LITTER FALL, LITTER DECOMPOSITION AND SOIL CONDITIONS OF SHIVAPURI NATIONAL PARK, KATHMANDU

BY

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A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIRMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN ZOOLOGY,

CENTRAL DEPARTMENT OF ZOOLOGY – ECOLOGY PROGRAMME

INSTITUTE OF SCIENCE AND TECHONOLOGY

TRIBHUVAN UNIVERSITY

KATHMANDU, NEPAL

DECEMBER, 2006

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RECOMMENDATION

It is my pleasure to mention that Ms. Emma Adhikari has carried out this thesis research entitled 'LITTER FALL, LITTER DECOMPOSITION AND SOIL CONDITIONS OF SHIVAPURI NATIONAL PARK, KATHMANDU' under my supervision and guidance. This is the candidate's original work that brings out important findings essential for conservation of ecosystem. To the best of my knowledge, this thesis has not been submitted for any other degree. I recommend that the thesis be accepted for partial fulfillment of the requirements for the Degree of Master of Science in Zoology specializing in Ecology

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ACKNOWLEDGEMENTS

I would like to express my sincere gratitude and heartfelt thanks to my honorable supervisor Dr. Khadga Basnet, for his plentiful suggestions, immemorial guidance, encouragement and support throughout the study. His motivation and assistance have been of immense value. I am grateful to Prof. Dr Tej Kumar Shrestha, Head of the Central Department of Zoology as well as other professors, lecturers and staffs of this department for providing valuable suggestions and academic support. I am very thankful to Prof. Dr. Krishna Kumar Shrestha, Central Department of Botany for helping me to identify trees.

I express my thanks to Department of National Park and Wildlife Conservation (DNPWC), Nepal for giving me permission to conduct my research. I am indebted to Mr. Phanindra Raj Kharel, Warden of Shivapuri National Park (ShNP) for his immense support and encourage for the research. I like to thank the staffs of ShNP, security personnel and local people who really helped me to complete my research work.Thanks are due to Kiran Hari Maskey (soil expert), Krishna Mandal, Kalpana Karki and Sabetri Dahal of Department of Agriculture, Harihar Bhawan for their valuable support for my laboratory work.

I extend my thanks to my sister Manasa Koirala and friend Suresh Basnet for helping me through entire field works. I want to express my thanks to my senior Bikram Shrestha, friends Laxman Chhetri, Laxmi paudel and Namrata Shreatha for their cooperation, help and suggestions. I am very grateful to my husband Mr. Bill Pandit for his valuable support, help and cooperation during this thesis work.

Last, but not the least I am greatly beholden to my family members for their endless love, continuous encouragement, and support.

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ABSTRACT

I conducted my research during January 2005 – December 2005 in Shivapuri National Park and as a quick reference in Coronation Garden of Tribhuvan University, Katmandu to explore litter fall, litter decomposition and soil conditions of the forest ecosystems. The site was divided into three stations which were again divided into three sampling plots of 50 meter squares. I identified tress and measured for DBH and collected nine samples of litter fall and soil each during autumn, winter, spring, and summer. The litter collections were separated into leaf litter and twigs, were oven dried for 24 hours and weighed in the Central Department of Zoology laboratory in every three months. Rate of litter decomposition was investigated by field experiments. Six nylon mesh bags with equal amount of fresh litter (100gm) from respective stations were buried in each forest and weight loss was noted by weighing after three months. The soil samples were analyzed for different parameters in the laboratory of Department of Agriculture, Harihar Bhawan. Field survey showed that there were a total number of 160 trees of 11 species belonging to 6 families in the natural forest and in the man-made forest there were 92 trees belonging to14 species and 12 families. In the natural forest, Fagaceae family was more common, *Quercus glauca* showed the highest density (555.6 trees/ha), the most frequent species was *Castanopsis indica, Rhododendron arboreum* was with the highest basal area (0.037 m^2) and the highest Importance value (IV) (49.9%). In the man-made forest, Fagaceae and Salicaceae families were more common, *Salix babylonica* showed the highest density, *Lagerstroemia indica* was the most frequent and *Populus euro-americana* showed the highest basal area with the highest IV (50.0%). The total annual litter fall recorded were 5037.50 kg/ha (79.8% leaf fall) in the natural forest and 4251.90 kg/ha (82.0% leaf fall) in the man-made forest. The litter fall was highest in autumn, 1632.6 kg/ha and 1362.7 kg/ha in the natural forest and in the man-made forest respectively. The litter decomposition rate was the highest in the summer season in which the weight loss was 38.0 ±1.7gm in the natural forest and 32.5 ± 1.61gm in the man-made forest. The mean weight loss rate was found slightly higher in the natural forest (0.3225 g/day) than in the man-made forest (0.2725 g/day). The organic matter, total nitrogen and Ph were the highest in the winter season whereas available potassium and phosphorus were the highest in the summer season in both the forest types. The man-made forest (Ph-5.6) was more acidic than the natural forest. The organic matter and total nitrogen were higher in the natural forest than the man-made forest whereas available phosphorus and potassium were higher in the man-made forest than in the natural forest. The major group of organisms contributing to decomposition process was oligochaeta, rootlets, fungi, isopods, araneae, coleopteran, wild boar, porcupine, monkey, deer, beer and jackal.

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1. INTRODUCTION

1. Background

1.1.1 Nutrient Cycling

Living organisms are constructed from chemical elements. An ecosystem describes the transfer of those elements between the living and non-living worlds. Smith (1974) directly relates the existence of living world with the flow of energy and circulation of materials through the ecosystem. The primary and secondary productivity of a population or a community is often limited by nutrients. Nutrients can be used as an organizing focus in the study of ecosystem. The biological community can be taken as a complex processor in which individuals move nutrients from one site to another within the ecosystem. These biological exchange of nutrients interact with physical exchanges, nutrients come into an ecosystem through meteorological, geological or biological transport mechanisms and leave an ecosystem via same routes. Nutrient Cycling is defined as the flow of the mineral components of an ecosystem through chain of inputs and outputs of essential elements (Odum 1971).

Nutrient dynamics in vegetation play a significant role in determining the circulation and storage of nutrients in an ecosystem. A major function of plant nutrients is their involvement in photosynthesis and growth. In addition to this, they also function in the physiological activities within the plant body. Nutrient cycling in natural ecosystem has played a vital function in balancing the interaction between organism and environment, so its knowledge is required to assess the effects of man's manipulation of environment. Study of nutrient cycles in forest ecosystem requires a basic conceptual framework to organize nutrient capitals and transfer processes as the nutrient cycling involves many important biological and physical processes. These processes have been described by Egunjobi (1971) and Johnson et al. (1982) as: a) inputs of elements into the ecosystem, b) nutrient transfer within the ecosystem, and c) outputs from the ecosystem.

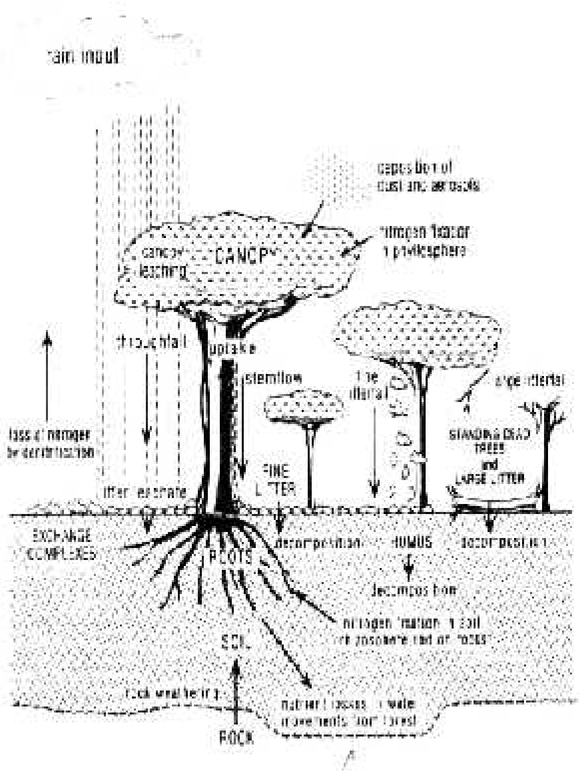


Figure 1. Diagrammatic Sketch of Nutrient Cycling (after Proctor1987).

1.1.2 Sources of Nutrients

Nutrient accumulation in the soil is directly related to the litter decomposition and the invertebrates involved in it. In terrestrial ecosystems 90% of net primary production returns to the forest floor as dead organic matter which is the major resource for the decomposer community (Swift 1979). Decomposition of dead organic matter results in mass loss, accompanied by changes in chemical composition and often with the reduction in particle size of the remainder. Soluble compounds are removed from organic matter by leaching. The breakdown of complex organic compounds by decomposer organisms yield apart from energy, smaller and simpler molecules, which are partly inorganic. These simple molecules of nutrients may be used by plants including micro flora for growth or may be leached out of the organic profile of the soil. Moreover, complex molecules are synthesized by polymerization, leading to stable humic compounds (Duchaufour 1982). Swift (1979) described the two most widely used measures of decomposition rates as: (a) mass loss and changes in nutrient content in confined litter (i.e. enclosed in litter bags) (b) steady- state residence times for organic matter (and nutrients) in the forest floor litter.

