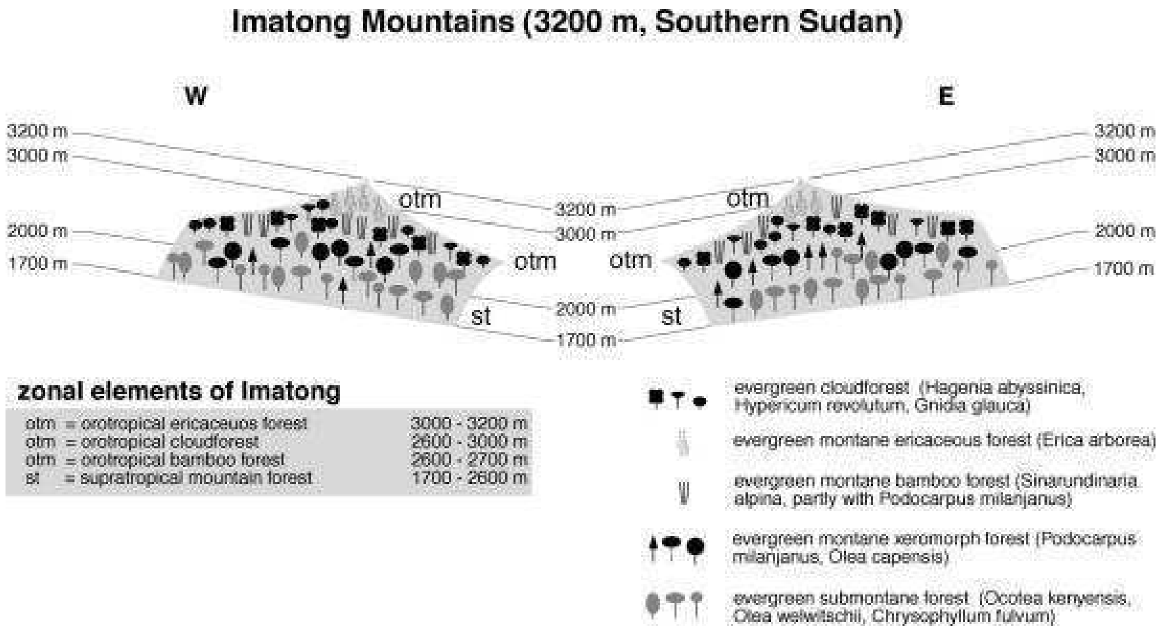

Fig. 8. Vegetation zonation in the Imatong Mts.

The by far largest area of afromontane and afroalpine environments is found in Ethiopia. This huge country displays notable differences in climate, and consequently relatively moist ranges as the Bale Mts. in the southern part are found, as well as extremely dry areas like the Simen Mts. in the north. The Bale Mountains (Figure 9) form the single largest afroalpine area, with a flora and vegetation being transient between East Africa and the drier northern part of Ethiopia (Weinert 1983). The southern foot zone emerges from dry *Combretum-Commiphora* savannah at 390 mm annual precipitation, but the southern Harenna escarpment receives around 850 mm at 3000 m asl. The central part of the range is a huge plateau in some 4000 m asl., where conditions become progressively moister towards the northern slope, which receives around 1000 mm (Miehe & Miehe 1994). This induces a clear zonation of very well pronounced vegetation belts. The lower southern slopes are covered with dense evergreen submontane deciduous forest from 1450-1900 m, where *Podocarpus gracilior, Filicium decipiens* and *Celtis africana* as well as *C. gomphophylla* form an open canopy (Lisanework & Mesfin 1989; Bussmann 1997). The undergrowth is often dominated by very dense thickets of wild coffee (*Coffea arabica*). Mid-altitudes from 1900-2300 m are covered by evergreen submontane forest (with *Ocotea kenyensis, Aningeria adolfi-friederici* and *Olea welwitschii* as most characteristic tree species), and thus resemble the Imatong Mountains closely. Above 2300 m, *Cassipourea malosana, Schefflera abyssinca*and *Croton macrostachyus* form the evergreen montane forest, which slowly gives way to cloud forest communities with *Hagenia abyssinica* and *Hypericum revolutum* from 2400 m onwards. Large areas of Bamboo are found between 2800-3100 m altitude. Cultivation has been more intense on the drier northern slopes, so only remnants of the natural vegetation survived. Dry orotropical Cedar and *Podocarpus* forests have been described up to 3000 m (Weinert 1983), but cloud forest with Kosso and Giant St. John's Worth is restricted to a band from 3000-3400 m.

Ericaceous vegetation with *E. trimera* sl. start to dominate the vegetation from this zone upwards to 4000 m. As elsewhere, the vegetation of the ericaceous belt has been severely altered by human influence, so mosaics of forests, scrub and afroalpine communities result. On the central Sanetti plateau, woody vegetation is restricted to sheltered sites as outcrops or boulder streams up to 4 up to 4000m. Instead, *Helichrysum* scrub and to a lesser extend tussock grasslands prevail up to the highest peaks (Menassie & Masresha 1996). Many of the grass and shrub species demonstrate clear affinities to the eastern African Mts. (e.g. *Pentaschistis pictigluma*, *Helichrysum citrispinum*), but the Giant Lobelias are present with only one endemic species (*Lobelia rhynchopetalum*), and the widespread forest species *Lobelia gibberoa*. Giant Groundsels are not found in Ethiopia. Strangely, an endemic thistle (*Echinops longisetus*) has developed a stem here resembling giant groundsels.

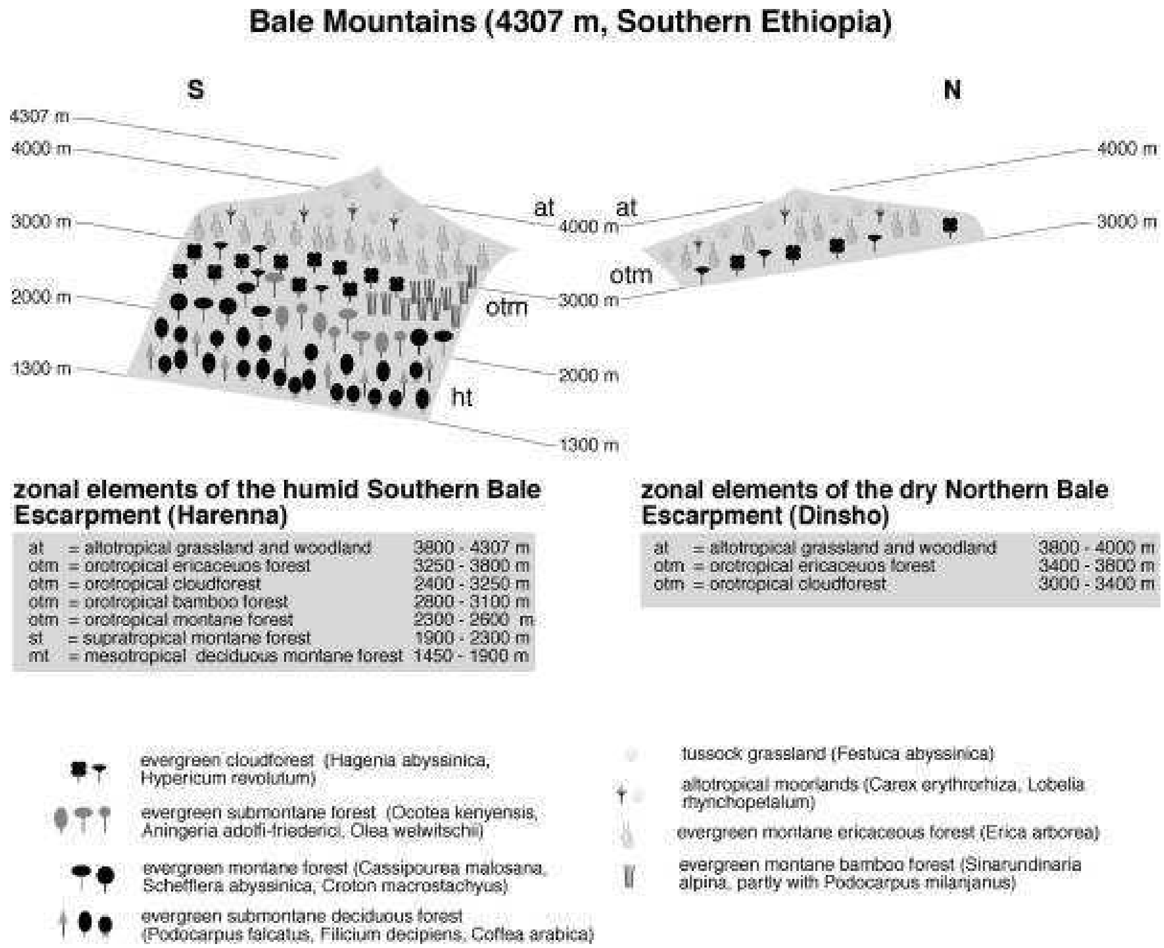

Fig. 9. Vegetation zonation of the Bale Mts.

Much of the Ethiopian highlands would bear montane forests if untouched, hence remnants of these forests still occur in the central part of the country (Tamrat 1993). The plant communities are still strikingly similar to those described for Mt. Kenya, but differences increase north-westwards, until the dry Simen Mts. (Figure 10) form the second largest afroalpine region in Ethiopia. Here, the precipitation regime finally becomes unimodal; the foot zone is rather dry but near the timberline 1500 mm have been measured (Hurni 1982). Savannahs below 2000 m are followed by evergreen montane forest with Cedar, *Olea europaea*, *Rapanea simensis* and finally Kosso between 2000-3500 m (3300 m in the southwest). Between 2900 and 3700 m ericaceous vegetation takes over, but here *Erica arborea* is the only tree heather; joined by *Hypericum revolutum*, as well as *Nuxia congesta* in the lower elevations (Klötzli 1975; Verfaille 1978; Nievergelt et al. 1998). Above this belt, *Festuca macrophylla*, *Carex erythrorhiza*, and *Lobelia rhynchopetalum* occur, the latter with an inflorescence up to 5m tall. In the highest regions, stands are gradually replaced by *Festuca abyssinica* and finally by *Helichrysum citrispinum* scrub up to the summit region.

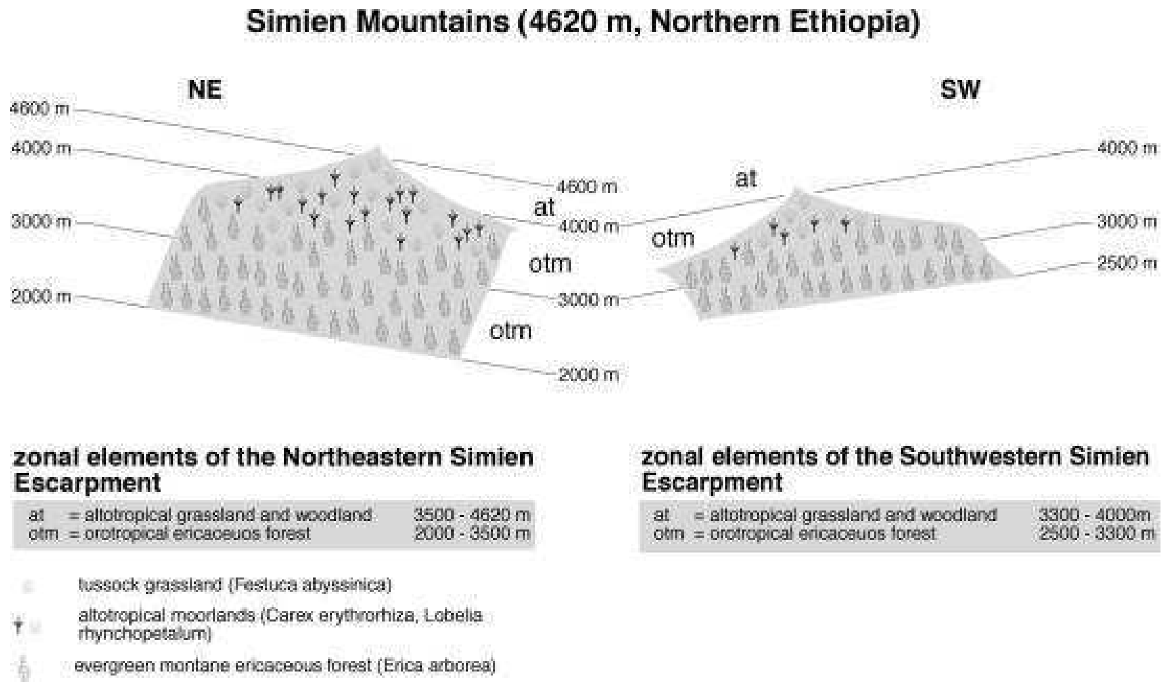

Fig. 10. Vegetation zonation in the Simien Mts.

