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Introduction

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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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Conflictos en el uso de la tierra y manejo integrado de bosques en áreas montañosas: Estrategias para la conservación de bosques montanos en África

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Land Use Conflict and Integrated Forest Management in Mountain Areas - Conservation Strategies for Mountain Forests in Africa

In Africa, land use and sustainable management schemes in highland areas and mountainous forest have become increasingly important and timely, as these areas, like the lowland forest, have come under serious exploitation and constant threat of disintegration, following the depletion of the majority of the lowland forest. Mountain forest, like most ecosystems, have been exploited and degraded mainly by anthropogenic activities either directly (through vegetation cover removed for timber/wood, construction, agriculture and other purposes) or indirectly (through pollution by environmental stresses such as hazardous gases/oils, global warming effects, heavy metal bioaccumulation and toxicity). These areas have also had their share of forest wildfire and defoliation, forest damage and decline by natural disasters and adverse climatic conditions. In order to arrest the situation, this paper suggests that appropriate and sustainable integrated forest management techniques be implemented and executed uncompromisingly. In this regard, geographic information system and remote sensing technologies should be employed along with appropriate methods of educating the rural populace in renewable resources utilization involving not only physical utilization of the forest resources, but also other areas of forest use peculiar to mountain forest such as profitable, sustainable ecotourism.

Resumen

En África, el uso de la tierra y esquemas de manejo sostenible en áreas de altura y bosques montanos son cada vez mas importantes, ya que estas áreas, de la misma manera que los bosques húmedos, están bajo de constante explotación y de desintegración, después de la destrucción de los bosques de la zona baja. Los bosques montanos han sido explotados y degradados especialmente por actividades antrópicas de manera directa (destrucción de la capa vegetal para madera, construcción, agricultura y otros usos) o indirecto (contaminación del medio ambiente por aceites, gas, calentamiento global, acumulación de metales pesadas, toxicidad). Estas áreas fueron afectadas por fuego, defoliación, y destrucción de bosques por desastres naturales y condiciones climáticas adversas. Para remediar esta situación, este trabajo sugiere el implementar técnicas apropiadas e integradas al manejo del bosque. De esta manera se aplica el uso conjunto de sistemas de información geográfica, con métodos propios para la educación de la población rural sobre uso de recursos renovables y uso de los recursos forestales por actividades comerciales como el ecoturismo.

Introduction

Mountains and hills cover about a third of the globe’s landmass. Mountains are highland areas found at great heights on the earth’s surface, many of which are covered and carpeted by a lush of green vegetation of trees, shrubs, herbs and grasses. Some mountains are adorned with white snowflakes especially at higher peaks while some are bare with smooth rocky surfaces. At times, plant species of the Bryophyta, Thallophyta and Pteridophyta colonized these surfaces, forming distinct micro-ecosystems.

Mountain forest ecosystems, like their lowland counterparts may possess the entire canopy strata and grades. Both plants and animals species flourish adequately well by virtue of the natural resource availability, especially in the lower slopes and upper valley planes. Most mountain ecosystems throughout the world exhibits similar patterns and characteristics, with the major structural feature being the tree line - the point on the upper slopes of mountains where the climate becomes too harsh to support trees and an alpine vegetation prevails.

Prolonged and extreme climatic conditions coupled with excessive and perturbing anthropogenic activities have made mountain forests, in many parts of Africa depreciate in both quality and quantity. For sustainability, an integrated forest management programme is necessary. This programme, which will include adequate forestry training for the local people and their immediate community, will contribute immensely to the preservation and the overall conservation efforts of these precious forest resources in Africa.

This paper presents a number of pertinent recommendations that could contribute immeasurably to land use and integrated forest management in the mountainous regions of the African continent.

Methods

Both primary and secondary data were gathered. While most of the work was based on the secondary data collection and analysis through desk research work, the primary data gathering was basically through reconnaissance visits to certain specific highland sites and cloud forests in Nigeria (e.g. Jos, Plateau) and Cameroon (e.g. Buea, Mount Cameroon).

Results

Ecology of mountain forest and their unique features

The climates of mountain forests are typically cool and humid. They are seldom warm due to high altitudes and hardly ever dry because of the ample supply of precipitation. Mountain environments have different climatic conditions from that of the lowland regions, hence the vegetation differs as well. The differences in climate result from two principal causes: altitude and relief. Altitude affects climate because atmospheric temperature drops with increasing altitude by about 0.5 0 C to 0.6 0 C per 100m. Relief of mountains affects climate because they stand in the path of wind systems and force air to rise over them. As the air rises it cools, leading to condensation and ultimately higher precipitation on windward mountain slopes (orographic precipitation); as it descends leeward slopes, it becomes warmer and relative humidity falls, reducing the likelihood of precipitation and creating areas of drier climate (rain shadows). Altitudinal modifications of vegetation are clearly discernible on the high East African peaks near the equator such as Kilimanjaro (the highest peak in Africa - 5, 895m) and Mounts Kenya (3, 100 m) and Elgon.

The mountainous forest, especially those at great proximity to water bodies, are unique in that they receive a steady and an abundant supply of rainfall from the nearby lakes, rivers and oceanic seas. Some of these regions are considered to be the wettest areas in the world. Three of such places are Debunsha, Cameroon; Cherrapunji, India; and Mount Waialeale, Hawaii. Debunsha village is at the foot of Mount Cameroon (peak - 4,095m) with a mean annual rainfall of more than 10,000mm. Cherrapunji is noted for having the world’s second highest recorded average annual precipitation of 11,430 mm over a 74-year period. Mount Waialeale holds the highest record of precipitation (11, 684 mm). The consequence is nothing but a great variety of biological resources. This is especially true in tropical mountain forests. Biu (800m), Mambilla (1000m) and Jos (1,500m) Plateaus in Northern Nigeria, as well as Buea in Cameroon, the Mounts Kenya and Kilimanjaro in East Africa are among the many examples of highland areas with a rich biological diversity. The effect of climate on vegetation in mountainous regions is often masked by edaphic and biotic factors.

Mountains and highland forest in Africa are noted for a variety of notable natural and man-made disturbances, such as acute climate, forest fires and deforestation. The impacts of these have led to forest defoliation and decline. Fire sources in mountain areas include volcanoes, lightning and intentional as well as accidental fires caused by humans (Horn, 1998). Because they are already under a great deal of environmental stress, mountain ecosystems cannot easily cope with further anthropomorphic perturbations, such as the introduction of exotic species, over-grazing, atmospheric pollution and other forms of misuse.

Threatened mountains forests

The rich biological diversity in many highland forests in Africa is threatened. The cause of this is not farfetched. Apart from 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).

Mountain forest floors in Africa are extremely rich in mineral nutrients. The volcanic soils, which are particularly fertile and highly suitable for plant growth, soon become impoverished after intense exposure to wind, solar energy and on-going arable, monoculture farming system. Having seriously exploited and utilized the resources found in the lowland areas and valley planes, more and more people have started to shift base uphill (Sanwo, 2002). With the same anthropogenic paraphernalia and activities used to devastate the lowland ecosystems, man has started to perturb, to a large degree, the mountain forest and it’s resources. His climbing up this former haven of great beauty and delight has resulted in a great shift/change in land use. The Holy Bible seems to support the climb upwards if one considers the passage in Haggai: Chapter 1 verse 8: "*Go up to the mountain to get the wood. And build the temple. Then I will be pleased with the temple and I will be honoured."* This great demand and excessive exploitation of land resources has been part of the product of land use conflict observed during and in the course of man's perturbations of mountain forests. In the long run both renewable resources and non-renewable resources are degraded and depleted in an unprecedented scale. If left unchecked, wastelands, unproductive soils and desert encroachment are usually the final outcome (Arimoro, 2001). In many African countries, forested highlands are stripped off their natural vegetation without proper environmental impact assessment studies (EIA). The land is then 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).

This is particularly noteworthy in many mountain forests in developing countries and the African sub-region. Some Afromontane forests as the Manengouba forest in Cameroon have shown indicators (e.g. presence of the date palm, *Phoenix reclinata*,) of undesirable encroachment due to cultivation and firewood collection, which has endangered several endemic birds, amphibians and rodents (Decoux et al., 1991). Other examples of such land use changes are found in Asia, East and West African countries including Nigeria. The forest landscape of the Sagarmatha 'international' Park on the Mount Everest's southern plains (earth's highest peak - 8, 848m) has been reported to be at risk from human encroachment and activities such as woodcutting, livestock grazing and uncontrolled tourism.

In Nigeria the vegetation of the Jos Plateau (1,500m) has been so devastated by human interference that little can be inferred from it to aid classification of the original vegetation. The greatest environmental abuse factors in Nigeria can be summarized as human activities resulting in drought and desertification, dissicating winds, forest fires, erosion and harsh climatic conditions (Okali, 1985; UN, 1977). According to Okali (1985), human abuse of the environment is driven by motives that are often outside the competence of ecological science to handle, this is because they are driven by "prevailing economic perspectives by technology, industrialization, urban development, inadequate planning and cultural attitudes". An example is the need to produce food and other materials for sustenance or economic gain that drive people to use ill-advised techniques on the forest land to exhaustion even though all along, they could see yields declining, forest disappearing, erosion and land wasting.

The highland areas of Nigeria have particularly experienced high population growth rate and accelerated urbanization. This has led to a considerable increase in the demand for wood and other forest products. To ensure a sustainable supply of these products, there was the need for better forest management and balanced land use planning based on adequate knowledge and information about the country's high forests and plantation estates. Consequently, a national forest resources study was put in place with the overall objective of enhancing industrial forestry development in the country, which will aid in facilitating the management of the remaining forest resources in an efficient and environmentally sound manner (FORMECU, 1999). Forest management objectives in highland areas of Plateau, Nasarawa, Taraba, Adamawa and Benue States were designed to manage forest resources in a sustainable way and to ensure a continuous supply of timber and non-timber products, the provision of employment opportunities, and the maintenance of a stable environment in these and other States of the Federation.

Sustainable integrated 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; Jerkins et al, 2000; Gane, 1992) and human development (U.N, 1997). Gane (1992) describes sustainability as finding a path of economic progress that does not impair the welfare of future generations. 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. Sustainable human development therefore takes care of the poor urban and rural dwellers in Africa by not only generating economic growth for them but also by distributing its benefits equitably and by regenerating the environment (Sanwo, 2002).

A sustainable forest management approach to the conservation of mountain forest resources will greatly contribute to human welfare in Africa. 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 including ecotourism (FAO, 1985; Sanwo, 2002).

The field of ecotourism emerged in the mid-1990s and it is increasing in popularity within the context of economic growth, development and natural resource sustainability. Ecotourism, unlike uncontrolled and exploitative tourism, is being developed with the aim of helping indigenous people to disengage from subsistence practices that degrade the environment and cause biodiversity erosion (Sam, 1999). This form of ecological and economic tourism as well as controlled recreational and educational exploration aims at sustainability. Thus, ecotourism promotes the progressive economic growth and development of a nation without stressing or degrading environmental resources. The activity helps to contribute to biodiversity conservation, wildlife inheritance protection and the preservation of the cultural heritage of natural landscapes and aesthetics. Ecotourism is essentially defined as tourism practiced in relatively undisturbed natural areas, for the main purposes of admiring and learning more about them. Hence, ecotourism must be accomplished with the view to producing minimal impact on and in the area visited. The European Federation of National Parks also defined sustainable tourism in natural areas as: "all forms of tourism development, management and operations which maintain the environmental, social and economic integrity and well-being of natural, built and cultural resources in perpetuity" (Yunis, 2001). Developing countries in Africa and beyond continue to experience increases in the ecotourism market, exposing more visitors and recreationists to their cultural heritage, no doubt boosting the local economy. Integrating sustainable ecotourism in mountain environments, therefore, benefits host nations both economically and ecologically.

An integrated environmental management technique will make use of the other necessary workable management techniques available to preserve and conserve forest resources. An efficient sustainable integrated forest management (SIFM) strategy aims at environmental friendliness and sustainability. It is one that will enhance proper forest resources utilization and optimal land use schemes. The application of SIFM strategy is not limited to researchers, policy makers and governments alone. Rural and urban dwellers and other stakeholders are all part of the process. Co-operation between them is also needed. The bottom-up approach method of actively involving community dwellers in community-based development programmes are of utmost importance as this is now achieving greater success in sustainable environmental management and ecosystem conservation methods (FAO, 1985; FORMECU 2001; Lusigi, 2001). Various SIFM methods are working for mountain forest in Africa by regenerating and rehabilitating forest areas. Regions in the developing countries of Latin America, Asia and Africa such as Cameroon, Tanzania, Kenya, Zaire, Nigeria, Venezuela, Peru and Nepal where forested highlands are being devastated are encouraged to employ more of these techniques as the case may be (Noss, 1999).

An integrated forest management approach that will enhance sustainability, however, will incorporate viable facets to proper land use schemes. The management may allow for the establishment and maintenance of the following: secondary/high forests; afforestation/plantation; agroforestry/alley cropping; aesthetics and ecotourism; and national parks/sanctuaries and game/forest reserves.

The execution of *in situ* and *ex situ* conservation methods is of utmost importance for sustainable management and development. *In situ* conservation involves the maintenance of biological diversity in their wild state and within their exiting range. On the other hand, *ex situ* conservation is the maintenance of biodiversity in cultivation or captivity. Plants may be maintained in seed banks or germplasm collections. *Ex situ* measures include the conservation of species in botanical gardens, game farms, zoos and gene banks, where possible. In addition, bioremediation techniques could be applied at appropriate stages during ecological restoration programmes. Bioremediation is a principle as well as a technique whereby biological resources are utilized to restore a degraded area to its original state (Arimoro, 2001).

The role of remote sensing and geographical information systems

The role of remote sensing and geographical information system (GIS) technologies as well as other computer models in ecosystem management is indispensable. These are proficient, analytical and evaluation tools in forestry and other environmental sciences. Their contribution to efficient forest assessment, monitoring and management in developed countries is inestimable. Hence, their application and optimum utilization in integrated forest management for mountain forests in the Africa are highly recommended. It has, however, been shown that their application in the developing world is quite limited due to inadequate information, facilities and technological know-how. (Arimoro et al., 2002).

Remote sensing is a procedure for collecting data about features and targets on earth’s surface, often in the form of photographs and images. It involves the detection, recognition, and evaluation of objects by mean of distant sensing or recording devices. It is indeed one of the most powerful tools available for collecting, collating, analyzing, monitoring, quantifying and mapping environmental data and their associated changes (Franklin, 2001). It is effectively modified and designed to support sustained forest management especially in presenting and reporting criteria and indicators of sustainable forestry and land use (FORMECU, 1998; FORMECU, 1999).

GIS is a computer-based system for the digital entry, storage, transformation, analysis and display of spatial data (spatial data will include maps of vegetation types and land use; point observations of rainfall; images from satellite a data or remote sensing; and tabular data associated with geographical areas such as demographic reports). The synergy between remote sensing, GIS and other scientific application and models has resulted in the formation of the geographic information science (GIScience). GIScience has thus become a masterpiece set of tools for integrate management of mountain forests (Franklin, 2001). Institutional capacity building through training, education and technology transfer especially at the grass-root level will crown the process of a good mountain forest management strategy. All parties need training on new techniques for continuity and maintenance. The necessity for stakeholders, government agents and the rural dwellers to be trained and educated in modern forest skills is especially essential in Africa, where the level of illiteracy is high and modern tools and equipment are lacking. This is mandatory, if the needs of the people and the sustainability of the forests are to be met at the same time.

The use of these modern techniques have been clearly demonstrated and successfully applied in Africa. Between 1976 and 1995, using satellite imagery and GIS technologies, changes in the land use and vegetation was mapped, analyzed and recorded for most parts of Nigeria. For example, Table 1.1 (under the list of attachments) shows that some changes in the land use and vegetation of Nigeria did occur over a 20-year period.

This regional data [[(Table 1.1)]]on the national development (FORMECU, 1998) reveals that there is a general decrease on forested areas that are not located on highlands. A general increase can be seen in the size of agricultural and grazing lands, suggesting encroachment on the plane lands by bad agricultural practices.

Table 1.1: National Area Increase/ Decrease between 1976/78 and 1993/95

Category	%Change Increase	% Change Decrease	New Area Involved km2
Intensive (crop agriculture)	5		42,697
Extensive (grazing) agriculture	3		20,910
Agriculture within denuded area	0.6		5,688
Floodplain agriculture	1.3		11,467
Savanna: Guinea		8	69,907
Sudan		3.5	32,186
Sahel			No change
Forests: Undisturbed		1.6	13,837
Disturbed	0.5		4,417
Riparian		0.2	2,148
Montane: Forest			No change
Grassland	0.1		1,373
Grassland: Continuous	0.8		6,955
Discontinuous	0.5		5,111
Floodplain: Swamp	0.1		7,651
Grass marsh		0.5	4,011
Coastal: Freshwater		0.9	7,651
Mangrove			Negligible
Tidal flats saltwater swamp	0.1		541
Exposed Areas: Gully Erosion	2.0		18,395
Sand dunes	0.4		4,017
Rock Outcrops	0.1		1,208
Reservoirs	0.1		1,561

Source: FORMECU, 1998

Similarly Tables 1.2 and 1.3 show changes in land use in the lowland as well as highland areas of Adamawa State (with a total land area of over 36,000 km2) and Bauchi State (with a total land area of about 66,000km2).

[[Tables 1.2]] shows that some changes did occur in the forested areas of Adamawa State. Before 1976 there ware apparently no disturbed forest ecosystems, however due to perturbation this area increased to 1,543 km2 of the total land area of the State in 1995. It is also important to note that the montane ecosystems (especially forest and grassland) have not been seriously encroached during this period. However, with increased population moving upland in the recent times, in search of ’fresh’ natural resource including land, these areas and their ecosystems are in danger of serious and irreparable depletion.

[[Table 1.3]] shows that intensive and extensive agricultural practices by man have reduced the natural vegetation and undisturbed forests to less than 1% of Bauchi State’s total land area of 66,000 km2. The degradation has lead to the formation of gullies and disturbed forest ecosystems. This illustrates the urgent need of a more sustainable management practice that will promote proper natural resource utilization, hence, protecting and conserving the valuable biological resources for the benefit of both the present and future generations.

GIS and remote sensing tools allow for the generation and mapping of these pieces of information as well as monitoring and future research work with a view to updating such information for further analyses and assessment.

Table 1.2: Dominant Vegetation and Land Use Classes in Adamawa State, 1976/78 and 1993/95.

Vegetation & Land Use Categories	**Area (km2) 1976/78**	Percent of State **1976/78**	**Area (km2) 1993/95**	**Percent of State 1993/95**
Extensive (grazing) Agriculture	9291	25.4	10928	29.8
Shrubs/Grasses	11723	32.0	10062	27.5
Intensive (crop) Agriculture	8487	23.2	8082	22.1
Trees/ Woodlands/ Shrubs	4361	11.9	2319	6.3
Disturbed Forest	0	0	1543	4.0
Floodplain Agriculture	348	1.0	1120	3.1
Montane Grassland	0	0	614	1.7
Montane Forest	281	0.8	573	1.6
Rock Outcrop	5	<0.1	169	0.5
Shrub/Sedge/Graminoid Fresh water marsh/Swamp	679	1.9	129	0.4
Undisturbed Forest	1022	2.8	119	0.3

Source: FORMECU, 1998

Table 1.3: Dominant Vegetation and Land Use Classes in Bauchi State, 1976/78 and 1993/95.

Vegetation & Land Use Categories	Area (km2) 1976/78	Percent of State 1976/78	Area (km2) 1993/95	Percent of State 1993/95
Intensive (Crop) Agriculture	20,026	30.3	27,338	41.4
Shrubs/Grasses	14,833	22.5	15,593	23.6
Extensive (grazing) Agriculture	11,049	16.7	12,050	18.3
Trees/Woodlands/Shrubs	14,754	22.3	3,571	5.4
Gullies	0	0	1,403	2.1
Disturbed Forest	0	0	1,322	2.0
Grassland	0	0	470	0.7
Undisturbed Forest	2367	3.6	125	0.2

Source: FORMECU, 1998

Discussion

In order to avoid increasing deterioration of the mountain forests of Africa and the fertile land on which they stand, sustainable integrated forest management programmes should be implemented and applied. Integrated forest management methods will contribute to the many efforts to conserve the ecosystems and protect the global environment as a whole. Integrated forest management for mountain ecosystems in the developing world of Africa would be sustainable and environmentally sound if implemented, administered and executed in the appropriate ways, bearing in mind the peculiarities of the forest to be managed, the foresters and communities concerned. For greater successes in mountain forest management procedures, therefore, the following recommendations will be of great benefit to forest managers and all stakeholders, especially the rural communities (Sanwo, 2002; Arimoro, 2001; FAO, 1994):

Conservation techniques should include the maintenance of large establishment of reserves, sanctuaries and parks for sustainability and ecotourism development.

Private, communities/groups could promote forest development initiatives such as individuals establishing plantations, orchards or wood lots and planting trees on the farm or compound.

In situ and *ex situ* conservation should be reinforced.

Sustainable ecotourism should be implemented. Influx of peoples during educational and recreational activities of exploring and appreciating natural landscapes and aesthetic areas should be adequately controlled. While income is being generated through ecotourism, the environment should be adequately protected from population pressure, stress and disturbance

Proper and sustainable utilization of forest resource products for food and medicine (such as fruits, nuts, barks and leaves) should be implemented. Teaching the rural communities the simple act of forest management and positively changing their life styles towards a care for nature should prevent over-harvesting of food and cash crop. It is essential that outside inputs be injected into rural forest areas such as extension, training, guidance, technical assistance and financial aid. Overgrazing should be stopped. Controlled grazing at particular areas designated for such will prove more sustainable. Practice bioremediation techniques to help restore wastelands, eroded habitats, degraded communities and other ecologically sensitive zones. Fast growing trees (e.g. Teak, Eucalyptus and Gmelina sp.) native shrubs and leguminous plants could also be grown to help rehabilitate the area and increase soil fertility.

Indigenous knowledge, community participation and cooperation should be developed and strengthened among all concerned. Forestry seems to be a male-dominated profession in both public and private sectors. There is a need for gender sensitizing at all levels and the recognition of the traditional and potential important roles played by women in resource management. Genuine and proper conduct of Environmental Impact assessment (EIA) process before, during and after proposed projects should be seriously advocated and executed. Land use policies should be reviewed carefully to ensure that they do not lead to negative impacts to vital forest resources through land use conflicts. Training and technology transfer between and among researchers, extension agents and the community dwellers are vital for sustainable development and progress. There is an urgent need for extension education and training (for adults and youths, male and female) to help people develop sustainable forest management procedures and maintain them. Researchers will also benefit from the traditional knowledge of the rural populace.

The use of GIS, remote sensing and other models for collecting, analyzing, assessing, and monitoring forest activities will boost mountain forests management in Africa.

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Vegetation and soil status on an 80 year old lava flow of Mt. Cameroon, West Africa

Vegetación y estado de los suelos en un flujo de lava de 80 años en Mt. Camerún, Oeste de África.

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Vegetation and soil status on an 80 year old lava flow of Mt. Cameroon, West Africa

Abstract

Vegetation surveys were carried out in 2001-2002 on the 1922 lava flow on Mount Cameroon in order to assess species richness and soil status. A total of 102 species were recorded belonging to 47 families, including 21 tree species belonging to 13 families, 13 shrubs belonging to seven families, 20 herb species belonging to 10 families, seven climbers belonging to five families, 17 ferns belonging to eight families, five moss species, four lichen species, 13 orchids species and two fungi species. The family Orchidaceae was the most represented herb family while Rubiaceae was the most represented tree family. A total of 106 trees with dbh from 1 - 10 cm were recorded, with mean dbh of 6.65 cm and mean total BA of 1885.3 cm2 recorded. *Syzygium guineense* had the highest BA (769.68 cm2), with highest relative density (16.807%), relative dominance (40.83%) and CVI (57.638%) with an Important Value Index = 68.24%). *Alchornea cordifolia* with BA = 537.21cm2 had a relative density = 15.966%, relative dominance = 28.495%, CVI = 44.462%, and IVI of 55.57. *Mangifera indica* had the least with BA = 0.785 cm2, relative density = 0.821, Relative dominance = 0.042, CVI = 0.882 and IVI = 2.84%. *Chromolaena odorata, Nephrolepis pumicicola, Nephrolepis biserrata* were frequent with *Nephrolepis pumicicola* having the highest density (3.35%) and 13.87% relative density. *Alstonia boonei and Maytenus* sp. had the lowest densities. Shannon-weaver diversity (H1) and Simpson diversity indices are 3.58 and 22.863 respectively. The physico-chemical parameters of the soil from the edges and the centre of the lava were analysed. Colour ranged from very dark grey (5y 3/1), in the centre, to dark reddish brown (5y 3/3, 5y 3/4). The topsoil was mostly made up of organic matter. The soils were acidic (pH from 4.62 - 5.31), soil sand content was highest at the right edges (56.5%) and lowest at the centre (16.8%). Total Nitrogen was found to be highest on the lava centre, (3.53%), and lowest at the right edge (1.65%) while the total phosphorus was highest at the left edge (27.15) and lower (19.3) on the centre; being relatively higher than all other soils in Cameroon (12 - 16%), Calcium (Ca) is relatively high in the complex and shows the highest percentages among all cations. The principal component analysis showed that PC1 (69.3%) is most strongly affected by total Nitrogen, exchangeable cations, CEC, organic carbon and organic matter, while PC2 (30.70%) is strongly associated with total phosphorus (Bray II) and sand silt content. These are the main factors that influence vegetation growth on this lava.