Litter invertebrates play a vital role in the decomposition of litter. Soil animals may belong to species from different taxonomic groups, such as Crustacean (isopods), Arachnid (mites), myriapoda (millipedes), insects (Cockroaches, beetles, ants, termites and spring tails) or Annelid (earthworms).The contribution of litter invertebrates in decomposition processes has been attributed to regulation of micro- organism populations and their activity, fragmentation of leaf material and burrowing activity (Swift 1979, Seastedt 1984). Faces of isopods showed an increase in nutrient availability as compared to that of the consumed leaf litter (Teuben 1991). The contribution of litter invertebrates to mineralization can be expected to vary considerably with ecological characteristics of the species (Verhoef and Brussaard 1990). Their contributions to nutrient cycling not only vary with body size, food choice, and population size but also with ecophysiological characteristics such as assimilation, excretion, storage and reproduction (Faber 1992).

Decomposition actually consists of a chain of successive processes in which a number of forest organisms take part. As one example, leaves of a tree are chewed by a herbivorous mammal such as a sloth, the dead tissues are attacked by digestive enzymes and by intestinal bacteria and protozoa, the faces are reconsumed by nematodes or beetles, the frass from these invertebrates is again exploited by soil-living bacteria, protozoa and fungi, until much of the available energy and carbon has been released, and only humus, minerals and water remain.

1.1.3 Process of nutrient accumulation

According to Johnson et al. (1982), nutrients enter in an ecosystem by particulate deposition, precipitation, gaseous fixation and weathering of soil parent materials and are transferred by a large number of interdependent processes like litter fall, decomposition, uptake and intratranslocation. The chemical elements of the soil removed by the plants are retained at the time of physiological death in certain plant parts particularly in the leaves, twigs and bark. Attiwill (1968) states that these chemical elements return to the soil in the form of plant litter and by route sloughage, excretion as well as by the process of canopy leaching or “recreation”.

In forest ecosystem, litter is the main component of detritus, which enters the decomposition subsystem and is broken down by decomposing organisms. By the action of these organisms, the organic forms are converted into inorganic forms and most of the nutrients are available for plant uptake. Litter fall and its subsequent decomposition form the major source of energy and nutrients for the soil and litter organisms of the woodlands. According to Spain (1973), litter fall plays a major role in the circulation of mineral elements and put influence on soil formation. Similarly Bray and Gorham (1964) considered litter fall as a major pathway for both energy and nutrient circulation through forest ecosystem. Plant nutrients are released from both mineral and organic complexes in soil as a result of either physical or biological processes. The major physical processes involve degradation by the soil fauna and decomposition by the micro flora. Redistribution of nutrients in the living biomass has its importance in biochemical cycling and hence in nutrient conservation within the standing crop. The major pathways in the flow of elements from and to the soil through vegetation are considered to be the fall and subsequent decomposition of litter by Ewel (1976) while the litter on the soil surface is considered as input- output system receiving inputs from the vegetation and in turn, decompose and thereby supply materials to the soil and roots.

Forest ecosystem is an open system which contains many elements entering and leaving, but only a number of these elements cycle more strictly within the ecosystem and is transferred continuously between the various compartments or pools. Nutrients enter the ecosystem with rain, dust and from the weathering of minerals in the underlying rock. The major above- ground compartment is the canopy from which nutrients are transferred to the forest floor via canopy leaching by through fall and stem flow, and in fine and large litter fall. In addition to intact and partly decomposed leaves, fine litter fall also includes reproduction tissue and frass of canopy insects. A proportion of the elements are in dead organic matter such as litter and dead standing trees. At the forest floor, nutrients are gradually released from the dead matter by decomposition which is mediated by soil animals and micro-organisms. Root, constituting a considerable below- ground pool, takes up nutrients from litter leachate and exchange complexes of the mineral soil and exports them back to the canopy. The roots also release nutrients to the soil either directly as exudates or indirectly by their death and subsequent decomposition. Nutrient losses may occur through surface erosion, occasional fires, leaching in drainage water to surface streams, and in the case of nitrogen, also by abiotic or microbial denitrification (Proctor 1987).

Trees are universally known to result in mark beneficent interactions with the surroundings in which they grow. Thus the soil, an important natural resource is influenced greatly by trees in many ways. The most efficient among these is the production of litter and nutrient recycling. Litter enriches the soil with organic matter (Gill et al. 1987) and essential nutrients. Its accumulation on the surface also checks weeds, protects the soil from the erosive impact of rain and reduces surface water run-off. Therefore, an investigation was conducted to assess litter production, decomposition and nutrient cycling in forest ecosystems.

1.2 Objectives

The main objective of my research was to examine the status of nutrient cycling in midhill forest ecosystems.

Specific objectives were to:-

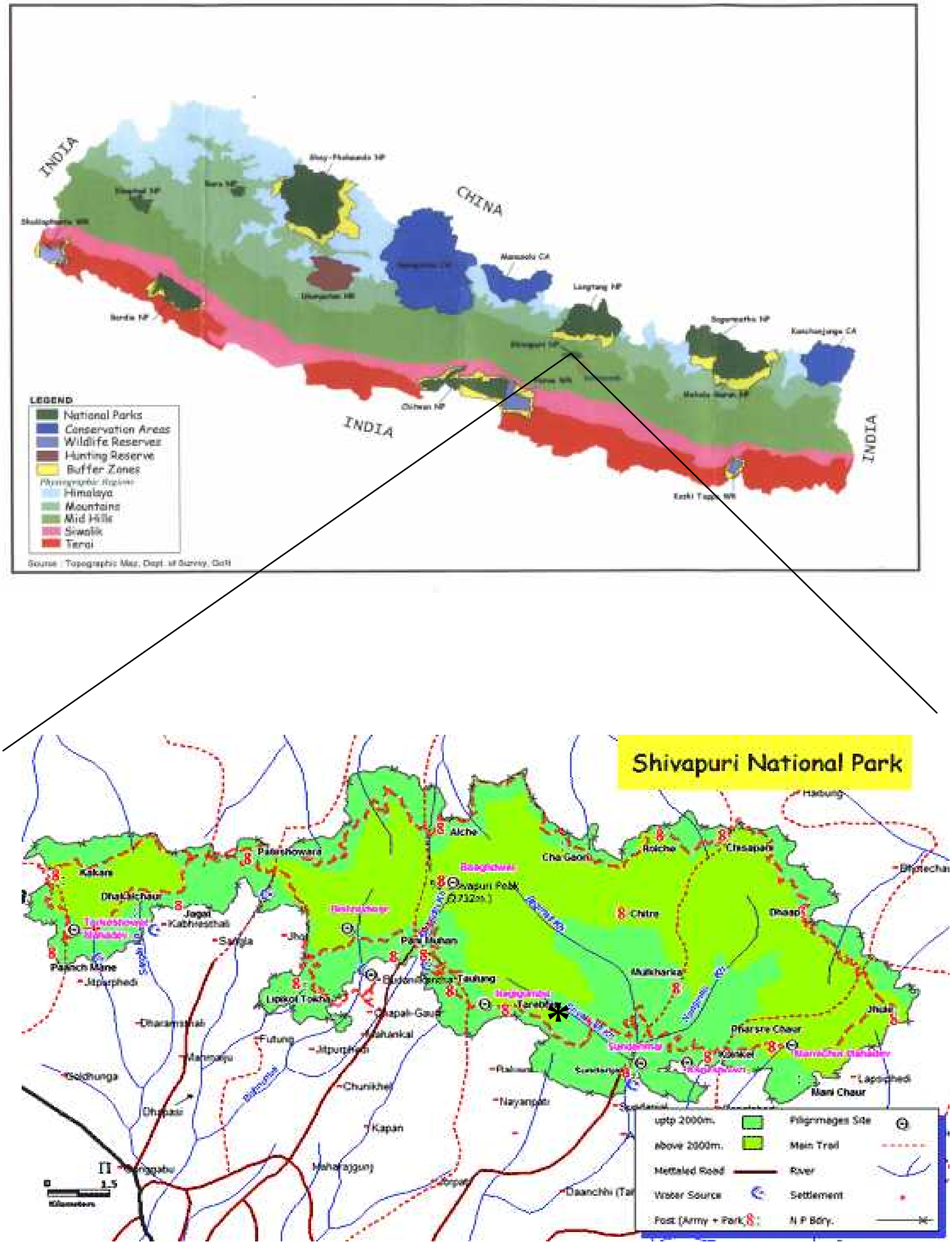
1. explore the existing conditions of the forest ecosystem,
2. investigate the dynamics of litter fall and litter decomposition in the forest ecosystem,
3. analyze soil nutrients (N, P, K), organic matter and PH of the forests,
4. compare the efficiency of nutrient cycle in the natural and man-made forest ecosystems, and
5. investigate the contribution of animals in nutrient cycling

1.3 Justification

Nutrient cycling in a forest ecosystem has played vital role in balancing the interaction between organism and environment. Nutrients whose major sources are litter fall and decomposition play a vital part in the productivity of a population or a community. So research on nutrients and nutrient cycling is essential to assess the effects of man's manipulation of environment.

Several studies have been conducted in Shivapuri National Park (ShNP) forest but nutrient cycle and its efficiency has not been investigated. ShNP represents middle mountain ecosystems, which are largely neglected particularly in research and development. Most of the researchers are concentrated only in the lowland or high mountains. The luxuriant vegetation distributed in the ShNP offers an excellent opportunity for ecological studies.

Coronation Garden, although small in size represents man-made forest. In spite of its size it contains high species diversity due to different alien species being planted.