Maloti-Drakensberg: Mountain vegetation in southern Africa

Environmental conditions

The Maloti-Drakensberg forms the highest part of the Great Escarpment which bounds the interior plateau of southern Africa. The geological structure is relatively homogenous and characterized by stratified Jurassic flood basalts in the upper portion, which cap the underlying fine-grained Clarens Sandstone (c. 1800-2200 m) and other formations of the Karroo Supergroup. For approximately 200 kilometers the towering scarp of the High Drakensberg constitutes the boundary between the eastern highlands of Lesotho and South Africa. An abrupt and rugged barrier ranging from the foothills at about 1400 m to numerous peaks, buttresses, pinnacles, and cutbacks of the escarpment edge lying roughly between 2800 and 3300 m marks the declivity towards South Africa. Some long spurs (the so-called Little Berg) run out at right angles to the escarpment. The mountain divide consists of two parts: the northern Berg, a north-east-facing portion between Mont aux Sources (3282 m) and Giant's Castle (3314 m), and the southern Berg, a south-east-facing part of the escarpment between Giant's Castle and Wilson's Peak (3310 m). Towards the west, the summit plateau gently slopes down to the foothills and lowlands of Lesotho below 2000 m. Rounded slopes, small cliffs and deeply incised valleys characterize the treeless plateau. The highest peak Thabana Ntlenyana (3482 m) lies about 4 km back from the edge of the escarpment (Hilliard & Burtt 1987; Killick 1990).

Mean annual precipitation in this high mountain area ranges from 1240 mm at the foot of the escarpment (1370 m) to a maximum of about 2000 mm at an altitude of 2300 m. The escarpment edge receives about 1600 mm (rainfall data from the Cathedral Peak area after Killick 1963). Letseng-la-draai (3050 m), located in the rain shadow receives 713 mm, and Mokhotlong Town (2377 m) about 35 km to the west of the escarpment receives only about 575 mm (Killick 1978b). Apart from these steep gradients in rainfall distribution, the humidity conditions are generally characterized by strong seasonal differences. Almost 80 % of the annual precipitation falls between October and March, resulting in generally humid conditions during the growing season (Killick 1978b). Frequent thunderstorms and recurrent periods of fog, which usually do not extent into Lesotho for more than 3 km contribute to summer humidity. Snow falls frequently between April and September and is usually restricted to the summit plateau and nearby slopes of the escarpment. Snow cover seldom lasts for longer periods, in exceptional years it may last for two months. Recurrent droughts force plants to sustain water stress. Generally, the southern Drakensberg is colder and drier than the northern portion. The temperature regime in the upper valley sections near the escarpment is characterized by a long frost period, lasting for approximately 180 days (Grab 1997a). Mean annual temperature is 5.7°C in Letseng-la-draai, and 11.5°C in Mokhotlong Town. Absolute minimum temperature exceeds

-20°C at the highest altitudes. Therefore, periglacial conditions with Thufur, needle ice, patterned ground, and soil movements are common at higher elevations (Grab 1994, 1997b, 1998). Prominent differences between the warmer and drier north facing slopes and the colder and moister southerly slopes result from different solar radiation income, especially during winter (Granger & Schulze 1977). Obviously, differences of snow cover duration and soil moisture are ecologically most important and mirrored by a more lush vegetation of the southerly exposures. Most plant species of the Drakensberg are adapted to intense solar radiation, long periods of low temperature and drought, and solifluction due to frost heaving. The frequency of strong winds, especially in spring and summer is considered to be "a powerful factor militating against tree growth" by Hilliard & Burtt (1987).

Phytogeographical position and altitudinal zonation: Problems of nomenclature

The vertical sequence of the Maloti Drakensberg has been differentiated into a montane (approximately 1280-1830 m), subalpine (1830-2870 m) and alpine belt by Killick (1963, 1990). Other studies like those of Herbst & Roberts (1974) and Morris et al. (1993) follow this altitudinal division. White (1983) includes the "afroalpine" belt as an "archipelago-like region of extreme floristic impoverishment" within the "afromontane region" On the other hand, Hilliard & Burtt (1987) reject the possibility to include the slopes and summits of the Maloti-Drakensberg in an "afromontane" and "afroalpine" region on the basis that floristic affinities with adjacent lowlands of southern Africa are stronger than with the tropical mountains of Tanzania and Kenya. They argue for the recognition of the area as a distinct phytochorion, the "South-eastern Mountain Regional Mosaic" instead. In the most recent overview of the vegetation of southern Africa, Cowling & Hilton Taylor (1997) include the Drakensberg and Lesotho mountains together with the mountains of the Cape Folded Belt in an "afromontane region". In his latest paper Killick (1997) describes the treeless vegetation of the summit plateau as tundra. The proposed nomenclature postulates a low-lying laural belt with supralaural forests up to approximately 2000 m and largely tree-deficient grass-savannas on the upper mountain slopes.

Altitudinal zonation of vegetation

Themeda triandra grasslands with *Trachypogon spicatus, Hyparrhenia hirta, Harpochloa falx* predominantly covers the slopes between approximately 1600 and 2750 m. Large tussocks of *Merxmuellera macowanii* (1830-2550 m) and *Festuca costata* (below 2900 m) occur along the streams. Depending on the kind of fire regime some of these grass slopes up to about 2400 m contain open *Protea* savannas, including 3-5 m high trees of *Protea caffra* and *P. roupelliae* with rounded crowns, and the fire-resistant dwarf species *Protea dracomontana*. Locally, 2-4 m high *Aloe ferox (=A. candelabrum)*, characteristic for drier conditions can be found as a grassland constituent on steep rocky north-facing slopes in the southern Drakensberg (Loteni valley) (Hilliard & Burtt 1987, Killick 1990). Small forest groves with the 12-18 m high Yellowwood (*Podocarpus latifolius,* up to 1900 m) and *Olinia emarginata* (up to 2150 m), often festooned with *Usnea* are confined to narrow valleys and southern aspects along stream gullies. These forests are larger and more numerous on the northern Berg (Hilliard & Burtt 1987). The forest margins are characterized by the Rosaceae *Leucosidea sericea*, the commonest woody plant on the Drakensberg (up to 2100 m), *Buddleia salviifolia* and *Bowkeria verticillata*, or by up to 2.5 m high *Miscanthus capensis-Cymbopogon validus* grasslands and the Berg bamboo *Thamnocalamus tessellatus*(1800-2000 m). The altitudinal distribution of forest margins roughly extends from the valley floors to the lowermost basalt cliffs at about 2000 m; some tree clumps persist up to 2400 m (Hilliard & Burtt 1987). Evergreen thickets with the Thymelaeaceae *Passerina drakensbergensis* (2100-2450 m on the northern Drakensberg), the Ericaceae *Phillipia evansii*(1800-2300 m), the Compositae *Euryops tysonii* (1800-2500 m) and the Cupressaceae *Widdringtonia nodiflora*("Subalpine Fynbos" after Killick 1963) are limited in extent because of recurrent grass fires. Forest in Lesotho only exists to a limited extent of 1 km2 (Leslie 1991, Low & Rebelo 1998) with the largest stand in Tsehlanyane (2100 m), which accommodates a 6 m high *Leucosidea sericea* forest.

The vegetation of the summit plateau of Lesotho between approximately 2850 m and the highest peaks comprise grasslands, dwarf scrub communities, wetland communities along the streams and moister slopes, and open scree and rock communities, colonized by small and scattered turf patches along the basalt outcrops. These vegetation types are best developed from December to the end of March. The grasslands are usually dominated by the Gramineae *Merxmuellera disticha, Festuca caprina, Pentaschistis oreodoxa*, *Harpochloa falx* and the Cyperaceae *Scirpus falsus* in moister places. Subtropical *Themeda triandra* grasslands are confined to the lower slopes and warmer north-facing aspects below 3000 m. Generally, species of temperate affinity like *Festuca caprina* are more abundant on the cooler aspects and at higher altitudes. These mixed grasslands are distributed as mosaics, often interspersed by dwarf scrubs and patches of up to 1 m high *Merxmuellera drakensbergensis* stands at water surplus sites. The evergreen tussock grass is adapted to low temperatures through accumulation of dead and decaying material that acts as an insulator at the base of the plant. The most common dwarf scrubs are *Helichrysum trilineatum* and *Erica dominans,* covering considerable areas with low heathlands, especially in the vicinity of Mont Aux Sources. Apparently, this led Killick (196, 1979) to consider *Erica-Helichrysum* heathland to be the climax community of the uppermost altitudinal belt. The cushion-forming succulent *Euphorbia clavarioides* is limited to steep rocky and mostly north-facing slopes (Hilliard & Burtt 1987). Furthermore, the two karroid invader species *Chrysocoma ciliata* and *Pentzia cooperi* (Morris et al. 1993) together with *Artemisia afra* dominate the dwarf scrub communities between Sani Pass and Mokhotlong. Wetlands and flat marshy grasslands in the riverheads contrast to the surrounding vegetation. The low-growing wetland vegetation contains a mixture of Gramineae (*Agrostis* sp., *Poa annua*) and Cyperaceae (*Scirpus falsus, S. ficinioides, Isolepis fluitans* and *Schoenoxiphium filiforme*). Pools and silt patches, often waterlogged in summer form a habitat for aquatic communities with *Limosella inflata, Aponogeton ranunculiflorus* and *Crassula inanis* surrounded by *Merxmuellera drakensbergensis* tussocks and hygrophilous forbs like *Ranunculus meyeri, Kniphofia caulescens, Moraea alticola*frequently accompanied by *Trifolium burchellianum* (van Zinderen Bakker 1955, Killick 1978c, Backéus & Grab 1995, Schwabe 1995). Thufur are often colonized by *Athrixia fontana*.

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Litterfall and nutrient fluxes in canopy oaks in neotropical cloud forest – Colombia

Litterfall and nutrient fluxes in canopy oaks in neotropical cloud forest – Colombia

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Litterfall and nutrient fluxes in canopy oaks in neotropical cloud forest – Colombia

Abstract

In a small part of a cloud forest located at 2700 m in the Eastern Colombian Andean mountain, where the dominant species is the oak *(Quercus humboldtii),* litterfall was determined by means of 12 litter traps. They were placed in two oak canopy trees at different heights, between 12 m and 22 m. It was found that in adult oak trees whose biomass of green leaves can vary between 20.52 kg and 27.22 kg, litterfall was presented throughout all the year. The concentrations of N, P, K, S and Ca were lower in litter rather than in green leaves, and the Mg concentrations did not vary. *Q. humboldtii* presented high concentrations of N (18.2 mg g-1) and low concentrations of P and K. Nevertheless, these two last nutrients presented a high retranslocation, which suggests that these two elements are limited in this ecosystem.