Resumen

La vegetación en el flujo de lava de 1922 del Mt. Camerún, fue estudiado entre 2001-2002 para investigar la riqueza de especies y el estado de suelo. Se encontraron 102 especies de plantas de 47 familias, incluyendo 21 especies de árboles en 13 familias, 13 arbustos pertenecientes a siete familias, 20 hierbas en 10 familias, siete trepadoras en cinco familias, 17 helechos en ocho familias, cinco briofitos, cuatro líquenes, 13 especies de orquídeas y dos en hongos. Las orquídeas representan la familia más importante de hierbas, mientras que las Rubiaceas son la familia más rica de árboles. Se encontró un total de 106 árboles con dap de 1-10 cm., y un dap medio de 6.65 cm., y un total de área basal (AB) de 1885.3 cm2. *Syzygium guineense* tuvo la AB más alta (769.68 cm2), la densidad relativa más alta (16.807%), dominancia relativa (40.83%) y CVI (57.638%) con índice de valor de importancia (IVA) = 68.24%. *Alchornea cordifolia* con BA = 537.21cm2 , densidad relativa de = 15.966%, dominancia relativa = 28.495%, CVI = 44.462%, y IVA de 55.57. *Mangifera indica* tuvo la AB mas pequeña con 0.785 cm2, densidad relativa = 0.821, dominancia relativa = 0.042, CVI = 0.882 y IVA = 2.84%. *Chromolaena odorata, Nephrolepis pumicicola, Nephrolepis biserrata* estuvieron frecuente con *Nephrolepis pumicicola* con la densidad más alta (3.35%) y 13.87% densidad relativa. *Alstonia boonei* y *Maytenus sp.* Tuvieron la densidad mas baja. Los índices de Shannon-weaver (H1) y Simpson fueron 3.58 y 22.863. Los parámetros físico-químicos de los suelos de los límites y del centro del flujo de lava fueron analizados. El color estuvo entre (5 y 3/1) en el centro hasta (5 y 3/3, 5 y 3/4). El primer horizonte del suelo consistió de materia orgánica. Los suelos se muestran ácidos (pH de 4.62 - 5.31), y el contenido de arena estuvo mas alto en los limites (56.5%) y mas bajo en el centro (16.8%). El Nitrógeno total estuvo mas alto en el centro (3.53%), y mas bajo en el lado derecho (1.65%) mientras que el fósforo estuvo mas alto en el lado izquierdo (27.15%) y mas bajo

(19.3%), una cantidad mas alta que en suelos normales de Camerún (12 - 16%).

Introduction

Mt Cameroon is located in the Gulf of Guinea at the South West Province of Cameroon. Its longest axis, as shown in **[[Figure1]]**, about 45 km long and 30 km wide runs SW to NE between latitudes 3°57' to 4°27'N and longitudes 8°58' to 9°24'E, with the main peak at 4°7'N and 9°10'E (Tchouto, 1996; Suh *et al*., 2003). It is considered to be one of the most active volcanoes in Africa, having erupted eight times within the past 100 years (1909, 1922, 1925, 1954, 1959, 1982, 1999 and 2000). Soils on Mt Cameroon are mostly of recent age and derived from active volcanic rocks. They are generally fertile but have a poor moisture retaining capacity (Cheek, 1992). The soil temperature, measured at depths of 10 cm, varies from 25°C (at 200 m) through 20°C (at 1100 m) to 15°C at 2200 m above sea level (Payton, 1993). The region has two main seasons: a wet season with heavy rains from June to October and a dry season from November to May. The mean annual rainfall of this area varies between 2085 mm, near Ekona on the leeward side, to 9086 mm at Debundscha on the windward side of the mountain. This is the wettest place in Africa (Fraser *et al*., 1999). Mean monthly temperatures, at sea level, vary from 19°C to a maximum at 30°C during the months of March and April (Fraser *et al*., 1998). The humidity range is between 75% and 80% throughout the year on the southwestern side of the mountain. The persistent cloud cover and mist make Mt Cameroon one of the areas, receiving the lowest annual sunshine in West Africa. Sunshine ranges from 900 to 1200 hours/year at sea level and decreases with altitude (Payton, 1993). Plant recovery on the different lava flows has resulted in a rich and mosaic type of vegetation on the mountain slopes. There have been a number of publications on the geology of the mountain and most of the eruptions of the twentieth century (Deruelle *et al*., 1987; Fitton *et al*., 1983; Géze, 1943; 1953; Suh *et al*., 2001; 2003). Very few studies have been concerned with reporting plant recolonisation of Mt Cameroon (Keay, 1959; Benl, 1976; Fraser *et al*., 1998; Ndam *et al*.; 2002). No studies so far have attempted to establish any relationship between the plant diversity and the soil nutrient status of any of the lava flows.

The present study thus aims at updating plant inventories on the 1922 lava flow and reporting on the present nutrient status of the soil 80 years after the eruption.

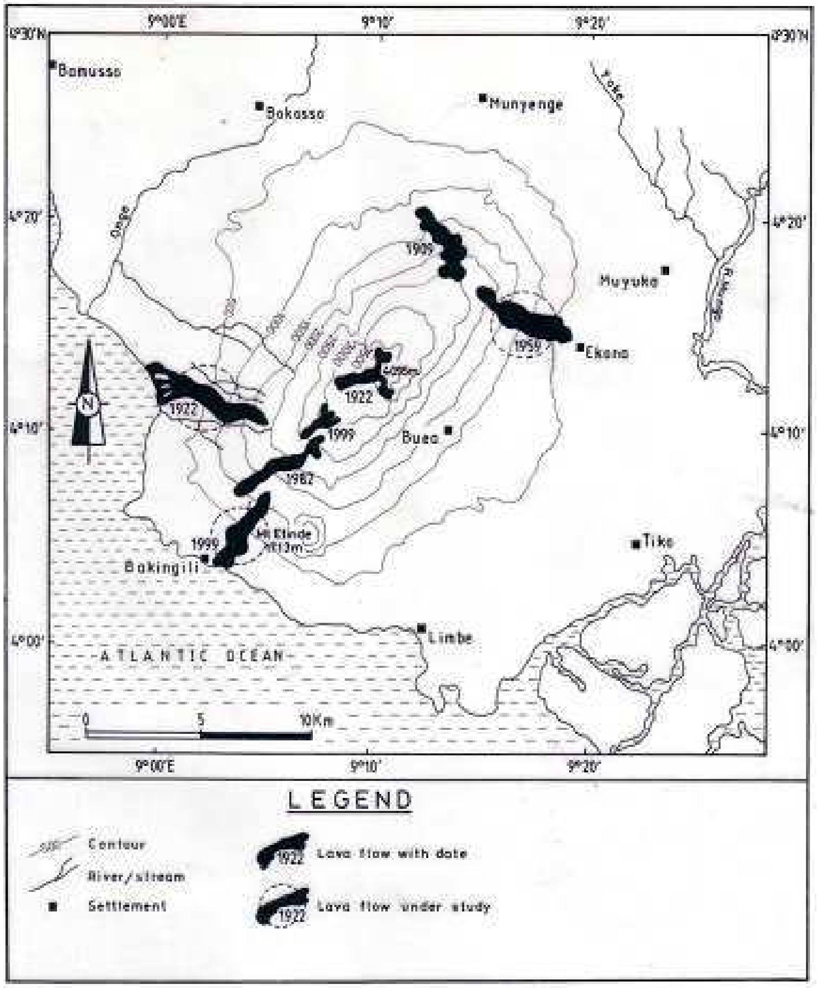

Fig. 1: Map showing the different lava sites on Mt. Cameroon

Materials and Methods

Study Sites

The eruption studied occurred from 2nd February and ended on 24th August 1922. It occurred in two locations, at 30-50 m above sea level (asl) (2nd -19th Feb) and between 900-1050 m asl (3rd of March - 24th August) (Haig, 1937; Géze, 1943; Fitton *et al*., 1983 and Déruelle, 1983). The lava flow is located at 9°1'W, 4° 1'N, 2 km south of Idenau and 10 km north of Debundscha. The lava is basaltic and typically pahoe-hoe lava, resulting from two viscous, fast flowing lava. The lava is smooth and has a ropy appearance. The surface of the lava now has plants and appears slimy and silky. Mean annual rainfall at Idenau is 8,392 mm, and that of Debundscha is 9086 mm (Fraser *et al*., 1998). The rainfall pattern is monomodal. The lava emerged from a crater at about 1,500 m asl, and moved 10 km from the crater to the sea. The flow is 1.5 km wide until it becomes divided at 170 m asl.

Sampling

Vegetation Survey

Fifteen plots of 20 m x 50 m, at a distance of 100 m from each other were located on the two edges, (1 plot each) and 13 plots in the centre of the flow. The plots were then surveyed using the Whittaker method as shown in **[[Figure 2]]** (Bullock, 1996). Plots were completely sampled in July 2001(rainy season), December 2001 (dry season), June 2002 and December 2002.

Plant species found on the different plots were identified, and their growth forms and distribution patterns noted. For each species, the number of individuals encountered in the plots was recorded. Information on modes of dispersal was obtained from collections from the Limbe Botanic Garden and other available literature. Voucher specimens were prepared, identified and deposited at the Limbe Botanic Garden herbarium (SCA).

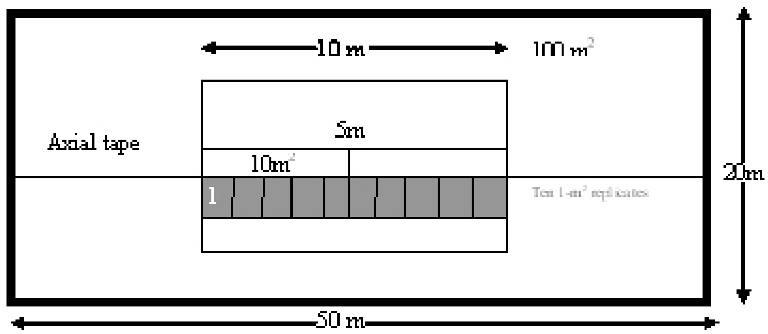

Fig. 2: Plot Layout by Whittacker's method

Soil Survey

Topsoil samples at 0-5 cm depth were collected from each of the plots in triplicates and bulked. Using standard procedures the following soil characteristics were determined.

Soil texture, Soil reaction (pH in H2O and in KCL), Organic Matter and Organic Carbon using the Walkley and Black method (Cottenie *et al*., 1982), Total Phosphorous, (using Bray's II method), Total Nitrogen was determined using a modified Kjedahl method, Exchangeable cations (Ca, Mg, K, and Na) were extracted and read using the Atomic Absorption. Spectrophotometer (AAS), CEC was determined using 1M Ammonium Acetate at pH 7 and 1 M KCl at pH 8.2, Amorphous Fe and Al using colorimeter (Blakemore *et al.*, 1981), Free Fe, Mn, Zn and Cu using AAS, Phosphorus retention (Blakemore *et al*., 1987).

Data Processing and Analysis

The Minitab (13.1) was used to analyse data collected.

Plant species were sorted out into different life forms. The species diversity was determined using Shannon-Weaver Diversity Index (*H*+):

$Hi = -\Sigma(pi)(\ln pi)$

Where *pi* = proportion of all individual in the samples belonging to species i (Magaurran, 1988).

Simpson's Diversity Index (1/D), was also used to compute the diversity of the species.

Where $D = \Sigma\ (pi)\ 2$

Jaccard's coefficient was used to calculate the similarity indices of species between plots in the lava.

Jaccard's coefficient

$(Cj) = J / (a = b - j)$

Where

J = Number of species common to both sites.

a = Number of species in site A

b = Number of species in site B (Fowler *et al.*, 1998; Krebs, 1999)

Species composition, basal areas and densities were also calculated.

The soil data were analysed using principal component analysis.

Results

Species Abundance

A total of 102 species belonging to 40 families were collected (Table 1 and Appendix 1). Seventy-four (74) of them were flowering plant species (belonging to 29 families), with 21 tree species belonging to 13 families, 13 shrubs belonging to 7 families, and 33 herbaceous species including 13 orchids belonging to 11 families, 7 climbers (belonging to 5 families), 17 fern species (belonging to 8 families), 5 mosses, 4 lichens, and 2 unidentified fungi species were also collected.

Table 1: Species abundance on the 1922 lava flow classified by family and life forms

Different Lifeform	No of Families	No of Species
Flowering plants	29	74
Climbers	5	7
Herbs	10	20
Orchids	1	13
Shrubs	7	13
Trees	13	21
Ferns	8	17
Fungi	1	2
Lichens	1	4
Mosses	1	5
Total	47	102

[[Figure 3]] shows, that the Orchidaceae was the most represnted family, with 13 species, while the Rubiaceae was the most represented tree family with 8 tree species. The Asteraceae, Poaceae, and Musci had 5 species each. Six other families had 3 species, 5 with 2 species and 18 with only a single species.

Table 2 shows 106 trees with dbh between 1-10 cm, belonging to 18 species and 10 families. The mean dbh was 3.65 cm and the mean total basal area (BA) was 1885.3 cm2.

Table 3 shows some quantitative characteristics of the vegetation found on the 1922 lava flow. The basal areas (BA), ranged from less than 1 cm2 in *Mangifera indica* to over 500 cm2 in *Alchornea cordifolia.* Relative densities (relden) value were generally less than 10%) except for *Syzygium guineense* that had the highest relative density (16.81 %), a relative abundance of 40.83 %, CVI. of 57.63 % and IVI of 68.74%. *Mangifera indica* had the lowest, relative density (0.84 0%), relative abundance (0.42 %) and CVI (0.88 %).

Species Similarity

Species similarities between the different plots in the lava are shown in **[[Figure 4]]** and Appendix II. The distance correlation coefficient (ward linkage) showed that the lava has two main types of plant communities based on their similarity indices. The first type includes plots 1, 2, 3, 5, 6, 4 and 7. The main species peculiar to this community include *Croton gratissimus, Melanthera scandens, Ageratum conyzoides, Elaeis guineensis, Psorospermum standis, Harungana madagascariensis, Solenostemon monostachyus and Dissotis rotundifolia.* The main plant species belonging to the second type include *Centrosema virginianum* and *Trichomanes africanum*.

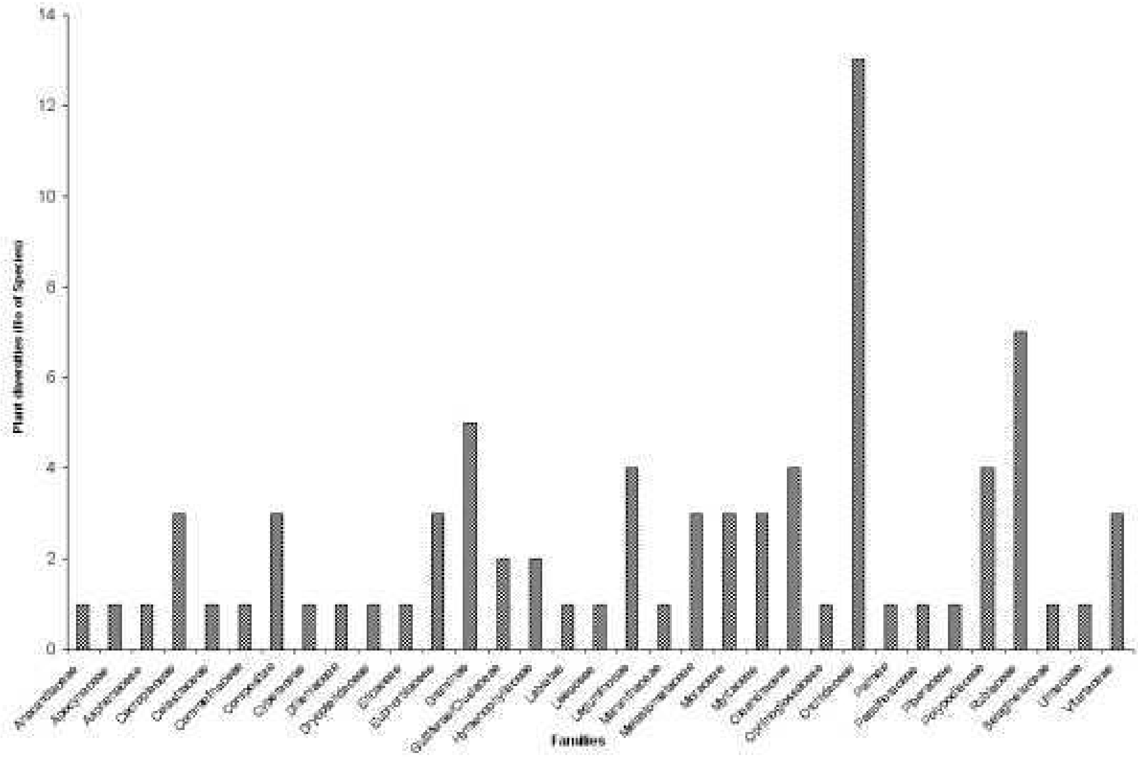

Fig. 3 Frequency of Plant Species found of different Families and Groups on the 1922 lava flow

No	Species	Family	Codes	Lifeform	No of Plants (nb)	DBH (cm)
1	*Albizia zygia*	Leguminosae/Mimosaceae	Alzy	Tree	3	3
2	*Alchornea cordifolia*	Euphorbiaceae	Alco	Tree	19	6
3	*Alstonia boonei*	Apocynaceae	Albo	Tree	1	2.2
4	*Bridelia micrantha*	Euphorbiaceae	Brmi	Tree	3	3
5	*Cecropia cecropioides*	Cecropiaceae	Cece	Tree	7	5
6	*Ficus lutea*	Moraceae	Filu	Tree	7	5
7	*Ficus sur*	Moraceae	Fisu	Tree	5	3.5
8	*Harungana madagascariensis*	Guttiferae/Clusiaceae	Hama	Tree	6	3.5
9	*Mangifera indica*	Anacardiaceae	Main	Tree	1	1
10	*Musanga cecropioides*	Cecropiaceae	Muce	Tree	4	3.8
11	*Psidium guajava*	Myrtaceae	Psqu	Tree	2	2.3
12	*Syzygium guineense*	Myrtaceae	Sygu	Tree	20	7
13	*Syzygium* sp.	Myrtaceae	Sysp	Tree	2	3.8
14	*Trema orientalis*	Ulmaceae	Tror	Tree	2	1

Mean dbh = 3.65 cm

Table 2: Families with tree species with DBH 1-10cm in the 2001-02 surveys on the 1922 lava flow.

Species	Family	**Code**	**Life forms**	**BA (cm2)**	**Relden (%)**	**RelDom (%)**	**CVI (%)**	**Freq**	**RelFreq**	**IVI (%)**
Macaranga occindentalis	Euphorbiaceae	Maoc	Tree	3.14	0.84	0.17	1.01	1	0.79	1.80
Alstonia boonei	Apocynaceae	Albo	Tree	3.80	0.84	0.20	1.04	1	0.79	1.84
Mangifera indica	Anacardiaceae	Main	Tree	0.79	0.84	0.04	0.88	2	1.59	2.47
Trema orientalis	Ulmaceae	Tror	Tree	1.57	1.68	0.08	1.76	2	1.59	3.35
Hymenodictyon biafranum	Rubiaceae	Hybi	shrub	3.54	1.68	0.19	1.87	3	2.38	4.25
Psidium guajava	Myrtaceae	Psqu	Tree	8.31	1.68	0.44	2.12	4	3.18	5.30
Tetracera alnifolia	Dilleniaceae	Teal	Tree	2.356	2.52	0.13	2.65	4	3.18	5.82
Albizia zygia	Leguminosae/Mimosaceae	Alzy	Tree	21.21	2.52	1.13	3.65	3	2.38	6.03
Bridelia micrantha	Euphorbiaceae	Brmi	Tree	21.21	2.52	1.13	3.65	3	2.38	6.03
Syzygium sp.	Myrtaceae	Sysp	Tree	22.68	1.68	1.20	2.88	7	5.56	8.44
Psorospermum staudtii	Guttiferae/Clusiaceae	Psst	shrub	12.57	3.36	0.67	4.03	6	4.76	8.79
Musanga cecropioides	Cecropiaceae	Muce	Tree	45.37	3.36	2.41	5.77	7	5.56	11.32
Ficus sur	Moraceae	Fisu	Tree	48.11	4.20	2.55	6.75	10	7.94	14.69
Mussaenda tenuiflora	Rubiaceae	Mute	Climber	7.85	8.40	0.42	8.82	10	7.94	16.76
Harungana madagascariensis	Guttiferae/Clusiaceae	Hama	Tree	57.73	5.04	3.06	8.10	11	8.73	16.83
Cecropia cecropioides	Cecropiaceae	Cece	Tree	137.44	5.88	7.29	13.17	5	3.97	17.14
Tarenna conferta	Rubiaceae	Taco	Shrub	43.26	14.28	2.29	16.58	7	5.56	22.14
Ficus lutea	Moraceae	Filu	Tree	137.44	5.88	7.29	13.17	12	9.52	22.70
Alchornea cordifolia	Euphorbiaceae	Alco	Tree	537.21	15.97	28.49	44.46	14	11.11	55.57
Syzygium guineense	Myrtaceae	Sygu	Tree	769.69	16.81	40.83	57.63	14	11.11	68.74
TOTALS				**1885.3**	**100**	**100**	**200.00**	**126**	**100.00**	

Table 3: The basal area, relative densities, relative abundances, cover value indices, frequencies, relative frequencies and the important value indices of species on the 1922 lava flow.

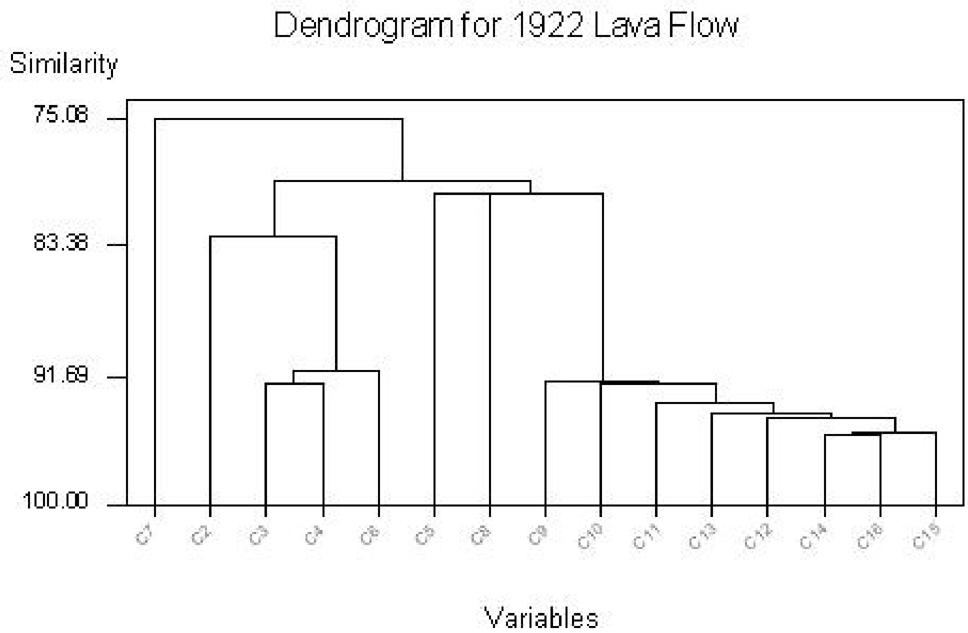

Fig. 4: Dendrogram showing similarity between different plots on the 1922 lava flow

Soil Analysis

The soil profile of the lava flows is given in Table 4 below.

Table 4: The soil profile of the 1922 lava flow on Mt Cameroon.

Parameter	**Centre**	**Right edge**	**Left edge**
Colour	Very dark grey (5Y311)	Dark reddish brown (5Y313)	Dark reddish brown (5Y3/4)
Top Soil	More organic matter about (1 cm thick)	Sandy loamy soil (3cm thick)	Loamy soil, silt moisture with clay about 3.5cm thick
Horizon B.	Hard parent rock	Gravel thin layer	Gravel thin layer.

The chemical and physical properties of soils collected from the edges and the centre of the lava flow are given in Table 5.

Texture

Table 5 shows that the sand content was highest on the right wing, with 56.5 % sand, while the centre and the left edges had 16.8 % and 19.3 % respectively. There is no front since this lava flowed into the sea. Silt is highest in the left wing (69 %), while it is lowest in the right wing (39 %). The clay content is highest in the centre (15 %) and lowest in the right wing (5 %).