*Study site (a, b, c)

Figure 2. Map of the Study Area

a. Canopy cover of Site I of Natural Forest

b. Part of the forest of Site I of Natural Forest

c. Canopy cover of Site II of Natural Forest

d. Part of the forest of Site II of Natural Forest

e. Canopy cover of Site III of Natural Forest

f. Part of the forest of Site III of Natural Forest

Plate 1. Natural forest

2. STUDY AREA

2.1 SHIVAPURI NATIONAL PARK

Shivapuri National Park (ShNP) is located on the northern edge of Katmandu valley. It represents the typical mid hill physiographic zone of the country's protected areas. The highest summit of the park (Shivapuri hill) is at 2732 m, which is the second largest peak that surrounds the Katmandu valley and the lowest point is about 1336 m. It is about 12 km from the main city. It is surrounded by 23 Village Development Committees (VDCs) of three districts, Katmandu (12), Nuwakot (9), and Sindupalchowk (2) (DNPWC 2002). It lies between $27° 45' – 27° 52'$ N latitude and $85° 15' – 85° 30'$ E longitude (SWWR 1999).

The Park is about 144 km^2 of which 22 km^2 is included by the park and the rest is covered by villages and croplands. Two villages Mulkharka and Okhreni comprising 309 households are located within the park. The park is extending from Chisapani in the east up to Kakani in the west. Average length (East – West) is about 20 km and average breadth (North – south) is nine kilometers.

Soil

The dominant rocks are gneiss and migmatite with mica schist and pegmatic granite. The soils of the area range from loamy sand on the northern side to sandy loam on the southern slope. Entire area is characterized by its steep topography. More than 50% of the area has greater than 30% slopes. In several spots soil erosion is a serious problem. Erosion hazard is very high in the northern slope. Both natural and man-induced landslides, gullies and stream bank erosion are found all over the area (SWWR 1999).

Climate

ShNP represents subtropical climate. Climate and rainfall in the southern slope of Shivapuri hill is more or less similar to Katmandu valley and the mean annual rainfall ranges between 1800mm to 3200mm. Temperature is highest up to 23^{o}C in August. (Subedi 2004). From the three years (2001 – 2003) meteorological data of recording stations of park, January is the coldest month in which the minimum temperature was 3.5^{o}C, 4.4^{o}C and 4.5^{o}C in Kakani station and 3.5^{o}C, 3.6^{o}C and 3.2^{o}C in Budhanilakantha station during 2001, 2002 and 2003.August is the hottest month in which maximum temperature of Kakani station was 23.3^{o}C, 23.1^{o}C and 24.3^{o}C during 2001, 2002 and 2003.Budanilakantha site was hotter than Kakani site in which the highest temperature was 28.1^{o}C in June 2001 followed by 27.6^{o}C in July 2002 and 27.3^{o}C in May, June and July 2003.The highest precipitation occurs during July and August. The precipitation was highest in July at Kakani station which was 928.8 mm, 969.2 mm and 1015.6 mm in 2001, 2002 and 2003 respectively. In Budhanilakantha station highest monthly precipitation was 791.2 mm in July 2002 followed by 716.4 mm in 2003 July and 538.6 mm in August 2001. In Sundarijal station highest monthly precipitation was 636.9 mm in 2001 August followed by 615.1 mm and 584.1 mm in July 2002 and 2003 respectively. Relative Humidity ranges from 61.5 % in April 95% in September.

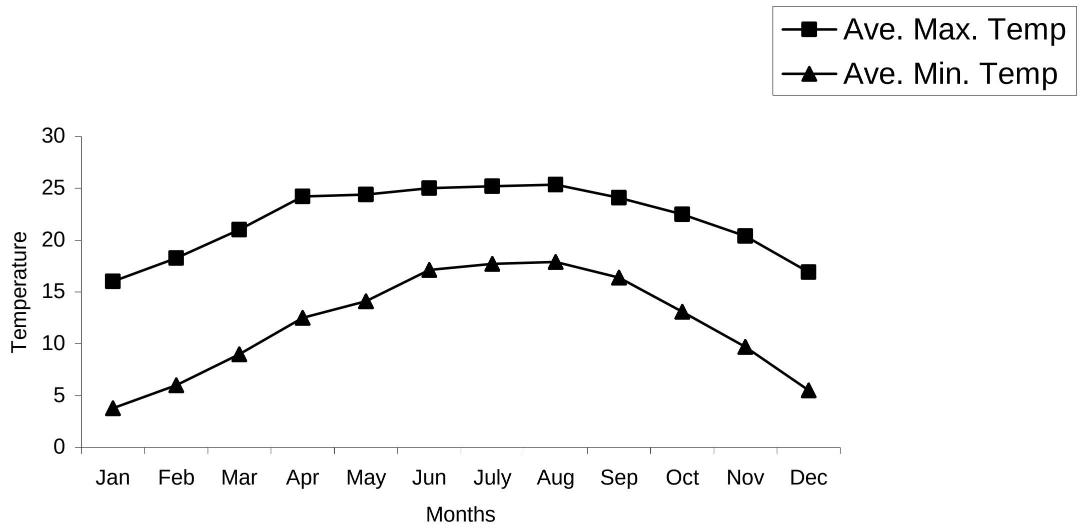


Figure 3. Average monthly maximum and minimum temperature of the park from three years (2001 – 2003) meteorological data of recording stations.

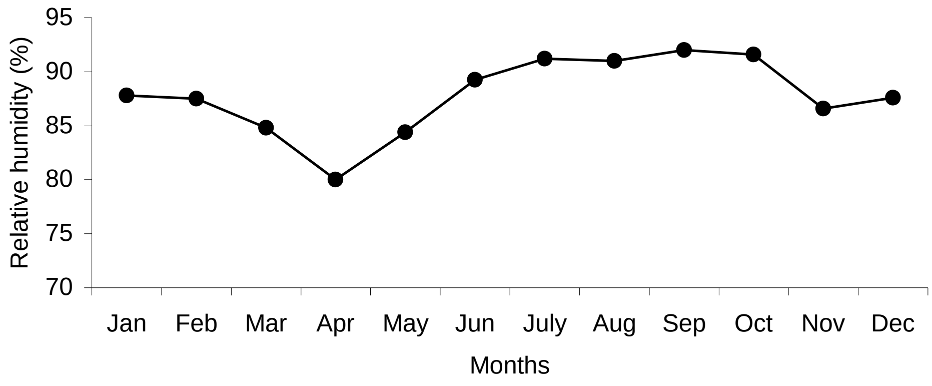


Figure 4. Average monthly relative humidity of the park from three years (2001 – 2003) meteorological data of recording stations.

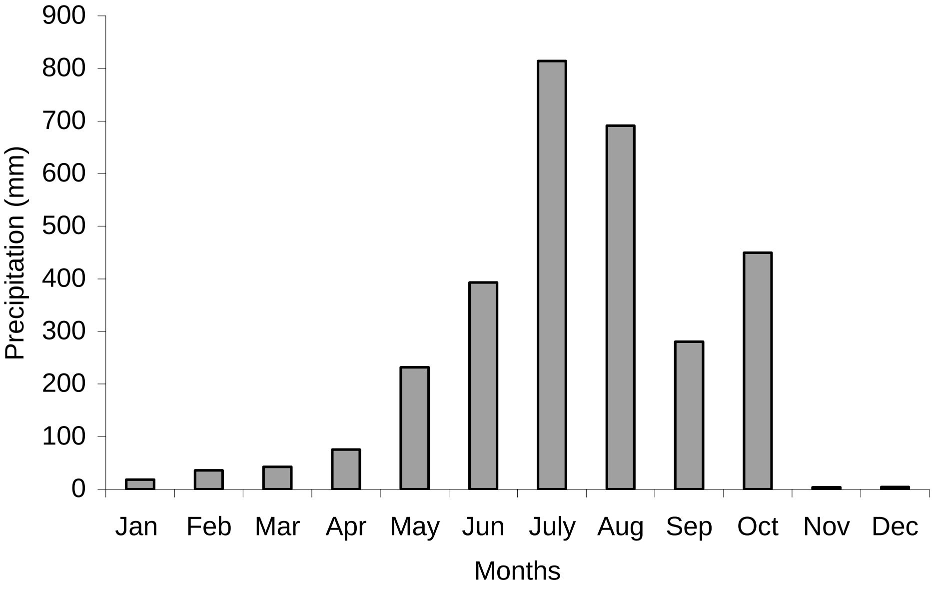


Figure 5. Average monthly precipitation of the park from three years (2001 – 2003) meteorological data of recording stations.

Biodiversity

ShNP lies in a transition zone between subtropical and temperate climates. Because of the variation in altitude and topography, diverse types of flora from subtropical species to temperate species are found in the park. About 80% of the area is covered by forest. As one ascends along the area of Bagmati river up to its origin he will find the forest of *Schima wallichii* and *Pinus roxburghii* gradually replaced by the *Quercus* forest that are eventually replaced by *Pinus wallichiana* (Karki 2002).Scrubs extensively cover the lower slope. Chir pine (*Pinus roxburghii*) is a dominant tree species in the subtropical zone. Other species are mainly *Alnus nepalensis*, *Castanopsis indica* and *Schima wallichii*. Northern slope at lower elevation is dominated by broad-leaved trees. *Quercus lanata* is the dominant tree species in the lower temperate zone and upper temperate zone is densely vegetated with *Quercus semecarpifolia* (Baral and Inskipp 2001).

Many species of medicinal plants and edible fruits includes *Rhus javanica*, *Paris polyphylla*, *Lobelia pyramidalis*, *Potentilla fulgens*, *Zanthoxylum armatum*, *Mahonia napaulensis*, *Choerospondias oxallaris*, *Arundinaria falcate*, *Juglans regia*, *Machilus odoratissima*, *Eriobotrya dubia*, *Rubus acuminatus*, *Berdaris aristata*, etc.