Key words: Cloud Forests, Canopy, Neotropic, Oaks, Bromeliads, Nutrients, Litterfall.

Resumen

En un relicto de bosque de niebla ubicado a 2700 m en la cordillera Oriental de los Andes de Colombia, donde la especie dominante es el roble (*Quercus humboldtii*),se determinó la caída de hojarasca por medio de la postura de 12 colectores, los cuales se pusieron en dos árboles de dosel de roble a diferentes alturas, entre 12 m y 22 m. Se encontró que en los árboles adultos de roble cuya biomasa de hojas verdes puede variar entre 20.52 kg y 27.22 kg se presentó una caída de hojarasca a lo largo de todo el año. Las concentraciones de N, P, K, S y Ca fueron menores en la hojarasca que en las hojas verdes, y las concentraciones Mg no variaron. *Q. humboldtii* presentó altas concentraciones de N (18.2 mg g-1) y bajas concentraciones de P y K, sin embargo, estos dos últimos nutrientes presentaron una alta retranslocación, lo que sugiere que estos dos elementos son limitantes en este ecosistema.

Palabras Claves: Bosques de niebla, dosel, neotropico, roble, bromelias, nutrientes, hojarasca.

Introduction

In the biogeochemical cycle of organic matter and mineral elements, litterfall plays an important role in the relations among soil, vegetation and surrounding environment, constituting one of the essential ecological phenomena in the wooded ecosystems (Vitousek *et al*. 1995). The litter production is an important process in the tropical forest nutrient cycle (Veneklaas 1995), since the litterfall dynamics to the soil, is one of the most important determinants in the renovation of these forests. Besides it is the most important pathway for the return and transference of carbon and nutrients from the aerial part of vegetal communities towards the surface of the soil (Spain 1984).

A forest constitutes an open system with chemical elements going in and out of it, or moving internally within it. The nutrients remain stored in the vegetation, constituting one of the greatest reserves of nutrients in the ecosystem (Vitousek *et al*. 1995). Later, the nutrients move until the soil by means of falling leaves and rainwater flows. Another proportion of nutrients is stored in litter and in the other organic matter entering into the forest, from where they are gradually released by its decomposition. The circulation of these nutrients in the ecosystem depends on the organic amount of matter and its rate of decomposition (Sundarapandian & Swamy 1999).

In the case of litter production and availability, this is determined by seasonal fluctuations, which are regulated by biological and climatological processes and factors. However, factors such as topography, edaphic conditions, vegetal species, age, and density of the forest are relevant as well (Hernandez *et al*. 1992). In any type of forest, the massive litterfall takes place every year in a determined time causing a great accumulation of organic remains at certain times, and producing variations in the dynamics of the nutrient cycling (Jenny 1980).

Due to the threats to the cloud forests present in tropical areas, to their barely short knowledge about them, and the lack of information about their location and importance, the acquisition of new information about the functioning of these tropical mountain forests becomes high-priority. All this with the purpose of obtaining basic tools for the implementation of conservation programs in the long-term. In the case of forests dominated by *Q. humboldtii,* in spite of their importance, the influence that canopy trees oak litterfall can have in the ecosystem had not been investigated. For this reason, the objective of to calculate the litterfall dynamics by individuals placed on the canopy of *Q. Humboldtii,* and to quantify the contributions of nutrients that these can make through litter.

Materials and Methods

Study Area

The project was carried out in the Macanal Reserve located in the eastern Colombian Andean Mountain -South America-, in a town called Bojaca, located 27 km far from Bogota. The study area is a montane cloud forest which is in a precipitous area with steep slopes, and it is located at 2700 m above the sea level. The vegetation presents different levels of human intervention, and this is shown in the fragments of mature forests where mature Oak trees *(Q. humboldtii)* are the predominant species.

The climatology data of the area is registered by the Acapulco weather station of the "Instituto de Hidrología, Meteorología y Estudios Ambientales (IDEAM)". According to the 13 year-old data analysis (from 1990 to 2002), it has a precipitation with a bimodal behavior with an annual average of 61.5 mm of rainfall; in which the most rainfall months that are March, April, and May in the first term of the year, and October and November in the second term. The average annual temperature is about 13º C, with the highest temperature on May with about 13.4ºC and the minimum on July with about 12.6ºC. The relative annual humidity average is about 91.9% for April, June, and July present the highest percentage with about 93%.

Methods

In a fragment of a conserved forest dominated by oak trees *(Quercus humboldtii),* a plot of 2125 m2 was made in which four oak canopy trees were chosen. Five platforms were built in the upper part of the tree top at an average height of 20 m and 23 m, with the purpose of having access to different parts of the tree and to the litter traps. The trees were selected under the following criteria: 1) they had to canopy trees; 2) they should allow the ascent with climbing equipment; 3) they had to be in good health; and 4) they had to part of the most mature trees of the fragment.

The monthly contributions of litter were measured through the fall of elements throughout a year. For this, twelve litter traps of 65 cm of diameter and 60 cm of depth were placed in two canopy trees, six in each tree. The litter traps were located in different areas of the top, between 12 m and 22 m. These were checked monthly from November 2004 to October 2005, collecting the material to be dried and weighed. This monthly contribution of litter was evaluated in terms of dry weight, contributed per time and surface. On the other hand, six samples of green leaves and six samples of falling leaves were selected, which were determined the contents of P, Mg, S, N, K, and Ca; these analyses were made in the laboratories of "Corpoica - Tibaitata". The contents of nutrients in litter and green leaves were compared by means of a t test or through the nonparametric test W Mann-Whitney, when the assumptions of normality and homogeneity of variances were not fulfilled; these analyses were made in the Statgraphics program plus 4.0.

The biomass estimate of green leaves of the four chosen trees was obtained by means of the gathering of six branches of different trees with approximate dimensions from 2m x 2m x 2m. All the leaves were taken off these branches in order to be dried and weighed. Subsequently, the number of branches that showed a covering of 2m x 2m x 2m was counted in each tree. With this, an approximation of the number of branches and the quantity of biomass that these held was made. The measurement of the covers of each one of the trees was obtained by direct calculation in m2 -this was convert into hectares for some measures- of the area that projects on the ground the top of each one of the individuals. For the determination of covers, it was used the equation proposed by Rangel (1997).

Results

Litterfall

The trees selected to quantify the biomass of green leaves presented heights that were between 25 m and 26 m, with top covers between 209.3 m2 and 253.98 m2. The amount of biomass of green leaves per tree was calculated between 20.52 kg and 27.22 kg (Table 1).

Tree	Cover (m^2)	DBH (m)	Trunk height (m)	Top height(m)	Total height (m)	Green leaves (kg)
Tree 1	253.98	0.99	5	21	26	24.84
Tree 2	209.30	0.86	5	20	25	21.17
Tree 3	241.50	0.73	5	21	26	20.52
Tree 4	233.91	1.70	7	18	25	27.22

Table 1. Characteristics of the sampled canopy trees of *Quercus humboldtii*.In trees 1 and 2, 12 organic matter traps were placed.

Litterfall distribution was uniform in the whole top of both trees throughout all the year, with some variations in the abscission among different months. Nevertheless, the partial results obtained showed that litter availability in this forest occurs throughout all the year. The fall of leaves in tree number one took place throughout all the year, but with greater intensity between the months of November-December-January and June-July; two periods of highest abscission during the months of December and June were registered; in tree number two the litterfall also took place throughout all the year, with greater intensity between January-February and April-May; three periods of highest abscission were registered during the months of January, February and May (Figure 1).

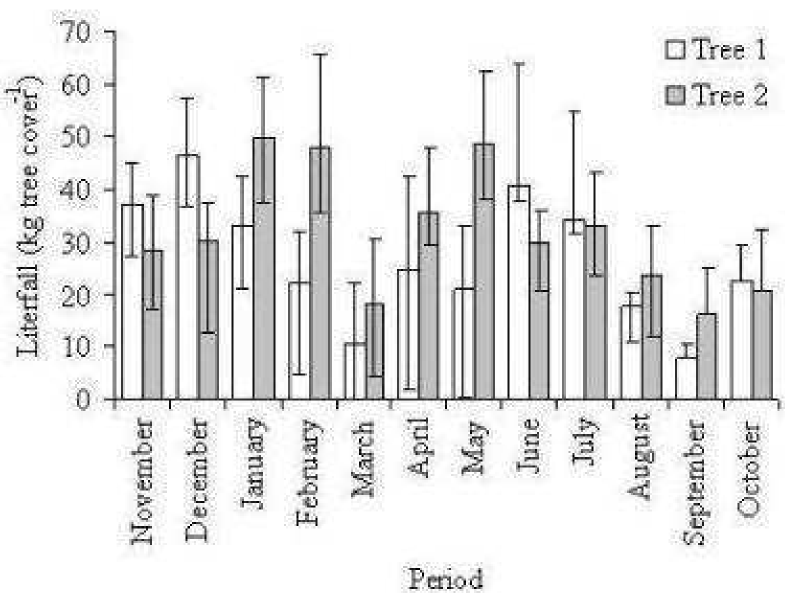

Figure 1. Litterfall (kg to cover tree-1) at 2700 m, contributed by leaves of canopy oaks, of trees number 1 and number 2. (Cover of the top: 253.98 m2 and 209.30 m2, trees number 1 and number 2, respectively).

Nutrients concentration

The concentrations of N, P, K, S and Ca were lower in litter than in green leaves, although these differences were only significant statistically for the content of Potassium and Calcium ($W = 3.0$, $p = 0.02$ and $t = 2.19$, $p = 0.05$, respectively). The Mg concentrations were similar in fresh leaves and in litter (Table 2).

		N		P		K		Ca		Mg		S	
	(n)	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD
Green leaves	6	18.15	2.85	0.65	0.35	4.47	2.12	2.28	0.54	0.48	0.19	1.16	0.79
Litter leaves	6	15.53	2.58	0.30	0.08	2.33	0.64	1.63	0.48	0.50	0.14	0.55	0.14

Table 2. Nutrient Contents (mg g-1) in green leaves and litter leaves of the oak *(Quercus humboldtii).* Where n is the number of analyzed samples; X is the average value; SD is the standard deviation.

The approximated annual contributions of nutrients through litterfall from canopy trees were the following: in the tree number one 4.94 kg of N, 0.095 of P, 0.73 of K, 0.51 of Ca, 0.16 of Mg and 0.17 of S for an area of 0.0253 ha corresponding to the cover of the top; in the tree number two 5.92 kg of N, 0.114 of P, 0.88 of K, 0.61 of Ca, 0.19 of Mg and 0.21 of S in an area of 0.0209 ha (Table 3).

	Cover (ha)	N (kg)	P (kg)	K (kg)	Ca (kg)	Mg (kg)	S (kg)
Tree 1	0.0253	4.94	0.095	0.73	0.51	0.16	0.17
Tree 2	0.0209	5.92	0.114	0.88	0.61	0.19	0.21

Table 3. Nutrient concentration in (kg) contributed by each one of the trees throughout a year. Nutrients present in the fresh leaves of oaks and in the litter expressed in kg.

Discussion

Litterfall

In the nor-western area of the South American Andean range, mainly in Colombia, in the middle part of the mountains, there are important areas of homogenous forests dominated by *Q. humboldtii* (Lozano & Torres 1974). These forests are covering an altitudinal rank from 1100 m up to 3450 m (Cavelier *et al*. 2001). In ecosystems dominated by this species, most of the nutrients that enter by means of the fall of organic matter come from litter produced by mature trees of *Q. humboldtii.* This fact makes the functioning of this ecosystem to be linked to the presence of these trees, as it has been described for other forests; there is a great influence of litterfall of the trees that dominate the canopy in the availability of nutrients in the ground under their tops (Finzi *et al*. 1998, Saldaña & Lusk 2003). This fact determines the space variation in the availability of nutrients in the ground (Finzi *et al*. 1998).