	Particle Size Analysis %			PH		Organic Matter				
	Sand	**Silt**	**Clay**	**H2O**	**KCl**	**%C**	**%N**	**C/N**	**%P Retention**	**Total %P**
Centre	16.8	68	15	4.62	4.31	1.10	3.53	31.4	51.02	19.30
Right Wing	56.5	39	5	5.31	4.66	4.44	1.65	27.0	50.64	21.88
Left Wing	19.3	69	12	5.05	4.55	3.70	2.40	15.4	48.20	27.13
	Exchangeable	**Cations**		**Meq/100g**			**Micronutrients**	**%**		
	Ca	**Mg**	**K**	**Na**	**CEC Meq/100g**	**Base Structure %**	**Total Fe**	**Liberated Fe**	**Amorphous Fe**	**Amorphous Al**
Centre	2.72	0.56	1.44	0.08	4.81	9	1.69	7.63	3.02	5.34
Right Wing	2.89	1.16	0.28	0.01	3.34	13	0.92	4.82	10.81	5.66
Left Wing	2.42	0.44	0.28	0.03	3.19	11	0.00	8.9	3.85	5.66

Table 5: Chemical analysis of soil from the 1922 lava flow on Mt Cameroon

Organic Carbon (Org C)

A comparison of the sampled sites shows that the centre on the 1922 lava had the highest Org C, while the left wing had the lowest (3.7 %).

Organic Matter (OM)

In 1922 lava flow, the centre had the highest OM (19.1%) while the left wing had the lowest OM (3.7 %).

Total Nitrogen (Tot N)

The total N is highest in the 1922 lava flow (3.53 %). Comparing the different sites at the 1922 lava, the centre had the highest Tot N (3.53 %) while the right wing had the lowest (1.65 %).

Exchangeable Cations

On the 1922 lava, Ca content is highest on the right edge (2.89 Meq/100g) and lowest in the left edge (2.42 Meq/100g). In the case of Mg, it is highest at the centre (0.46 Meq/100g) and lowest on the right edge (0.16 Meq/100g). The centre was richest in K and Na (1.44 Meq/100g and 0.08 Meq/100g)

Phosphorus Retention (P-Ret)

The amount of phosphorus retained in the soil on the 1922 lava is low (51.02 %). At the individual sites, the 1922 lava's left edge had the lowest (48.2 %) and the lava's centre, the highest (51.02 %).

Iron (Fe)

No soluble Fe was registered on the left edge of the lava but there was 7.63% liberated Fe and 10.81% amorphous Fe in it.

Principal Component Analysis (PCA) of Soil

Eigen-analysis**(Table 6a.)** shows that the first two components PC1 and PC2 explain 100% of the total variation. **Table 6b** indicates that PC1 is most strongly affected by the Na, K, CEC, base saturation, Org. C, and OM, Total Nitrogen, soluble Fe, and soil clay content. PC2 is strongly associated with Ca, C/N, P and sand-silt content.

Comparing Soil and Vegetation

The Principal Correlation Analysis of soil in relation to vegetation and sites shows that the main soil contents that affect vegetation are soil texture, Org C and OM, on the lava. In relation to vegetation composition and diversity, the soil sand content, Org C and OM, strongly affect vegetation development, while soil texture, pH (H2O, KCl and NaF), CEC, Base saturation, Total N and P, P-Retention, Fe, Soluble Fe, Liberated Fe, Amorphous Fe and Al are associated and closely related to vegetation development.

Discussion

The 1922 lava flow is located on the west coast of Mt. Cameroon. In this area the rainfall pattern is mono-modal and high, especially in Idenau and Debundscha. Fraser *et al*., (1998) reported that Debundscha is the second wettest region of the world with a mean annual rainfall of 9,086 mm (from 1965 - 1993) after Charrapanjee in India.

Debundscha is only about 1 Km from the sea and the 1922 lava flow where the flux of the wet monsoon winds influence precipitation. With this high precipitation the soils do not completely get dry, even when it does not rain for some days (Cable and Check, 1998).

According to Juvik and Merlin (2001) the type of lava also affects colonization patterns. The pahoe-hoe favours more plant diversity than the aa lava. This is because the cracks and fissures in pahoe-hoe, favour accumulation of rainfall and trap inorganic and organic particles from the surrounding impervious lava surface while the aa lava boulder fields are ubiquitous. This results in a lack of plant growth. The pahoe-hoe cracks also have thermal properties more conducive for plant growth. This maybe due to the persistent cloud cover and mist coupled with high rainfall, temperature and distance from the seacoast (Payton, 1993).

Throughout the year, the temperature is between 22°C - 30°C in Debundscha at an altitude of about 20 m asl. In Idenau at 40 m asl it ranges between 20°C - 30°C (Fraser *et al*., 1998; Tchouto, 1996). This may be because there is a gentle breeze blowing from the sea and that the air movements are very slow, thus modifying the temperature. Cable and Cheek (1998) reported that there are no hurricanes in this region.

Table 6a: Eigen-analysis of the Correlation Matrix 1922 Lava

	PC1	**PC2**	**PC3**
Eigenvalue	15.119	6.881	0.000
Proportion	0.687	0.313	0.000
Cumulative	0.687	1.000	1.000

Table 6b :

Variable	PC1	PC2	PC3
C2	-0.185	-0.264	0.135
C3	0.169	0.287	0.023
C4	0.222	0.191	-0.099
C5	-0.254	-0.060	0.179
C6	-0.256	-0.033	0.333
C7	-0.257	-0.000	0.115
C8	0.244	-0.118	-0.144
C9	0.244	-0.119	0.263
C10	0.253	0.070	-0.130
C11	0.138	-0.321	0.125
C12	-0.011	-0.381	0.006
C13	0.215	0.209	-0.004
C14	0.251	-0.085	0.266
C15	0.257	0.022	0.097
C16	0.245	-0.116	-0.126
C17	0.245	-0.116	-0.126
C18	-0.152	0.307	0.055
C19	0.106	-0.348	0.001
C20	0.179	-0.273	0.139
C21	-0.180	-0.272	0.129
C22	-0.178	-0.275	-0.719
C23	-0.251	0.085	-0.160

Where		
C2 = sand	C9 = Org. Matter (%)	C16 = S/CECE (%)
C3 = Total silt	C10 = Tot. N (g/kg)	C17 = CEC 7
C4 = Clay	C11 = C/N	C18 = Brays P2 (ppm)
C5 = pH H2O	C12 = Ca	C19 = P-ret (%)
C6 = pH KCl	C13 = Mg	C20 = Soluble Fe (g/kg)
C7 = pH NaF	C14 = K	C21 = Liberated Fe
C8 = Org. C (%)	C15 = Na	C22 = Amorphous Fe
		C23 = Amorphous Al

The mean annual relative humidity, on this Southwestern flank ranges between 75 % and 80 %. Generally, the climate is of the equatorial regime covering the entire land of the Atlantic oceanic plain. Rosevear conducted the first recolonization study on lava flows on Mt Cameroon in 1936 and 1937 on the 1922 eruption, fourteen years after it occurred (cited by Keay, 1959). Eighty years after the eruption, it is observed that the vegetation has moved from the mosses, lichens and ferns as observed by Rosevear, to a dominant shrubby forest with 74 flowering plant species belonging to 29 families, the family Orchidaceae being the most dominant. This is in contrast with the findings of Ndam *et al*. (2002), who stated after a survey, conducted in 1995, that in the third stage of succession, 90% of orchids disappear. The vegetation presently comprises of a semi- dense, forest 4-5 m tall with emergent that are 10-25 m tall. The co-dominant trees (about 40% of all those greater than 6 cm dbh recorded, and generally the tallest of all trees present) are *Syzygium guineense* var. *littorale* and *Alchornea cordifolia*. Fraser *et al.*, (1999) and Ndam, (2000) reported the presence of *Syzygium guineense*, during their 1995 survey. *Lannea* was not observed during this survey. This may be as a result of logging for fuel wood, which has already started on the lava flow (fig 5). The main trees and large shrubs, in descending order of importance (% of all trees between 1-10cm dbh) are *Syzygium guineense* (16.81%), *Alchornea cordifolia* (15.97%) and *Tarenna conferta* (14.29%). Seedlings of *Tarenna conferta*, in shrub surveys conducted done by Fraser *et al.*, 1999 and Ndam *et al.*, 2002, were shown to dominate those of smaller woody plants.
Some of the species found in the centre of the lava flow were not present on the edges. Plant diversity was higher in the centre than the edges. This may be as a result of the lava flow being surrounded by palm plantations (*Elaies guineensis*) and also because of the age of the lava (Déreulle *et al.*, 1987).
Shannon-Weaver and Simpson's Diversity Indices show that plant diversity is high as should be expected. They are 3.58 and 22.86 respectively, higher than those determined by Ndam *et al.* (2002) on the same lava in 1995 (3.1057 and 16.4201 respectively). This shows that plant diversity has increased. The Basal Area of 0.785m2/h was far less than that observed by Ndam (1998). This may be as a result of the logging for fuel wood that is going on in the area.
Species richness was highest on the edges probably because at this stage of succession, new species colonize from the edges. Thebaud and Stersberg (1997), while studying species colonization of 15, 48, 91 year old lava flows at Grand Bruté, la Reunion, observed that dispersal on the15 year old lava flow was stochastic but found that large sized plants on the old lava flows (e.g. 91 years) tended to grow from the edge at a very slow rate (less than 1 m per year). They also observed that most colonizing species are wind-dispersed. A similar observation was reported by Ndam *et al.,* (2002) on the 1922 lava flow and by Robyns(1932) in Kiva and Krakatua. This could also be due to the thickness of the lava at the centre compared to the edges (Fitton *et al*. 1983).
The Dendogram produced from the similarity indices shows that plants of the same species and life forms were found both on the edges and in the centre. Although the lava is chemically uniform, its structure can be variable resulting in differences in the colonization process (Bachelery, 1981). Another possible reason given earlier by Robyns (1932) for these differences could be that erosion from adjacent land, deposits soil on the edges of lava flows, favouring the development of species

that are not adapted to grow on the dry rock environment. This is in contrast with our findings. Species diversity is higher in the centre of the 1922 lava flow as a result of differences in the soil parameters. The amounts of organic matter and organic carbon from analyses were highest in the centre (19.10 and 11.10 % respectively). On the edges they were 4.07 and 7.1 % respectively. The main reason for the contrast of our findings with earlier reports may be that the lava is moving towards a more mature structure. The climatic conditions of the area could also be wielding an influence. According to Fraser *et al*. (1998), the area has the highest amount of rainfall in the country. This, coupled with the high temperature and humidity, leads to rapid decomposition of organic matter resulting in fast soil formation. The topography (gentle sloping and flat) and lava type (pahoe-pahoe) also influence disintegration of the surface rock and soil formation.

It could be said that the successional pathway on lava flow starts with lichens and mosses, followed by a second stage characterised by the presence of all other life forms, with woody species and climbers being the least abundant or even absent.

Lava Profile

The profile of the lava flow is divided into 2 horizons. The topsoil is 10 cm dbh did not conform to this observation. Comparing the observed data on species composition, basal area and plant density on the lava with those of other researchers showed some differences, which may be attributed to the logging for fuelwood -already taking place there. This means that colonization may be very difficult to assess.

The edaphic factors; climate (temperature between 19°C - 34°C), rainfall (between 227 - 9086 mm) and soil, play a very vital role on the plant colonization process. Also, the type and number of plant species tend to improve the nutrient level of the soil although the plants are selective to the type and amount of nutrients utilized. The soil pH is slightly acidic and tends to break down parent rock materials. Growing roots of trees also tend to break down the parent materials releasing nutrients. From our results it was found that soil texture, total Phosphorus, total Nitrogen, Organic matter, cation exchange capacity (CEC), exchangeable cations soil pH and Phosphorus retention strongly affect the plant colonization process on the lava flows of Mt Cameroon.

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APPENDIX I

List of species on the 1922 lava flow classified by family and life forms

	Family	*Plant*	Sp	Code	Life	Mechanism
		Names	**No**	**Code**	**Form**	**of dispersal**
1	**Convolvulaceae**	*Ipomoea batatas* (L.) Lam.		Ipba	Climber	Animal
2	**Convolvulaceae**	*Ipomoea involucrata* P. Beauv.		Ipin	Climber	Animal
3	**Convolvulaceae**	*Ipomoea* sp.	**3**	Ipsp	Climber	Animal
4	**Dilleniaceae**	*Tetracera alnifolia* Willd.	**1**	Teae	Climber	Animal
5	**Leeaceae**	*Leea guineensis* G. Don	**1**	Lequ	Climber	Animal
6	**Passifloraceae**	*Adenia lobata* (Jacq.) Engl.	**1**	Adlo	Climber	Wind
7	**Rubiaceae**	*Mussaenda tenuiflora* Benth.	**8**	Mute	Climber	Wind
8	**Aspleniaceae**	*Asplenium barteri* Hook.	**1**	Asba	Fern	Wind

9	**Dryopteridaceae**	*Ctenitis dimidiata* (Mett. Ex Kuhn)Tardieu	**1**	Ctdi	Fern	Wind
10	**Hymenophyllaceae**	*Trichomanes africanum* Christ.		Traf	Fern	Wind
11	**Hymenophyllaceae**	*Trichomanes borbonicum* Bosch	**2**	Trbu	Fern	Wind
12	**Oleandraceae**	*Arthropteris cameroonensis* Alston		Arca	Fern	Wind
13	**Oleandraceae**	*Nephrolepis biserrata* (Sw.) Schott		Nebi	Fern	Wind
14	**Oleandraceae**	*Nephrolepis cordiflora*	**4**	Neco	Fern	Wind
15	**Oleandraceae**	*Nephrolepis pumicicola* Ballard		Nepu	Fern	Wind
16	**Ophioglossaceae**	*Ophioglossum reticulatum* L.		Opre	Fern	Wind
17	**Polypodiaceae**	*Anapeltis lycopodioides* (L.) J.Sm.	**4**	Anly	Fern	Wind
18	**Polypodiaceae**	*Microgramma owariensis* (Desv.) Alston		Miow	Fern	Wind
19	**Polypodiaceae**	*Microsorum punctatum* (L.) Copel.		Mipu	Fern	Wind
20	**Polypodiaceae**	*Microsorum scolopendria* (Burm.f.)Copel		Misc	Fern	Wind
21	**Selaginellaceae**	*Selaginella* sp.	**1**	Sesp	Fern	Wind
22	**Vittariaceae**	*Antrophyum mannianum* Hook.		Anma	Fern	Wind
23	**Vittariaceae**	*Loxogramme abyssinica* (Baker)M.G.Price	**3**	Loab	Fern	Wind
24	**Vittariaceae**	*Loxogramme lanceolata*(Sw.)C.Presl		Lola	Fern	Wind
25	**Fungi**	*Unidentified*		0	Fungi	Wind
26	**Fungi**	*Unidentified*	**2**	0	Fungi	Wind
27	**Commelinaceae**	*Commelina diffusa* Burm.f.	**1**	Codi	Herb	Animal

28	**Compositae**	*Chromolaena odorata* (L.)R.M. King &H.Robinson		Chod	Herb	Wind
29	**Compositae**	*Crassocephalum crepidioides* (Benth.) S.Moore		Crcr	Herb	Wind
30	**Compositae**	*Emilia coccinea* (Sims.)G. Don		Emco	Herb	Wind
31	**Compositae**	*Melanthera scandens* (Schumach.& Thonn.)Roberty	**5**	Mesc	Herb	Wind
32	**Compositae/Asteraceae**	*Ageratum conyzoides* L.		Agco	Herb	Wind
33	**Cyperaceae**	*Mariscus alternifolius* Sensu Hooper	**1**	Maal	Herb	Animal
34	**Euphorbiaceae**	*Phyllanthus amarus* Schumach. & Thonn.	**5**	Pham	Herb	Animal
35	**Fabaceae**	*Pueraria phaseolioides* (Roxb) Benth.	**3**	Puph	Herb	Animal
36	**Fabaceae**	*Centrosema virginiana* (L.) Benth.	**2**	Cevi	Herb	Animal
37	**Gramineae**	*Hyparrhenia rufa* (Nees) Stapf.	**5**	Hyru	Herb	Wind
38	**Gramineae**	*Panicum maximum* Jacq.		Pama	Herb	Wind
39	**Gramineae**	*Paspalum conjugatum* Berg		Paco	Herb	Wind
40	**Gramineae**	*Pennisetum hordeoides* (Lam.) Steud.		Peho	Herb	Wind
41	**Gramineae/Poaceae**	*Axonopus compressus* (Sw.) P. Beauv.		Axca	Herb	Wind
42	**Labiatae/Lamiaceae**	*Solenostemon monostachyus* (P.Beauv.) Briq.		Somo	Herb	Wind
43	**Marantaceae**	*Megaphrynium macrostachyum* (Benth.) *Milne-Redh.*	**1**	Mema	Herb	Animal
44	**Melastomataceae**	*Dissotis rotundifolia*(Sm.)*Triana*		Diro	Herb	Animal
45	**Piperaceae**	*Piper umbellatum* L.	**1**	Pium	Herb	Animal

46	**Rubiaceae**	*Diodia sarmentosa* Sw.		Disa	Herb	Animal
47	**Lichens**	*Coccocarpia* sp.		Cosp	Lichens	Wind
48	**Lichens**	*Dictyonema* sp.		Disp	Lichens	Wind
49	**Lichens**	*Leptogium* sp.		Lesp	Lichens	Wind
50	**Lichens**	*Parmelia laevigata*	**4**	Pala	Lichens	Wind
51	**Musci**	*Campylopus dusenii* C.M		Cadu	Moss	Wind
52	**Musci**	*Campylopus horridus* Welw.&Duby		Caho	Moss	Wind
53	**Musci**	*Ectropothecium afro-molluscum (*C.M) Broth.Keay		Ecmu	Moss	Wind
54	**Musci**	*Ectropothecium regulare* (Brid.)Jaeg		Ecre	Moss	Wind
55	**Musci**	*Sematophyllum calspitosum (*Sw) Mitt Sensu lato H.n.Dixon	**5**	Seca	Moss	Wind
56	**Orchidaceae**	*Ancistrochilus rothschildianus* O'Brien		Anro	Orchid	Wind
57	**Orchidaceae**	*Ancistrorhynchus cephelotes*		Ance	Orchid	Wind
58	**Orchidaceae**	*Angraecum birrimense* Rolfe		Anbi	Orchid	Wind
59	**Orchidaceae**	*Bulbophyllum bifarium* Hook.f.		Bubi	Orchid	Wind
60	**Orchidaceae**	*Bulbophyllum calvum* Summerh		Buca	Orchid	Wind
61	**Orchidaceae**	*Bulbophyllum calyptratum* Kraenzl.		Buca	Orchid	Wind
62	**Orchidaceae**	*Bulbophyllum intertextum* Lindl.		Buin	Orchid	Wind
63	**Orchidaceae**	*Bulbophyllum josephii* (Kuntze) Summerh. *var. josephii*		Bujo	Orchid	Wind
64	**Orchidaceae**	*Bulbophyllum simonii* Summerh.		Busi	Orchid	Wind
65	**Orchidaceae**	*Hebenaria* sp.	**13**	Hesp	Orchid	Wind

66	**Orchidaceae**	*Polystachya affinis* Lindl.		Poaf	Orchid	Wind
67	**Orchidaceae**	*Polystachya tessellata* Lindl.		Pote	Orchid	Wind
68	**Orchidaceae**	*Polystachya laxiflora* Lindl.		Polu	Orchid	Wind
69	**Costaceae**	*Costus afer* Ker Gawl.	**1**	Coaf	Shrub	Animal
70	**Euphorbiaceae**	*Croton gratissimus* Burch.		crhi	Shrub	Animal
71	**Guttiferae/Clusiaceae**	*Psorospermum staudtii* Engl.		Psst	Shrub	Wind
72	**Malavaceae**	*Urena lobata* L.	**1**	Urlo	Shrub	Animal
73	**Melastomataceae**	*Dissotis erecta* (Guill. & Perr.)Dandy		Dier	Shrub	Animal
74	**Melastomataceae**	*Tristemma hirtum* P.Beauv.	**3**	Trhi	Shrub	Animal
75	**Mimosoidae**	*Mimosa pudica* L.		Mipu	Shrub	Animal
76	**Rubiaceae**	*Hymenodictyon biafranum* Hiern		Hybi	Shrub	Wind
77	**Rubiaceae**	*Oldenlandia lancifolia* (Schumach.) DC.		Olla	Shrub	Animal
78	**Rubiaceae**	*Pauridiantha venusta* N.Halle		Pave	Shrub	Animal
79	**Rubiaceae**	*Tarenna conferta* (Benth.)Hiern		Taco	Shrub	Animal
80	**Rubiaceae**	*Tarenna* sp.		Tasp	Shrub	Animal
81	**Rubiaceae**	*Tricalysia discolor* Brenan		Trdi	Shrub	Animal
82	**Anacardiaceae**	*Magifera indica* L.	**1**	Main	Tree	Animal
83	**Apocynaceae**	*Alstonia boonei* De Wild.	**1**	Albo	Tree	Animal
84	**Cecropiaceae**	*Cecropia cecropioides*		Cece	Tree	Animal
85	**Cecropiaceae**	*Cecropia peltata*		Cepe	Tree	Animal
86	**Cecropiaceae**	*Musanga cecropioides* R.Br. ex Tedlie	**3**	Muce	Tree	Animal
87	**Celastraceae**	*Maytenus* sp.	**1**	Masp	Tree	Animal
88	**Ericaceae**	*Agauria salicifolia* (Comm.ex Lam.)Hook.f.ex Oliv.	**1**	Agsa	Tree	Animal

89	**Euphorbiaceae**	*Alchornea cordifolia* (Schum. $ Thonn.)Mull.Arg.		Alco	Tree	Animal
90	**Euphorbiaceae**	*Bridelia micrantha* (Hochst.)Baill.		Brmi	Tree	Animal
91	**Euphorbiaceae**	*Macaranga occidentalis* (Mull.Arg.)Mull.Arg.		Maoc	Tree	Animal
92	**Fabaceae**	*Desmodium adscendens* (Sw.)DC. var.*adscendens*		Dead	Tree	Animal
93	**Guttiferae/Clusiaceae**	*Harungana madagascariensis* Lam. Ex Poir.	**2**	Hama	Tree	Bird
94	**Mimosaceae**	*Albizia zygia* (DC.)J.F.Macbr.		Alzy	Tree	Wind
95	**Moraceae**	*Ficus conraui* Warb.	**3**	Fico	Tree	Animal/Bird
96	**Moraceae**	*Ficus lutea* Vahl		Filu	Tree	Animal/Bird
97	**Moraceae**	*Ficus sur* Forssk.		Fisu	Tree	Animal/Bird
98	**Myrtaceae**	*Psidium guajava* L.	**3**	Psqu	Tree	Animal
99	**Myrtaceae**	*Syzygium guineense* (Wild.)DC		Sygu	Tree	Animal
100	**Myrtaceae**	*Syzygium* sp.		Sysp	Tree	Animal
101	**Palmae**	*Elaies guineensis* Jacq.	**1**	Elgu	Tree	Animal/Rodents
102	**Ulmaceae**	*Trema orientalis* (L.)Blume	**1**	Tror	Tree	Animal

Appendix: II Similarity Index (Jaccard's) on the different plots in the 1922 lava flow.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0	0.452	0.368	0.320	0.373	0.310	0.267	0.231	0.203	0.226	0.233	0.210	0.233	0.193	0.190
2.		0	0.467	0.544	0.361	0.281	0.403	0.387	0.361	0.367	0.356	0.328	0.379	0.321	0.316
3.			0	0.585	0.352	0.270	0.478	0.448	0.350	0.333	0.345	0.386	0.345	0.286	0.327
4.				0	0.319	0.250	0.567	0.463	0.382	0.442	0.431	0.423	0.404	0.340	0.360
5.					0	0.581	0.299	0.358	0.353	0.360	0.347	0.340	0.375	0.363	0.386
6.						0	0.224	0.333	0.325	0.300	0.316	0.342	0.389	0.419	0.452
7.							0	0.500	0.440	0.449	0.408	0.489	0.390	0.286	0.333
8.								0	0.583	0.600	0.742	0.719	0.543	0.500	0.581
9.									0	0.559	0.594	0.677	0.500	0.552	0.586
10.										0	0.667	0.700	0.613	0.517	0.552
11.											0	0.750	0.548	0.615	0.593
12.												0	0.531	0.593	0.630
13.													0	0.500	0.536
14.														0	0.850
15.															0

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Ethnomedicine of Dolpa district, Nepal: the plants, their vernacular names and uses

Etnomedicina del Cantón Dolpa, Nepal: las plantas, sus nombres vernaculares y usos.