Some other representative vegetations of the park area are *Castanopsis tribuloides*, *Quercus glauca*, *Q. lamellose*, *Rhododendron arboreum*, *Lyonia ovalifolia*, *Cinnamomum sp.*, *Litsea pblonga*, *Lindera pulcherrima*, *Michalis kisopa*, *Myrica esculenta*, *Myrsine semiserrata*, *Prunus cerrasoides*, *Prunus pashia*, *Alnus nepalensis*, *Pyracantha crenulata*, *Osyris wightiana* etc (Thapa 1998).Besides these species the park also includes 20 species of orchids (Karki 2002) and 129 species of mushroom (DNPWC 2003).

The forest type of the park can be broadly catagorized into following four types (SWWR 2002),

a) Lower mixed hardwood forests (1000 – 1500m) – dominant tree species are *Schima wallichii*, *Castanopsis indica*, *Alnus nepalensis*, *Anthosaphalus cadamba*.

b) Chirpine forest (1000 – 1600m) – dominant tree species are *Pinus Roxburghii*, *Castanopsis indica*, *Myrica esculanta*, *Pyrus pashia*.

c) Upper mixed hardwood forests (1500 – 2700m) – dominant tree species are *Quercus semecarpifolia*, *Eurya acuminate*, *Ilex dipyrens*, *Michelia champaca*, *Rhododendron arboreum*, *Symplocus sp*.

d) Oak forest (2300 – 2700) – dominant tree species are *Acer aesculus*, *Juglans regia*, *Betula fraxinus*, *Alnus nepalensis*, *Salix sp*., *Quercus sp*., *Celtis sp*.

The establishment of the protected area has led to an important increase in forest cover and standing stock. This has resulted in a considerable improvement in wildlife habitats and an increase in forest dependent species. Recorded mammalian species in the Shivapuri area are 19 species of which are eight threatened mammal species, such as leopard (*Panthera paradus*), leopard cat (*Prionailurus bengalensis*), and clouded leopard (*Neofelis nebulosa*).Some other are Himalayan Black Bear (*Selenarctos thibetana*), Jungle cat (*Felis chaus*), Rhesus Macaque (*Macaca mulata*), Hanuman langhur (*Semnopithecus entellus*), Wild Boar (*Sus scrofa*), Himalayan Goral (*Naemorhedus goral*) and Barking Deer (*Muntiacus muntjak*) (Baral and Inskipp 2001).

The area is popularly known as “bird paradise” as it is well suited for many Himalayan bird species including Kalij Pheasant (*Lophura leucomelana*) (Karki 2002) and many subtropical species. The park provides habitat for 177 bird species including 13 threatened species but many more are likely to occur. The park area supports 26 breeding species of birds for which Nepal may hold significant populations including the endemic Spiny Babbler (*Turdoides nipalensis*), the endangered Oriental Hobby (*Falco severus*), Grey Sided Laughing Thrush (*Garrulax caerulatus*) and the vulnerable Cinerous Vulture (*Aegypius monachus*).

The park also inhabits102 species of butterfly, including a number of rare and endangered species, such as the Kaiser – I – Hind (*Teinopalpus imperalis*). It is also one of the few sites where the rare relict Himalayan dragonfly (*Epiophlebia laidlaw*) is found (SWWR 1999).

2.2 KING BIRENDRA CORONATION GARDEN

King Birendra Coronation Garden was taken as a quick reference of man-made forest. It is situated inside the Tribhuvan University, Kirtipur which is five kilometers to the south-west of Katmandu. This coronation garden was inaugurated on the auspicious occasion of the eve of His Majesty Late King Birendra Bir Bikram Shah Dev's coronation on February 25, 1975 (B.S. Falgun 13, 2031). The area of the garden is spread out to 37 acres of land and the garden is structured in Japanese style.

Tribhuvan University being interested in making this garden as a model garden for the plants of diverse climatic conditions, sixty distinguished royal guests of 45 different countries and one UN representative planted 46 different varieties of plants. This coronation garden has become a symbol of international unity, peace and friendship. Furthermore, it has proved to be a useful area for teachers and students to do research and practical work in semi-natural setting.

Some of the plant species include: *Castanopsis tribuloids* (Katus), *Lagerstroemia indica* (Asare phool), *Juglans regia* (Okhar), *Quercus glauca* (Falat), *Grevillea robusta* (Kaioo phool), *Callistemon citrinus* (Kalki phool), *Albizia julibrissin* (Seerish), *Populus euro-americana* (Lahare pipal), *Cinnamomum camphora* (Kapoor), *Melia azedarach* (Bakaino), *Morus indica* (Kimboo), *Celtis indica* (Khari), *Pinus roxburghii* (Rani-Sallo), *Salix babylonica* (Bains) etc.

a. Part of the man-made forest (site I)

b. Part of the man-made forest (site II)

c. Part of the man-made forest (site III)

Plate 2. Man-made forest

3. LITERATURE REVIEW

3.1 Vegetation

The main composition of forest stand is determined by the nature of the soil. As the physical characteristics of the soil determine its exact nature, the rigidity and supporting power, drainage and moisture storage capacity, plasticity, cause of penetration by roots, aeration and retention of plant nutrients are also intimately correlated with the physical condition of the soil (Forth 1984). Gazizulin et al. (1997) showed that the forest composition and productivity are influenced by the nature of the soil in their study in the interrelations between soils, topography and forest vegetation within the zones of mixed and broad leafed forest of the middle hills Volga region. Seasonal fluctuation in mineral element concentration is demonstrated by a variety of plants and plant communities as trees and forest (Sah 1983) in shrubs (Grigal and Mc Coll 1977). Other physiological activities are also reported to play significant role in fluctuation of mineral composition in plants. Visalakshi (1995) studied the vegetation in two tropical forests viz., Marakkanam reserve forest and Puthupet sacred grove in the Coromandel Coast of India and found out that soil property is attributed as the major factor influencing the vegetation in the forests.

Johnson et al. (1982) in an ecosystem analysis established the nutrient cycling as an important component that involves biological, chemical and geological interactions. Nutrients enter in an ecosystem by particulate deposition, precipitation, gaseous fixation and weathering of soil parent materials, that are transferred by a large number of processes as litter fall, decomposition, uptake and intratranslocation. Tandon et al. (1996) made an analytical study on mineral cycling in four different aged *Eucalyptus* hybrid plantations. They found out that maximum nutrients are returned to the soil through leaf litter, out of the total litter, leaf litter contributed between 73 to 82 percent. Maximum return was observed for Nitrogen followed by calcium, Potassium, Magnesium and Phosphorus. Shrestha et al. (2000) in a vegetation analysis of natural and degraded forests in Chitrapani in Siwalik region of central Nepal showed that total volume and bio-mass of trees were higher in natural forests. Oli and Manandhar (2001) reported that forest litter is one of the major sources of soil nutrients in the hills of Nepal in an analysis of role of forest in supplying soil nutrients in agricultural production system.

3.2 Litter fall/ Litter decomposition

Bray and Gorham (1964) considered litter fall as a major pathway for energy and nutrient transfer in the forest ecosystem. Litter, as a whole consists of a complex and changeable mixture of plant and animal materials of various structure and chemical composition. Typical components are dead animals, animal frass, and the remains of over story and under story plants, cones, barks, twigs etc.Connell (1988) measured rates of weight loss and release of N, P, K, S, Ca, Mg, Na and Cl from decomposing leaf litter in regrown Karri forest and found that decomposing leaf litter lost 47-55% of original dry weight after exposure for 82 weeks on the forest floor. Garg (1997) assessed that the litter yield increased with increasing plantation densities and the macro-nutrients did not change due to plantation spaces although difference between species existed in a study of litter production and nutrient concentration on Sodic soils.

Spain (1973) found out that the development of the forest soils and ultimately the growth of the forest are affected by litter fall from trees and chemical composition of litter. Litter is a chief component in the circulation of mineral elements and contains many complex organic compounds that vary in biological degradability and it has an important influence on soil formation. Ewel (1976) considered the major pathways, for the flow of elements from and to the soil through vegetation, to be the litter fall and subsequent decomposition of litter. The litter acts as input- output systems that receive inputs from the vegetation and in turn, decompose and thereby supply materials to the soil and roots. Mall et al. (1991) in a study in monogeneric mangrove forest and mixed mangrove forest showed that mixed mangrove forest litter always decomposes faster than monogeneric mangrove forest. Gill et al. (1987) investigated the litter production and nutrient recycling behavior of acacia and eucalyptus plantations raised on a highly alkaline soil. Results showed that litter production in an acacia plantation was significantly higher than in a eucalyptus plantation of the same age and stocking rate.

Khadka et al. (1982) reported 70% to 90% leaf litter fall and 10% to 25% twigs fall in Godawari hills. Litter, the organic debris shed by forest vegetation upon the soil surface has an important role the soil development. Pant and Tiwari (1992) studied litter fall and leaf litter decomposition. They found out the trend of litter fall of different components in the order: Leaves> Twigs> Floral parts+ Seeds/ fruits> Bark. Total annual litter fall was 934gm^{-2}, of the total fall 78% was contributed by leaves. The total litter fall was found to be maximum in springs and minimum in rainy season. Maximum rate of leaf litter decomposition was observed in rainy season and the minimum in spring season. Roy and Nigam (2001) investigated on the pattern of litter production in an *Acacia tortilis* based Silvo pastoral system, raised on degraded land in semi-arid conditions of Jhansi (India) and showed that average litter production was 4.72 t/ha. The leaves contributed about 62.4%, reproductive structures 23.02% and twigs 14.58%.