In general, mature trees of *Q. humboldtii* tended to present tops of great cover and great depth, in which an important amount of green leaves all over the top was developed, presenting a high photosynthetic biomass in comparison with other species of canopy trees which grow in other tropical cloud forests, whose values can be between 9.9 kg (Walter & Ataroff 2000) and 15.38 kg (Hofstede *et al.* 1993) per tree. The depth of the top of these trees and their great amount of biomass of green leaves can be related to the higher tolerance in the shade that this species has in comparison with other arboreal species of cloud forests. It has been registered that the tolerant arboreal species in the shade tend to present tops of greater depth and greater index of foliage area than the intolerants species (Canham *et al.* 1994).

According to the data collected in relation to the photosynthetic biomass of *Q. humboldtii* and its litterfall, it was found that foliage renewal in these trees is very high throughout all the year. It is possible that the high litter production can be related to the fact that adult individuals were selected, which might have a more continuous foliage renovation than those individuals in formation stage. This constant litter production of mature *Q. Humboldtii* probably allows them to be able to keep the nutrients in their leaves until previous moments of their detachment. According to what has been registered, the species with periods of short abscission have determined, with greater precision, the moment in which the leaves are shed. This allows these species to be able to maintain their nutrients until the previous moment to their fall, as well as a high photosynthetic efficiency and a high efficiency in the retranslocation process (Martin *et al*. 1996).

The greater contributions of organic matter that fell from the top of canopy trees throughout a year were from oak litter. The other organic matter coming from bromeliads, lichens, bryophytes, wood, fruits and flowers neither presented great contributions nor had continuity in their dynamics of fall. Litter production of mature oak canopy trees was high and permanent, reaching a value of 15.4 t ha-1 year-1. In addition to this, the high values of the litter production in this study are also related to the location of the organic matter traps, since these were located at different heights within the top of the same tree from 12 m high, near the places where litter takes place. In most of the studies that are carried out in litterfall, the collectors are set up at a meter from the ground, and part of litterfall that falls is intercepted by epiphytes and another part by vegetation of the intermediate layers and the undergrowth (Veneklaas 1991). Aside from this, the litterfall of trees in its process from fall is often dragged by the wind to distant areas far from where it is placed.

On the other hand, in this investigation the important contributions of biomass that can have mature canopy trees by means of litterfall per hectare is shown. However, the collected data are only generalized about adult individuals of *Q. humboldtii,* and not about great extensions of cover of this type of forests, since in these forests there is not a continuity of these trees. For this reason, it is possible to incur an overestimate of the aerial biomass and, therefore, of the content of nutrients. Brown and Lugo (1982) affirm that the presence of trees with great diameters can have a great influence on the vegetal biomass as well as on the amount of nutrients.

Leaf nutrients

The chemical analyses of the nutrient contents from leaves and litter of oaks showed that in all the macronutrients except in magnesium, the percentage of concentration is greater in green leaves than in litter. This indicates that before having a process of total fall of leaves, there is a retranslocation of nutrients that is increased in the case of phosphorus and potassium (54 and 48 %, respectively).

When comparing the concentrations of the main nutrients with those of species from other mountain forests of the world, it is observed that the leaves of *Q. humboldtii* have high concentrations of N (18.2 mg g-1), and its litter contributes a great percentage of this nutrient to the soil of the forest. This can also explain the high productivity of this forest in terms of the production of litterfall and the biomass that the trees of this species reach. The high levels of N in the leaves of oaks have been reported for canopy individuals of *Quercus costaricensis* and *Quercus copeyensis* (Kappelle & Leal 1996). These high levels of N in leaves of oaks probably are related to the presence of mycorrhizas in the ground of this type of forests (Chaverri & Rojas 1985)

The concentrations of P were low in comparison with other present vegetal species in other mountain forests of the world (Table 4). Nevertheless, in fresh leaves the levels of P were similar to the reported ones for mountain forests in Puerto Rico (Medina *et al.* 1981) and in Jamaica (Tanner 1977). In the case of concentrations of K, these were also low in comparison with other vegetal species present in other mountain forests of the world (Table 4), presenting similarity in some values of fresh leaves with the reported ones for mountain forests in Sabah (Proctor *et al*. 1989) and in Puerto Rico (Medina *et al.* 1981). The high retranslocation of these two nutrients in oak trees suggests that these elements the availability of these elements is limited in this ecosystem, which has already been suggested for other mountain tropical forests of the world (Vitousek *et al.* 1995).

		N			P			K		
Location	Height	Fresh	Shed	%	Fresh	Shed	%	Fresh	Shed	%
Sabah	610	14.5	10.5	-28	0.47	0.17	-64	5.1	2.6	-52
	790	16.2	10.5	-39	0.54	0.17	-69	4.4	1.9	-77
	870	13.4	8.3	-38	0.46	0.2	-57	3.2	0.9	-72
New Guinea		13.2	11.4	-46	0.86	0.59	-31	14.4	4.4	-60
Jamaica		13	7.6	-42	0.68	0.30	-56	9.9	4.6	-54
Puerto Rico		9.9	7.7	-22	0.63	0.24	-62	5.1	1.4	-73
Venezuela		16.4	11.5	-30	1.11	0.62	-44	12.5	5.7	-54
Colombia	2550	17.8	10.8	-39	1.27	0.70	-45	12.4	8.1	-34
	3370	14.7	9.0	-39	0.9	0.32	-65	6.4	4.0	-34
Costa Rica	2975	16.4			1.1			12.9		
	2975	11.3			1.0			10.3		
	2975	10.8			0.9			9.2		
Colombia	2700	18.2	15.5	-14	0.65	0.30	-54	4.5	2.3	-48

Table 4. Concentrations (mg g-1 dry weight) and percentage of N, P and K in fresh leaves (tree leaves) and just fallen leaves (litter leaves) in different mountain forests of the world. References. Sabah: Proctor *et al.* (1989); New Guinea: Grubb & Edwards (1982) Jamaica: Tanner (1977); Venezuela: Steiahard (1979) In: Veneklaas (1991); Puerto Rico: Medina *et al.* (1981); Colombia: Veneklaas (1991); Costa Rica: Kappelle & Leal (1996).

The information provided in this study constitutes a base to emphasize the importance of canopy trees in a forest. In the case of canopy trees of *Q. humboldtii,* these are an important center for the cycle of several nutrients through their litter contributions, and the nutritional networks that are generated for the return of these nutrients to the ecosystem. At the present time, the presence of these mature trees in fragments of oaks that are still conserved is little, due to the cutting pressure that was exerted on them in previous years. The absence of these trees alters the functioning of these ecosystems, leaving them in certain degree of threat. Apart from this, it should be kept in mind that cloud forests have been investigated superficially in comparison to other tropical ecosystems. However, this is one of the most threatened ecosystems because of the fragmentation and its constant destruction. For this reason there is an important interest in advancing a great number of investigations that allow to know in a detailed way the functioning of these ecosystems with the purpose of being able to take actions to conserve them.

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Forest Resource Management in Mountain Regions: A Case for the Pindar Basin of Uttaranchal Himalaya

Forest Resource Management in Mountain Regions: A Case for the Pindar Basin of Uttaranchal Himalaya

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Forest Resource Management in Mountain Regions: A Case for the Pindar Basin of Uttaranchal Himalaya

Abstract

This paper examines the forest diversity and degradation of forest in the Pindar Basin of Uttaranchal Himalaya and suggests the management of forest resources in this fragile mountain terrain, as sustainable management schemes for forests have become increasingly important and timely, because these areas have come under serious exploitation and constant threat of disintegration, following the depletion of forest. The natural hazards and man-induced activities, both are equally responsible for depletion of forest in mountain areas, while, the mountains are having the highest biodiversity of fauna and flora. In the Pindar Basin, four zones of forests exist according to altitudes. These zones are characterized by eucalyptus and *Dendrocalamus spp.* trees in the low-lying region, pine trees in the mid altitude, coniferous forests along with oak in the temperate zone and extensive alpine meadows. This basin is rich in forest resources particularly in temperate coniferous forest while, the proper management of forest could not take place due to high inaccessibility of forest cover areas on the one hand and over utilization of forest resources, on the other. This study is mainly based upon the primary collection of data, which were gathered through case studies of the villages.
Keywords: Biodiversity, natural vegetation, alpine meadow, vertical zonation, coniferous forest.

Introduction

Forests play crucial roles in the sustainable development of mountain regions because; the entire population is dependent on forest resources for firewood, fodder, valuable timber and food needs. These forests are rich in biodiversity and are distributed according to altitudes and aspect of slopes. On the one hand, they regulate climate, conserve soil and maintain moisture in the atmosphere and on the other, they are the homes to wild lives, birds and wild fruits. Recently, due to high pressure of population on the land, particularly on forestland, the forests are on the verge of depletion and consequently, some species of the forests have been vanished and some are endangered.

The Pindar Basin constitutes an integral part of the Ganges sub-system in the Uttaranchal Himalaya. Characterized by rough, rugged and precipitous slopes, the entire land is more prone to landslide, landslip, mass wasting and slope failure. Ecologically, the whole landscape is fragile. It possesses about 65.6% forestland out of the total geographical area. Ranging from the sub-tropical climate to temperate and alpine meadows, the diversity in the natural vegetation is high. The depletion of forest, due to over exploitation, is creating severe threats for instability of slopes and future catastrophe. This situation can be noticed in the low-lying areas and mid-slopes, where concentration of population is high. During summer, transhumance migrates in the highland for grazing cattle. This practice also leads for degradation of forest at a large scale.

In the present study area, the rate of forest depletion is high, which creates severe impediments, such as instability of land and environmental hazards. Most of the forest patches, on the hilly slopes of the basin, are clearing for agricultural fields due to over population. It is reported that the highest rate of deforestation in any biome is in tropical upland forest, i.e., 1.1% per year (FAO 1993). Apart from the adverse climatic stress, increased human population and the insatiable demand for more natural resources including land, forest and food are major factors contributing to natural resources depletion and losses in biodiversity (Arimoro et al., 2002; Okali 1985).

Materials and Methods

This study is thoroughly based upon the collection of primary data and case studies of the villages, located in different altitudes, were done to facilitate the further interpretation of data. The study of forest types, firewood-fodder need and potential areas of firewood and fodder in the Pindar Basin was done after case study of the villages. Structured questionnaire was prepared to avail the information about the interaction of the people with forest-based products. Interviews were equally done and the author made rapid field visit. Secondary sources of data were also used.

Study Area

The Pindar Basin comprising of 1826.0 km2 extends from 30o N to 30 deg 18'N and 79 deg 13' E to 80o E. It represents the eastern part of the Garhwal Himalaya with height ranging from 800 m to 6800 m. River Pindar originates from the 'Pindari Glacier' in Almora District (32 km) and flowing an approximate 124 km with its numerous tributaries, confluences into the Alaknanda river at Karanprayag in Chamoli District. The watersheds of the Ram Ganga in the south, the Saryu in the east, the Nandakini in the north and the Alaknanda in the northwest delimit it and give it a distinct socio-geographical identity.