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Ethnomedicine of Dolpa district, Nepal: the plants, their vernacular names and uses

Abstract

An account of 58 medicinal plant species used by local people of Dunai, Juphal, Suu, Sahartara and Majphal villages of Dolpa district is given. Greater numbers of species were found to be used in fever (17 spp.) and diarrhea & dysentery (17 spp.). Roots and rhizomes of 29 species; leaves of 27 species; and stem and barks of 17 species were mostly used. Juice, raw items, paste and decoction of plant species were the common method of usages. The ethnomedicinal contribution from Nardostachys grandiflora 'Vulte', and Neopicrorhiza scrophulariiflora 'Katuko', each for eight ailments was important. Local people have adequate knowledge on ethnomedicine, while ethnomedicinal plants are under threat due to habitat destruction and over exploitation, indicating an urgent need for conservation of species and their habitats and indigenous knowledge as well. Key words: Ethnomedicine, Dolpa, ailments, parts used, group discussion

Resumen

Se presenta 58 plantas medicinales usadas por la población local de los pueblos Dunai, Juphal, Suu, Sahartara y Majphal en el Canton Dolpa en Nepal. Varias especies se usan contra fiebre (17 spp.), diarrea y disentería (17 spp.). Raíces de 29 especies, hojas de 27 especies, tallos y corteza de 17 especies son usadas. En la mayoría de los casos se usa el "jugo" de plantas frescas maceradas y planchadas. La contribución etnomedicinal de Nardostachys grandiflora 'Vulte', y Neopicrorhiza scrophulariiflora 'Katuko', son ambos usados para ocho enfermedades. Las poblaciones locales tienen conocimiento propio de la etnomedicina, mientras las plantas medicinales están bajo de peligro de extinción por destrucción de habitats y sobre-explotación, indicando la necesidad urgente de conservación de las especies y sus habitats, junto con el conocimiento tradicional. Palabras claves: Etnomedicina, Dolpa, partes usadas, discusión en grupo, enfermedades

Introduction

The art of use, treatment and prevention of disease is pre historic (Gill & Ogbor 1997) noticeably in south Asia (Bawa & Godoy 1993). About 80% of the world's population depends wholly or partially on traditional medicine for its primary health care needs (Wambebe 1990). Nepal is an excellent repository of cultural heritage for diverse ethnic groups and it has a rich tradition of folk practices for utilization of wild plants (Manandhar 1993). Rural people have used plants particularly wild for fulfilling their subsistence needs (Bhattarai 1992) and treating disease since time immemorial. About 70-80% rural population depends on traditional medicine for health care (Manandhar 1980). Bhattarai (1988) and Justice (1981) reported that when modern health care fails, the patient frequently turns to use of indigenous health care. It is evident that indigenous system of health care is mostly the first choice as well as last resort of Nepal (Bhattarai 1998). Understanding the local people's indigenous knowledge in relation to biodiversity/resource management is one of the key issues for the development today (Kunwar & Duwadee 2003). However, due to changing perception of the forest dwellers, commercialization and socio-economic transformation all over the world, there has been a general observation that the indigenous knowledge on resource use has degraded severely (Gadgil et al. 1993; Silori & Rana 2000).

Recognizing these facts, of late, efforts have been made in Nepal to document such knowledge that has accumulated through a long series of observations, interactions and practices with and of local people and thus contains important information relevant to sustainable use of medicinal plant resources. Over the last three decades, intensive ethnomedicinal surveys have been carried out among the rural and tribal population in different parts of the world, however, such studies started in Nepal since 1990. Information on the ethnomedicinal plants of Dolpa is lacking and the work related to medicinal plants and ethnic groups, culture etc. has not been carried out so far. Hence, an attempt has been made to collect information on ethnomedicinal uses by the local people in Dolpa district, Nepal.

Materials and Methods

Study area

Dolpa, the largest but the least developed and remote district lies in mid-western region of Nepal. Most of the hills are naked, open and dry due to low rainfall (450-850 mm), dry air, and severe anthropogenic interference like firing, over-grazing, over exploitation, deforestation, slash and burn agriculture, etc. (Kunwar 2002). The district ranges from as low as sub tropical (1575m) to as high as nival zone (6883m) and extends between 27 21' 27 40' north longitude to 84 35' 84 41' east latitude. This physical intersection coupled with other abiotic factors such as geology, soil and climate has allowed supporting many endemic, threatened, ethnobotanically and economically useful medicinal plants and unique trans-himalayan ecosystems. Some noteworthy medicinal plants, which are more valued, include *Cordyceps sinensis* 'Jibanbuti', *Morchella conica* 'Mathyaura', *Nardostachys grandiflora* 'Vulte', *Valeriana jatanmansi* 'Samayo', *Taxus wallichiana* 'Kandelotto' etc. The major ethnic groups/castes in study area are 'Kshetri', 'Dangi', 'Rokaya', 'Shahi', 'Budha', 'Thakuri', 'Thakulla', 'Brahmin', 'Karki', 'Shrestha', 'Sherpa', etc. They are Indo-Aryan and Tibeti-Burmans, speaking Nepali, Tibetan and Kham (Tibetan dialect), being involved in cultivation of wild rice (Chino), wheat, buckwheat (Phapar), potato, etc. in less fertile land. Due to low productive soil, most of them rely upon wild medicinal plants for the subsistence. They are engaged particularly in collecting medicinal herbs and raw food items as part of their traditional ventures.

Methods

Ethnomedicinal notes of plants being used by local people were recorded in July 2001 and May 2003 at 'Dunai', 'Juphal', 'Suu', 'Sahartara' and 'Majphal' villages of Dolpa district. Group discussions, field observations, informal interviews, institutional survey, etc. were used as tools under participatory rural appraisal. Checklist was also made and asked to gather the information. Altogether, 15 group discussions (GDs), three in each village, were carried out. Participants for checklist survey, group discussion and crosschecking were local people: layman, collectors, farmers, traders, leaders, elderly people, traditional healers, witch doctors and Amchis. The information was further verified by crosschecking and validated by the common response from all villages on same species treatment. The plants were identified comparing with authentic specimens at Tribhuvan University Central Herbarium (TUCH) and housed in TUCH.

Results and Discussion

Fifty-eight plant species belonging to 42 families and 56 genera are listed in alphabetical order by their scientific names along with their family name; followed by vernacular names; location from where specimens recorded and collected; and uses. Of 42 families, Rosaceae was important in terms of ethnomedicinal contribution.

Of total 45 types of ailments recorded, diarrhea & dysentery and fever were indigenously treated with use of the most number of plant species (17). Contribution from 16 species was for curing cough & cold. It was followed by cuts & wounds and bleedings treated from 14 species. In terms of parts used, roots and rhizomes were used most (29 species). Leaves of 27 species; stems and barks of 17 species; flowers, fruits and inflorescence of 15 species; seeds of five species; and wood, resin and whole plant of five species were reported to be used. Juice, raw items, paste and decoction of 21, 20, 19, 18 medicinal plant species respectively were used to treat ailments indigenously.

Species wise contribution to ethnomedicine in Dolpa district was highest for *Neopicrorhiza scrophulariiflora* 'Katuko' and *Nardostachys grandiflora* 'Vulte' each for eight ailments, followed by *Plantago major* 'Sajaino', and *Valeriana jatanmansi* 'Samayo' each for seven ailments. However, N. grandiflora is most vulnerable (Ghimire et al. 2005b). The uses of Cedrus deodara oil in skin diseases and respiratory troubles, raw rhizome of Dactylorhiza hatagirea as tonic, ripen fruits of Ephedra gerardiana to control blood pressure and Hippophae salicifolia as appetizer were important. Dolpa district is rich in medicinal herbs and indigenous knowledge. However, the knowledge is constricting within the few healers and medicinal plants are less available. Human impact has been considered an important factor in Dolpa in structuring the resources available nearby (Kunwar and Sharma 2004). The plants are under threat due to habitat destruction and over exploitation. Premature harvesting and over harvesting of tradable medicinal herbs was eminent posing serious threats (Ghimire et al. 2005a). High demand of Nardostachys oil in world market has also led un-sustainable harvesting. An urgent need, therefore, for conservation of species as well as their habitats and indigenous knowledge, is required (Agrawal 2002; Ghimire et al. 2005b). Medicinal tree species Taxus wallichiana and Cedrus deodara are in great peril due to overexploitation as thatching material and furniture respectively.

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Aconitum spicatum (Bruhl) Stapf., Kunwar 0655 TUCH (**Ranunculaceae**) *Bish,* **Juphal***.* Root juice is used in cuts & wounds, cough & cold and liver problems. Leaf paste is applied in fever and headache.

Acorus calamus L., (**Araceae**) *Bojho*, **Juphal**. Small dried rhizome is used to treat cough & cold, toothache, headache and throat pain. It is also used as pesticide. The extract is taken to cure measles.

Aesculus indica (Colebr. ex Cambess) Hook., (**Hippocastanaceae**) *Naru, Ghodepangro,* **Suu**. Seed oil is used for rheumatism and skin diseases.

Amaranthus spinosus L., Kunwar 0454 TUCH (**Amaranthaceae**) *Kathgainya, Lunde,* **Dunai**. Decoction of leaf and root is taken for digestive disorders. Root paste is applied on boils & scalds to remove scars & pus. Root juice is given to get relief from acute fever.

Arisaema flavum (Forsk.) Schott., Kunwar 0423 TUCH (**Araceae**) *Bhalebanko,* **Suu**. Root is boiled and taken to treat stomach pain. Root extract is also used as anthelmintic and insecticide.

Artemisia dubia Wall. ex Besser, (**Compositae**) *Titepati,* **Juphal**. Fresh leaf juice is used to cure cuts & wounds. Flower and leaf juice is also applied as antileech and antiseptic. Leaf extracts are used as pesticide.

Asparagus filicinus Buch.-Ham. ex D. Don, (**Liliaceae**) *Kurilo, Satawari,* **Dunai**. Root powder is given as tonic. Paste of root is also used in fever, cough & cold. Fruits are taken to treat pimples.

Berberis aristata DC., (**Berberidaceae**) *Chutro,* **Majphal**. Fruit and leaf juice is applied for diarrhea & dysentery. Bark and root decoction is used for jaundice and fever.

Berberis mucrofolia Ahrendt, (**Berberidaceae**) *Chutro,* **Majphal**. Bark decoction is used in lymph disorder and swelling.

Bergenia ciliata (Haw.) Sternb., (**Saxifragaceae**) *Silpari, Pakhanbed, Dhungephul,* **Juphal**. Root decoction is taken in diarrhea & dysentery, fever and respiratory problems. It is also used as antiemetic and anthelmintic properties.

Betula utilis D.Don, Adhikari 0788 TUCH (**Betulaceae**), *Bhojpatra*, **Juphal**. Leaf decoction is taken as diuretics. Bark paper is used to release fear and cure fever. A portion of papery bark is kept in indoor spaces to get harmony in families.

Cedrus deodara (Roxb. ex D.Don) Hook. f., (**Pinaceae**) *Dewdar,* **Juphal**. Wood oil is used in skin diseases and respiratory troubles. It is also applied as antileech. The dried bark decoction is used in fever, diarrhea & dysentery. Leaf extract is messaged to get relief body pain.

Celosia argentea L., Kunwar 0454 TUCH (**Amaranthaceae**) *Sahastrajadi,* **Juphal**. Leaf juice is used in diarrhea & dysentery. Root juice and paste is applied in piles and menstrual disorders. Seed is used to cure eye problems.

Centella asiatica (L.) Urb., (**Umbelliferae**) *Ghodtapre,* **Juphal**. Fresh leaf is used to stimulate nervous system. Plant extract is taken in pneumonia, skin diseases, toothache and indigestion. Leaf paste is used to treat dysentery.

Chenopodium murale L., (**Chenopodiaceae**) *Bhatebethu*, **Dunai**. Fresh leaf is used to treat diarrhea & dysentery. Seed is abortive in function and applied to control blood pressure.

Cinnamomum tamala (Buch.-Ham.) Nees & Eb., (**Lauraceae**) *Dalchini, Sinkauili,* **Sahartara**. Bark powder is applied in astringent and controlling nausea. Bark extract is used in treatment of intestinal disorder. Leaf is used as spice, which is considered to control diarrhea.

Cordyceps sinensis (Berk.) Sacc., (**Hypocreaceae**) *Yarsagumba, Jibanbuti,* **Majphal**. Dried shoot portion is used as tonic, expectorant and sex stimulant. It is also applied in diarrhea and rheumatism.

Dactylorhiza hatagirea (D.Don) Soo, (**Orchidaceae**) *Hathajadi, Panchaunle,* **Juphal**. Paste of the rhizome is applied on fever, cuts & wounds. Decoction of rhizome is given in intestinal pain. Powder of rhizome is sprayed on wounds to control bleedings. Rhizome is eaten raw as tonic.

Delphinium himalayai Munz., Kunwar 0468 TUCH (**Ranunculaceae**) *Atis,* **Majphal**. Decoction of root is used in cough, fever and stomach pain. Root juice is also used in snake bite. Root paste is considered as antiseptic properties.

Ephedra gerardiana Wall., (**Ephedraceae**) *Sallejari,* **Sahartara**. Leaf and stem powder is taken to control asthma. Ripe fruit is eaten to maintain blood pressure, altitude sickness, hydrocoel and indigestion.

Fragaria nubicola Lindl. ex Lacaita, (**Rosaceae**) *Bhuiainselu,* **Juphal**. Root paste is used in controlling bleeding, cough & cold. Fruit is taken as digestive and laxative.

Gnaphalium hypoleucum DC., (**Compositae**) *Jhulo,* **Suu**. Root juice is used in indigestion and stomach pain.

Hippophae salicifolia D. Don., Adhikari 0777 TUCH (**Elaegnaceae**) *Dalenchuk,* **Majphal**. Ripe fruit is eaten as tonic and appetizer. It is also taken in tuberculosis and diabetes.

Juglans regia L., (**Juglandaceae**) *Okhar,***Juphal**. Stem bark decoction is taken to cure arthritis, rheumatism, skin diseases and toothache. Dried young shoot bark is taken as anthelmintic.

Juniperus indica Bertol., (**Cupressaceae**) *Dhupi,* **Juphal**. Seed is eaten to get relief from the kidney disorders, cough & cold.

Jurinea dolomiaea Boiss., Kunwar 0492 TUCH (**Compositae**) *Dhupjadi,* **Suu**. Root juice is used in diarrhea & dysentery as well as stomach pain.

Justicia adhatoda L., (**Acanthaceae**) *Asuro,* **Sahartara**. Decoction of leaf is used in fever, headache and bronchitis. Leaf and inflorescence juice is applied in jaundice and rheumatism. Root juice is taken to relief cough and bronchitis.

Nardostachys grandiflora DC., Adhikari 0710 TUCH (**Valerianaceae**) *Vulte, Jatanmansi,* **Majphal***.* Leaf juice is applied in headache, altitude sickness, epilepsy, cough & cold, cuts & wounds. Rhizome decoction is taken as diuretics and tonic. Its paste is applied to cure piles.

Neopicrorhiza scrophulariiflora (Wall. ex Benth.) Hemsl., Kunwar 0502 TUCH (**Scrophulariaceae**) *Katuko,* **Suu***.*Root paste is applied in cough & cold, snakebite, stomachache and liver troubles. Root powder is used as laxative and administered for getting relief from abdominal pain. It is also used in anaemia and jaundice.

Orobanche alba Steph. ex Willd, (**Orobanchaceae**), **Juphal**. Root paste is applied on burns & scalds.

Osyris quadripartita Salz. ex Dacne., Adhikari 0706 TUCH (**Santalaceae**) *Nundhiki,* **Sahartara***.*Stem bark paste is applied in fracture & sprain. Leaf infusion has emetic properties.

Parispolyphyla Smith, Kunwar 0498 TUCH (**Liliaceae**) *Satuwa,* **Majphal***.*Decoction of root is used as anthelmintic and antiseptic. Root paste is applied to cuts & wounds. Root powder is used for fever and sprain.

Parnassia nubicola Wall., Adhikari 0746 TUCH (**Parnassiaceae**) *Mamira, Nirbansi,* **Majphal.** Root paste is taken to get relief from cuts & wounds. Leaf juice is applied to treat eye problems and inflammation.

Phytolacca acinosa Roxb., (**Phytolaccaceae**) *Jaringo,* **Juphal**. Root juice is taken to cure sinusitis. Fruit is used as laxative.

Pinus wallichiana A.B. Jackson, (**Pinaceae**) *Gobresalla,* ***Dunai****.* Resin is employed to treat stomachache and body pain. It is also used to cure snake bite.

Plantago major L., (**Plantaginaceae**) *Sajaino,* **Dunai***.* Flower and fruits are used to cure cough & cold, indigestion, diarrhea & dysentery. Root paste is applied in boils, joints, fever and headache.

Podophyllum hexandrum Royle, (**Berberidaceae**), *Laghupatra, Shinmedo*, **Majphal**. Fruit is eaten to control menstrual disorder, cold & cough. Paste from rhizome is applied for worm infection and controlling bleeding.

Populus ciliata Wall. ex Royle, (**Salicaceae**) *Pipal,* **Juphal***.* Bark juice is taken as blood purifier and tonic.

Potentilla microphylla D.Don, (**Rosaceae**) *Bajradante,* **Suu***.* Root extract is taken to cure tooth and gum problems. Root paste is taken with milk to cure diarrhea.

Princepia utilis Royle, (**Rosaceae**) *Dhatelo,* **Juphal***.* Seed oil is used as sedative and used during pregnancy for easy delivery. It is used to get relief the muscular pain.

Punica grantum L., (**Punicaceae**) *Anar, Darim,* **Juphal***.* Root juice and fruit is taken in dysentery. Extract of bark and fruit is used to treat diarrhea. Root and bark decoction is used as anthelmintic. Fruit pulp is beneficial in cardiac disorders and stomachache.

Rheum australe D. Don., Adhikari 0702 TUCH (**Polygonaceae**) *Latechuk, Padamchal,* **Juphal.** Root paste is applied in sprain & fractures. It is also taken to relief from headache. Juice of shoot portion is taken in dysentery and intestinal problems. Petiole is eaten as an appetizer.

Rheum moorcroftianum Royle, (**Polygonaceae**) *Halejwaro,* **Suu***.* Root juice is used in bile problems, fever and dysentery. Decoction of stem is taken in arthritis.

Rhododendron arboreum D. Don., (**Ericaceae**) *Gurans,* **Dunai.** Flower is used in diarrhea and throat pain. Young leaf is chewed to get relief from headache.

Rosasericea Lindl., (**Rosaceae**) *Jangaligulab,* **Juphal***.*Juice of Flowers, fruits and stem barks are used in menstrual and lymph disorders. Decoction of leaf is used to wash wounds. Flower paste is taken to treat headache.

Roscoea purpurea Smith., (**Zingiberaceae**) *Kaklo, Rasgari,* **Suu***.* Rhizome juice is used in cleaning wounds.

Rubia manjith Roxb., (**Rubiaceae**) *Majitho,***Juphal***.* Leaf and root juice is applied in fever, stomachache and dysentery. Fruit is taken to lower the body temperature and used as laxative. Decoction of leaves and stems is used as a vermifuge.

Rumex nepalensis Spreng., (**Polygonaceae**) *Halhale,* **Sahartara***.* Root paste is applied for body pain, skin disease and sprain. Leaf extract is used in cuts & wounds and swellings.

Sapindus mukorossi Gaertn., (**Sapindaceae**) *Riththa, Uristha,* **Juphal***.* Fruit is taken to wash wounds. It is believed to have expectorant and emetic properties.

Selenium teuifolium Wall., Adhikari 0709 TUCH (**Umbelliferae**) *Bhutkesh, Bhatauri,* **Majphal***.* Root decoction is taken to cure diarrhea, cuts & wounds, fever, stomachache, shock and vomiting. Extract of root is also used in cough & cold.

Silene conoidea L., Kunwar 0495 TUCH (**Caryophyllaceae**) *Naru*, **Majphal**. Root is dried, crushed and used as soap to wash wounds and hair.
Swertia nervosa (G. Don) C.B. Clarke, Adhikari 0783 TUCH (**Gentianaceae**) *Tite, Chirayito,* **Juphal.** Decoction of plant is used for controlling fever, food poisoning, cough & cold and liver problems. Young leaf juice has property to stimulate appetite.
Taxus wallichiana (Zucc.) Pilger, (**Taxaceae**) *Kandelotto, Loathsalla,* **Juphal***.* Leaf extract is used in skin diseases and cancer. It is also used in asthma and bronchitis.
Thymus linearis Benth., Kunwar 0497 TUCH (**Labiatae**) *Godamarcha,* **Suu***.* Leaf juice is used as blood purifier, digestive and appetizer. It is also used to get relief from body pain. Young flower is taken to cure gum and toothache.
Toona ciliata M. Roem., (**Meliaceae**) *Kansilo,* **Suu**. Stem bark is taken to cure toothache. Fruit is used for chest pain, fever and measles.
Urtica dioca L., (**Urticaceae**) *Sisnu,***Juphal***.* Root juice is taken in skin diseases and kidney problems. Root extract is used in toothache, asthma and easy delivery.
Valeriana jatamansi Jones, (**Valerianaceae**) *Sugandhwal, Samayo,* **Juphal***.* Rhizome paste is used in headache, sore throat and shock. It is also taken as tonic. Leaf and rhizome extract is applied in common cold, boils & scalds, eye problems and stomachache.
Zanthoxulum armatum DC., (**Rutaceae**) *Timur,* **Sahartara***.* Fruit is used as appetizer. Fruits and stem barks are taken in indigestion and toothache. Decoction of fruits is used in cold and stomachache and as anthelmintic.

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Conservational status of plant seedlings in Ayubia National Park, Pakistan

Estado de conservacion de germinantes en el Parque Nacional Ayubia, Pakistan

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Conservational status of plant seedlings in Ayubia National Park, Pakistan

Abstract

During recent and past Centuries, nature reserves and National Parks have been cornerstone in preservation of species and natural areas. However, as humans modify more and more of the earth, the mismatch in scale between present nature reserves and natural dynamics of ecosystem becomes more pronounced. To predict such influences studies have been conducted to observe conservational status of all of the trees of Ayubia National Park, taking simple parameters of number of seedling and samplings of these plants in selected plots. In this study borderline area has been divided into twelve regions. Total 240 number of quadrates (0.25 x 0.25m) have been laid. On the basis of number of seedlings and saplings each region is specified a category. Except one region all have some sort of disturbances which hinder the proper growth of seedlings and consequently the relative tree species in that region. It shows that species used as fuel wood like *Quercus dilatata*, *Quercus incana*, *Abies pindrow*, *Taxus wallichiana*, *Aesculus indica* and *Picea smithiana* were in serious threats of extinction based on the number of seedlings and saplings in each region. The major reasons behind this dilemma are, firstly the people are unaware of the importance of the plant resources and there is no alternative source of fuel for them. Secondly their grazing animals destroy these seedlings and saplings despite of restricted area.

Key Words: National Park, Conservation, Sustainability, Fuel wood, Biodiversity, Density, gymnosperm, Conservation, Pakistan, Seedling, Sapling.

Resumen

Durante los centenarios pasados, los parques nacionales ya estuvieron para la preservación de especies y áreas naturales. Sin embargo la población humana esta en constante proceso de modificar la tierra, y la discrepancia entre el tamaño de áreas protegidas y la dinámica natural de los ecosistemas se vuelve un tema más profundo. Para pronosticar estos impactos se estudio el estado de conservación de todas especies de árboles en el Parque Nacional Alubia. Contando el numero de germinantes y árboles pequeños en parcelas. En este estudio el área limite se ha dividido en doce regiones. El numero total de parcelas de 0.25 x 0.25m fueron 240. En base del número de germinantes cada región fue categorizada. Todas las regiones a excepción de una, muestran de alguna manera perturbación lo cual inhibe el crecimiento de germinantes y en consecuencia la afecta la regeneración de árboles en la región. Especies usadas como leña (Quercus dilatata, Quercus incana, Abies pindrow, Taxus wallichiana, Aesculus indica y Picea smithiana) se encuentran en peligro de extinción, basado en el numero de germinantes en cada región. Las razones más importantes por esta situación son, la falta de conocimiento de la importancia de estos árboles en la población local y la falta de alternativas para suplir combustible. En segundo lugar el numero elevado de ganado esta destruyendo los germinantes, dentro y fuera de la área protegida. Palabras claves: Parque Nacional, conservación, sostenibilidad, leña, biodiversidad, densidad, gimnospermas, Pakistán, germinantes

Introduction

Pakistan is a sub-tropical country situated between 20 and 37 N latitude and 75 E longitudes. The forest area under the control of government is 4.3 million hectares that is 4.8% of the total area. The area of privately owned forest is 1.5 million hectares, which lies in the Northern area of Punjab and NWFP. These areas called -guzara or community forest". The study area (Ayubia National Park) is the only moist temperate forest in Pakistan with a high diversity of vulnerable plant and animal species. There are about 200 species of herbs and shrubs and about 10 species of Gymnosperm trees found in park area. It is situated in the Gallies Forest division of Abbottabad between 34-1 to 34-3.8 N latitude and 73-22.8 to 73-27.1 E longitude over an area of 1684 hectares. The area was declared as National Park in April 17, 1984. (Source: Work Plan for Gallies Reserved Forest). The park is located on range of hills running north to south in proximity of Abbottabad and northwestern end of Murree. Altitude ranges from 1220-2865m. Highest peak area Mirangani (i.e. 2228m) and Mukshpuri (i.e. 2865m) (Shinwari & Khan 1998). Mean annual

rainfall is above 1,500 mm, in addition to precipitation received in form of heavy snow in winter and mean annual temperature is 21 C and relative humidity is 66% (Khan 1998). Important villages around the park are Kundala, Toheedabad, Mallach, Lahurkas, Kalabun, Derwaza, Mominabad, Ram kot, Raila and Pasala. In Ayubia National Park the vegetation is extensively being impoverishment due to heavy population pressure from surrounding villages. The resources of the Park are exploited by the people mainly in form of fuel wood, fodder, enthnomedicinal and grazing of animals.
Fauna of park include Mammals like leopard, deer, fox and birds like Kestrel, Wagle owl, Indian cuckoo, Purple sunbird, Black bird. (Source: Wildlife Department WWFP). Although reserves have been crucial for preserving species and habitats in the short term, with few exceptions they have not incorporated in the long term and large scale dynamics of ecosystems (Groom 1992, Holling et al 1995). Reserves and National Parks are geographically defined areas protected by the law and in which human activities are restricted or prohibited (Caldecott 1996). Ecosystems are subject to natural and human induced disturbances at various spatial and temporal scales (Groom 1992, Khan 1984). Recent work shown that human tries to manage frequent and sometimes intermediately frequent disturbances. This will result in extinction or rareness of some species from nature.
The main objectives of the study are to explore the conservation status of Gymnospermous species and suggest some methods for future re-forestation and conservation of natural resources.