Sanchez and Sada (1993) reported that in a tropical rain forest, litter fall occurred continuously throughout the year showing significant differences between the seasons. The highest proportion was recorded in the dry season, fruit production was higher in the rainy season; values for branch fall were higher during the “nortes” (March) season. The average value of litter fall was highest for the leaves (67.9%) and the lowest for the flowers (0.60%) in three annual cycles. Similarly, Sanchez and Sada (1993) showed that litterfall occurred continuously throughout the year showing significant differences between the seasons in a tropical rain forest in Los Tuxtlas, Veracruz Mexico.

3.3 Soil nutrients

Carlisle et al. (1967) reported that litter, being the fuel for nutrient cycles in the upper soil horizons, is particularly important in the nutrition of woodlands on the soils of low nutrient status where the trees rely to a great extent upon the recycling of litter nutrients. It is the return of the accumulated organic matter and nutrients to the upper soil layers, which accounts for a large part of the restoration of fertility. Attiwill (1968) reported that the plant from the soil removes the chemical elements. Such chemical elements are retained at the time of physiological death in certain plant’s parts particularly in the leaves, twigs and bark get returned to the soil in the form of plant litter and by litter, root sloughage, excretion as well as by the processes of canopy leaching or “recreation”. Over 65% of Ca, S, Mg, Na and N and 56% and 54% of K and P respectively of estimated uptake, were returned to the soil through the litter and recreation. Except for K and Na, a high proportion of these elements were returned through litter. Bhatnagar (1965) reported that forest soils influence the composition of the forest stand and ground cover, rate of tree growth, vigor of natural reproduction and other silviculturaly important feature in a study of different quality Sal forests of Uttar Pradesh. Foster (1974) also recorded tree litter as the most important source of N, P, Ca and Mg for the forest floor (51.69%) where as through fall supplied 54% of K. Verma and Sharma (1989) studied the chemical and physical nature of Bhata waste soils from protected and unprotected sites of Raipur. Soils range from gravelly loam-sand to sand-loam and the available phosphorus and potassium content differed significantly among months at both sites, where as the available nitrogen differed among months only at the protected site. Barbosa and Fearnside (1996) reported that of the total litter, Carbon represented 45.6%, concentrations of nitrogen (1.51%), Calcium (0.61%) and magnesium (0.15%) in a study of Carbon and nutrient flows in Amazonian forest.

Pandey and Singh (1990) in a study of Nitrogen uptake, storage and transfer on an abandoned field at Vanarasi measured that annual uptake of N did not show any consistent trend. Singh (1968) found out the nutrient status of forest soils in humid tropical regions of Western Ghats to be highly fertile which was quite comparable with those of other rich tropical regions. Banerjee et al. (1989) assessed ranges of some of the soil attributes suitable for the optimum growth of the species under more or less similar climatic conditions in a study in the nature and properties of some Coppica Sal growing soils in the Lateritic region of west Bengal.

3.4 Wildlife and soil organisms

Plowman (1983) in a study of the macro-invertebrate litter fauna of two montane forests in Papua New Guinea found out that rootlets and fungi invaded the fragmenting litter; larvae and pupae of all insects (the majority of which were ants) and spiders were the most abundant animals taking part in the decomposition process. He also added that Pigs bury leaves beneath the soil promoting a horizon of decomposing matter as opposed to a litter layer lying on a mineral soil. Acarina, pseudoscorpionida, scorpionida and isopteran were observed in significantly higher densities and abundance in the primary forest plot whereas isopods, diplopoda, coleopteran, formicidae and oligochaeta showed higher pitfall catches in the logged forest plots in the upper Ulu Segama area, Sabah, Malaysia thus indicating difference in the decomposition process in two forests (Burghouts et al. 1992).

SIWDP (1996) reported that 352 wild boars were seen in 17 survey spots of ShNP in three months (April, May and June) of 1995.Gurung (2002) in a study of Wild boar, distribution and conflict between Park and people of ShNP, found out that the major destruction were due to the presence of animals like Wild boar (*Sus Scrofa*), Porcupine (*Hystix indica*), Monkey (*Macaca mulatta*), Beer (*Selenarctos thibetanus*), Deer (*Muntiacus muntijak*) and various types of birds. Wild boar mainly eats wild foods like fruits of *Castanopsis sps.*, acorns of *Quercus sps*., nigalo (*Arundinaria sps*.) thus helping in decomposition process.

a. Trap for litter collection

b. A quadrat of 1m x 1m for litter collection

c. Collecting litter fall.

d. Collected litter fall.

e. Partially decomposed litter

Plate 3. Litter fall and decomposition

4. MATERIALS AND METHODS

4.1 Vegetation Analysis

I used three 10m by 5m plots for vegetation sampling. In each plot three quadrats of 2m $\times$ 2m, altogether nine quadrats, were used. Since the study site showed altitudinal gradient, steep topography and discontinuous vegetation, random sampling was adopted. Within each quadrat, tree species were measured for the DBH (Diameter at Breast Height). In total around 252 trees were studied. Both absolute and relative values of frequency, density and basal area were determined and relative values were used to calculate importance value index.

4.1.1 Density and Relative density

Density is defined as the number of individuals of a species per unit area. It requires actual count of individuals in a definite space and time. Density was calculated by using following formula

$$\text{Density of a species (per hectare)} = \frac{\text{Total number of a species in all quadrats}}{\text{Total number of quadrats} \times \text{Area in one plot}} \times 1000$$

Relative density is the numerical strength of a species in relation to the total number of individuals of all species

$$\text{Relative density} = \frac{\text{Number of individual of a species}}{\text{Total number of all species}} \times 100$$

4.1.2 Frequency and Relative frequency

Frequency indicates the number of sampling units in which a given species occurs showing a degree of dispersion of species in terms of percentage occurrence.

$$\text{Frequency (F \%)} = \frac{\text{Number of sampling units at which a species occured}}{\text{Total number of sampling units}} \times 100$$

Relative frequency is the frequency of a species in relation to total frequency of all.

$$\text{Relative frequency} = \frac{\text{Frequency of a species}}{\text{Sum of frequencies of all species}} \times 100$$

4.1.3 Basal Area and Relative Basal area

Basal area of a measured tree (BA) $= \frac{\pi d^2}{4}$, Where d = diameter of a tree at breast height.

$$\text{Relative Basal area (RBA)} = \frac{\text{Basal area of all trees of a species}}{\text{Total basal area of all species}} \times 100$$

$$\text{Average Basal area per tree} = \frac{\text{Total basal area of all measured trees}}{\text{Number of trees measured}}$$

Total Basal area per hectare = Density of all species $\times$ average basal area per tree.

$$\text{BA per hectare for a species} = \frac{\text{Total basal area per hectare} \times \text{R.B.A of the species}}{100}$$

4.1.4 Importance Value

Importance value (IV) of any species gives the ecological success of that species and can be computed by the sum of relative density, relative frequency and relative basal area;

Importance Value (IV) = RD + RF + RBA.

4.1.5 Similarity Index

The similarity index compare samples of vegetation in terms of which species are present. It is calculated by using Sorensen's index of similarity.

$$\text{Sorensen's index of similarity (ISS)} = \frac{2C \times 100}{A \times B}$$

Where, A = Total number of species in one site;

B = Total number of species in other site;

C = Number of species which occur in both sites

4.2 Litter fall production

I measured litter fall in nine traps (1m by 1m each), randomly placed in the forest floor. Litter from each trap was collected at seasonal intervals from Jan 2005 – Dec 2005 (four times throughout the year in January, April, July and October). Once the area for litter traps (1m by 1m) were designated by putting polythene bags, the same area was used throughout the study period. On each sampling date, litter from each trap was packed in separate polythene bags and were brought to laboratory. Due to the weather conditions the litter traps were damaged so litter collection was sometimes done by quadrat method.

The litter was sorted into leaves and twigs and was oven dried at 70^{o}c for 24 hours and weighted in Central Department of Zoology laboratory. The dry weight was converted to litter fall per hectare following Zobel et al. (1987).

$$\text{Litter fall (Kg/ha)} = \frac{10w}{na}$$

Where, w= dry weight of litter in grams

n= number of litter traps

a= area of one litter trap in m^2

4.3 Rate of litter decomposition

I investigated decomposition of litter by litter bag technique reported by Bocock et al. (1960). For litter decomposition, I confined 100 gm of fresh litter samples in nylon net bags and buried under forest soil at three different stations of each site (1x3x2). The bags were buried at five centimeter under the ground so as to maintain maximum decomposition. Zobel et al. (1987) and Gupta and Singh (1981) achieved the maximum decomposition rate at five cm below the ground. After three months the bags were taken out and weighted again. This process was repeated in every three months of interval throughout the year. The rate of decomposition was calculated by,

$$\text{Weight loss (WL)} = \frac{\text{Original weight} - \text{Final weight}}{\text{Original weight}} \times 100$$

$$\text{Weight loss rate (WLR)} = \frac{\text{Weight loss}}{\text{Days in field}}$$

4.4 Soil Analysis

I sampled the soil during the months of January, April, July and October (seasonally).After removing the superficial deposit of freshly fallen and decomposing litter each profile was sampled at the depth of 12 cm. I collected three samples of soil from three plots of both sites for the soil analysis. All together nine soil samples from each site were collected four times a year and put into tightly closed polythene bags and was taken to the laboratory (Department of Agriculture, Harihar Bhawan) for the analysis of chemical and physical parameters.