Results and Discussion

Forest diversity in the Pindar Basin

The Pindar Basin is very rich in terms of forest resources and diversity. From the valley region to the highly elevated alpine meadows, locally known as *Kharak* or *Bugyal*, the rich diversity in plants is found. In the mid slopes, *Chir* (pine) is common, while in the upper reaches, temperate coniferous forests, mainly *Banj* (oak), *Tilonj (Querces dilitata) and Devadar* (*Cedrus deodara),* are found extensively. Except these forest types, many other fodder plants also grow along with the edges of agricultural fields. Oak is the predominant flora of moist temperate forest, which starts growing from 1676 m with Rhododendron trees, a very rich fodder and ideal fuel has been an inseparable part of folk life in hills. The oak forest of the Pindar Basin appears to be thriving due to the imposing presence of pine trees. A note in The Hindustan Times by a correspondence, 'will oak disappear from Nainital' is a real story in the hills of Uttaranchal (The Hindustan Times 2000). According to an altitude and forest types, the basin can be divided into the following zones (Table 1):

Table 1: Forest diversity based on altitude

Belt/altitude	Geographical area	Main species
Valley regions/below 1000 m	Along the valley of Pindar River	Eucalyptus, *Dendrocalamus spp.*
Middle altitude 1000 m to 1600 m	Slope of the various streams such as Kaver Gadhera, Ming Gadhera, Pranmati and Atagarh	Pine dominate (blue pine and chir forest)
Temperate zone 1600 m to 2000 m	Watershed regions, Love-Kush tope, Kanpur Garhi, Khankhrakhet, Shubhtal-Chhaltal, Kurur-Kwarad and Sol-Dungri	Deodar forests (*Cedrus deodara)*, oak forests (*Quercus species*), fir (*Abies pindrow*) & spruce (*Picea smithiana),* ringal (bamboo) forests (*Dendrocalamus spp.*)
Alpine meadows/between 2600 m to snow line	Bedni Bugyal, Roopkund and Shail Samunder	Dominated by herbs

Sources of Data: Adopted from Vishwambhar Prasad Sati's paper on " Natural Resource Conditions and Economical Development in the Uttaranchal Himalaya, India" published in 'Journal of Mountain Science', 2005, Vol 2, No 4, Pp. 336-350 (modified).

(1) Low-lying river valleys (below 1000 m) are comprised by the areas, which are located along the valley of the Pindar River (from Karanprayag to Tharali). Presently, the campaign for afforestation is carried out by the Department of Forest to control landslides. The main species in this region are eucalyptus and *Dendrocalamus spp.*

(2) Middle altitude lies between 1000 m and 1600 m. Pine is the main tree species. There are many patches, where dense pine forests are found. These patches start from Bagoli to Dewal, on the course of the Pindar River and also both sides of its tributaries, such as, the slope of Kaver Gadhera, Ming Gadhera and Pranmati Gad. Presently, the pine trees are invading the temperate evergreen coniferous regime, particularly on the south-facing slopes of the basin. The pine forests are divided into two types. The first is blue pine forest (*Pinus wallichiana*), which is locally known as *Kail* and mostly found mixed with *deodar* (*Cedrus deodara)* forest. The second is chir forest (*Pinus roxburghii*).

(3) Temperate belt is ranging between 1600 and 2000 m, and it constitutes Love-Kush top, watershed of Pindar and Ramganga, Kanpur Garhi, Kankhrakhet, Shubhtal and Chhaltal, Kurur-Kwarad and Sol- Dungri areas. The region is very rich in economically viable forest wood. The forest timbers are fully unutilized due to inaccessibility of the places. The main forest includes; (i) Deodar forests (*Cedrus deodara*), which are found between 1650 m and 2300 m in the basin. *Deodar* is a tall coniferous tree used for house construction and also for paneling. It is much prized for its wood. Ancient temples of the region have deodar beams with a length not found in present time owing to large-scale felling in the past; (ii) Oak forests (*Quercus* spp.) are found in entire Pindar Basin between 1325 m and 1625 m. It is used for firewood and charcoal manufacturing. It is the best firewood with high caloric value. It is a broad-leaved tree; (iii) Fir (*Abies pindrow*) & spruce (*Picea smithiana*) forests are found mostly between 2300 m and 2950 m. They are mostly used for interior decoration and packing cases. These are coniferous trees and represent high intensity of snowfall in their region; (iv) Ringal (bamboo) forests (*Dendrocalamus spp.*) are found mostly in the highly elevated watersheds of the main river and its tributaries between 2200 m and 2500 m above sea level.

(4) Highly elevated regions from 2600 m to snow line are accounted for herbs. They are extensive grasslands and locally called *kharak or bugyal*. The main *bugyals* are Khankhrakhet, Bedni Bugyal, Roopkund and Shail Samunder. Bedni Bugyal and Roopkund are world famous spots and they are being developed as the major tourist places. Varieties of herbs are found in these *bugyals*. The alpine and temperate forests that cover most parts of the basin make natural habitats of some of the best-known wildlife creatures of India.

The Pindar basin contains 65.6% forestland. Out of the total forestland, pine and oak forests dominate. [[Table 2]] exhibits total area (ha), forest cover area (ha), population according to census of 2001and per-capita forestland in the six development blocks of the Pindar Basin. Mostly, the trend of forest cover areas is increasing with increasing height. Kapkot and Dewal development blocks are located in the remote areas of the basin having 79.8% and 80.8% forest cover while Tharali and Karanprayag development blocks have 25.2% and 52.2% forest cover because the development activities and concentration of population is high in these two blocks. Gairsain and Narain Bagar developmental blocks have 74.0% and 67.2% forest cover respectively. When we look upon the per-capita forestland we find that the areas where population is high the per-capita forestland is comparatively low. For example, Karanprayag development block has highest population (61150 persons), while per-capita forestland is only 0.14 ha, which is lowest after Tharali development block (00.06 ha). Similarly, Deval and Kapkot developmental blocks have less population (34315 and 32088 persons respectively), while per-capita forestland is highest (0.43 and 0.47 ha respectively). It indicates that the dependency of the people on forestland is high.

Table 2: Forest cover area and per-capita forestland

Development block	Total area (ha)	Forest cover (ha)	Forest cover (%)	Population 2001	Per-capita forestland (ha)
Karanprayag	16515	8620.83	52.2	61150	0.14
Gairsain	18138	13422.12	74.0	45502	0.29
Narain Bagar	13538	9097.54	67.2	46607	0.19
Tharali	12555	3163.86	25.2	50442	0.06
Dewal	18394	14862.35	80.8	34315	0.43
Kapkot	19203	15323.10	79.8	32088	0.47
Total	98343	64489.80	65.6	270104	0.24

Sources of data: Statistical Diary of Chamoli and Bageshwar Districts (2002)

Degradation of natural forest

Degradation of natural forests is a global problem (Guppy 1984; Sayer & Whitmore 1991). Mankind has been destroying forest for millennia even since agriculture was discovered (William

1989). In the Himalaya too, deforestation is argued to be not a recent phenomenon. It has a long history, being well established in late eighteenth century at least (Mahat et al. 1986). However, extent of impairment of various processes attributed to vegetal degradation depends upon a range of other factors including past histories, intensity of removal of natural vegetation, patterns of natural regeneration and /or other human interferences (Valdiya & Bartarya 1989; Gilmour et al. 1989; Ramakrishnan et al. 1992; Alford 1992).

Over the centuries, forests have been converted into agriculture fields and grazed by increasing animal population. They are divided up and utilized for the following major unsustainable human uses: poor arable farming and terracing, monocropping and livestock grazing; extensive archaeological, mining, quarry and other exploration activities; and huge construction of buildings, roads, bridges and other infrastructures. Such areas of land use associated primarily for economic activities and pursuits create serious challenges for conservation and good management strategies (Zimmerer and Young 1998). The close relationship among population growth, expanding area under subsistence crops and increase in livestock numbers is closely related to intensifying demands on the forests. While there are serious problems in determining total available forest cover, biomass productivity, biomass demands and actual consumption, there are also conflicting estimates of the amount of forest/support land needed to support one unit of cultivated land. Ives & Messerli (1989) put such estimates for forestland to fourth-fifth times of cultivated land. But the quality of such support land is not defined. Rao & Saxena (1994) indicated that there was little conversion of forest to agriculture during the last sixty years in central Himalaya.

The other aspect of deforestation is growing firewood demands are the cause of receding forest perimeters around the habitations in the mountains (Bajracharya 1983a, b). Most of the degradation of forest to unpalatable weeds stage is due to increased human and animal populations (Jackson 1983).

In the entire Pindar Basin, degradation of natural forest is the main phenomenon particularly in the recent period. Due to excessive use of forest as a form of timber, firewood and fodder, and furthermore fragility of the terrain accentuated deterioration of natural forest resources. Human induced activities such as grazing animals, lumbering, construction of roads, dams and settlements are more prone to deforestation in the basin. Degradation of forest in the basin is mainly taken place due to the following activities:

(1) Firewood is required for cooking food and warming rooms. Mid slopes and highlands are characterized by temperate and cold climates. Therefore, the firewood needs in these regions are high, particularly during the winter, when highlands receive snowfall. Inaccessibility of the settlements does not provide a base for consuming other means of fuel such as liquid petroleum gas (LPG). Therefore, the dependency on the forest for firewood consumption is high and it is the major cause of deforestation in the basin. However, in the areas, which are located on the road heads, LPG is being popularized slowly. Table 3 reveals the per-day consumption of firewood in the basin.

Table 3: Per day firewood consumption (in kg)

Name of village	Elevation (m)	Distance from the road head	No. of families inhabited	Forest type	Per day firewood consumption (kg) Summer	Per day firewood consumption (kg) Winter	Ratio (per family consumption) (S+W)
Dimri	550	1 km	145	Scarce pine and bushes	400	580	6.8
Kaiwar	1200	2 km	150	Pine	700	900	10.6
Khainoli	1900	11 km	150	Oak, buransh, tilong and pine	1000	1400	16
Kwarad	2200	15 km	130	Oak, buransh, tilong and pine	900	1300	17
Lolti	1800	0 km	120	Oak dominated	600	840	12

Sources of Data: Adopted from Vishwambhar Prasad Sati's paper on " Natural Resource Conditions and Economical Development in the Uttaranchal Himalaya, India" published in 'Journal of Mountain Science', 2005 Vol, 2 No 4, Pp. 336-350.

Table 3 reveals that the elevation and distance from the road play a crucial role for determining per day firewood consumption in the basin. The author did a case study of five villages of the basin. The villages were selected on the basis of their elevation and distance from the road. It is penetrated that the highly elevated villages consume more firewood than the low-lying villages. Firewood consumption also depends on the availability of forests. The areas, which obtain dense vegetal cover, the firewood consumption is high comparatively to the other areas. Except small service centers, fuel consumption is thoroughly made from the forest.

(2) Highlands and lowlands have multiple and diverse ecological and environmental linkages. The fundamental basis of highland - lowland economic linkages is provided by the differences in their natural resource endowments and potential production and exchange opportunities they generate. Equally important are the man-made arrangements, ranging from infrastructure and institutions to technological and human capabilities, which shape the pace and pattern of harnessing the above opportunities. The biophysical conditions also play a crucial role in determining the above man-made arrangements. In the basin, the lowland-highland interaction is basically practiced for the purpose of grazing animals, which is based upon the availability of fodder and grassland. During the summer, the migrants reach in the highland along with their animals and in the winter, when the high reaches receive snow, the migrants move towards lowland. This practice leads a way for large-scale depletion of forest.

Table 4: Potential areas of fodder and grassland during the summer

Location	Height (in m)	Nature of slope	Forest type	Human population (persons)	Animal population/ type
Bedani Bugyal	3200-3400	Gentle to moderate /south-east facing	Alpine meadows & extensive grassland	100-120	300-350/ goats, oxen and buffalos
Ghais-blan region	2400-2600	Moderate to high/south-east facing	Coniferous/oak forest and grassland	80-100	300-320/ goats, oxen and buffalos
Khankharakhet region	2800-3000	Moderate to high/north east facing	Coniferous forest and grassland	100-120	300-350 goats, cows, oxen and buffalos
Kanpur garhi region	2400-2600	Gentle to moderate /norht-east facing	Coniferous/oak forest and grassland	100-120	300-350 goats, cows, oxen and buffalos
Love-kush top	2200-2600	Moderate to high/north east facing	Coniferous/oak forest and grassland	60-80	150-170 cows, oxen and buffalos
Bhararisen region	1900-2100	Moderate to high/north east facing	Coniferous/oak forest and grassland	60-80	150-170 cows, oxen and buffalos
Naini Danda	1900-2100	Moderate to high/north east facing	Coniferous/oak forest and grassland	60-80	150-170 cows, oxen and buffalos

Sources of Data: Collected by the author

Table 4 shows potential areas of fodder and grassland in the highlands, where the people of lowland migrate during the summer. A case study of seven locations of the highland is carried out. Altitude of these areas varies from 1900 m to 3400 m. The table incorporates height, nature of slope, forest type, human population and animal population/type. The number of animals is high along with high forest depletion in the high altitude in comparison of low altitude. The highland-lowland interaction in the basin is mainly done for grazing animals and the areas, which are having comparatively high elevation the interaction is high. Presently, the interaction is slowly converting into other economic activities such as cultivation of herbs and off-season vegetables and also leading a way for frequent forest depletion.