Materials and Methods

Study area

Ecology of the Park

Ayubia National Park is situated in the Gallis Forest Division of Abbotabad District, North West Frontier Province (Fig. 1). As originally designated in 1984, it lay between 34°-1’ to 34°-3.8’ north latitude and 73°-22.8’ to 73°-27.1’ east longitude, cobering an area of 1684 hectares. In March 1998, the park area was more than doubled to 3,312 hectares under the NWFP Wildlife Act of 1975 (Fig. 2). The forests of the park represent one of the best moist temperate forests in Pakistan, with a wide diversity of plant and animal species. The national park was established to preserve the ecosystem and its biodiversity for scientific research, education and recreation(Fig. 3 and Fig. 4).
The national park consists entirely of reserve forests, which spill out of the park area on the west and south sides. Beyond the reserve forests are "guzara" forests and waste land which is the communal or private property of the people. With increasing population, the pressure on land and its resources is enormous. The forests are a source of fuelwood, timber, fodder, medicinal plants and wild vegetables for the surrounding communities. As guzara lands become increasingly denuded the pressure on forests is increasing.
As evident in the map, the park is surrounded by dense population, with seven major villages consisting of a larger number of linked settlements. The total population in and adjoining the national park is about 50,000 and, in line with national statistics, is growing at the rate of 3% per year. Social services (schools, dispensaries, water supply schemes, roads etc.) are far below the national average, which, in turn, is below the South Asian norm. The high rate of illiteracy is a major constraint in spreading conservation awareness.

Figure 1. National Park System of Pakistan.

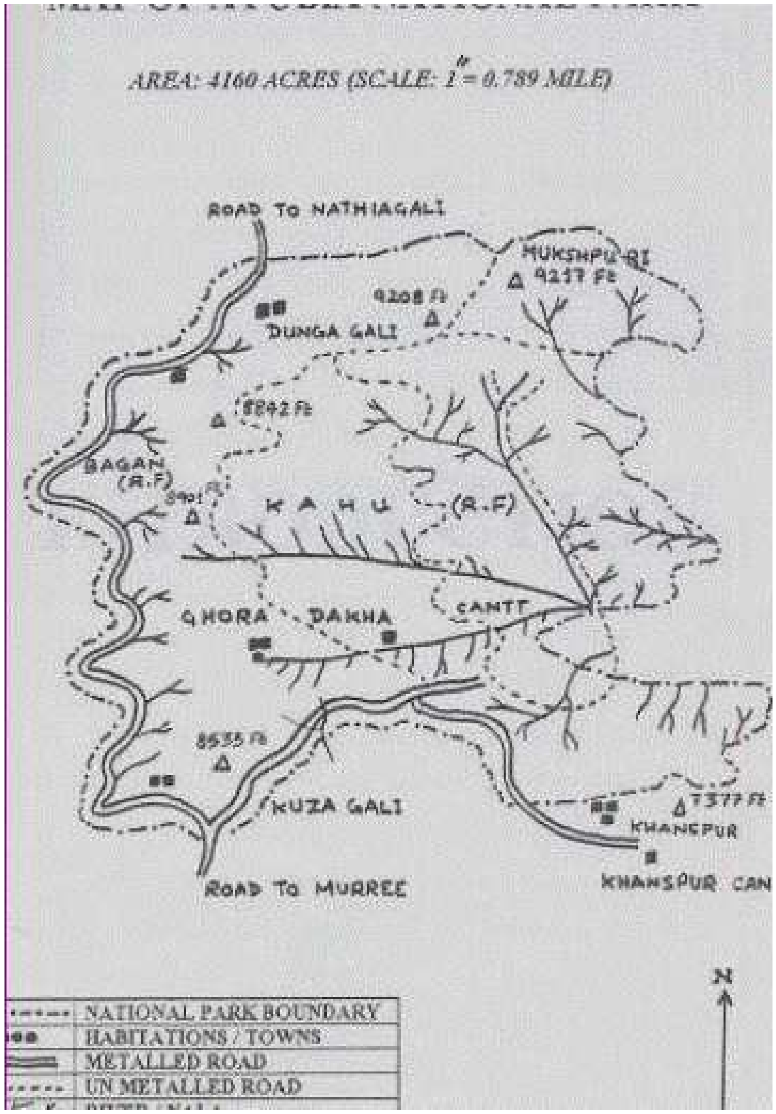

Figure 2. Study Area in Ayubia National Park.

Figure 3. Panoramic View of Ayubia National Park Pakistan.

Figure 4. Blue Pine forest in Ayubia National Park.

Stratification

The field work was carried out in the Park from Jan. 1999-Jan. 2000 and border line area has been choose as it facing major anthropogenic disturbance. This boundary area has been divided into twelve focused regions (FR) and each FR 20 quadrates (0.25 x 0.25m) have been laid randomly and number of seedlings and saplings of all tree species (i.e *Pinus wallichiana*, *Cedrus deodara*, *Prunus padus*, *Cornus macrophylla*, *Quercus dilatata*, *Quercus incana*, *Abies pindrow*, *Taxus wallichiana*, *Aesculus indica* and *Picea smithiana*) have been recorded.

On the basis of number of seedlings plus saplings, each focus region categorized into a class of disturbed or undisturbed patch.

Table 1. Categories on the basis of Number of Seedlings and Saplings

S.#	**Number of Seedlings+Saplings/m2**	**Category**
1	25-30	Undisturbed
2	20-25	Least Disturbed
3	15-20	Mildly Disturbed
4	10-15	Average Disturbed
5	5-10	Highly Disturbed
6	>5	Extremely Disturbed

Results

On the basis of table one the results of trees like *Quercus dilatata*, *Quercus incana*, *Abies pindrow*, *Taxus wallichiana*, *Aesculus indica* and *Picea smithiana* for the twelve focused regions are shown in the table 2.

In FR 1 the total number of seedlings and saplings of trees (i.e. *Cedrus deodara* and *Pinus wallichiana* and *Cornus microphylla*)/ m is 33 and thus it categorized as Undisturbed patch of the park.

FR 2 includes saplings and seedlings (i.e *Abies pindrow* and *Picea smithiana*) falls in category of Highly Disturbed patch. While in FR 3 & FR 4 also includes in the same one and seedlings and saplings belong to *Abies pindrow*, *Taxus wallichiana* , *Pinus wallichiana*, *Quercus dilatata*).

In FR 5 & 6 four and three number of seedling plus sapling (i.e *Abies pindrow*, *Taxus wallichiana*, *Pinus wallichiana* and *Quercus dilatata*) are observed respectively and both of these categorized as extremely disturbed patches.

FR 7 & 8, both have values of number of seedlings and saplings (*Abies pindrow* and *Pinus wallichiana*) are twelve and hence include in Average Disturbed patch of the park.

While FR 9 is extremely disturbed with the value of seedling and saplings only 2/m (*Pinus wallichiana* and *Quercus dilatata*). Similarly the focused regions 10th and 11th are also very disturbed having value is 7 and 6 respectively (In this tree species are *Abies pindrow*, *Taxus wallichiana*, *Pinus wallichiana* and *Quercus dilatata*)

The twelveth region is also extremely disturbed.

Table 2. Categorization of the FR (Focus Regions) on the basis of Number of Seedlings plus Saplings.

FR	Number of Seedlings + Saplings	Category
1	33	Undisturbed
2	5	Highly Disturbed
3	8	Highly Disturbed
4	7	Highly Disturbed
5	3	Extremely Disturbed
6	4	Extremely Disturbed
7	12	Average Disturbed
8	12	Average Disturbed
9	2	Extremely Disturbed
10	7	Highly Disturbed
11	6	Highly Disturbed
12	4	Extremely Disturbed

Discussion

As indicated in the results that only one FR is undisturbed and two are average disturbed. Remaining all either are higly or extremely disturbed . The species richness is focal component in nature conservation (Ulf 2004). It indicates that in almost all of plot there was no regeneration of *Cornus macrophylla*, *Abies pindrow* and *Picea smithiana*.

Damages includes illicit cutting. In the suburbs of the Park there are about 2311 households of the forest dweller with a population of 18,097 Individuals. The average weight of wood found to be stored per household during the period mid-June to mid-September was 2,385 kg. Families use an average of 19.8 kg of wood per day in summer and 42.2 kg in winter. Assuming 150 days of winter and 215 days of summer, average annual consumption is calculated to be 10,578 kg. (Aumeeruddy 1998). As a result of the collection of such enormous quantity of the fuel wood especially by killing or damaging the trees, forest patches situated in about 5-6 km radius of each tribal colony shows clear sign of disturbance. Only about 10 % of the forest shows no sign of damage. However about 90% of trees in fuel wood collection areas showed clear sign of damage to their bole and branches.

Fuel wood consumption in Pakistan is more than 565 million cubic meters per year and is constantly increasing. A preliminary survey showed that more than 70 % of people all over the tribal areas use timber as fuel wood, 10 % use animal dung cakes for domestic use, 10 % use natural, 4 % use kerosene oil and less than 4 % use electricity. These people have no alternative but to cut plant if they want to cook their food (Shinwari et al 1996; Shinwari et el 2003).

Besides deforestation, overgrazing, rapid colonization thousands of families are totally dependent on the local plants for their daily domestic purpose (Shinwari et al 2003).

Khan et al (1996) studied the impact of fuel shortage on conservation of biodiversity of Hindu-Kush Himalayas Mountain region. They mentioned in their paper that northern areas of Pakistan are endowed with immense natural resources which are being rapidly unchecked and uncontrolled. The most serious crisis to the loss of the biodiversity is fuel shortage, which mainly affects firewood species.

In Margala Hills National Park, Islamabad over 35 species are used, among which Acacia modesta, Acacia nilotica, Buxes papillosa and Dodonaea viscosa were under high fuel wood pressure (Shinwari and Khan 1998). In Chitral district 15 species of gymnosperms used as local medicines Firewood was also a one of the factor for poor conservational status of the tree species (Rashid et al 1997). Human influence on the natural resources of Mount Aelum, Swat Analysis showed that land and ownerships conflict were the basic cause of the depletion of the natural resources and ecological degradation and poor conservational status (Rehman & Ghafoor 2000).

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A Silvicultural Approach to Restoration of Native Hawaiian Rainforests

Methodos silviculturales para la restoracion de los bosques humedos nativos de Hawaii

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A Silvicultural Approach to Restoration of Native Hawaiian Rainforests

Abstract

Restoration of native Hawaiian rainforests should be based on a silvicultural rather than horticultural approach. A silvicultural approach applies knowledge from forest ecological research and focuses on simulating and enhancing natural processes for "low input management." Historically, a horticultural approach of planting alien trees was used to restore Hawaiian watersheds. This form of "high input management" was the result of insufficient understanding of how the Hawaiian rainforest perpetuates itself. It left out a major component, the change of substrate in mature rainforests. Mature rainforests usually have an abundance of decaying moss-covered nurse logs on the ground and a sufficient availability of tree fern trunks, both of which serve as the principal germination sites for native ferns and seed plants. A set of seven silvicultural tasks is suggested for application on an operational experimental basis. They begin with partially delimbing or cutting of alien trees and allowing their larger limbs and trunks to rot in situ. A special task is undermining alien forests with reintroduction of native tree ferns in kipuka-like fashion combined with out-fencing feral pigs. Other important tasks involve weed control, inoculation of moss-covered rotting logs and tree fern trunks with disseminules of robust native seed plants (wherever they are not anymore in seeding range), frequent monitoring, and for koa in particular, soil scarification. Key words: Applied forest ecology, low input management, key species, ecological properties and strategies, undermining in kipuka-like fashion.

Resumen

La restoración de los bosques húmedos nativos de Hawai debe ser basada en una metodología silvicultural y no en métodos de horticultura. La metodología silvicultural aplica conocimientos de estudios ecológicos y tiene un enfoque en la simulación y el mejoramiento de procesos naturales para un "manejo con impacto bajo". Históricamente se había usado una metodología de horticultura en manera de plantar árboles exóticos para restorar las captaciones de agua en Hawai. Esta manera de "manejo con impacto alto" estaba el resultado de entendimiento insufiente de cómo los bosques de Hawai esta regenerando naturalmente. Dejaba fuera de consideración un componente mayor - el cambio de substrato en bosques húmedos maduros. Bosques húmedos maduros normalmente tienen una abundancia de troncos en varios estados de descomposición, cubiertas de briofitos en su piso, y una cantidad elevada de troncos de helechos arbóreos, cuales ambos sirven como sitios principales para la germinación de helechos y plantas vasculares nativas. Un juego de siete métodos silviculturales esta propósito para la aplicación en base experimental operacional. Empieza de la corte parcial de las ramas de árboles exóticos o del árbol entero y bajar sus ramas grandes y troncos para descomposición en situ. Una tarea especial esta infiltrar a los bosques exóticos por la reintroducción de especias nativas de helechos arbóreos en manera de *kipuka* combinado con cercos para excluir los cerdos salvajes. Otras tareas importantes envuelven control de hierbas invasivas, inoculación de troncos decompositos y cubiertos de briofitos y troncos de helechos arbóreos con germinantes de plantas nativas robustas si no están suficientemente cerca para sembrase mismo, monitoreo frecuente, y para "koa" especialmente escarificación del suelo.
Palabras claves: Ecología forestal aplicada, manejo de impacto bajo, especies claves, propiedades y estrategias ecológicas, infiltración en manera *kipuka*

Introduction

In Webster's dictionary, silviculture is defined as "A branch of forestry dealing with the development and care of forests." Silviculture can also be understood as the practical application of forest science or forest ecological knowledge. Silviculture always has an applied research component and may involve experiments on an operational scale. When not applied to commercial forestry, silviculture can be considered a branch of applied conservation biology. Silvicultural approaches must be based on simulating and enhancing **natural processes**. In terms of labor and materials, they should be considered "low input management." As such, silviculture can be contrasted to horticulture.

Horticulture, by definition, is garden culture, which requires "high input management." In Webster's dictionary, horticulture is defined as "The art and science of growing fruits, vegetables, or ornamental plants." When applied to conservation of plant species, horticulture can also be considered a branch of applied conservation biology. But for restructuring or restoring native rainforests, silvicultural rather than horticultural techniques should be developed. Such silvicultural techniques should be based on ecological research done in the Hawaiian rainforests.

Up to the mid-1960s, rainforest research in Hawai'i had been very limited. The most significant ecological research was that of Harold L. Lyon and a few of his contemporaries, who spent a decade researching the "Maui Forest Trouble" (Holt 1983). This phase ended with Lyon's (1918) conclusion that (quote) "Our native forests are doomed."

Lyon's conclusion was based on his implication that the native *Metrosideros* dominated rainforest was made up largely of pioneer species that could not adapt to aging soils. He thereafter postulated the idea that the missing climax species component has to be introduced from outside Hawai'i in order to save the Hawaiian watersheds. This was still the unwritten forest restoration policy in the state of Hawaiʻi until about the mid-1970s.

Research under the Hawai'i IBP (International Biological Program) during the 1970's focused on the biological organization of selected native Hawaiian communities (Mueller-Dombois et al 1981). Among these was an 80 ha study plot in the Kilauea rainforest on the Big Island of Hawaiʻi. Subsequent research on the canopy dieback syndrome in the Hawaiian rainforests was extended across the islands of Hawai'i, Maui, O'ahu, and Kaua'i and from there to the Pacific and Atlantic regions (Huettl and Mueller-Dombois 1993). A good number of dissertations and masters theses done under the advisor ship of the author dealt with questions relating to the successional dynamics of the native Hawaiian rainforest. They revealed that Lyon's conclusion was only partially correct and thus rather unfortunate. The "Maui Forest Trouble" was not simply related to soil aging but to bog formation, a fundamental process in geomorphological aging and landscape change (Mueller-Dombois 2005).

For using a silvicultural approach to restoration, one needs to know first some of the key species that either stabilize or disrupt a specific rainforest community. Second, one needs to know about their ecological properties and strategies. Such aspects will be discussed next. This will be followed by a set of silvicultural prescriptions for restoring Hawaiian rainforests.

Key species

Among plants, key species are usually the dominants or the more robust ones in the community. In particular they are those whose population dynamics has a strong effect on the other species in the community. In the mature Hawaiian rainforest such species are the 'ohi'a lehua tree (*Metrosideros polymorpha*) and the hapu'u tree fern (*Cibotium* spp.). 'Ohi'a lehua dominates the canopy and the hapu'u typically the sub-canopy. In less wet rain forests, the koa tree (*Acacia koa*) often joins the upper canopy as a second key species. Depending on habitat factors and geographic location, koa may even become an emergent tree reaching above the general canopy. Locally, other native tree, shrub, and vine species, can be added as playing key roles. Among trees they include in upper Manoa Valley for example, 'ahakea lau nui (*Bobea elatior*), hame (*Antidesma platyphyllum*), olomea (*Perrotettia sandwicensis*), lama (*Diospyros* spp.), kopiko (*Psychotria kaduana*), and ʻolapa (*Cheirodendron* spp.), among shrubs they include 'ohelo kau la'au (*Vaccinium calycinum*), ha'iwale (*Cyrtandra* spp.), ho'awa (*Pittosporum glabrum*), naupaka kuahiwi (*Scaevola gaudichaudiana*), and mamaki (*Pipturus albidus*), among vines 'ie'ie (*Freycinetia arborea*) and maile (*Alyxia oliviformis*). Many other robust native rain forest plants are listed by Stone and Pratt (1994:173)

A number of alien invasives have now assumed the role of key species. Foremost among them is the feral pig (*Sus scrofa*). Pigs tend to destabilize the Hawaiian rainforest, in particular, because they seek out the native tree ferns, the hapu'u, as a favored food item. They also promote locally the spread of strawberry guava (*Psidium cattleianum*), which is a key invasive tree in pig frequented sections of the Hawaiian rainforest. A shrub in this category is Koster's curse (*Clidemia hirta*). Locally in watershed forests on 'O'ahu, a particularly disturbing invasive key species is the often very tall (>30 m), canopy emergent albizia tree (*Falcataria moluccana*). Other recently spreading and penetrating trees are the introduced secondary and fast growing shoe button ardisia (*Ardisia elliptica*) and the octopus tree (*Schefflera actinophylla*). These secondary, fast growing trees form a new life-form group with several other alien species, which never really developed among the native species.

In the Hawaiian Islands, the primary rainforest has always renewed itself through the generational turnover of primary species without an intermediate successional phase that could be considered a secondary forest. As is well known, a secondary forest is a typical phase in disturbed continental tropical rainforests, in which recovery of primary forest is considered a very long-term process.

Ecological properties and strategies

For the purpose of this paper, only a few characteristics will be emphasized, which can be used for a silvicultural approach to forest restoration. During the IBP and canopy dieback studies, we surveyed many rainforest plots and transects. We enumerated all woody species by cover, density and size. We also studied their substrate and found that most of the native rainforest species became established on decaying wood in developed mature forests. This stands in contrast to rainforest development on lava flows, where an assortment of hardy native pioneer species establish themselves in rock fissures without or with only very little organic matter.

In mature rainforests we noted only three species that started commonly on mineral soil. These were the hapu'u tree ferns, the koa, and naio (*Myoporum sandwicense*) trees. Most others had a significant log establishment index, meaning they started as seedlings on logs above the mineral surface (Cooray 1974). That means that most Hawaiian plants have an epiphytic beginning.

Such observation can be made easily in mature native rainforests, if one knows where to look for native fern sporlings and tree seedlings. The first place to look for, are the tree fern trunks. They often are the most favorable seed beds for 'ohi'a lehua germinants and small seedlings. If left alone, eventually one of them may succeed in becoming a sapling and thereafter a mature tree by extending its roots into the mineral soil. A precondition for this to happen is a canopy opening. This may occur naturally by loss of a tree fern frond or the decline of the tree fern itself after canopy opening. Many times one can observe stilt rooted 'ohi'a lehua trees that had an epiphytic start, either on a tree fern trunk or on a moss-covered dead tree trunk. For ʻalapa this seems to be the only mode of its natural establishment.

Silvicultural restoration tasks

Delimbing: Cutting off the limbs or big branches of the taller alien trees would be a useful first step in silvicultural restoration. This should not be a clear-cut logging operation, but rather a carefully selected cutting and partial delimbing of selected alien trees. Their limbs should be left on the ground, allowing them to decompose in situ. To accelerate the decomposition process, the limbs, or thick branches, and in some situations the trunks of selected trees, may be cut into meter sections and split open. In mature and senescing Hawaiian rainforests, decaying logs, particularly when moss-covered, were found to be the favored micro-habitats for native fern sporelings and woody plant seedlings to become established.

Fencing: Any section of rainforest considered for restoration needs to be fenced against pigs. Depending on financial resources one can begin with fencing of small enclosures, such as 100 m plots. Of course, anything larger would always be preferable. The purpose is to create a safe island in kipuka fashion within the larger forest infested by alien neophytes.

Reintroduction: From field research observations, it appears most efficient to begin with reintroducing the appropriate Hawaiian tree ferns into the fenced enclosures. On ʻOʻahu Island this would preferably be *Cibotium chamissoi*, formerly named *C. splendens* (Palmer 2003). But *C. menziesii* may also be considered. A natural hybrid of these two species was recently discovered in the Koʻolau mountains and called *Cibotium x heleniae*. Such tree ferns are easily transplanted at any stage of their life cycle and/or raised in nurseries. Mature tree ferns are preferred. The reasons for reintroducing tree ferns are several. They can be planted directly into the mineral soil as they do not require a raised organic seedbed as do most of the other Hawaiian woody plants with exception of *Acacia koa* and *Myoporum sandwicense*. Tree ferns have a high value as watershed protectors in that they slow down the impact of heavy showers by forming a second canopy under the tree layer. They disperse the water away from their trunks in contrast to, for example, albizia trees. Albizia trees act as funnels for rain water because of their generally upward angled branch system. Because of this, they have a high rate of stem run-off, which is further accelerated due to their smooth bark. They are thus ill adapted as watershed tree cover in wet forests, where excess water is a problem. In contrast, tree ferns are expected to increase the rate of water percolation into the soil rather than contributing to run-off and erosion as do the alien albizia trees. A third major advantage is that tree fern trunks serve as epiphytic seed beds for many native ferns and woody plants. As mentioned before, many *Metrosideros* trees and almost all *Cheirodendron* trees start as seedlings epiphytically on tree fern trunks.

Weed control: In some situations, weed control may be the prerequisite prior to the introduction of native tree ferns into the Kipuka-type enclosures. Certainly, weed control may be considered an ongoing task until the tree ferns themselves become excluders of weeds on account of having developed a closed canopy in the Kipuka-type enclosures.

Inoculation: Wherever native woody plants and ferns are too far removed from the Kipuka-type enclosures, it may become necessary to inoculate the tree fern trunks and decaying coarse woody log segments on the ground with seeds and spores of selected native plants.

Monitoring: Another silvicultural research task involves monitoring the tree fern trunks and inoculated decaying wood segments for native plant establishment, growth, and survival. Monitoring will also be necessary in the Kipuka-type enclosures to keep weeds under control and the fencing in repair.

Soil scarification: In some of ʻOʻahu's watershed forests, for example in the Kahana ahupuaʻa, it has been found that soil scarification will encourage germination of koa seeds. An abundance of koa seedlings has been observed there by Wirawan (1978), after removal of the hala (*Pandanus tectorius*) litter associated with scarification of the surface mineral soil. Currently, there are only a few old senescing *Acacia koa* trees left in the canopy otherwise dominated by native hala trees. Soil scarification in forest gaps will increase the koa component in the inland forest (the wao nahele) of the Kahana ahupuaʻa. It may also work in other ahupuaʻa where koa is in decline.

Conclusions

The seven silvicultural restoration tasks for Hawaiian rainforests discussed above may be considered a first set of prescriptions. It is suggested that these are applied in kipuka-like fashion. This means that restoration should begin with fenced-in island-like nuclei of robust native plants. These comprise the ancient vegetation in usually a larger area of vegetation composed of neophytes. These native plant kipuka may be small areas such as 10 by 10 m plots to begin with. They should be protected, monitored, and studied. Such native vegetation kipuka will certainly provide a sense of Hawaiian place in our watershed forests. If they prove to have a reasonable survival value, they may eventually be expanded by silvicultural nurturing to become the vegetation matrix for reintroducing rare and endangered Hawaiian plants and animals. With further practical experiences gained from silvicultural experimentation at an operational scale, additional prescriptions will surely be developed.