Organic matter: I used Walkley – Black method to determine organic matter in soil samples. On one gm of 0.2 mm sieved sample taken in a 500 ml conical flask, 10 ml of $K_2Cr_2O_7$ solution and 20 ml of concentrated H_2S0_4 were added and mixed properly by rotating for one minute. This mixture and standardization bank was allowed to stand for 30 minutes. After half an hour, about 200 ml of distilled water, 30 drops of diphenylamine indicator and 0.2 gm of NaF (Sodium Fluoride) were added and was bank titrated with 0.5 N FAS (Ferrous Ammonium Sulphate) solution. The volume of FAS consumed for bank titration with the brilliant green end point was noted. The amount of organic matter (%) was calculated as,

Organic Matter (%) = 0.67 $\times$ Normality of FAS $\times$ Volume of FAS used up.

Normality of FAS (N) = Volume of $K_2Cr_2O_7$ taken $\times$ Normality of $K_2Cr_2O_7$ /Vol. of FAS consumed by blank.

Total Nitrogen: Following Kjeldhal digestion method I took one gm of soil, two gm of catalyst digestion, 10 ml of Conc. H_2So_4 and pieces of broken porcelain in a 50 ml

Kjeldhal digestion flask. Sulphuric acid was mixed with soil by rotating the flask and heated in low flame until frothing stops. The flask was rotated till the mixture changes into green-blue color and this process was continued for 1 – 1.5 hours.

After cooling down the flask by adding 20 ml of distilled water, the solution was transferred to 100 ml volumetric flask and the volume was made up. 20 ml of the mixture and 20 ml of 40 % NaOH was taken in a distillation flask and distilled. The liberated NH_3 is taken in a 125 ml conical flask with 10 ml 4% boric acid and two drops of mixed indicator. This mixture was then titrated with 0.01N HCl. The blank was also run with distilled water and reagent. The total nitrogen was calculated as,

$$\text{Total nitrogen (\%)} = 7 \times N \times (T - B) / S$$

Where, N = Normality of acid

T = Volume of acid used in titration (ml)

B = Volume of acid used in titration for blank (ml)

S = Weight of sample taken for digestion (gm)

Available Phosphorus: I used modified Olsen's bicarbonate method to determine available Phosphorus. About 2.5 gm of air dried soil sample (<2mm) was taken in a 100 ml polythene bottle. 50 ml of $NaHCo_3$ (extracting reagent) was added and the bottle was shake for 30 minutes in a mechanical shaker. The solution was filtered through Whatman number 42 filter paper. The blank was run through 50 ml extracting reagent. About five ml of the sample and blank were pipetted out in volumetric flask with 5 N H_2So_4 to acidify to PH 5. The volume of acid required to adjust PH 5.0 was noted and the same volume of acid was added to all samples. Distilled water was poured till 40 ml volume and 8 ml of reagent B was added. At the same time 0, 1, 2, 4, 6, 8, 10, 12 and 15 ml of two ppm standards were pipetted in 50 ml of volumetric flask and $NaHCo_3$ (extracting reagent) was added to them and treated with same procedure as for sample. Then the absorbance at 785nm was noted after 10 minutes.

Available potassium: Available potassium in soil samples was calculated by using Flame Photometer Method. I took about 2 gm air dried soil sample, 20 ml 1N Ammonium acetate solution in a 125 ml conical flask and shaked in a mechanical shaker for 5 minutes. It was then filtered through Whatman No. 42, 12.5 cm filter paper. A standard curve of Potassium (K) is prepared by using different standard liquids. The standard curve is matched with the flame photometer of the soil sample and the amount of K was found out.

PH: I took about 20 gm of air dried (< 2 mm) soil sample in 50 ml beaker and add 20 ml of distilled water. The mixture was shaked for 1 minute in a mechanical shaker and is kept for about one hour. The PH of the solution was measured by using PH meter.

a. Collecting soil sample

b. Collected soil samples

c. Nitrogen determination process

d. Weighing soil for analysis

Plate 4. Soil analysis

4. 5 Wildlife and soil organisms

I found out the wild animals and soil organisms taking part in nutrient cycling through literature review process. I reviewed literature such as books, reports, thesis and scientific papers consulting different library. I mainly focused on the literature related to litter fauna and wildlife helping in decomposition process.

4.6 Data analysis

The experimental data (field and laboratory) were qualitatively and quantitatively analyzed following Bailey (1995) and Fowler et al. (1998).

Relationship between litter fall, litter decomposition and organic matter

I used correlation analysis to asses the relation between the rate of litter fall and litter decomposition as well as between the organic matter content of the soil and rate of litter decomposition. The value of ‘r’ was calculated by using following formula,

$$r = \frac{\Sigma\left(x-\bar{x}\right).\left(y-\bar{y}\right)}{\sqrt{\Sigma\left(x-\bar{x}\right)^2 .\Sigma\left(y-\bar{y}\right)^2}}$$

Comparing two forests

A comparative analysis was made between means of two samples of the rate of litter fall and rate of leaf litter decomposition from the natural and man-made forests. For this I used a student’s t – test to test whether there was a significant difference between the means of two forests by testing a hypothesis H_o: There is no significant difference between the natural and man-made forests in terms of litter fall and litter decomposition. H_1: there is a significant difference between the natural and man-made forests in terms of litter fall and litter decomposition.

The value of‘t’ was calculated using following formula,

$$t = \frac{\overline{x_1} - \overline{x_2}}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

The relation between experimental sites (ShNP and Coronation garden) and units (Litter fall, litter decomposition, soil PH, organic matter, nitrogen, phosphorus and potassium) were tested by one way ANOVA which is a powerful statistical tool of significance. I tested a hypothesis that there is no a significance difference between the variances in the natural and man-made forests. Following formula was used to analyze the experimental data,

$T = \sum x$ where, x = variable

Correction factor (CF) = T^2/ N

Sum of squares between samples (SSC) = $(x_1)^2/ n_1 + (x_2)^2/ n_2 \ldots\ldots\ldots (x_n)^2/ n_n - CF$

Total sum of square (SST) = $x_1^2 + x_2^2 + x_3^2 \ldots\ldots\ldots\ldots\ldots\ldots x_n^2 - CF$

Sum of squares within samples (SSE) = SST – SSC

ANOVA Table for one way classified data

Source of variation	Sum of squares(SS)	Degree of freedom	Mean sum of squares (MS)	Variance ratio or F - ratio
Between samples	SS between	(K – 1)	$\frac{SS\,between}{K-1}$	$\frac{MS\,between}{MS\,within}$
Within samples	SS within	(N – K)	$\frac{SS\,within}{N-K}$	
Total	SS total	(N – 1)		

5. Results

5.1 Vegetation Composition

I recorded a total number of 160 trees in about 150 meter square plot and a total number of 11 species belonging to 6 families (Ericaceae, Fagaceae, Theaceae, Myrsinaceae, Betulaceae, and Myricaceae).

Table 5.1. Tree species in the natural forest study site.

S.N	Name of tree species	Local name	Family
1	*Rhododendron arboreum*	Gurash	Ericaceae
2	*Castanopsis tribuloids*	Musure Katus	Fagaceae
3	*Castanopsis indica*	Dhale Katus	Fagaceae
4	*Schima wallichi*	Chilaune	Theaceae
5	*Myrsine capitellata*	Seti-Kath	Myrsinaceae
6	*Myrsine semiserrata*	Kali-Kath	Myrsinaceae
7	*Prunus cerrasoids*	Paiyu	Betulaceae
8	*Quercus lanata*	Banjh	Fagaceae
9	*Quercus glauca*	Musure-Falant	Fagaceae
10	*Lyonia ovalifolia*	Angeri	Ericaceae
11	*Myrica esculenta*	Hada-Kafal	Myricaceae

5.1.1 Density and Relative Density

In the natural forest the highest and the lowest densities 555.6 trees/ha and 44.4 trees/ha with relative densities 15.6% and 1.2% were found for *Quercus glauca*, and *Prunus cerrasoids* and *Myrica esculenta* respectively. In between these species were, *Castanopsis sps., Rhododendron arboreum, Schima wallichi, Myrsine sps., Lyonia ovalifolia* and *Quercus lanata* whose density ranged between 488.9 trees/ha to 88.9 trees/ha (Table 5.2).

Table 5. 2. Density and Relative density of tree species

Name of tree species	Density Trees/ha	Relative Density (%)
Rhododendron arboreum	444.4	12.5
Castanopsis tribuloids	488.9	13.6
Castanopsis indica	488.9	13.6
Schima wallichi	333.3	9.3
Myrsine capitellata	422.2	11.9
Myrsine semiserrata	355.6	10.0
Prunus cerrasoids	44.4	1.2
Quercus lanata	88.9	2.5
Quercus glauca	555.6	15.6
Lyonia ovalifolia	288.9	8.1
Myrica esculenta	44.4	1.2

5.1.2 Frequency and Relative Frequency

In the natural forest, the highest frequency 100% and relative frequency 12.9% were observed in *Castanopsis indica* and Q*uercus glauca* whereas the lowest frequency 22.2% and relative frequency 2.9% were found in *Prunus cerrasoids* and *Myrica esculenta*. The intermediate species with frequencies between 88.9% to 33.3% were *Rhododendron arboreum, Castanopsis tribuloids, Lyonia ovalifolia, Myrsine sps.*, *Schima wallichi* and Q*uercus lanata* (Table 5.3)

Table 5.3. Frequency and Relative Frequency of tree species

Name of tree species	Frequency (%)	Relative Frequency (%)
Rhododendron arboreum	88.9	11.4
Castanopsis tribuloids	88.9	11.4
Castanopsis indica	100.0	12.9
Schima wallichi	66.7	8.6
Myrsine capitellata	77.8	10.0
Myrsine semiserrata	88.9	11.4
Prunus cerrasoids	22.2	2.9
Quercus lanata	33.3	4.2
Quercus glauca	100.0	12.9
Lyonia ovalifolia	88.9	11.4
Myrica esculenta	22.2	2.9

5.1.3 Basal Area and Relative Basal Area

In the natural forest, *Rhododendron arboreum* possessed the highest basal area 0.037 m^2 with relative basal area 26.0% and *Prunus cerrasoids* possessed the lowest basal area 0.005 m^2 with relative basal area 3.3%. The species like *Myrica esculenta, Quercus sps., Castanopsis sps., Schima wallichi, Myrsine sps.* and *Lyonia ovalifolia* were between the highest and the lowest with basal area between 0.019 m^2 to 0.006m^2 (Table 5.4)

Table 5.4. Basal Area and Relative Basal Area of Tree species.