(3) Development activities like construction of roads, dams, terraced agricultural fields and stone mining are the major factors for forests depletion in the basin. After creation of Uttaranchal State, construction of roads and dams got tremendous pace in the economic activities. A road connecting Gwaldom and Gairsain (about 75 km) is being traversed from the dense oak forest, which already led a worst situation of landslide and huge forest depletion. A plan for construction of a diversion road from Kulsari to Karanprayag, due to construction of two dams on the course of the Pindar River in Bagoli and Simli is the top agenda of present government. Stone mining in the areas of dense forest, particularly in the mid and high altitude is also a major cause for forest depletion. Due to increasing population in the basin, people are searching for additional agricultural land and making terraced fields in the hilly slopes. Electrification in the rural areas is also causing for forest depletion because the line is passing though the forest areas.

Sustainable forest management Sustainability has recently become a fashionable concept in relation to everyday life (Gane 1992), the management of renewable resources including forests

(Sanwo 2002) and human development (U.N 1997). UNEP further describes sustainable living as the lifestyle of an individual who feels the obligation to care for nature and every human individual who acts accordingly. A sustainable forest management approach to the conservation of mountain forest resources will greatly contribute to human welfare in the Himalaya. The most recent innovation and key factor in forest management, which conforms to a sustainable forest management, is the use of new forest practices that will enhance the maintenance of forest ecosystem in a sustainable way. In other words, human activities in the forest should not negatively affect the ability of the forest to continue in the way it was originally (Franklin 2001). This can only be achieved through the promotion of self-reliance amongst the rural people through their active participation in natural resource and forest activities (FAO 1985).

Most of the world's mountain communities are strongly influenced by surrounding lowland and urban areas with regard to timber extraction. The interests of these outside forces, which are mainly economic, do not necessarily include a sustainable future for either mountain forests or mountain communities. There is a tremendous need for balance between the demands of lowland populations (e.g. timber, clean water) and the needs of mountain communities (e.g. sustainable livelihoods, opportunities for youth). There is also a strong need to balance productive use of forests with their protection. This need for balance applies equally to developing countries and many countries in transition, where many mountain people depend on forest products for subsistence and survival; and to the industrial world, where short-term profit-taking may conflict with conservation values.

The forests of the Pindar Basin have great importance both for economic growth and environmental restoration, because the basin is economically backward and environmentally fragile. Proper management of forest will serve both purposes. However, the rate of forest depletion is high due to its high demand as a form of timber, firewood and fodder. Meanwhile, the entire region is characterized by plenty of forest resources, which have great economic value and are comprized by sub-tropical, temperate and alpine species. The management of the forest resources on the other hand did not take place properly, partly due to lack of rational planning and because of inaccessibility of the forest cover areas. The economic viability of forests, which are found in highly elevated regions of the basin is high but due to inaccessibility of these regions, forests are utterly unutilized.

In the basin, rural people are fully dependent on variety of forest species for food, fodder and medicine. Sacred or religious values are also important attributes of some forest products. People of the region recognize sacred forests, groves and trees. Traditional natural resource management knowledge and close cultural links between people and their forests and trees combined as appropriate with technical or science-based approaches can be essential elements in ensuring the mountain forests and trees are sustainably managed. Management of the basin's forest is being done on the following manner for sustainable use and environmental protection:

(1) Watershed Management Department was estabilished during the 1980's as a part of Forest Department. The key characteristics of the basin's forest are that they are controled by the Forest Department. The community and private forestland is very less or negligible. Extensive grazing land is owned by community people. The people grow trees to meet their specific household needs, which often change over time the private and community land.

The role of Watershed Management Department is to plan the areas where less forest cover is found. Plantation of trees according to the conditions of the region is carried out by the department. Apart from that the deparmtment has the responsibility to check the illegal felling of trees. There are more than five sub-offices of Watershed Management Department in a development block with its one headquarter. Recently, most of the patches, where complete depletion of forests took place during the past, reforestation is taken place by the help of Watershed Management Department. These patches are located along the courses of small perennial streams such as Kaiwer Gadhera, Meing Gadhera, Pranmati Garh and Ata Garh.

(2) Local poople's participation in both decision-making processes and the implementation of management plans is crucial for sustainable resource management. In the basin, local involvement is achieved in many areas. Extensive community grasslands and fodder trees are managed by the local people themselves and they are also supporting the government forest department.

During the eighties, the popular "Chipco Movement" was launched by the local people in Uttaranchal and that movement spread throughout the basin and people were able to conserve the forest of the region from the hands of the contractors appointed by the Forest Department for mass cutting of trees.

In the basin, Gram Sabha (village assembly), the lowest unit of Governance in federal system of India, works for taking discision on the various developmental works including forest resource management. It has the control over community forestlands and grasslands and they manage it for the need of the people. At the same time, for the timber need of the inhabitants, a policy was framed by the Forest Department. According to this policy, a needy person will apply to Forest Department mentioning his/her timber need. The department will evaluate the application with the help of Gram Sabha and finally allot a tree based upon the need.

(3) A wide variety of policies affect mountain people and the forests on which they depend. Directing these policies in ways that contribute to sustainable mountain development requires detailed understanding of the broad range of relevant environmental, economic, political and social factors and of the potentials of the different options in moving towards desired goals. Given the long lifetime of most mountain trees and the changing functions of mountain forests, policy-making for these forests has to be a dynamic, flexible and reflective process. A policy made in one century may lead to the effects that were desired then but may be quite inappropriate in the next century when economic and social circumstances have changed. The need for framing relevent policies and planning and its implementation is inevitable particularly in the fragile slope of the basin, where due to mass cutting of trees, stability of slope is on the verge and landslides and landslipes are the common features. Forest Bill of 1982 has been successfully implemented, particularly in the hill areas and its result can be seen in the entire basin.

Conclusions

In the Pindar Basin, forest resource depletion is the part of needs of the people for firewood and fodder while, the irrational policies of the Forest Department toward the forests is also a vital factor for its depletion. It was seen in the decades of sixties and seventies, the dense pine trees in the basin were cut down by the Forest Department at a large scale. In 1982, the Central Government of India passed Forest Bill for conservation of forests. This bill led a way for banning illegal felling of trees in the Pindar Basin also.

In 1980's, Watershed Management Department was established to conserve forests and to control over the illegal felling of trees in the hill regions. As the efforts made by the said department along with implementation of Forest Bill, the condition of forests in the basin is presently better. Similarly, the campaign for afforestation over the fragile slope is also successful.

The basin is characterized by primitive economy, which depends either on the production of subsistance cereal crops, livestock rearing or forest resource for firewood, fodder and food need. For the basic requirement, natural forests are degenerating at a large scale. Use of timber for construction of houses and furniture is also a major factor for degeneration of forest resource. The lowland-highland interaction in the basin as a form of rearing animal is also most prominent feature for deforestation. Mostly, during the summer, the people of lowland migrate to highland along with their animals for 3-4 months and during the winter they move downwards. This movement excesses the timber need and increases the process of deforestation. Over and under use of forest resources is the characteristic features of the basin. Temperate vegetation (coniferous forest) is found extensively in the highland and is under used due to inaccessiblity. While, in the lowlands and mid-slopes, forests are over used because of high concentration of population. Under such circumstances, sustainable use of forest resources is inevitable. Forest resource management is also essential to control soil erosion and landslide in an ecologically fragile terrain. The following suggestions are given for forest conservation in the basin:

Reducing the need of firewood through introduction of biogas, which is quite successful in the lowalnd area.

Pasturelands are required to be conserved and for that community people should plan properly for their management. The areas where instability of land is high, plantation of trees can be done to stope the erosion and restore the vegetation there.

The areas should be selected for plantation of fast growing or slow growing trees according to the need of the region. Community forestland should be taken for the use of fuel and fodder need and the natural forestland should be kept as protected and reserved forest so that the stability of the terrain could be maintained and fragility could be reduced.

Ropeways should be introduced in place of road construction for transportation, which will reduce the unnecessary cutting of trees and control the soil erosion.

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Ficus (Fig) species in Nepal: a review of diversity and indigenous uses

Ficus (Fig) species in Nepal: a review of diversity and indigenous uses

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Ficus (Fig) species in Nepal: a review of diversity and indigenous uses

Abstract

Ficus (Fig) species have a wide range of distribution and uses in Nepal. Of the 36 *Ficus* species native to Nepal, 21 are indigenously used as food, fodder, fuel wood, vegetable, medicine, etc. and some are used religeously in Nepal, and 10 in the closer study area. *Ficus religiosa* (Pipal), *F. benghalensis* (Bar), *F. benjamina* (Sami), *F. racemosa* (Dumri), especially have a high religious value for both Hindus and Buddhists and are deemed sacred. The indigenous use as medicine is very important. *F. benghalensis* (Bar) was found as the medicinally most important species , used to treat 22 ailments.

Key words: *Ficus*, Nepal, traditional use, biodiversity

Introduction

Plants are of utmost interest to the human race and our ancestor also lived on nuts, roots, succulent stems, fruits, and other parts of plants. Today, our existence can still not be imagined without plants. The use and conservation of plants and plant products is rooted in Nepalese culture since time immemorial (Kunwar and Adhikari 2005a). There is a general tendency among villagers in Nepal to preserve useful plants on their own farms (Pokharel 1998).
Fodder plants, long an integral part of farming systems, provide a source of green fodder during the dry season when the decreased forage far exceeds the sustainable supply for livestock (Amatya 1992; Lekhak 1998). Over 300 species of fodder trees are found in Nepal and more than 50% of these are *Ficus* species (Kunwar 2002), which are being cultivated in and around farmlands. The common *Ficus* species in cultivation are *Ficus hispida* (Kharsu), *F. semicordata* (Khaniyu), *F. neriifolia* (Dudhilo), *F. lacor* (Kavro), etc. Their role in Nepal's agriculture is very high, as they provide 40-50% of the animal feed (Pandey 1982). 36 species of *Ficus* are reported so far from Nepal (Table 1) (HMGN 2001) but a detail investigation of their indigenous uses was never undertaken. The present study therefore explored and collated the indigenous uses of *Ficus* species in Nepal.

Methods

Both primary and secondary data were collected. Notes on indigenous uses of plants by the local population were collected from Bardia, Dolpa, Kaski and Kathmandu districts in the central and western part of Nepal. The surveyed study sites range from the tropical zone (250m) to as high as the temperate zone (2950m). Secondary data came from a large range of published and unpublished literature. Plants collected were identified at Tribhuvan University Central Herbarium (TUCH) and specimens are deposited there.