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Landslides as ecosystem disturbance - their implications and importance in South Ecuador

Derumbes como perturacion en un ecosistema - implicaciones y importancia en el Sur de Ecuador

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Landslides as ecosystem disturbance - their implications and importance in South Ecuador

Abstract

Landslides along the Andean mountain chain produce serious damage with widespread environmental and economical effects for the Andean countries. Landslides have a particularly high significance in Southern Ecuador. Only few studies address the causes and effects of landslides, and much more data is needed to understand this phenomenon. In this paper the causes as well of landslides, their shapes in different environments and the environmental effects of landsliding are discussed from the biological and economical point of view. Special attention is given to South Ecuador, where constant landslides are characterized by a distinct vegetation and specialized pioneer flora. The lack of knowledge about gap size, seed bank and other internal or environmental factors does not allow advance mitigation of landslide effects. Key words: Ecuador, Landslide, Disturbance, Species loss

Resumen

Los derrumbos en las montañas Andinas, han ocasionado serios daños con amplias repercusiones ambientales y efectos económicos para los países andinos. Los derrumbos tienen una particular alta significancia en el sur del Ecuador. Solamente pocos estudios han direccionado las causas y efectos que estos producen, siendo necesario poner más atención en este tipo de estudios. En este trabajo se enfoca las diferentes causas así como las formas que se presentan y las repercusiones en el ambiente, tanto desde el punto de vista biológico así como un análisis económico. Se realiza un enfoque dirigido al sur del Ecuador, sitio de constantes derrumbos, con una flora especializada en colonizar estos ecosistemas perturbados. La falta de atención a factores como tamaños del gap, banco de semillas entre otros intrínsicos y ambientales no nos permite actuar con precaución en la mitigación de sus efectos. Palabras clave: Ecuador, Derrumbo, Perturbación, Pérdida de especies,

Introduction

For many years, vegetation recovery was studied as an important topic in plant ecology (Peet & Christensen 1980). The study of environmental disturbances has a long research tradition, focusing on different impacts, restoration and succession (White & Jentsch 2001). Some studies suggest that natural disturbance plays an important role in maintaining biodiversity (Christensen *et al*. 1989). These processes of regeneration and succession are highly important in view of increasing forest changes caused by natural or human activities. Habitat fragmentation may increase the disturbance rates (Bergeron & Brisson 1990).

Natural and anthropogenic landslides are common all over the Andes including Ecuador, and are producing serious and continuous damage (Benitez 1989). Unfortunately very few studies have been carried out in Ecuador (Ohl & Bussmann 2004; Stern 1992; Benitez 1989). Landslides are influenced by a series of internal (cryoclastic or thermoplastic phenomena) and external environmental factors, especially climate, slope, soil type, earthquake frequency and road construction. These factors, sometimes combined, are the main driving forces to produce debris and slides. The Andean mountains have always been influenced by drastic climate processes, which directly influence land movements and plant composition, as a part of a natural dynamics. The disturbance regimens, have critical implications in ecosystem maintenance, and influence species loss. Native or alien species invasions play an important role in the recovery process after landslides.

Discussion

Fall and Movement

In many mountain ranges, continuing movements of material occur on steep slopes. "Rock fall" is often used as the general term without further reference to the material involved (Dikau et al. 1996). A fall occurs when the natural slope exceeds the limit for the balance of the material composing it. The fall may have various direct and indirect natural or anthropogenic causes.

It is noteworthy to consider that the Andes are characterized by active plate convergence and uplift due to the South American Plate colliding with the Nazca Plate (Van der Hammen 1988). Intense seismic activity occurs constantly. The uplift average is as much as a meter per thousand years, and rapid erosion has resulted in widespread unstable slopes (Eriksen *et al*. 1989). The way landslides move and their velocity have inter-relations with the nature of the fall, size and provenance of the material. Different fall classifications based on either genetic or descriptive approaches are used (Whalley 1974). The most common international classification is based on the origin and nature of the material, although many other descriptions and suggestions exist. Terzaghi (1962) for example describes falls according to the rock type, focusing on the rupture mechanism and the action of water in the rock.

Slide and Landslide

The term landslide is used for a movement of material along a recognizable shear surface (Buma & Van Asch 1996). At least two different kinds of slides are recognized: Rotational, which basically describes how, after failure is initiated, the slump mass starts to rotate; and translational, which is not a circular failure, but a movement largely controlled by surface of weakness within the structure of the slope-forming material. Translational slides may occur in three types of material: rock, debris and soil. Depending on the slope angle and the velocity, slides will either stay as a discrete block on the failure surface or break into debris. According to Varnes (1978), cited in Dikau et al. (1997), show the following classification (Table 1):

Table 1. Classification of Landslides suggested by Varnes (1978)

Type of movement			Type of material		
Bedrock				**Engineering soils**	
				Predominantly coarse	**Predominantly fine**
Falls			**Rock fall**	**Debris fall**	**Earth fall**
Topples			**Rock topple**	**Debris topple**	**Earth topple**
Slides	**Rotational**	**Few units**	**Rock slump**	**Debris slump**	**Earth slump**
	Translational	**Many units**	**Rock block slide**	**Debris block slide**	**Earth block slide**
Lateral spreads			**Rock slide Rock spread**	**Debris slide Debris spread**	**Earth slide Earth spread**
Flows			**Rock flow (deep creep)**	**Debris flow**	**Earth flow (soil creep)**
Complex	**Combination of two or more principal types of movements**				

Table 1. Classification of Landslides suggested by Varnes (1978).

Disturbances and Species Loss

Different kinds of disturbances, such as fire, landslides, flooding, grazing among others change the biological organization of ecosystems. "Disturbances play a crucial role in maintaining biotic diversity" (Darwin 1859). Species evolve a diverse spectrum of abilities relative to disturbance (Vogl 1974). After a particular disturbance, some species increase in number or invade, while others decrease or retreat (Walker *et al*. 1999). Dominant and minor species can occur in the same functional group and can be similar with respect to their contribution to ecosystem function. Dominant and less dominant species switch in abundance under changing environmental conditions allowing "functional stability".

Latin America has the largest extend of all tropical forest (Whitmore 1997), but also the highest deforestation rate, with approximately 32 million ha or 0.96%/yr. Plant diversity in the Ecuadorian Andes is considered extreme with a high degree of endemism (Lozano *et al*. 2003; Lozano & Bussmann in prep), probably due to the composition of different lineages, and also influenced by environmental as well as geographic factors (Richter 2003). Many mountain plant species are restricted to narrow and specific elevation ranges (Young 1994), allowing explosive radiation as reported by Gentry (1982) and Jost (2004). The best examples are the narrow altitudinal belts of the "San Francisco Reserve" in the elfin forest, where Bussmann (2002) reports an extremely diverse community complex. Disturbance in areas with such speciation conditions affects a whole "micro-ecosystem" and requires "complex" processes to recover again.

During the last decades, tropical American forests are rapidly altered and disappearing, with logging statistics showing a loss of 2.6 millions ha/year. Their extreme biodiversity richness is changing and high species loss occurs, with long term effects difficult to predict.

No data exist on the exact deforestation rate in Ecuador. Data suggest a forest loss to deforestation of 136.000 to 340.000 ha/year (FAO 2001). South Ecuador does not show a very high rate of deforestation because most of the logging is concentrated in the North and West of the country. A high amount of logging occurs however in the South as well.

Succession

Succession of vegetation usually follows natural and anthropogenic processes. The term succession is used to describe many types of vegetation changes on widely different scales in both space and time (Finegan 1984). Earliest studies describe the sequence of species that successively invade a site (Cooper 1913), show changes in Biomass, productivity, diversity and niche (Odum 1969), while others have focused on physical stresses to plants and competition for resources between plants as the main mechanisms determining the course of succession (Colinvaux 1973). Therefore competitive interactions with herbivores, predators, and pathogens are of critical importance to the course of succession (Connell & Slatyer 1977). The high primary net productivity of successional ecosystem can support large animal populations (Linares 1976), hence such standing patch interaction serve as important nuclei of species establishment during succession process.

Factors of the physical environment (light, temperature, soil, relative humidity) triggerecophysiological responses, for example seeds if pioneer species in soil seed banks take advantage of disturbance enhancing the optimal conditions of early successional plants. Few data and comparative studies of fragmented ranges exit (Young 1994). Distribution and size of patches probably reflect seed dispersal more than site differences (Ewel 1983). Other considerations on succession are described by Richter (2003), specifically for Southern Ecuador. There, climatic conditions, mainly humidity and physiography of mountain chains, depict micro-site and environments varieties. These, combined with regimens of frequent and different sized disturbance, especially "landslides", can be considered optimum spots for a high rate of genetic exchange as consequence of micro-geographic niche partitioning.

Succession is important for two reasons: the value of the concept in the development of ecology as a science and it’s enormous potential in the development of programs for the conservation and exploitation of biological resources (Richards, 1976 cited in Finegan, 1984).

The pioneer vegetation on landslides in South Ecuador shows often a high number of species. Fifty six families, 127 genera and 264 species were found on natural landslides, while man-made landslides had 69 plant families, 127 genera and 313 species (Lozano & Bussmann 2005).

Anthropogenic Disturbance and Economical Significance

From an engineer point of view, mountains offer very difficult conditions for road construction and maintenance (Young 1994). Because road maintenance is politically unattractive compared to the establishment of new roads, minimal efforts are made to maintain existing infrastructure. The socio-economical expenses after "landslides" triggered by road construction have been studied in St. Vincent, St. Lucia and Dominica, where the average annual cost for landslide damage to roads range from $115,000 to $121,000 in normal years (De Graff *et al*. 1989). The average annual cost of landslide investigation, repair and maintenance in the larger islands of Trinidad and Tobago are $1,26 millions and $0,96 millions, respectively. In an average year the cost of repairing landslide damage to roads throughout the Caribbean amounts to $15 million. Ericksen et al. (1989), indicate that in the central and southern Andes the average annual property damage is on the order of few millions to several tens of millions of dollars. Major landslides, which occur at 5- to 10-year intervals, may however cause property damage of hundreds of millions of dollars, in addition to personal insurance claims involved.

Stern (1992) describes how earthquakes caused a nationwide socio-economic tragedy and environmental disaster on Mach 5, 1987 in Northeastern Ecuador. Thousands of human lives and countless homes were lost in the aftermath of landslide and floods, Chávez and Lara (1989) estimate 400000000 m3 of debris material and Figueroa et al. (1987) reported up to 6000000000 m3 of landslide-related silt and debris was deposited in and transported downstream by the Aguarico and Coca rivers. Thirty-three km of the trans-Ecuadorian oil pipeline and 45 km of the natural gas pipeline were destroyed, and it took eight month repair the damage. Benitez (1989) reports that a landslide near Chunchi 1983 blocked the Pan American Highway, seriously damaged homes, and a loss of 150 lives was the final result of this tragedy. The social economic impact related to cattle-raising and agriculture activities, without considering life insurance claims, exceed $4 millions on the past decade. In southern Ecuador "landslides" continuously damage roads, especially on the way to Zamora and Valladolid. This has led to serious disasters and large economical expenses.

Conclusions

Landslides at the Ecuadorian Andes are wide-spread, because of unstable slopes combined with environmental conditions as well as inappropriate road construction and other anthropogenic factors. Millions of dollars have been expended during the lasts decades in the mitigation of landslides hazards in Ecuador alone. The disturbance of watersheds still continues, without any mitigation plan or conservation measures, and no strategies for forest preservation and restoration are included in the national policy.

In cloud forests succession of gaps starts with a slow cover of mosses and other cryptogams, followed by herbs, shrubs and trees arriving in the final stages. Many mountain plant species are restricted to narrow and specific elevation ranges. The species richness in southern Ecuador indicates high amount of pioneer plants in regeneration. It is however still not sufficiently understood if perturbations act as a motor for the maintenance of biodiversity.

Fragmentation by natural and anthropogenic disturbance regimens, especially landslides in the Ecuadorian Andes, seems usually to be linked to legal and economical factors. Policy evaluations need to include criteria such as social requirements, and tools of environmental management must be applied to a constant landslide mitigation plan effort maintain biodiversity.

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Species diversity in Bhitarkanika Mangove ecosystem in Orissa, India

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Species diversity in Bhitarkanika Mangove ecosystem in Orissa, India

Mangroves forests serve as ecotones between land and sea and elements from both are stratified horizontally and vertically, between the forest canopy and subsurface soil. In India, mangroves occur in two groups, the mangroves of the West coast and those of the East coast. The present study is an effort to collect ecological information by carrying out field studies based on phytosociological methods at four forest sites in Mangrove Ecosystems of Orissa coast. 16 species were recorded from 11 families at Thakurdia site. The Dangmal forest block encompasses a total of 20 tree species belonging to 14 families at Dangmal, 24 tree species belonging to 13 families at Bhitarkanika and 17 tree species from 10 families at Kakranasi forest sites. The Bhitarkanika site has the highest number of species among all the 4 study sites. This block along with Dangmal is also designated as the core area of the Bhitarkanika wildlife sanctuary. Number of plants/ha was recorded higher in the Thakurdia and Kakranasi sites than the Dangmal and Bhitarkanika sites. Excoecaria agallocha, Ceriops decandra, Avicennia officinalis, and Sonneratia caeseolaris exhibited highest number of plants /ha in Thakurdiha and Kakranasi and Heritiera fomes, E. agallocha and Cynometra ramiflora in the Dangmal and Bhitarkanika sites. H. fomes E. agallocha and C. ramiflora make up 84 % of the total number of plants/ha in the Dangmal forest block. In Bhitarkanika H. fomes (42. 05 %) exhibited highest density/ha followed by E. agallocha (24. 18 %), and C. ramiflora (10. 36 %) and these three speciestogether accounted for 77 % of the total number of plants/ha. In the Thakurdia block, E. agallocha and C. decandra represented 36.13 % and 26.24 %, respectively.It is observed that the classification usually done for terrestrial forests (Misra, 1968) to determine seedlings, trees etc. does not apply to mangroves and a large number of individuals in the mangrove forest belong to the DBH category of 2.5- 5 cm. H. fomes and E. agallocha have maximum basal area in the Dangmal and Bhitarkanika sites and Thakurdia and Kakranasi forest sites respectively. In the Dangmal forest block, H. fomes E. agallocha and A. officinalis. constitute 81 % of the basal area. In the Bhitarkanika forest block, H. fomes A. officinalis, E. agallocha, and Sonneratia apetala accounted for 78 % of the total basal area. In Thakurdia and Kakranasi blocks, E. agallocha, L. racemosa, C. decandra, and H. fomes accounted for 74 -75 % of the total basal area. It is observed that most of the characteristics of Orissa mangroves of India are not similar to other riverine mangroves of the world. The Orissa mangroves are of low height having less basal area and higher number of species compared to the mangroves of Mexico and Costa Rica. The riverine mangrove forests of Florida surprisingly have similar values of height and the basal area as in the forest of the present study.

Introduction

Mangrove forests, dominated by estuarine trees serve as ecotones between land and sea and elements from both are stratified horizontally and vertically, between the forest canopy and subsurface soil (Rao & Deshmukh, 1994). Mangrove has been defined as "any woody, tropical halophyte that is an obligate inhabitant of 'mangal' (wetland community) (Tomlinson ,1986). The word mangrove has traditionally been used to describe either the total community or the individual tree/ bushes, growing in the clayey, silty, inter-tidal coastal zones, deltaic and estuarine coasts and backwaters/ sheltered regions, in the tropical/subtropical belts of the world (Nayak & Bahuguna, 2001). Mangroves can often survive non- saline habitats (Cintron & Schaeffer-Novelli, 1983; Walsh, 1974). However, according to Lugo (1980), a saline environment is required for stable mangrove ecosystems. About 54-70 species (including hybrids) in 20-27 genera and 16-19 families fit comfortably into this broad category (Tomlinson, 1986; Cronquist, 1981; Duke, 1992). Mangrove areas have wide range of families, including ferns, grasses, sedges, palms and legumes.Mangroves grow throughout the tropics wherever the average monthly minimum temperature is 200 C (Chapman, 1976)and are believed to be limited in their subtropical distribution by lack of low temperature resistance (Dodd et al. 1995). Between 250 N and 250 S, mangroves colonize almost 75 % of the coastline (Day et al., 1987) although they only represent 1 % (100000 km2) of the area of tropical forest are quite productive (350 to 500 gram C m-2 yr-1) (Mann, 1982). Mangroves may show strong, weak or no spatial zonation (Tomlinson, 1986; Ellison et. al., 2000), although the abundance of individual species may follow the gradient of salinity (Helalsiddiqui, 1999). Mangroves prefer a salinity range of 5- 30 parts per thousand.

The ecological importance of these ecosystems for maintaining marine life was stressed by Upadhyay et al. (2002); Fromard et al. (1998); Odum & Heald (1975). Studies have demonstrated their role in supplying organic material to coastal marine ecosystems (Odum & Heald, 1972; Lugo et al. 1980; Boto & Bunt, 1981; Rojas-Beltran, 1986; Hutching & Saengar, 1987). Mangrove ecosystems are being studied with more interest worldwide because of their economic importance in support of commercial fisheries alone (Cintron et al. 1980). Uses and values of mangroves are many and varied. For example, they provide habitat as well as spawning and nursery ground for various marine species (fish, shellfish, crustaceans etc), enrich the near-shore environment, act as windbreakers and protects the shoreline from storms, stabilize the shoreline, and decrease coastal erosion (Nayak & Bahuguna, 2001).

Out of 4,87,100 ha. of mangrove wetlands in India, nearly 56. 7 % (2,75,800 ha.) is present along the east coast, 23. 5 % (1,14,700 ha.) along the west coast, and the remaining 19.8 % (96,600 ha.) is found in the Andaman and Nicobar islands (FSI,1999),. Mangroves in the densely populated East Coast of India have been degraded for decades and are still continuing to be degraded due to loss of biomass, species composition simplification mainly due to overgrazing, fuel wood extraction and conversions (Blasco & Aizpuru, 2002).

Mangroves are spread over an area of 214 sq. km (FSI, 1999) in Orissa. The assessment has indicated an increase of 20 sq. Km (FSI, 1997, 1999) in Bhadrak and Kendrapara districts. Although the overall assessment shows an increase, several areas have shown marked decrease in quality and quantity of the vegetation cover. Causes for degradation of mangroves in Orissa are, shoreline changes, settlements, conversion for agriculture and aqua culture (Upadhyay et al. 2002). Recent researches carried out on biosystematics of mangrove phanerogams (Dodd et. al. 1995; Duke, 1995; Tomlinson, 1986); on biogeography (Saengar, 1996); ecology (Snedaker, 1995) and distribution (Spalding et al. 1997) can be considered as being of direct interest to the knowledge of the mangroves of India (Blasco & Aizpuru, 1997). Taxonomical works on mangroves have been done by Banerjee et al. (1989), Banerjee (1984, 1987); Banerjee & Rao (1990); Choudhury (1984, 1990); Choudhury et al. (1991, 1995); Majumdar & Banerjee (1985); Mishra & Panigrahi (1987).The present paper highlights ecological structures of mangroves ecosystem of Orissa coast based on phytosociological studies.

The Study Site

The state of Orissa has a geographical area of 155707 sq. km with an actual forest cover of 47107 sq. km. (30.3 %). Area under Mangrove forests is 195 sq. km which comes to 0.125 % of geographical area and 0.414 % of actual forest cover (Daniels & Acharjyo, 1997). The study site located at 200 4'- 200 8' N Latitude and 860 45'- 870 5' E Longitude, in the north-eastern coastal plain of Kendrapara district in Orissa is in Bhitarkanika sanctuary. Total area of sanctuary is 672 Sq. km of which mangrove forests constitute 130 sq. km. This area receives water from three rivers, known to be rich in species diversity and trees are dense and tall like those of Sunderbans (Selvam, 2003). Four forest blocks in the Bhitarkanika wildlife sanctuary were selected for carrying out vegetation survey. The area of Bhitarkanika forest block is 1712 ha., Dangmal 636 ha., Kakranasi 310 ha., and Thakurdia 272 ha. (Chadha & Kar, 1999). Bhitarkanika and Dangmal Bocks constitute the core area. These sites experience tide of semi diurnal type. The mean sea level in the region is about 1. 66 meters. The Bhitarkanika sanctuary is bounded by river Dhamra in the north, the river Hansua to the west and Bay of Bengal on the eastern and southern sides. The sanctuary encompasses 35 km sea coast known as 'Gahirmatha Coast' from Dhamra mouth to Barunei, the mouth of river Hansua. The area has about 200 km. of water body inside the sanctuaryand falls in the deltaic region of the river Brahmani, Baitarani, and their tributaries. The estuarine rivers- Brahmani, Baitarani, Kharasrota, Dhamra, Pathasala, Maipura, Hansua, and Hansina during their course flow into the Bay of Bengal are further criss crossed by numerous creeks, channels, and nallahs, thus providing the peculiar ecological niche for the growth, development of rich and varied mangrove life forms, both flora and fauna along with their associates. There are many villages within the sanctuary as well as surrounding it. The population in these villages has been growing very fast. Part of the population rise is because of the heavy influx of refugees from East Bengal and West Bengal and habitations are reported to have been started by clearing mangrove forests. A total of 81 villages are adjacent to the mangrove forests. The population increase is attributed as one of the reasons for decreasing mangrove of the area.

Climate

The region comes under the tropical monsoon climate with three pronounced seasons: winter (October to January), summer (February to May) and rainy (June to September). The maximum temperature is recorded in the month of April and May and the minimum temperature in winter during the month of January. The relative humidity ranges from 70% to 84% through out the year. Wind speed from March to June is over 20 km. per hour, and the predominant wind direction is from south and south-west. Rainfall is around 1642.34 cm per annum and maximum rainfall is received between June and October. The most important weather phenomenon is the prevalence of tropical cyclones. The mean track of the cyclone passes over this region (Singh & Panda, 1999). Rainfall conditions decide the sequence of mangrove distribution in the different zones in the tidal region. A successive tidal flood inundates the land surface and the subsequent exposure of the soil substratum evaporates the water. This result in thick salt crust on the soil surface and these salt crusts inhibit or limit the regeneration and growth of the mangroves. Frequent rainwater flushing helps in washing off the surface and leaching down the salt particles and makes the land suitable for growth of mangroves. Tidal amplitude in the Baunsagada River ranges from 1.5 to 2.5 meters in summer months to 3 to 5 meters during monsoon months. In the Bhitarkanika River, and especially in creeks such as Khola (which receives tidal water from both ends) tidal amplitude reaches 3- 4 meters in summer months to 5-6 meters during rainy season.

Soils and Geology

The soil sediments are divided into two categories, indicating recent or sub-recent forms named as ’newer alluvium’ and Pleistocene forms named as ’older alluvium’ (GSI, 1974). The recent sediments are represented by sand, silt, and clay with assorted boulders and pebbles. These are dark and loosely compacted with high moisture content. The Pleistocene deposits comprise of clay, sand, silt, and ’kankar’, with locally cemented pebbles and gravels. These are reddish brown due to high degree of oxidation (Banerjee & Rao, 1990).

Methods

Phytosociological Analysis in four forest blocks was carried out by quadrat method following Misra (1968), Kershaw (1973), Cintron and Schaefer-Novelli (1984) and Snedaker & Snedaker (1984). Thirty quadrats of 10m X 10 m size were laid out at each site. Each site was divided into 6 segments of 1 km each along tidal line from the riverbank. A line transect was laid towards landward side from the water line. In each segment, 6 quadrats of 10 m X 10 m size were laid at 0, 50, 100, 150, 200 and 250 meter interval towards the land ward side for phytosociological analysis. 120 quadrats were laid in four forest blocks to study forest structure (trees). On the basis of data obtained from quadrat samples, the structural parameters like frequency, abundance, density, basal area, and IVI were calculated (Tables 1a-d).

Results and Discussion

Vegetation Analysis

The Bhitarkanika forest block contains highest number of tree species followed by Dangmal, Kakranasi and Thakurdia blocks. Bhitarkanika and Dangmal are part of core area of the Bhitarkanika wildlife sanctuary. Availability of fresh water through Bhitarkanika (Maipura river) and Brahmani rivers and saline water from sea in core area help wide range of niches for different species to occur and, thus, species diversity is the highest. Table 1 provides details on structural parameters of vegetation of study sites. *H. fomes* and *E. agallocha* exhibited greater density, frequency and IVI values across all sites. The species with lower density and IVI are different from one site to the other. All the species show contagious distribution. A/F ratio range in Dangmal block is proportionately less wide compared to other blocks. According to Odum (1971) contagious distribution is commonest in nature, random distribution is found only in very uniform environment and regular distribution occurs where severe competition exists between individuals.