Name of tree species	Basal Area (m^2)	Relative Basal Area (%)
Rhododendron arboreum	0.037	26.0
Castanopsis tribuloids	0.009	6.7
Castanopsis indica	0.012	8.5
Schima wallichi	0.008	6.0
Myrsine capitellata	0.008	6.0
Myrsine semiserrata	0.006	4.3
Prunus cerrasoids	0.005	3.3
Quercus lanata	0.009	6.8
Quercus glauca	0.018	12.6
Lyonia ovalifolia	0.009	6.8
Myrica esculenta	0.019	13.3

5.1.4 Importance Value

The highest IV 49.9% for *Rhododendron arboreum* and the lowest IV 7.3% for *Prunus cerrasoids* were recorded in the natural forest. In between them were *Quercus sps., Castanopsis sps., Schima wallichi, Myrsine sps., Lyonia* ovalifolia and *Myrica esculenta* with IV 41.1% to 13.1% (Table 5.5)

Table 5.5. ImportanceValue of Tree Species.

Name of tree species	Natural Forest
Rhododendron arboreum	49.9
Castanopsis tribuloids	31.7
Castanopsis indica	33.5
Schima wallichi	28.2
Myrsine capitellata	27.9
Myrsine semiserrata	25.7
Prunus cerrasoids	7.3
Quercus lanata	13.5
Quercus glauca	41.1
Lyonia ovalifolia	26.3
Myrica esculenta	17.4

5.2 Vegetation composition of the man-made forest

In the man-made forest I recorded 92 trees of 14 species belonging to 12 families (Fagaceae, Lythraceae, Juglandaceae, Proteaceae, Myrtaceae, Leguminosae, Salicaceae, Lauraceae, Meliaceae, Pinaceae, Moraceae and Ulmaceae) in about 150 meter squares plot (Table 5.6).

Table 5.6. Tree species in man-made forest study site

S.N	Name of tree species	Local name	Family
1	*Castanopsis tribuloids*	Katus	Fagaceae
2	*Lagerstroemia indica*	Asare phool	Lythraceae
3	*Juglans regia*	Okhar	Juglandaceae
4	*Quercus glauca*	Falat	Fagaceae
5	*Grevillea robusta*	Kaioo phool	Proteaceae
6	*Callistemon citrinus*	Kalki phool	Myrtaceae
7	*Albizia julibrissin*	Seerish	Leguminosae
8	*Populus euro-americana*	Lahare pipal	Salicaceae
9	*Cinnamomum camphora*	Kapoor	Lauraceae
10	*Melia azedarach*	Bakaino	Meliaceae
11	*Morus indica*	Kimboo	Moraceae
12	*Celtis indica*	Khari	Ulmaceae
13	*Pinus roxburghii*	Rani-Sallo	Pinaceae
14	*Salix babylonica*	Bains	Salicaceae

In the man-made forest the highest density 466.6 trees/ha of *Salix babylonica* and the lowest density 22.2 trees/ha of *Cinnamomum camphora*, *Melia azedarach*, *Morus indica* and *Celtis australis* were observed. In between these species were *Lagerstroemia indica, Pinus roxburghii, Juglana regia, Populus euro-americana, Grevillea robusta, Albizia julibrissin* and *Callistemon citrinus* whose density ranged between 444.4 trees/ha to 44.4 trees/ha.

Similarly, the highest frequency 88.9% was for *Lagerstroemia indica* and the lowest frequency 11.1% was for *Cinnamomum camphora*, *Melia azedarach*, *Morus indica* and *Celtis australis*. The intermediate species with frequencies between 33.3% to 22.2% were *Castanopsis tribuloids, Quercus glauca, Juglans regia, Populus euro-americana, Grevillea robust, Callistemon citrinus* and *Albizia julibrissin*.

The highest basal area 0.24 m^2 of *Populus euro-americana* and the lowest basal area 0.003 m^2 of *Celtis australis* were recorded in the man-made forest. The species like *Grevillea robusta, Callistemon citrinus, Albizia julibrissin, Pinus roxburghii, Lagerstroemia indica*, *Melia azedarach*, *Salix babylonica, Juglans regia, Cinnamomum camphora* and *Morus indica* were between the highest and the lowest with basal area between 0.08 m^2 to 0.004 m^2.

Similarly, the IV 50% was highest for *Populus euro-americana* and the IV 4.3% was lowest for *Celtis australis*. In between them were *Lagerstroemia indica, Salix babylonica, Quercus glauca*, *Pinus roxburghii, Grevillea robusta, Castanopsis tribuloids, Juglans regia, Albizia julibrissin, Callistemon citrinus, Meli azedarach*, *Cinnamomum camphora* and *Morus indica* with IV 47.1% to 4.5% (Table 5.7)

Table 5.7. Density, Frequency, Basal area and Importance value of tree species

Name of tree species	Density Trees/ha	Frequency (%)	Basal area (m^2)	Important value
Castanopsis tribuloids	155.5	33.3	0.038	21.5
Quercus glauca	200.0	33.3	0.06	26.9
Lagerstroemia indica	444.4	88.9	0.022	47.1
Juglana regia	133.3	33.3	0.016	17.2
Grevillea robusta	88.9	22.2	0.08	21.6
Callistemon citrinus	44.4	22.2	0.05	14.9
Albizia julibrissin	111.1	22.2	0.03	15.3
Populus euro-americana	133.3	33.3	0.24	50.0
Cinnamomum camphora	22.2	11.1	0.012	5.7
Melia azedarach	22.2	11.1	0.021	7.0
Morus indica	22.2	11.1	0.004	4.5
Celtis australis	22.2	11.1	0.003	4.3
Pinus roxburghii	177.7	33.3	0.066	26.7
Salix babylonica	466.6	33.3	0.04	37.0

Similarity and dissimilarity analysis showed that the Sorenson's index of similarity between natural forest and man-made forest was 2.6 % whereas the dissimilarity was 97.4%.

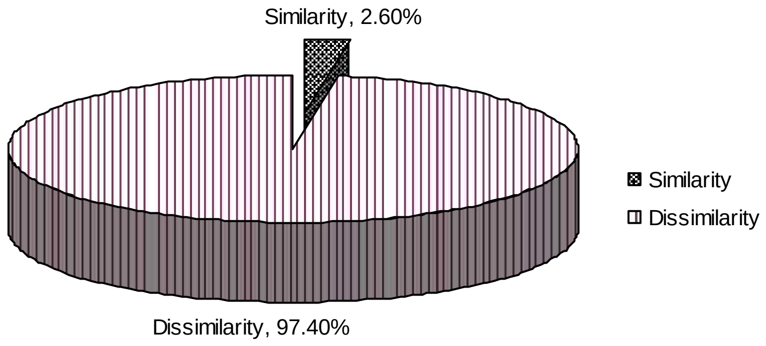


Figure 6. Sorenson's index of similarity between the natural and man-made forest

5.3 Litter fall production

Annual litter production of the natural forest was higher (5037.5 kg/ha) than that of the man-made forest (4251.9 kg/ha). In the natural forest total annual litter fall was 5037.5 kg/ha of which 79.8% (4018.4 kg/ha) was contributed by leaf fall and 20.2% (1019.1 kg/ha) by twigs fall. Similarly, in the man-made forest total annual litter fall was 4251.9 kg/ha of which 82% (3482.9 kg/ha) was contributed by leaf fall and 18% (769.0 kg/ha) by twigs.

Seasonal litter fall in both natural and man-made forests indicated a uniform pattern with its peak in the autumn season followed by winter, spring, and the least in summer season. In the natural forest the leaf fall and twigs fall ranged between 1292.6 ± 5.03 kg/ha to 879.6 ± 3.92 kg/ha and 340.0 ± 1.58 kg/ha to 182.9 ± 1.01 kg/ha respectively. Likewise in the man-made forest the leaf fall and twigs fall ranged between 1082.7 ± 4.78 kg/ha to 705.4 ± 2.13 kg/ha and 280.0 ± 1.35 kg/ha to 146.7 ± 1.16 kg/ha respectively (Table 5.8).

Table 5.8. Seasonal litter falls in the natural and man-made forests.