Results and Discussion

Diversity

Ficus species are the most interesting group of trees in Nepal, not only of their useful value but also of their growth habits and religious significance. The genus *Ficus* is an exceptionally large pantropical genus with over 700 species (Berg 1989) and belongs to the family Moraceae. It is retained as a single, large genus because it is well defined by its unique reproductive system, involving Syconia fig- and specialized pollinator wasps (Novotny et al 2002).
Out of 36 species of *Ficus* found in Nepal, 16 species are reported from the study area in western and central Nepal (Table 1). Their distribution is either restricted to one region or they are common throughout Nepal. 11 species were found only in the Makalu Barun region, Eastern Nepal (Chaudhary et al. 2001), with their altitudinal range higher in subtropical region. *Ficus palmata* was observed to be restricted in Western Nepal. These species provide good fodder and various ecological services. They provide nectar, refuge habitat for several bird species and a wide variety of insects, and host orchids and mistletoes. *Ficus benghalensis, F. benjamina, F. religiosa, F. lacor, F. neriifolia, F. glaberrima* are common host plants for orchids (Subedi & Paudyal 2001). Some orchid species are restricted to the tree trunks and branches of *Ficus*

glaberrima. *Ficus religiosa,* and *F. hispida* are frequent hosts for mistletoes *Scurrula pulverulenta* and *Dendropthoe falcata* (Kunwar et al. 2005).

Ficus religiosa (Peepal), *F. benghalensis* (Bar), *F. benjamina* (Sami), *F. racemosa* (Dumri) etc. possess high religious value for both Hindus and Buddhists (Subedi et al 1998, Shrestha 1999) and are deemed sacred. *Ficus religiosa* is not uprooted, it grows on shrines and buildings, because it represents the Hindu god lord Vishnu, the god of sustenance. It is widely worshipped as Bodhi tree under which lord Buddha attained enlightenment (Majupuria and Joshi 1989). For antiquity and veneration the Peepal is unrivalled throughout the world. No other tree is claimed to have such long life's part of one in Ceylon, said to have been planted in the year 288 B.C., still lives and flourishes (Cowen 1970).

Table 1. Diversity of Ficus species in Nepal

S.No	Species	Altitude	Habit	Distribution
1	*Ficus altisima* Blume		Tree	Himalaya
2	*F. abelii* Miq.		Tree	C
3	*F. arnottiana* (Miq.) Miq.	850-1500	Small tree	EW
4	*F. auriculata* Lour.*	250-1700	Tree	CW
5	*F. benghalensis* L.*	500-1200	Tree	CEW
6	*F. benjamina* L.*	150-1000	Tree	CW
7	*F. curtipes* Corner	450-600	Small tree	E
8	*F. drupacea* Thunb.	1100	Tree	E
9	*F. elastica* Roxb. ex. Hornem*		Tree	C
10	*F. geniculata* Kurz	650	Tree	E
11	*F. glaberrima* Blume*	600-1500	Tree	CW
12	*F. hederacea* Roxb.*	500-1500	Climber	CW
13	*F. heterophylla* L.f.	300	Shrub	W
14	*F. hirta* Vahl	900	Small tree	C
15	*F. hispida* L.*	450-1100	Small tree	CEW
16	*F. hookeriana* Corner	1800	Small tree	E
17	*F. lacor* Buch.-Ham.*	500	Tree	CW
18	*F. laevis* Blume	300	Tree epiphyte	CE
19	*F. microcarpa* L.f.	300-1100	Tree epiphyte	CW
20	*F. nepalensis* Spreng.		Small tree	C
21	*F. neriifolia* Sm.*	1400-2200	Tree	CW
22	*F. nervosa* Heyne ex Roth	450-600	Tree	E
23	*F. oligodon* Miq.*	1000-1800	Tree	CEW

24	*F. palmata* Forssk*	600-2300	Small tree	W
25	*F. pubigera* (Wall ex Miq.) Brandis		Small tree	C
26	*F. pumila* L.*	1400	Tree	C
27	*F. racemosa* L.*	300	Tree	CW
28	*F. religiosa* L.*	150-1500	Tree	CEW
29	*F. rumphii* Blume	200	Tree	W
30	*F. sarmentosa* Buch.-Ham. ex Sm.*	1400-2500	Shrub	CEW
31	*F. semicordata* Buch.-Ham. ex Sm.*	200-1700	Tree	CE
32	*F. squamosa* Roxb.	500-600	Shrub	CE
33	*F. subincisa* Buch.-Ham. ex Sm.	300-1800	Tree	CEW
34	*F. subulata* Blume	300	Shrub	E
35	*F. tinctoria* G. Forst.		Shrub	W
36	*F. virens* Aiton	80-200	Tree	E

* Species observed in study area C= Central Nepal, E = East Nepal, W = West Nepal

Indigenous use

21 *Ficus* species are indigenously used in Nepal for various purposes. Of 21 *Ficus* species, 16 species are used as ethnomedicine and five species (*F. glaberrima, F. hederacea, F. hookeriana, F. oligodon* and *F. virens*) are used only as fodder and fuelwood. Only 10 species (*Ficus auriculata, F. benghalensis, F. benjamina, F. hederacea, F. hispida, F. palmata, F racemosa, F. religiosa, F sermentosa*, and *F. semicordata*) are reported to be extensively used in study area. The use of *Ficus* species as ethnomedicine in Nepal is quite noteworthy (Kunwar & Adhikari 2005b). *F. benghalensis* (Bar) is most important, used to heal 22 ailments. For enumeration, taxa are arranged alphabetically. Vernacular names are given in *italics*, followed by synonyms and ethnobotanical uses.

1. *Ficus auriculata* Lour.

Vernacular names: *Kaitak* - Chepang; *Eve's apron, Roxburgh fig* - English; *Paingi* - Gurung; *Tirmal, Timla* - Hindi; *Poyepa* - Limbu; *Anjir, Nimaro, Gopa, Timila, Bhutuk* -Nepali; *Mago* - Tamang.

Syn.*Ficus roxburghii*, *F. macrophylla*

Uses:Fodder and edible (Gajurel et al. 1987; Shrestha 1988b; Shakya 1992; Muller-Boker 1993; Chapa 1994; Kaundinya 1998; Manandhar & Acharya 2003; Nepal & Sapkota 2005).

Leaves are crushed and the paste is applied on the wounds (Shrestha & Dhillion 2003). They are also used in diarrhea and dysentery (Manandhar 1991b). Leaves are used for making plates for festive banquets (Chhetry 1996). Stem bark juice is effective for diarrhea (Bhattarai 1992, 1993b), cuts and wounds. Roasted figs are taken for diarrhea and dysentery (CECI 2004). Root latex is used in mumps (Oli 2001), cholera, diarrhea and vomiting (Devkota & Karmacharya 2003; Pant & Panta 2004). Mixture of root powder of *F. auriculata* and bark of *Oroxylum indicum* is taken in jaundice.

2. *Ficus benghalensis* L.

Vernacular names: *Bar* - Bhojpuri; *Bar* - Chepang; *Bar* -Danuwar; *Banyan tree* - English; *Bar* - Gurung; *Bargad, Watam* - Hindi; *Kungiyi* - Lepcha; *Lara* -Limbu; *Paramsing* - Magar; *Bar* - Mooshar; *Bar* - Nepali; *Bara, Dariyongma* - Rai; *Avaroha, Bahupada, Bhringi, Jatalo, Vat* - Sanskrit; *Banidare* -Satar; *Bargadh* - Tharu; *Ni-gro-dha* - Tibetan.

Syn.*Ficus indica, Urostigma benghalensis*

Uses:Edible, fodder, fuelwood and ceremonial (Manandhar 1972; HMGN 1982; Tiwari 1983; Siwakoti et al. 1997; Bhatta 1999; Ghimire et al. 2000; Pandey 2000; Sah et al. 2002; Nepal &

Sapkota 2005).
Stem bark is used as antihelminthic. It is used for diarrhea, dysentery, diabetes, cuts and wounds, joint pain, cracked heel and toe (Sarkar 1994; Siwakoti & Varma 1996; Karna 1997; Shakya et al. 1999; Joshi & Joshi 2001; Panthi & Chaudhary 2003). Stem bark of *F. benghalensis*, root of *Asparagus racemosus*, fruits of *Annona squamata*, and shoot of *Colebrookea oppositifolia* are crushed and eaten on empty stomach to cure urinary problems (Paudyal 2000). Bark decoction is taken as antidote (Thapa 2001), used in epitaxis (Bhattarai 1993c) and stomachache. Boiled bark is employed in cold, cough and asthma. Milky sap from bark is used for diarrhea, dysentery, indigestion, joint pain (Shakya 2000), dermatitis, gum swelling, gonorrhea, and snake bite. It is valued to take out pus of wounds (Manandhar 1986) and is mixed with sugar to give to children suffering dysentery (Yadav 1999). The latex is also used for polishing copper, brass and bronze (Vihari 1995). Leaves latex causes allergy to children (Dangol 2002).
Aerial root juice is used for stopping menstruation and applied externally for body pain, toothache, diabetes, joint pain (Mishara 1998) and rheumatism (Kharel & Siwakoti 2002). Root bark powder is mixed with *Desmostachys bipinnata* (Kush) and sugar and considered to control leucorrhoea. Root latex treats boils and wounds (Parajuli 2001; Siwakoti et al. 2005) and obstinates vomiting (Chopra et al. 1956). The decoction from aerial roots and water obtained from rice wash is used in diarrhea.
3. *Ficus benjamina* L.
Vernacular names: *Golden fig, Java fig* - English; *Pukar* - Hindi; *Sami, Sarane, Swami* - Nepali; *Banij* - Sanskrit;*Jhinpatiya* - Tharu.
Syn. *Ficus comosa*, *F. nuda*
Uses: Ceremonial and fodder (Singh 1968; Thapa et al. 1997; Parajuli 2000; Bhattarai 2002).
Twigs are used as insect repellant by keeping them under the beds (Bhandary & Shrestha 1986). Leaf juice is used as flea and bug repellant (Shrestha 1985). Latex is applied on boils.
4. *Ficus glaberrima* Blume
Vernacular names: *Pakhuri* - Nepali.
Syn.*Ficus angustifolia*
Uses: Fodder, edible and fuelwood (Upadhyay 1992; Tiwari 1994; Kaundinya 1998; Manandhar 2002). Ceremonial (Rijal 1994; Pokhrel 1998; Pandey 2000; Panthi and Chaudhary 2002).
5. *Ficus hederacea* Roxb.
Vernacular names: *Dudhe lahara* - Nepali.
Syn.*Ficus fruticosa, F. scandens*
Uses: Fodder (Dangol and Gurung 1995; Manandhar 2002).
Inner bark is used for temporary binding (Manandhar 2002).
6. *Ficus hirta* Vahl
Vernacular names: *Khoksa* - Danuwar; *Khasreto* - Nepali; *Khahatya* - Raute.
Syn.*Ficus hirsuta*, *F. triloba*
Uses:Edible (Manandhar 2002). Stem latex is used for wounds (Manandhar 1990a, 1990b). Stem bark is boiled and its gel is used in fever (Manandhar 1998b).
7. *Ficus hispida* L.f.
Vernacular names: *Kautaik* - Chepang; *Kothayo* - Darai; *Hairy fig* - English; *Khasre, Thotne* - Gurung; *Kathumber, Daduri* - Hindi; *Bhutu* - Magar; *Kharsu, Khasreto, Tote, Koksa, Kothedumar* - Nepali; *Seta podo* - Satar; *Mogu* - Tamang; *Khur hur, Kharaha, Kothaiya* -Tharu.
Syn.*Ficus caudiculata, F. daemanum, F. daemonum*, *F. prominens*
Uses: Fodder and edible (HMGN 1982; Shrestha 1990; Amatya 1991; Dhakal & Aizz 1996; Amatya 1999; Kunwar 2002; Manandhar & Acharya 2003; Bishokarma et al. 2005; Khatri 2005).
Leaf juice is taken for earache (Basnet 1998). Fumes from twigs are used against earache (Dangol & Gurung 1995; Ghimire et al. 2000) and liver troubles. Fruit, seed and bark are emetic and purgative in nature (Kharel & Siwakoti 2002). Root juice is used for fever (Manandhar 1993).
8. *Ficus hookeriana* Corner
Syn.*Ficus hookeri*
Uses: Fodder (Manandhar 1972b, Lekhak 1998).
9. *Ficus lacor* Buch.-Ham.
Vernacular names: *Kushi* - Danuwar; *Kabro* - Darai; *Elephant fig, Java fig* - English; *Khatarumba* - Limbu; *Kapara* - Magar; *Kavro, Gular, Pakadi* - Nepali; *Chaspou, Chokchi* - Rai; *Katho, Nakkali* - Tamang; *Rikhi* - Thami; *Kapro* - Tharu.
Syn.*Ficus infestoria*

Uses: Ceremonial, edible and fodder. Young buds (*Surulo*) are used in making pickles (Shrestha 1983; Amatya & Rajbhandary 1991; Tiwari 1994; Shakya et al. 1995; Thapa 2000).