Table1.A : Phytosociological Parameters of Dangmal Block

Sl. No.	Species	Density	% Frequency	Abundance	Abundance/ Frequency Ratio*	Relative Density	Relative Frequency	Relative Dominance	I.V.I
1	*E. agallocha*	15.7	100	15.70	0.16	21.83	19.35	15.36	56.54
2	*H. fomes*	32.7	100	32.70	0.33	45.46	19.35	56.98	121.80
3	*C. ramiflora*	12	56.67	21.18	0.37	16.68	10.97	4.91	32.56
4	*P. paludosa*	0.7	20	3.50	0.18	0.97	3.87	0.50	5.35
5	*H. tiliaceous*	2.6	40	6.50	0.16	3.61	7.74	1.49	12.85
6	*P. pinnata*	1.8	30	6.00	0.20	2.50	5.81	3.95	12.26
7	*A. officinalis*	0.8	20	4.00	0.20	1.11	3.87	8.67	13.65
8	*S. apetala*	0.5	10	5.00	0.50	0.70	1.94	2.43	5.06
9	*K. candel*	0.27	10	2.67	0.27	0.37	1.94	0.17	2.47
10	*A. cucullata*	0.4	13.33	3.00	0.23	0.56	2.58	0.89	4.03
11	*R. mucronata*	0.4	20	2.00	0.10	0.56	3.87	0.57	5.00
12	*H. littoralis*	0.47	16.67	2.80	0.17	0.65	3.23	0.96	4.83
13	*C. manghas*	0.17	6.67	2.50	0.38	0.23	1.29	0.31	1.83
14	*X. granatum*	0.37	10	3.67	0.37	0.51	1.94	0.75	3.20
15	*A. corniculatum*	1.77	20	8.83	0.44	2.46	3.87	0.55	6.87
16	*B. gymnorrhiza*	0.7	16.67	4.20	0.25	0.97	3.23	1.14	5.34
17	*T. troupii*	0.2	6.67	3.00	0.45	0.28	1.29	0.11	1.68
18	*C. decandra*	0.3	10	3.00	0.30	0.42	1.94	0.11	2.46
19	*X. molluccensis*	0.03	3.33	1.00	0.30	0.05	0.65	0.08	0.77
20	*B. tersa*	0.07	6.67	1.00	0.15	0.09	1.29	0.07	1.45
	Total	**71.93**	**516.67**	**132.25**	**5.49**	**100.00**	**100**	**100**	**300**

* A/F Ratio- below 0.025- regular distribution/ between 0.025 to 0.05- random distribution/ More than 0.05- contagious distribution

Table 1A. Phytosociological parameters of Dangmal Block

Table 1B: Phytosociological Parameters in Bhitarkanika Block

SL No.	Species	Density	% Frequency	Abundance	Abundance/ Frequency Ratio	Relative Density	Relative Frequency	Relative Dominance	I.V.I
1	*A. officinalis*	1.97	36.67	5.36	0.15	2.68	6.59	18.25	27.51
2	*H. fomes*	30.83	100	30.83	0.31	42.05	17.96	35.46	95.47
3	*E. agallocha*	17.73	90.00	19.70	0.22	24.18	16.17	14.14	54.49
4	*S. apetala*	2.37	36.67	6.45	0.18	3.23	6.59	10.59	20.40
5	*P. pinnata*	0.67	20	3.33	0.17	0.91	3.59	3.11	7.61
6	*I. bijuga*	0.27	13.33	2.00	0.15	0.36	2.40	0.82	3.58
7	*A. corniculatum*	3.63	26.67	13.63	0.51	4.95	4.79	0.97	10.71
8	*C. ramiflora*	7.6	43.33	17.54	0.40	10.36	7.78	3.00	21.15
9	*A. cucullata*	1.23	16.67	7.40	0.44	1.68	2.99	2.98	7.66
10	*X. granatum*	0.73	23.33	3.14	0.13	1.00	4.19	1.83	7.02
11	*S. caeseolaris*	0.73	10	7.33	0.73	1.00	1.80	1.21	4.00
12	*R. mucronata*	0.63	20.00	3.17	0.16	0.86	3.59	1.96	6.41
13	*K. candel*	0.53	16.67	3.20	0.19	0.73	2.99	0.57	4.29
14	*C. manghas*	0.43	13.33	3.25	0.24	0.59	2.40	1.33	4.32
15	*C. decandra*	1.03	23.33	4.43	0.19	1.41	4.19	0.24	5.84
16	*A. alba*	0.1	3.33	3.00	0.90	0.14	0.60	0.83	1.57
17	*T. populnea*	0.1	3.33	3.00	0.90	0.14	0.60	0.08	0.82
18	*X. molluccensis*	0.4	3.33	4.00	1.20	0.55	1.80	0.95	3.29
19	*B. gymnorrhiza*	0.6	6.67	9.00	1.35	0.82	1.20	0.32	2.33
20	*R. apiculata*	0.20	3.33	6.00	1.80	0.27	0.60	0.18	1.05
21	*H. tiliaceous*	0.83	16.67	5.00	0.30	1.14	2.99	0.59	4.72
22	*X. mekongensis*	0.33	10.00	3.33	0.33	0.45	1.80	0.39	2.64
23	*B. tersa*	0.13	667.00	2.00	0.30	0.18	1.20	0.06	1.44
24	*P. paludosa*	0.23	6.67	3.50	0.53	0.32	1.20	0.15	1.67
	Total	**73.33**	**550.00**	**169.61**	**11.7**	**100.00**	**100**	**100**	**300**

* A/F Ratio- below 0.025- regular distribution/ between 0.025 to 0.05- random distribution/ More than 0.05- contagious distribution

Table 1B. Phytosociological parameters of Phitarkanika Block

Table 1C: Phytosociological Parameters in Thakurdia Block

SL No.	Species	Density	% Frequency	Abundance	Abundance/ Frequency Ratio	Relative Density	Relative Frequency	Relative Dominance	I.V.I
1	*H. fomes*	8.33	43.33	19.23	0.44	5.17	10.74	6.22	22.13
2	*E. agallocha*	58.20	83.33	69.84	0.84	36.13	20.66	37.17	93.95
3	*C. decandra*	42.27	80.00	52.83	0.66	26.24	19.83	10.83	56.90
4	*P. paludosa*	1.60	16.67	9.60	0.58	0.99	4.13	0.76	5.89
5	*A. alba*	7.27	30.00	24.22	0.81	4.51	7.44	7.78	19.73
6	*A. officinalis*	0.50	13.33	3.75	0.28	0.31	3.31	1.72	5.34
7	*R. mucronata*	0.30	6.67	4.50	0.68	0.19	1.65	0.79	2.63
8	*T. populnea*	0.17	10.00	1.67	0.17	0.10	2.48	0.21	2.80
9	*A. rotundifolia*	2.03	30.00	6.78	0.23	1.26	7.44	2.31	11.01
10	*L. racemosa*	18.77	33.33	56.30	1.69	11.65	8.26	19.69	39.61
11	*X. granatum*	0.1	3.33	3.00	0.90	0.06	0.83	0.21	1.10
12	*A. corniculatum*	18.70	26.67	70.13	2.63	11.61	6.61	6.91	25.13
13	*S. caeseolaris*	0.17	6.67	2.50	0.38	0.10	1.65	0.83	2.59
14	*A. marina*	2.47	10.00	24.67	2.47	1.53	2.48	4.11	8.12
15	*S. apetala*	0.13	3.33	4.00	1.20	0.08	0.83	0.41	1.32
16	*K. candel*	0.10	6.67	1.50	0.23	0.06	1.65	0.04	1.76
	Total	**161.10**	**403.33**	**354.52**	**14.19**	**100.00**	**100.00**	**100.00**	**300.00**

* A/F Ratio- below 0.025- regular distribution/ between 0.025 to 0.05- random distribution/ More than 0.05- contagious distribution

Table 1C. Phytosociological parameters of Thakurdia Block

Table.1D: Phytosociological Parameters in Kakranasi Block

Sl. No.	Species	Density	% Frequency	Abundance	Abundance/ Frequency Ratio	Relative Density	Relative Frequency	Relative Dominance	I.V.I
1	*A. alba*	9.7	30	32.33	1.08	7.16	7.38	7.15	21.69
2	*C. decandra*	37.53	70	53.62	0.77	27.70	17.21	14.50	59.41
3	*A corniculatum*	1.5	13.33	11.25	0.84	1.11	3.28	0.44	4.83
4	*H. fomes*	8.67	53.33	16.25	0.30	6.40	13.11	7.68	27.19
5	*A. rotundifolia*	1.07	26.67	4.00	0.15	0.79	6.56	1.35	8.70
6	*S. caseolaris*	10.13	30	33.78	1.13	7.48	7.38	12.85	27.70
7	*A. officinalis*	12.13	56.67	21.41	0.38	8.95	13.93	14.46	37.35
8	*L. racemosa*	1.5	13.33	11.25	0.84	1.11	3.28	1.06	5.44
9	*E. agallocha*	51.93	66.67	77.90	1.17	38.33	16.39	38.20	92.92
10	*X. granatum*	0.13	10.00	1.33	0.13	0.10	2.46	0.40	2.96
11	*R. apiculata*	0.1	6.67	1.50	0.23	0.07	1.64	0.67	2.38
12	*T. populnea*	0.07	3.33	2.00	0.60	0.05	0.82	0.10	0.97
13	*X. mekongensis*	0.10	3.33	3.00	0.90	0.07	0.82	0.26	1.16
14	*R. mucronata*	0.40	6.67	6.00	0.90	0.30	1.64	0.37	2.31
15	*H. tiliaceous*	0.30	6.67	4.50	0.68	0.22	1.64	0.19	2.05
16	*B. gymnorrhiza*	0.07	6.67	1.00	0.15	0.05	1.64	0.13	1.81
17	*S. apetala*	0.17	3.33	5.00	1.50	0.12	0.82	0.19	1.13
	Total	**135.5**	**406.67**	**286.13**	**11.74**	**100.00**	**100**	**100**	**300**

* A/F Ratio- below 0.025- regular distribution/ between 0.025 to 0.05- random distribution/ More than 0.05- contagious distribution

Table 1D. Phytosociological parameters of Kakranasi Block

From list of species encountered through quadrat surveys of trees and seedlings (Table 2), it is observed that the family Rhizophoraceae and Meliaceae represented maximum number of species followed by Avicenniaceae. Bhitarkanika is the most species rich site with 24 species and Thakurdia has the lowest species number with 16 species (Table 3). Bhitarkanika has the highest mean species value per quadrat (5.56 species per quadrat). The average value for all the forest blocks is 4.69 species per quadrat. Ellison (2002) established a correlation between latitude and longitude and species richness and observed that the species richness is higher (> 30 to 55 species) between 0 and 200 N lat and at 70 and 1350 E long. Species richness is highest in the Indo West Pacific and declines relatively smoothly from 1000 E which is the longitude of peak species richness (Ellison et al. 1999).

Table 2. Mangrove and associated species in the study area

Sl No	Species encountered through quadrat survey	Species encountered through seedling survey	Other species encountered during survey
	Dicotyledons		
1	**Acanthaceae**		
		Acanthus ilicifolius	
2	**Aizoaceae**		
		Sesuvium portulacastrum	
3	**Apocynaceae**		
	Cerbera manghas	*Cerbera manghas*	

4	**Avicenniaceae**		
	Avicennia alba		
	Avicennia officinalis	*Avicennia officinalis*	
	Avicennia marina		
5	**Caesalpiniaceae**		
		Caesalpinia crista	
	Cynometra ramiflora	*Cynometra ramiflora*	
	Intsia bijuga	*Intsia bijuga*	
6	**Chenopodiaceae**		
			Salicornia brachiata
			S. maritima
7	**Combretaceae**		
	Lumnitzera racemosa		
8	**Euphorbiaceae**		
	Excoecaria agallocha	*Excoecaria agallocha*	
9	**Malvaceae**		
	Thespesia populnea	*Thespesia populnea*	
	Hibiscus tiliaceous	*Hibiscus tiliaceous*	
10	**Meliaceae**		
	Amoora cucullata		
	Xylocarpus granatum	*Xylocarpus granatum*	
	Xylocarpus mekongensis	*Xylocarpus mekongensis*	
	Xylocarpus molluccensis	*Xylocarpus molluccensis*	
11	**Myrsinaceae**		
	Aegiceras corniculatum	*Aegiceras corniculatum*	
12	**Papilonaceae**		
		Dalbergia spinosa	
	Pongamia pinnata	*Pongamia pinnata*	
13	**Peripocaceae**		
			Finlaysonia obovata
14	**Plumbaginaceae**		

	Aegialitis rotundifolia		
15	**Rhizophoraceae**		
	Bruguiera gymnorrhiza	*Bruguiera gymnorrhiza*	
	Ceriops decandra	*Ceriops decandra*	
	Kandelia candel	*Kandelia candel*	
	Rhizophora apiculata	*Rhizophora apiculata*	
16	**Rutaceae**		
			Merope angulata
17	**Salvadoraceae**		
			Salvadora persica
18	**Sonneratiaceae**		
	Sonneratia apetala	*Sonneratia apetala*	
	Sonneratia caeseolaris	*Sonneratia caeseolaris*	
19	**Sterculiaceae**		
	Heritiera fomes	*Heritiera fomes*	
	Heritiera littoralis	*Heritiera littoralis*	
20	**Tamaricaceae**		
	Tamarix troupii	*Tamarix troupii*	
21	**Tiliaceae**		
	Brownlowia tersa	*Brownlowia tersa*	
22	**Verbenaceae**		
			Clerodendrum inerme
	Monocotyledons		
23	Arecaceae		
	Phoenix paludosa	*Phoenix paludosa*	
24	**Flagellariaceae**		
			Flagellaria indica
25	**Poaceae**		
		Myriostachya wighitiana	
		Porteresia coarctata	
26	**Polypodiaceae**		

	(fern)	*Acrostichum aurum*	

A total of 22 families of Dicotyledons and 4 families of Monocotyledons were represented across all sites in Bhitarkanika Mangrove ecosystem. A total of 43 species of mangrove and associated plants belonging to 32 genera were recorded from 26 families of Angiosperms. The flora is extremely diverse in the estuarine regions of Bhitarkanika, (Banerjee & Rao 1985, 1990).Abundance of phanerogams is presumably higher than that of the Sunderbans Gangetic delta. Though the factors influencing biodiversity and floristic richness in each deltaic region is not fully understood (Duke et al. 1998), the assumption is that the propagules originated in the Sunderbans are water buoyant and dispersed to the nearest deltaic area which is the mouth of the Mahanadi river. This could explain the high degrees of relationship between the flora of the Gangetic and the Mahanadi deltas (Blasco & Aizpuru, 2002). *H. fomes, Sonneratia. griffithii and Aegialitis rotundifolia* Roxb. are endemic to the coastal part of South Asia (Blasco et al. 2001) and later two species are not recorded during the study.

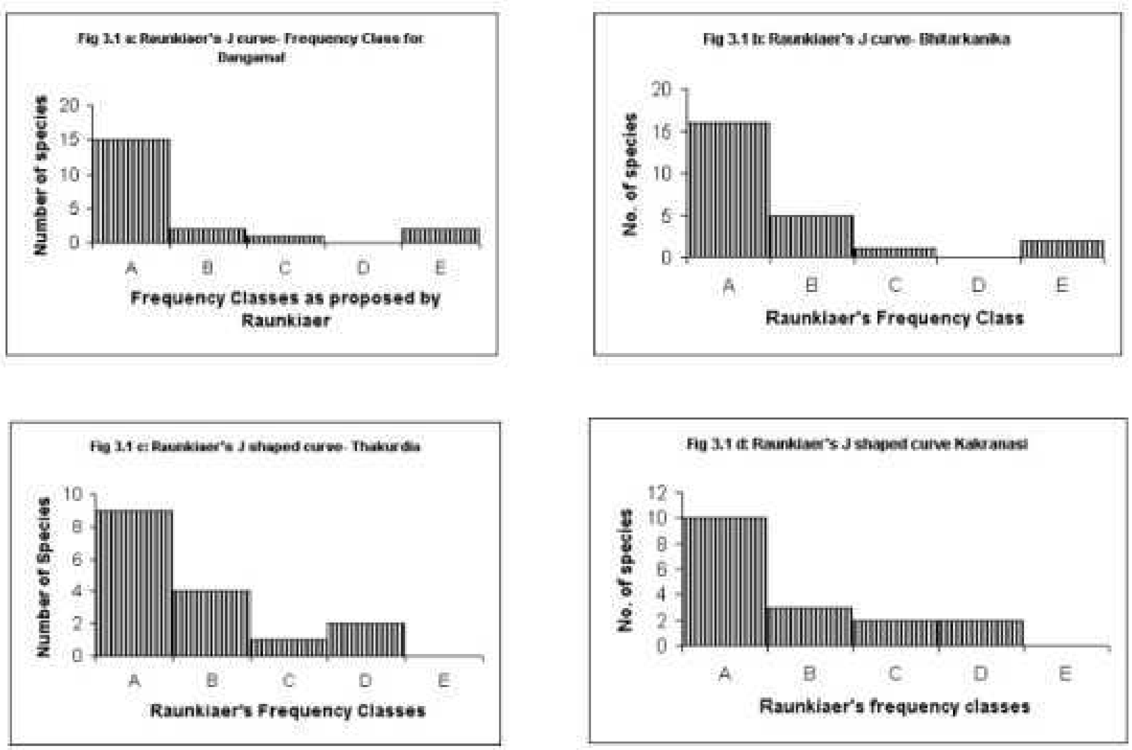
Table 3. Number of species/ mean number of species per quadrat at various sites

Forest Block	Total number of species	Mean Number of tree species per Quadrat (± SE)
Dangmal	20	5.16 ± 0.23
Bhitarkanika	24	5.56 ± 0.27
Thakurdia	16	4.03 ± 0.22
Kakranasi	17	4.06 ± 0.18

Table 3. Number of species / mean number of species at various quardat sites

Raunkiaer's Frequency Class Distribution

Raunkiaer's Law of Frequency (in graphical form referred to as Raunkiaer's J shaped distribution curves) was studied (Raunkiaer, 1934). The law (also known as the law of homogeneity) was expressed as A> B > C ≤≥D E, wherein, A to E are frequency classes suggested by Raunkiaer's from 0 to 100. According to Kershaw (1973), "the increase in class E reflects the theoretical infinite range of density and contrasts with the more strictly defined limits for classes A, B, C, and D. This E class has a density range greatly exceeding frequency classes A to D. Accordingly many more species fall into this class, despite the general tendency for 'common' species to be relatively few in number in a community"(Fig.1).



Raunkiear's Frequency classes for the study sites

Species Diversity

The species diversity depends upon adaptation of species and increases with stability of community (Singh et al, 1994). Species diversity was 0.72, 0.82, 0.75, 0.73, respectively, in Dangmal, Bhitarkanika, Thakurdia, and Kakranasi blocks. The above data indicate that Bhitarkanika site is highly diverse and Dangmal the least. The Concentration of Dominance was 0.28, 0.25, 0.23, 0.24, respectively, in Dangmal, Bhitarkanika, Thakurdia, and Kakranasi indicating the dominance is more pronounced in Dangmal block (Table 4). The Dangmal and Kakranasi blocks exhibited least similarity in species composition (59.46 %) with each other followed by Thakurdia and Bhitarkanika (65 %), Thakurdia and Kakranasi (78.79 %), and Bhitarkanika and Dangmal blocks (86.36%) (Table 5). The latter two sites are adjacent to each other and thereby there is a great deal of species mix. In the Eastern hemisphere number of mangrove species reported by Tomlinson (1986) and Duke (1992) are 58 compared to only 12 in Western hemisphere. High mangrove diversity in South East Asian region is because it has been the center of origin of mangrove speciation. There is presence of adjacent diverse terrestrial flora which has enabled diversity to increase and prevented extinctions (Ricklefs & Latham, 1993). Duke et al. (1998) found the Indo-Malaysia region with most mangrove species number with 48 species.

Table 4. Species diversity and Concentration of dominance in the study area

Forest Block	Species Diversity	Concentration of Dominance
Dangmal	0.72	0.28
Bhitarkanika	0.82	0.25
Thakurdia	0.75	0.23
Kakranasi	0.73	0.24

Table 4. Species diversity and concentration of dominance in the study area

Table 5. Similarity Index in species composition among study sites

	Dangmal	Bhitarkanika	Thakurdia	Kakranasi
Dangmal	100			
Bhitarkanika	86.36	100		
Thakurdia	61.11	65	100	
Kakranasi	59.46	73.17	78.79	100

Table 5.Similarity index in species composition between study sites

Table 6. Total forest block wise (for all the species together) Basal Area and number of plants at study sites (per Hectare)

Forest Block	Total Basal Area (m^2 per hectare)	Total number of plants per hectare
Dangmal	24.37	7186
Bhitarkanika	37.04	7326
Thakurdia	21.69	16094
Kakranasi	23.87	13536
Average for the area	**26.74**	**11036**

Table 6. Total Basal Area and number of species per study site

The species diversity is higher in the India mangrove ecosystems compared to that of Latin America and Africa. Large physical forces in tidewater, salinity level, and lack of stable substratum are some of the natural factors that affect the species diversity (Pathway et al. 2002).Studies on the changes in the species composition for Bhitarkanika are not available like other mangrove areas on the east coast i.e., Sunderbans, Pichavaram and Muthupet, Guava, and Andaman & Nicobar Islands (Kannupandi & Kannan, 1998; Caratini et al., 1973; Mathuda, 1959; Azariah et al. 1992). H. fomes is known to require low soil and water salinities. When the salinity increases, the species becomes stunted, rare, and ultimately disappears. It is known to be 'top dying' (trees shedding their leaves due to stress and could be dying) in parts of Bangladesh(Siddiqi, 1998) and Sunderban because of the increase in dry season demand for freshwater, damming of rivers and apparent downstream effects of increase in soil salinities (Blasco et al. 2001). Therefore, this species is a leading dominant in the mangroves of Bhitarkanika, and thereby confirms to the availability of good ecological conditions that harbours it well. However, caution has to be exercised to see that the preconditions that are now suitable continue to be so. In the mangrove areas of Myanmar H. fomes was available in plenty between the mouth of Mayu and Lamu city about 50 years back and has been completely depleted due to high salinity stress (Blasco, et al. 2001). Others have also reported about die back of Heritiera fomes due to adverse increase in soil salinity (Christensen & Snedaker, 1984; Chaffey et al. 1985). Several authors have worked on phytosociological parameters of Tropical Mangroves. In French Guiana forests Fromard et al. (1998) observed that in mature coastal and adult riverine mangrove sites *Avicennia* exhibited the highest value of IVI (144 - 181) followed by *Rhizophora* species. These mangrove types are more frequent in Guiana and are homogenous and dominated by *A. germinatus*. The mangroves on sea fronts generally have high basal area (24.6 - 33.6 m2 ha-1). The riverine mangrove ecosystems are more diversified and mixed type and richer in species having tree density. However, the species, *H. fomes and E. agallocha* exhibited dominance with high value of IVI followed by *A. officinalis* in the mangroves of Orissa coast at Bhitarkanika.

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Non-timber forest produces utilization, distribution and status in a trekking corridor of Sikkim, india.

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Non-timber forest produces utilization, distribution and status in a trekking corridor of Sikkim, india.

Sikkim Himalaya is endowed with wide variety of non-timber forest produce (NTFP). The ethno-cultural fabrics of this tiny state are rich in traditional practices. As a result, the people living in the Khangchendzonga complex use these natural resources in various ways for their subsistence. The study recorded 94 odd numbers of NTFPs from the area. Above 50% of these species are marketed in the local Hats with a minimum price, which otherwise have good potential in local economy. Overexploitation of NTFP is bringing some visible threat to these species in these areas. About 10% of the total species distribution was found to be a concern for conservation. Some of the high value medicinal plants have potential for value addition as well as domestication. Therefore, a proper strategic plan is needed for conservation of these valuable resources and for sustainable development.

Introduction

The Himalayan chain that stretches from Indus to Bhramaputra valley is a unique storehouse of precious biotic and abiotic reserves (Sahu 1986). It is not only mammoth of cultural symbol but also an important determinant in shaping the economy, milieu and climate (Pant 1980). The Indian Himalayan region endows with bounties of natural and cultural resources evolved and preserved through process of civilization, and contain some of the most restricted and threatened ecological systems on earth (Myers et al. 2000). Most of the spectacular and rugged mountain range of the Himalaya is biologically unexplored, thus the biological diversity of entire Himalaya is not properly known. The Himalaya offers an array of forest types with diversity in forest produce such as medicine, vegetables, nuts, wild edible fruits and decorative as non-timber forest products (NTFPs) from time immemorial. The folk medicinal practices are quite common among the ethno-cultural groups of this region (Biswas 1956). The knowledge of flora and fauna and their value as NTFP is rich among the ethnic groups of this region. During the course of human civilization nearly 3000 plants species have been used as food but only about 150 species have been cultivated (NRC 1982) and less that 10 plant species are meeting over 90% of the world food demand (Wilkes 1981). Many such food resources and valuable plants are still to be explored (Mohan Ram, 2000). In Sikkim alone, about 175 wild edible plants are available and some of them have high potential for their use as food (Sundriyal & Rai 1996, Sundriyal 1999). But many of these species are threatened and in the verge of extinction due to over extraction (Rai et al. 2000) Therefore, exploration and listing of plants and animals with their ethnobiological value are important for knowing and evaluating human-plant relationship, potential for their use in day-to-day life and for proper management (Alcorn 1981a,b; Bye 1979). The present study is based on the extensive survey of NTFPs and their regular monitoring undertaken by the G.B. Pant Institute of Himalayan Environment and Development, Sikkim Unit as a part of Sikkim Biodiversity and Ecotourism Project.

[[Materials and methods]]

Study area

Yuksam-Dzongri trekking corridor (26 km long) encompasses from 1780 m to 4000 m amsl. The trail passes through Sachen, Bakhim and Tshoka in the southwestern part of Khangchendzonga Biosphere Reserve (KBR) in Sikkim, India. Yuksam is a trailhead for this corridor and leads through Tshoka, Dzongri, Thangsing to the Khangchendzonga Base Camp and Gocha La in West Sikkim. Yuksam (1780 m) has 11 settlements with 274 households comprising 1573 number of individuals. One settlement with 8 households resides inside the Khangchendzonga Biosphere Reserve (KBR) at Tshoka (3000 m) along the trail. (Figure1). The area is rich and pristine in its forests resources and treasured with innumerable non timber forest products (Chettri 2000). Different ethnic groups like Subbas, Bhutias, Lepchas, Nepalis and Tibetan Refugees live at the buffer area of the Reserve. NTFPs available in these forests are important alternative to livihood of the local communities. They consist of house construction materials, edible fruits and vegetables, medicinal plants, fiber, broom grass and natural decorative. Due to the mountainous terrain and difficulties in communication, communities living in the area uses large number of plants as foods, vegetables, ingredients for house construction and medicines to cure serious diseases, sprains, cuts and fractures since ancient time. Disturbances such as firewood extraction, fodder lopping and cattle grazing have increased during the last two decades due to growth in tourism and rise in population that has affected natural population of these NTFPs. The present study is an attempt to highlight the traditional knowledge on use of NTFPs and reflect their potentials in local economy.

Methods

The methods employed in this study were designed with the purpose of providing baseline information on the use of plants species in the local systems and their status in the study area. Extensive household level surveys were conducted in 14 villages with structured (preset formats) with queries on names of the non-timber forest products (NTFPs) used in their daily life. In each village at least the 10% of the total households were covered. Special emphasis was also given for survey in the local *hats* (markets) for their market prices. This information was then crosschecked through informal but focus group discussion with the communities, specially the elders and local traditional medicine practitioners. The final list of species was then used in the field surveys to crosscheck their altitudinal distribution and status. The altitudinal distribution of the enlisted species and their population were recorded from systematic survey as part of the other studies made in the same study area (see Singh 2000; Chettri et al. 2002; Chettri et al. 2005)

Results and discussion]]

Ninety-four species of NTFPs were recorded from the survey and crosschecked their distribution and status in the study area. All 94 species were categorized into five major categories. Eight species were found to use for construction purposes; 42 species as wild edibles; 31 species as medicinal purpose, eight species as decorative and five species as fiber and incense (see Appendix). Among these, above 50% were found marketed and majority of them were wild edibles and medicinal herbs.

Construction and local handicrafts

Bamboos (*Dendrocalamus* spp) were widely used by the local inhabitants for construction of houses, bridges and fences other that timber and stone. In Yuksam and Khecheopalri Watershed, there are more than eight varieties of bamboos available. Most of the bamboos are cultivated except a few (*Arundanaria intermedia, A. racemosa, Cephalostachium* sp.) and some bamboos (*A. hookerian, Bambusa nutans*) though cultivated by the local people are also found in community as well as government forests. These bamboos are found scattered in steep slopes of community forests in lower elevations and in reserve forests at higher reaches ranging from 1700 m to 2750m. The economic importance of bamboo is very high as they are widely used in different purposes. Leaves are used as excellent fodder for livestock, stems are extensively used for house construction, handicraft preparation (making mats, baskets, decorative pieces) and young shoots are used as vegetables or used in preparation of pickles.

Edible fruits and other produce

Wild edible plants that are found in the forests and in the private lands offer a variety of fruits to the local people as nutritional diet. These fruits are also a good source of fruit for wildlife and birds. Some of the species such as *Rhus semialata, Litsae citrata* and *Juglan regia* happens to be a good medicinal value. The leaves of *Machilus edulis*, *M. odoratissima*, *Basia butyracea* and *Bauhinia variagata* offer a good fodder for cattle. *Machilus edulis*, *M. odoratissima* have also been seen to rehabilitate drier rocky hilly slopes. There are a number of trees in forests, whose young shoots (*Pentapanax leschenaultii*), leaves (*Girardinia palmate, Urtica dioica*)) and flowers (*Tupistra nutans*) are eaten as vegetables or made pickles. Some of them are also source of medicines that are widely used by the local practitioners. About seven edible varieties of mushrooms were recorded from the area and most of them are found on naturally dead woods during the monsoon season. These mushrooms form a part of delicacies in the food of local people, and are also a good source of nutrition.

There are varieties of *Diplazium* spp. (wild ferns) used as vegetables. These species are mostly found in moist and shady places and available in local market during the monsoon seasons. Many local people even directly collect them from the forest and use them as vegetable. Yuksam-Dzongri forests have a number of dioscoreas, which provide food to people through their yams. Among them, only one species *Dioscorea* sp (Ban Tarul) is available in the private forest of some villages. It is most esteemed among wild yams but difficult to dig. However, pits are dug up to 1.2 m deep to extract the tuber.

Medicinal plants

About 31 species of widely used medicinal plants were recorded from Yuksam, Tshoka, Dzongri and Khecheopalri area. *Artemesia vulgaris, Eupatorium adenophorum* and *Hydrocotyle asiatica* are widely used for different purposes but are not marketed. On the other hand, *Aconitum* sp, *Berginia ligulata*, *Heracleum nepalense*, *Litsae citrata*, *Oroxylum indicum* are openly marketed in the local markets. *Picrorhiza kurrooa, Piper longum, Orchis latifolia, Rubia cordifolia* are even exported to other states through local agents. Most of these species are also use by local practitioner (Bijuwa and Baidya) as herbal medicines. These plants are found in open areas and some in bushy areas of the forests along the altitudinal range of 1600 to 4500 m. At present, they are found in small quantity due to over exploitation in the past.

Natural decorative

Natural forests are source of varieties of attractive natural plants which are used by locals as decorative. Roots of plants, dry flowers, capsules, dry mushrooms, cones of conifers, leaves of fern, fern shoots and seeds of different plant form the decorative of all designs and types. In Yuksam and Khecheopalri more than eight types of such decorative are found, which are mostly used for only local purposes. Dried *Anophalis contorta*, *A. triplinervis* and *Lycopodium clavatum* are widely used as decorative in different occasions whereas *Pollinium mollis* and *Raphidophora* sp are used as decorative in houses. Cones of *Pinus longifolia, Abies densa* and *Tsuga dumosa* are also found to be use as decorative in different forms.

Broom and fiber plants

Broom grass is of great importance in the mountainous region as it provides good quality fodder, fuel, broomsticks and also acts as a soil stabilizer. Recently government had supported its extension through social forestry scheme and the local people are willing to plant this grass as cash crop for broomstick. This grass grow in the sub-tropical Himalayas from plains to 2000 m altitude and are extensively planted in the hills specially in wasteland and also as inter-cropping in agroforestry systems or on the edges of terraces. Some villagers in Yuksam cultivated Amliso (*Thysanolaena maxima*) since last couple of years in some small areas with government incentives. The inflorescence of the broom grass produces the soft broom for cleaning floors. The sticks are used as firewood after drying and the leaves are good fodder. Argeli (*Edgeworthia gardeneri*) and Lokta (*Daphne cannabina*) are widely used by locals for making fibers, papers and also for tying cattle.

Management implications

In Yuksam, Tshoka, Dzongri and Khecheopalri, a considerable number of families use these NTFPs as food, medicine and house construction. These practices play a major role in the local economy of the people and many of these species are use as substituted for the commercial timber, medicine and even food and vegetables. Some of the family members are also involved in selling these items at local markets as a part of their livelihood. Wide variety of edible fruits, vegetables and berries are used as NTFP. These variations have provided additional charm in the biological diversity of the area. Traditional systems of medicine notably Aurvedic and Tibetan practices from NTFPs are extensively used in the day-to-day life by the people in Sikkim Himalaya (Rai & Sharma 1994). A large number of such plants are collected from the wild even from the protected areas. The exploitation of NTFPs from the Yuksam-Dzongri trekking corridor and Khecheopalri Watershed contribute to the biotic impoverishment of the forest through extraction activities, possibly because extractors do not leave enough seed in the forest for further propagation. Field survey revealed that a wide variety of medicinal plants, incense and decorative are collected from higher elevation, which are still in fragile condition. It was also noted that the use of these NTFPs have decreased drastically due to un-availability of resources. The distributions of about 10% of the total species are quite sparse showing rarity (Appendix).

NTFP collecting activities appear to be compatible with conservation only when supported by careful resource management regulations with wide local community participation. Moreover, human pressure on natural resources like firewood, fodder, cattle grazing, tourism and infrastructure development have been increasing since last few decades, resulting threats to the fragile ecosystems of the region (Rai & Sundriyal 1997, Chettri et al 2002). Unless immediate decisive steps are taken to counter the effects of habitat degradation in the remaining wilderness areas, pragmatic assumption foretell that much of the valuable resources will be lost within a few decades. Poor socio-economic condition of people is directly causing to loss of the valuable resources. Collection of NTFPs such as fruits, nuts, oils, resins and medicinal plants in a sustainable manner is an integrated process for development and conservation (Hall & Bawa 1993). But a real economic potential of extractive activities and their compatibility with conservation of biodiversity should be properly known (Sundriyal & Sundriyal 2001). Therefore, participatory planning with the local people for area specific development and provisions for economic incentives to them seems to be a promising effort for conservation of these valuable resources. *Castanopsis* spp., *Machilus edulis*, etc. are all nutritious fruits that can be use as local product. Young shoots (tama) from *Dendrocalamus* spp. *Arundanaria* spp. for preparation of pickles, *Diplazium* and wild mushroom as vegetables have high potential as a part of the menu for the tourists. The area possesses high potential in micro enterprises development for medicinal plants. Market survey revealed that Jatamasi (*Nardostachys jatamasi*), Kutki (*Picrorhiza kurrooa*), Chirata (*Swertia chirata*) and Panch Aunlay (*Orchis latifolia*) have high potential for commercialization. Broom grass (*Thysanolaena maxima*), Bamboo (*Dedrocalamus* spp, *Bambusa* spp, *Arundanaria* spp) cultivations are other means to support local handicraft production that brings economy *vis a vis* control soil erosion. These micro enterprises development can certainly boosts the economy of people if value addition is done to them as being done to some wild plants in other part of the Himalaya (Dhyani & Khali 1993, Maikhuri et al. 1994). However, detailed study of regeneration status and potential in the natural habitat and extraction pressure can bring in understanding in management options.

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[[Appendix]] List of NTFPs with their distribution, status market and uses that were recorded from fringe villages of Khangchendzonga Biosphere Reserve (A = abundant, C = common, D = common but declining, R = rare, MR = marketable, NM = non-marketable, NA = data not available)

Species	Vernacular name	Distribution (m)	Marketable/non marketable	Market rate (Rs)	Uses	Status	Availability
Construction and local handicrafts							
Arundinaria hookeriana Munro	Pareng	1200-2100	MR	40 per bundle Tama 10-15 per kg	Mats, house construction, baskets, young shoots as vegetables etc.	D	Whole year
Arundinaria intermedia Munro	Tite nigalo	1200-2100	MR	40 per bundle Tama 10-15 per kg	Mats, baskets, house construction etc.	C	Whole year
Arundinaria malling Gamble	Maling	1850-2750	MR	40 per bundle	Mats, baskets, fencing, walking sticks, flute etc.	C	Whole year
Bambusa nutans Gamble	Mala bans	300-1550	MR	30/individual	House construction, support for prayer flags by Buddhist	D	Whole year
Cephalostachium sp.	Gopey bans	600-2400	NR	30/individual	Fodder, bow and arrow preparation, flutes and straw for drinking local beer.	R	Whole year
Dendrocalamus hamiltonii Nees & Arn. Ex Munro	Choya bans	Upto 1730	MR	30/individual Tama 10-15 per kg	Water pipes, water vessels, young shoots as vegetables, house construction, local handicrafts, fodder for cattle etc.	C	Whole year
Dendrocalamus hookeri Munro	Chilley bans	Upto 1750	MR	30/individual	House construction, fencings, baskets, etc.	C	Whole year

Dendrocalamus sikkimensis Gamble	Bhalu bans	Upto 1800	MR	30/individual	Water vessel, house construction, local handicrafts etc.	R	Whole year
Edible fruits and other product							
Agapetes serpens (White) Sleumer	Bandare khorsane	1500-2600	NM		Flowers are eaten along with the juice in them	A	February-June
Agaricus silvaticus	Kalunge chew	Upto 1300	MR	40 per kg	Used as vegetables.	C	April-September
Allium wallichii Kunth.	Jungli piyaj	2200-4000	NM		Edible and aromatic	R	June-October
Bassia butyracea Roxb.	Chewri	1200-1775	MR	2 per 5 pieces	Fruits edible, oil is extracted from thee seeds and used. Leaves are good fodder.	R	June-July
Bauhinia variegata L.	Kiorala	Upto 600	NM		Flowers are eaten as curry, good fodder.	R	March-April
Castanopsis hystrix Miq.	Patle katus	1800-2400	MR	15 per kg	Fruits edible, fuelwood, leaves are good ingredients for composts.	A	Feb-April
Castanopsis tribuloides (Smith) A.DC.	Musre katus	1700-2300	MR	60 per kg	Fruits edible, fuelwood, leaves are good ingredients for composts.	C	Feb-April
Cinnamomum impressinervium Meissn.	Sisi	1220-1830	NR		Seeds edible	A	Whole year
Citrullus colocenthus Schrad.	Indrenni	Upto 1900	MR	5 per piece	Fruits edible	D	Jan-March
Dioscorea bulbifera Br.	Ban tarul	Upto 2000	MR	20 per kg	Used as food.	C	Jan-Feb
Diplazium sp.	Sauney ningro	Upto 2000	MR	5 per bundle	Used as vegetables.	C	May-July
Elaeocarpus lanceafolius Roxb.	Bhadrase	1830-2450	MR	18 per kg	Fruits edible	D	April-June
Evodia fraxinifolia Hk.f.	Khanakpa	1200-2100	NM		Fruits used as pickles and as medicine for dysentery	C	Aug-Sep
Ficus infectoria L.	Kabra	Upto 1700	NM		Shoots are edible, good fodder.	C	Feb-March
Myrica gale L.	Kaphal	Upto 1725	MR	NA	Fruits edible, gums and resins are extracted for local use.	R	July-Sep

Girardinia palmate Gand.	Bhangre sisnu	1000-2500	MR	5 per bundle	Young leaves and shoots use as substitute for dal which are good for blood pressure patients.	A	July-Sep
Gaultheria trichophyla Royle		2700-4500	NM		Fruits are eaten by children	A	May-July
Pentapanax leschenaultii Seem.	Chinde	1750-3000	MR	10 per kg	Young shots edible, used as fodder.	D	March-April
Juglans regia L.	Okhar	1000-2000	MR	2 per piece	Fruit edible, bark-anthelminthic and detergent, leaves- astringent and tonic, oil of kernel cures skin diseases etc.	D	April-Sep
Urtica dioica L.	Patle sisnu	Upto 2700	MR	8 per bundle	Young leaves and shoots use as substitute for dal which are good for blood pressure patients.	A	May-Aug
Machilus edulis King.	Lapche kawla	1220-2400	MR	1 per piece	Fruits edible, leaves are good fodder.	C	Nov-Dec
Machilus odoratissima (Nees) Kosterm	Lalikaulo	1500-2150	NM		Fruits edible, leaves are good fodder.	C	Nov-Dec
Mahonia sikkimensis Takeda.	Chutro	1300-2700	NM		Berries edible	A	July-Aug
Pleurotus sp.	Chamrey	NA	NM		Used as vegetables.	C	NA
Pleurotus sp.	Kanney chew	1500-2450	MR	50 per kg	Used as vegetables.	C	Julu-Aug
Prunus nepaulensis (Seringe) Steud.	Arupate	1800-above	NM		Fruits edible, fairly good fodder and fuelwood.	C	March-Aug
Pyrularia edulis A DC.	Amphi	600-1800	MR	NA	Fruits edible, posses wax in kernel and were use this wax for lighting.	D	NA
Pyrus pashia Buch.-Ham. Ex D. Don	Mehel	800-2400	MR	10 per kg	Fruit extracts used for curing blood dysentery	D	Nov-Dec
Quercus sp.	Phalant	1850-2700	NM		Acorns are good food for beer, fuelwood etc.	A	March-May
Quercus sp.	Sungure katus	1830-3000	NM		Nuts edible, bark and acorns used as astringent	D	March-May
Rhus semialata Murr.	Bhakimlo	900-1850	MR	NA	Seeds use as medicine dysentery	A	July-Aug
Rubus ellipticus Smith.	Aselu	1000-2200	MR	40 per kg	Fruits edible	A	March-May

Rubus hypargyrus Edgew.	Kalo aselu		MR	40 per kg	Fruits edible	C	March-May
Spondias axillaries Roxb.	Lapsi	300-1400	MR	20 per kg	Fruits edible, pickles are also prepared.	D	May-Oct
Symplocos theifolia D.Don	Kharanay	1800-3000	NM		In the past, people use to extract oil from the seeds for cooking.	A	July-Aug
Tupistra nutans Wall.	Nakima	1800-3000	MR	60 per kg	Flower are taken as curry	D	Sep-Oct
Utica dioica L.	Gharia sisnu	1000-2500	MR	5 per bundle	Dried plants are use to prepare paste and applied on minor fractures. Leaves and shoots use as substitute for dal.	A	April-July
	Kali ningro	Above 1750	NM		Used dysentery.	C	May-Sep
	Jhari chew	1800-2000	NM		Used as vegetables.	C	May-Sep
	Hieun chew	Above 2500	NM		Used as vegetables.	C	May-Sep
	Katuse chew	Upto 1800	NM		Used as vegetables.	C	May-Sep
	Kalamen uneu	1650-2450	NM		Used as vegetables.	C	May-Sep
Medicinal							
Abies densa Griffith ex R. Parker	Gobrey salla	2550-3700	NM		Leaf extracts use in repeated doses for asthma, bronchitis and stomach trouble.	A	Whole year
Aconitum ferox Wall.	Bikhuma	2100-4000	MR	1350/kg	High medicinal value, use in diaphoretic, diuretic, expectorant, febrifuge, diabetes,	D	July-Sep
Acorus calamus Linn.	Bonjho	1000-2000	MR	NA	Paste prepared from rhizome used in skin diseases, powder taken orally for cough, malaria and asthma	D	Whole year
Artemisia vulgaris Linn.	Titepate	800-2000	NM		Use in different medication as deobstruent, antispasmodic, obstructed menses and hysteria.	A	Whole year

Astilbe rivularis Ham.	Buro okhati	1200-2100	MR	NA	Rhizomes chewed as areca nut and used as pain relief.	D	July-Aug
Bergenia ciliata (Haw.) Stenb.	Pakhan bet	Upto 3000	MR	75 per kg	Roots use in analgesic, tridosha, piles, heart diseases, spleen enlargement and many other diseases.	D	Whole year
Bergenia purpurascens (Hook. F. & Thoms.) Engl.	Khokim	3400-4200	NM		Dried roots use in as substitute for tea and believe to give relief from body ache.		
Clematis buchananiana DC.	Pinasay lahara	1800-2800	NM		Fresh roots are mashed and the effluvium is drawn through nose to cure sinusitis and nose-blocks.	D	Whole year
Dichroa febrifuga Lour.	Basak	900-2400	NM		Dried leaves orally taken in fever	C	July-Aug
Drymaria cordata Wild.	Abijalo	1000-2000	NM		Used in nose dysentery.	C	Whole year
Eupatorium canabinum Linn.	Banmara, kalijhar	1000-2000	NM		Crushed juice from leaves are applied in cuts and bleeding spots immediately	A	Whole year
Heracleum nepalense D.Don	Chimphing	1550-3600	MR	3 per packet	Fruits are used as pickles, used as anti-typhoid, nausea and vomiting	D	Aug-Oct
Hydrocotyle asiatica Linn.	Golpatta	1300-2000	NM		Fresh leaves are crushed and administered orally to relieve blood pressure and throat pain.	C	Whole year
Holboellia latifolia Wallich.		2400-3200	NM	NA	Fruits edible, stem used to make bangles, which are believe to give relief from orthopedic problems.	R	Whole year
Kaempfera rotunda Linn.	Bhuin champa	1300-2000	MR	NA	Tubers used as poultice in fracture, healing fresh woods and removes coagulated bloods from the body.	R	NA
Litsae citrata Bl	Siltimur	Upto-2700	MR	NA	Dried fruits are used as medicine for nausea and giddiness, fresh fruits used as pickles.	D	Aug-Sep

Dactylorhiza hatagirea (D.Don) Soo	Panch aunle	3000-4000	MR	80/kg	Paste made out of the tubers is applied over cuts and bruises. It is also used orally for body ache	R	Aug-Sep
Oroxylum indicum Vent.	Totala	Upto 1000	MR	10 per garland	Flower edible, root bark improves appetite, use in vomiting, asthma, bronchitis etc.	R	Aug-Dec
Picrorhiza kurrooa Royle ex Benth.	Kutki	3000-5000	MR	210/kg	Dried roots are used orally in malarial fever. It is also used as cathartic, purgative and dyspepsia.	D	Whole year
Piper longum Linn.	Pipla	Upto 1700	MR	60 per kg	Roots use in anthelminthic, improves appetite, abdominal pain. Fruits use for anti-diarrhoeatic, anti-dysenteric, piles, leprosy etc.	C	Whole year
Plantago sp.	Isabgol	Upto 1750	NM		Plant use as medicine for rheumatism, roots as astringent and fever, and seed in dysentery.	C	Whole year
Polygala arillata Buch.-Ham ex D.Don	Marcha	600-1800	MR	NA	Roots use for preparation of yeasts.	D	NA
Rheum australe D.Don	Padamchal	3600-4500	MR		Dried roots use as tea.	D	July-Sep
Rheum nobile Hook.f.& Thoms.	Kenjo	3600-4500	NM	60/kg	Whole plant is eaten, used as pickles, have medicinal value.	R	July-Sep
Rhododendron arboreum Smith	Lali guras	1500-3300	NM		Dried flowers use for curing dysentery	A	Jan-March
Rubia manjith Roxb. Ex Fleming	Majhito	1000-2000	MR	650 per ton	Color extracts are used in dying. Roots have medicinal value.	C	Whole year
Rumex nepalensis Sprengel	Halhalay	1800-3000	NM		Dried root is use in preparation of paste and taken orally in hepatistis. It is also applied during loss of hairs.	A	Whole year

Solanum sp.	Jungli bihin	Upto 1800	NM		Root use in bronchitis, asthma, fever, pains. Piles etc. Fruits increase appetite and good for heart diseases and fever. Fruits are burnt and use its smoke for relief from toothache.	C	Whole year
Swertia chirata Ham.	Chirato	1225-3000	MR	20-30/kg	Medicinal use for anthelmintic, antipyretic, antiperiodic, laxative, leucoderma, inflammation, ulcer, asthma piles etc.	D	May-Oct
Viscum articulatum Burn.f.	Harchur	300-2000	MR	80 per kg	Dried plants are use to prepare paste and applied on minor fractures.	R	Whole year
Zanthoxylum acanthopodium DC.	Boke timur	Upto-2250	MR	40 per kg	Medicine for ear diseases, headache, leucoderma, asthma and good appetizer	D	May-Sep
Natural decorative							
Abies densa Griffith ex R. Parker	Gobre salla	2800-4000	NM		Cones are used as decorative		April-May
Anaphalis sp.	Bukiphul	1700-2750	NM		Dried flowers are decorative and also used for preparation of pillow	A	July-Sep
Anaphalis sp.	Bukiphul	1850-2750	NM		Dried flowers are decorative and also used for preparation of pillow.	A	July-Sep
Pinus longifolia Roxb.	Salla	500-2000	NM		Cones are used as decorative		Feb-April
Lycopodeum sp.	Nagbelli	1850-2750	NM		Entire plant is decorative and pollen is used as gunpowder.	C	Whole year
Pollinia mollis (Griseb.) Hack.	Memkesh	1550-2450	NM		Flowers spikes are decorative	R	Whole year
Raphidophora sp.	Kanchirna	Upto-2000	NM		Planted as decorative, leaves good fodder, stems used as feed for pig and cattle.	A	Whole year
Tsuga dumosa (D Don) Eichler		2100-3500	NM		Cones are used as decorative		May-June

Fiber, broom and incense species							
Daphne cannabina var. bholua (Buch.-Ham. ex D. Don) Keissl.	Kagatay	1850-3000	MR	NA	Bark is used as ropes but also have potential for preparation of paper.	C	Whole year
Edgeworthia gardneri (Wall.) Meisner	Argeli	Upto 1850	MR	NA	Bark is used for preparation of paper, making ropes and even tying cattle.	C	Whole year
Thysanolaena maxima Kuntze.	Amliso	Upto-2000	MR	Broom 1000 per ton.	Broom are prepared from the inflorescence,, fodder, soil binder and fuelwood after drying the sticks.	A	Whole year
Juniperus recurva Buch-Ham. ex D. Don	Bhairun patay	3600 above	MR	NA	Local Buddhist uses leaves as incense.	C	Whole year
Rhododendron setosum D. Don.	Sunpatay	3600 above	MR	NA	Local Buddhist uses leaves as incense.	C	Whole year