Stem bark is used in gastric and ulcer (Bajracharya et al. 1978; Bhattarai et al. 2000; Pandey 2001; Rai et al. 2004). Milky latex of stem is used in typhoid and heavy fever, dysentery (Oli 2001) and boils. Decoction of buds is considered for ulcer and leucorrhoea (Chopra et al. 1956; HMG 1970), gargle in salivation (Malla 1994), boils (Manandhar 1985), pimples and blisters. Dried buds are used to treat harsa (Nakarmi 2001). Seeds are tonic in nature and used in treatment of stomach disorder (Bhatt 1977).

10. *Ficus neriifolia* Sm.

Vernacular names: *Cheksi* - Chepang; *Ghara, Gnta, Tauchhi* - Gurung; *Khepsewa* - Limbu; *Dudhilo, Dudhe* - Nepali; *Ngerpou, Didulang, Wakasi* - Rai; *Nunuthi* - Thami; *Mago, Grebanam, Nedhar, Nelam* - Tamang.

Syn.*Ficus nemoralis, F. gemella*, *F. trilepis*, *F. fieldingii, F. binata*

Uses: Fodder and fuelwood (Singh 1968; Shrestha 1985; Shrestha 1989; Upton 1990; Kapali 1992; Shakya 1992; Chhetry 1996; Nepal 1999; Thapa 2000; Niraula 2001; Manandhar 2002; Panthi and Chaudhary 2002; Gurung 2003; Turin 2003; Manandhar and Acharya 2003; Rajbhandary and Dhakal 2003).

Stem bark juice is given in conjunctivitis and boils (Manandhar 2001, 2002).

11. *Ficus oligodon* Miq.

Vernacular names: *Namsi* - Chepang; *Nimaro* - Nepali, *Waspou* -Rai; *Kholtu, Chanadumri* - Tharu.

Syn.*Ficus hamiltoniana*, *F. pomifera*

Uses: Edible (Muller-Boker 1993; Rijal 1994; Shrestha et al 2003).

Fodder (Nepal 1999; Karki 2001; Chaudhary et al 2001; Shrestha and Kunwar 2003).

12. *Ficus palmata* Forssk.

Vernacular names: *Anjir* - Hindi; *Kappa* - Magar; *Bendu, Anjir, Timilo, Beru, Bedu* - Nepali.

Syn. *Ficus caricoides*, *F. virgata*

Uses: Edible, fodder and fuelwood (HMGN 1982; Bhatta 1999; Panthi & Chaudhary 2002).

Fruit paste is used in ringworm and skin diseases (Thapa 2001). Ripe fruits are used in dysentery and vomiting (Devkota & Karmacharya 2003; Pant & Panta 2004). Stem latex is applied to extract spines deeply lodged in the flesh (Manandhar 1995, 2002).

13. *Ficus microcarpa* Linn.f.

Vernacular names: *Golden fig*-English; *Sami*-Nepali

Syn. *Ficus retusa*

Uses: Leaf extracts is used as insecticide against housefly (Franenkel 1959; Sahu 1997).

14. *Ficus racemosa* L.

Vernacular names: *Dumri* - Bankariya; *Gular* - Danuwar; *Cluster fig* - English; *Dumri, Gular* - Nepali; *Loa* -Satar; *Udumbara* - Sanskrit; *Gullar, Gullri* - Tharu.

Syn.*Ficus glomerata*, *F. goolereea*

Uses: Fodder, edible and ceremonial (Manandhar 1972; HMGN 1982; Dhakal & Aizz 1996; Chaudhary et al. 1999; Pathak 2000; Priya 2000; Sah et al. 2002; Manandhar & Acharya 2003).

Milky juice of stem is used to cure stomachache (Ghimire et al. 2000), cholera and mumps (Basnet 1998). It is used in boils, diarrhea, dysentery and piles (Yadav 1999). Root sap cures heat stroke, chronic wounds and malaria in cattle (Thapa 2001). Leaf latex and cow milk are mixed and used for boils and blisters (Siwakoti & Siwakoti 2000) and measles. Leaf juice is massaged in hair to check splitting. Infusion of leaves is used in menorrhoea. Fruit paste is applied in regulating diarrhea and constipation (Vihari 1995). Seed paste is taken in measles and smallpox (Acharya 1996) and diarrhea (Singh 1994). Paste of stem bark is taken in burns, swelling and leucorrhoea (Paudyal 2000), dysentery, diarrhea and used as astringent (Tiwari 2001). The powder from stem bark is used in curing boils and secretion of milk for lactating mother. Latex is used as adhesive (Dangol 2002).

15. *Ficus religiosa* L.

Vernacular names: *Pipal* - Bhojpuri; *Pipal* - Chepang; *Pipar* - Danuwar; *Pipal, Bo tree, Peepal tree* - English; *Pipal* - Gurung; *Pipal, Pipali* - Hindi; *Tongiyar* - Lepcha; *Pendi, Pirimsing* - Limbu; *Pipal* -Magar; *Pipar* - Mooshar; *Pipal* - Nepali; *Ashawatha, Bodhidruma, Pippala, Suchudruma, Vrikshraj, Yajnika* -Sanskrit; *Pipal* - Tamang; *Pipra* - Tharu; *Bo-de-tsa* - Tibetan.

Uses: Edible, ceremonial, fodder and fuelwood (Manandhar 1972; Upadhyay 1992; Acharya 1999; Parajuli 2000; Rajbhandary & Dhakal 2003; Khatri 2005).

Leaf juice and honey is applied on asthma, cough, sexual disorders (Yadav 1999; Gurung 2002), diarrhoea (Bhattarai 1993b), haematuria (Jain et al. 1991), earache and toothache (Muller Boker 1999; Kharel & Siwakoti 2002), migraine (Mandar & Chaudhary 1993), eye troubles (Tiwari 2001), gastric problems (Kattel & Kurmi 2004) and scabies. Leaf decoction is used as analgesic for toothache. Fruits are eaten to facilitate asthma (Bhattarai 1993a) and respiratory system. Fruit paste is taken to cure scabies (Siwakoti et al. 2005). Stem bark is used in gonorrhoea (Joshi & Joshi 2000), bleeding (Shrestha 1997; Dangol 2002), cuts, wounds (Manandhar 1998a), paralysis, diabetes (Thapa 2001), diarrhea, bone fracture (Karki 2001) and used as antiseptic, astringent and antidote. Bark infusion is taken in scabies. Bark juice taken with *Dolichus biflorus* (*Ghahata* in Nepali and *Karthi* in Tharu) is used to reduce fever in cattle (Chaudhary 1994). Paste of bark is taken with honey to treat cough and cold as well as accompanying mild fever. Aerial root juice is used for menustral problems (Manandhar 1998b).

16. *Ficus rumphii* Blume

Vernacular names: *Wagrans* - Chepang; *Kathepipal, Paharepipal* - Nepali; *Pekle, Dango* - Tamang.

Syn.*Ficus cordifolia,*

Uses: Fodder (Manandhar 2002). Foot and mouth disease of cattle is treated by feeding *F. rumphii* (Manandhar 1992, 2002).

17. *Ficus sarmentosa* Buch.-Ham. ex Sm.

Vernacular names: *Dumri* - Darai; *Aagjara* - Magar; *Berulo, Gai berulo, Bantimila* - Nepali; *Mogu* - Tamang.

Syn.*Ficus foveolata*, *F. luducca*

Uses: Edible (Manandhar 1980, 1991a, 2002; Shrestha 1988a, b; Dangol and Gurung 2000).

Bark powder is taken to cure boils and secrete more milk during delivery.

Root extract is used in malaria (Dangol and Gurung 2000).

18. *Ficus semicordata* Buch.-Ham. ex Sm.

Vernacular names: *Kokshi* - Chepang; *Khurhur* - Danuwar; *Nepal fodder fig, Red earth fig, Wedgeleaf fig* - English; *Khajare* - Gurung; *Kokse, Yangkhoppa* - Limbu; *Aarkhot* -Magar; *Khaniyu* - Nepali; *Khuksi, Khokpou* - Rai; *Kho* - Raute; *Hor podo* - Satar; *Koshing* -Tamang; *Khurburia, Khurkhuri* - Tharu.

Syn.*Ficus cunia, F. conglomerata*

Uses: Fodder and edible (Singh 1968; Bajracharya et al. 1978; Maskey & Shah 1982; Karki 1994; Khan 1997; Bhatta 1999; Rajbhandary & Dhakal 2003; Shrestha & Kunwar 2003; Uprety 2005).

The use of latex to cure boils is so ancient that it is also reported from the Holy Bible. A bath made from the fruit and bark is a cure for leprosy. Latex is drunk to cure fever (Rijal 1994). Raw fruits are eaten in diarrhea (Bhattarai 2002). Young fruit juice is applied in forehead to relieve headache (Manandhar 1998b). Young twigs are fed to cattle for facilitating the discharge of placenta (Dangol & Gurung 1995). Fume of twigs is used in earache (Muller-Boker 1993). Bark of *Ficus semicordata, Schima wallichii, Syzygium cumini, Phyllanthus emblica* and *Mangifera indica* are pounded and given in ulcer and gastric (Manandhar 1993). Root paste is taken to cure headache.

19. *Ficus subincisa* Buch.-Ham. ex Sm.

Vernacular names: *Cheksi* - Chepang; *Kane chhi* - Gurung; *Belda* - Lohar; *Birula, Lekho* - Magar; *Bedulo, Bello, Aankhpakuwa* - Nepali; *Lomago, Soror* - Tamang.

Syn. *Ficus chincha*, *Ficus clavata, F. caudata, F. trachycarpa*

Uses: Long term feeding results eye infection. Seed is antihelminthic (Devkota and Karmacharya 2003; Pant and Panta 2004).

Leafy biomass 60-80 Kg/Yr, Crude protein 18 % (Amatya et al 1994), 15.2% (Malla 2004).

Fodder, *Fuelwood* (Pandey 1982, Shrestha 1985, Shrestha 1988a, Shrestha 1988b, Rijal 1994, Amatya et al 1994, Pokhrel 1998, Pandey 2000, Manandhar 2002; Panthi and Chaudhary 2002, Manandhar and Acharya 2003).

20. *Ficus virens* Aiton

Vernacular names: *White fig, sour fig, grey fig* - English; *Pilkhan* - Hindi; *Pakar* - Nepali; *Pakhar* - Satar.

Syn. *Ficus infectoria*

Uses: Foliage buds are eaten as vegetable and pickle (Siwakoti et al 1997).

21. *Ficus* spec. indet.

Vernacular names: *Dhungre, Ghansbar* - Nepali; *Paphu* - Rai.

Uses: Plant is used as fodder (Pandey 1982).

Leaves are used for making plates use in ceremony (Nepal 1999). Plant is useful as food for butterfly larvae (*Cyrestis thyodamus* - Common map, *Euploea core* - Common Indian crow) (Khanal & Bhandary 1982).

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