Seasons→ Falls↓	Autumn	Winter	Spring	Summer	Total
Leaves kg/ha (NF)	1292.6 ± 5.03	962.9 ± 4.80	883.3 ± 2.10	879.6 ± 3.92	4018.4
Leaves kg/ha (MMF)	1082.7 ± 4.78	930.0 ± 3.26	764.8 ± 2.05	705.4 ± 2.13	3482.9
Twigs kg/ha (NF)	340.0 ± 1.58	264.8 ± 1.26	231.4 ± 1.05	182.9 ± 1.01	1019.1
Twigs kg/ha (MMF)	280.0 ± 1.35	175.5 ± 1.21	166.8 ± 1.08	146.7 ± 1.16	769.0
Total litter fall kg/ha (NF)	1632.6	1227.7	1114.7	1062.5	5037.5
Total litter fall kg/ha (MMF)	1362.7	1105.5	931.6	851.7	4251.9

(NF- Natural forest; MMF – Man made forest)

5.4 Rate of litter decomposition

The pattern of leaf litter decomposition indicated most rapid weight loss during summer season and the minimum during winter season. The highest weight loss was 38.0 ± 1.70 gm in the natural forest and 32.5 ± 1.61 gm in the man-made forest, the decomposition rate being 0.42 ± 0.021 gm/day and 0.36 ± 0.40 gm/day respectively (Table 5.8).The average rate of litter decomposition was higher in the natural forest (0.32gm/day) than the man-made forest (0.27gm/day) but they did not show any significant difference (Table 5.9).

Table 5.9. Seasonal weight loss (gm) and rate of litter decomposition (gm/day) in the natural and man-made forests.

S.N	Season	Natural forest		Man-made forest	
		Weight loss (gm)	Weight loss rate (gm/day)	Weight loss (gm)	Weight loss rate (gm/day)
1	Autumn(fall)	27.3 ± 2.36	0.30 ± 0.025	21.6 ± 0.75	0.24 ± 0.04
2	Winter	21.4 ± 0.92	0.23 ± 0.30	19.0 ± 2.16	0.21 ± 0.014
3	Spring	30.6 ± 1.56	0.34 ± 0.063	24.8 ± 2.06	0.28 ± 0.021
4	Summer	38.0 ± 1.70	0.42 ± 0.021	32.5 ± 1.61	0.36 ± 0.40
	Total	117.3		97.9	

5.5 Soil

Samples of soil (three samples from three stations = nine samples) were collected every three months for the analysis of physical and chemical parameters. Determinations were carried out separately for each sample from both sites. In general, the soil of the study area ranged from loamy sand to sandy loam. The chemical parameters included Ph, organic matter, total nitrogen, available potassium and available phosphorus.

The Ph in the natural forest ranged from 4.5 – 5.07, the highest being in winter season and lowest in spring season. In the man-made forest the Ph ranged from 5.33 – 5.92 which was little higher than the natural forest showing the same trend. The organic matter in both the forest types was very high ranging from 4.94 – 10.53% with highest in winter season followed by spring, autumn and least in summer season. Total nitrogen content of the soil samples collected seasonally ranged from 0.40 – 0.52% in the natural forest where as from 0.25 – 0.39% in the man-made forest. At both the sites it decreased in the summer season and was high during winter season. The available phosphorus was the highest in summer season which was followed by autumn, winter and spring in both the forest types. It ranged from 7.95 – 45.13 kg/ha in the natural forest and from 90.25 – 311.23 kg/ha in the man-made forest. The value of available potassium was highest in summer season followed by autumn, spring and winter. The value ranged from 250.04 – 303.02 kg/ha in the natural forest whereas from 300.61 – 483.61 kg/ha in the man-made forest (Table 5.10).

Table 5.10. Soil parameters in natural and man-made forests.

Seasons ↓		Organic matter (%) (Very high)	Total nitrogen (%) (Medium-V.high)	Available Phosphorus(kg/ha) (Medium)	Available Potassium(kg/ha) (High)	PH (Acidic)
N - Forest	Autumn	8.13	0.41	26.93	279.43	4.5
	Winter	10.53	0.52	10.25	250.04	5.07
	Spring	10.38	0.52	7.95	276.38	4.31
	Summer	7.83	0.40	45.13	303.02	4.60
M – M Forest	Autumn	6.70	0.33	125.0	420.70	5.44
	Winter	7.82	0.39	96.61	300.61	5.92
	Spring	6.80	0.34	90.25	360.75	5.33
	Summer	4.94	0.25	311.23	483.61	5.72

5.6 Wildlife and soil organisms

I found out following different groups of animals taking part in litter decomposition process, thus leading to nutrient cycling process.

Table 5.11 Group of organisms taking part in litter decomposition process

SN	Group of Organisms	Effects	Sources
1	Oligochaeta	Burrowing animal	Plowman (1983)
2	Rootlets and fungi	Invaded the fragmenting litter	Plowman (1983)
3	Pigs	Buried litter beneath soil	Plowman (1983)
4	Macroarthropods (Isopoda, Araneae, Blattodea and coleopteran)	Fragmented litter	Burghouts et al. (1992)
5	Wild boar, Porcupine, Monkey, Beer, Deer	Destroyed ground vegetation	Gurung (2002)
6	Monkey, Wild boar, Porcupine, jungle cat, jackal	Crop depredators	Bajracharya (2005)

5.7 Relation between litter fall, litter decomposition and organic matter

The calculated value of correlation coefficient in natural forest (0.72) was high which indicated that litter fall and litter decomposition were highly correlated with each other. The value of correlation coefficient of the man-made forest indicated an average correlation ($r = 0.54$) between litter fall and litter decomposition.

The calculated values of 'r' in the natural forest (0.88) and in the man-made forest (0.98) were very high which indicated that the organic matters of the soil and litter decomposition were highly correlated with each other.

The result of 't' test showed that there was no significant difference between the means of litter fall as well as means of litter decomposition in the natural and disturbed forest (Table 5.12).

Table 5.12. Student's 't' test for litter fall and litter decomposition between the natural and man-made forests. ($P = 0.05$)

Source of mean	d.f. ($n_1 + n_2 - 2$)	Calculated 't'	Tabulated 't"	Significance
Rate of litter fall	6	1.32	1.943	NS
Rate of litter decomposition	6	1.25	1.943	NS

($n_1 = 4$ and $n_2 = 4$) (NS = Not significant)

5.8 Comparison between the Natural and Man-made forests

The results of one way ANOVA showed that there was no significant difference between the natural and the man-made forests in terms of litter accumulation, litter decomposition and soil nutrients (Table 5.13). The value of F-ratio for litter decomposition was 0.014 and that for litter fall was 2.56. The F-ratio for soil parameters ranged between '0.716 to 0.0183', the highest value was for available phosphorus and the lowest for soil PH (Table 5.13).

Table 5.13. Results of one way ANOVA

(Confidence level 95%)

Source of Variation	d. f.	Sum of squares (SS)	Mean sum of squares (MS)	F ratio	Significance
Between Litter fall	1	9785087.628	9785087.628	2.56	NS
Residual	6	22883345.33	3813890.888		
Between Litter decomposition	1	0.005	0.005	0.014	NS
Residual	6	2.139	0.356		
Between PH	1	1.93	1.93	0.0183	NS
Residual	6	632.79	105.465		
Between Organic matter	1	14.04	14.04	0.055	NS
Residual	6	1536.76	256.126		
Between Total Nitrogen	1	0.035	0.035	0.054	NS
Residual	6	3.865	0.644		
Between Available phosphorus	1	35488.47	35488.47	0.716	NS
Residual	6	297291.04	49548.506		
Between Available Potassium	1	26083.31	26083.31	0.057	NS
Residual	6	2760686.386	46114.4		

(F- Tab – 5.987) (NS – Not significant)

6. Discussion

6.1 Vegetation

Forest structure and composition, number of species and families and densities of trees were different in the natural and the man-made forests. This variation depended mainly on what species were planted in the man-made forest and what environmental conditions prevailed in the natural forest. There were 11 tree species of 6 families in the natural forest and 14 tree species of 12 families in the man-made forest. According to the dominant species, the natural forest proved to be the Oak- Rhododendron forest type. The Fagaceae family was more common in both the forest types.

In the natural forest, *Quercus glauca* consisted of the highest frequency and *Prunus cerrasoids* and *Myrica esculenta* the lowest frequency whereas, in the man-made forest, *Lagerstroemia indica* possessed the highest frequency and *Cinnamomum camphora*, *Melia azedarach*, *Morus indica* and *Celtis australis* possessed the lowest frequency (Table 5.3 and 5.7).

A comparison of vegetation characteristics of different forests of Nepal.

The range of density of individual species (44.4 – 555.6 trees/ha) in the natural forest found in the present study was in the lower range of the individual species (390 – 710 trees/ha) of Shivapuri reported by Yadav et al. (1984). The similarity index 2.6% recorded was very much lower in comparison to the similarity index 81.48% recorded by Dhungana (2004) between natural and degraded forest of Trisuli Watershed area. This indicated a vast difference between man-made and degraded forest ecosystems.

The value of mean stand density of 323.2 trees/ha of the natural forest was little higher than that of the natural forest of Karne forest and was little lower than that of the natural forest of Trisuli Watershed area. Similarly the values of mean stand density of 146 trees/ha of the man-made forest was higher than that of degraded forest of Chitrepani Leasehold forest and was lower than that of degraded forest of Trisuli Watershed area (Shrestha et al.2000 and Dhungana 2004). Shrestha et al. (2000) reported the mean stand density of natural and degraded forests of Karne and Chitrepani to be 264 trees/ha and 23 trees/ha respectively.

Dhungana (2004) reported the mean stand density of natural and degraded forests of Trisuli Watershed area to be 370.2 trees/ha and 240.9 trees/ha respectively. Compared to the man-made forest, the natural forest showed a greater stand density. This was due to randomly grown different tree species in the natural forest.

Table 6.1. Vegetation Characteristics of various forest ecosystems in Nepal

Forest type	Location	Stand density (no./ha)	Basal area (m^2/ha)	Source
Oak-Rhododendron forest (N-F)	Shivapuri national Park	332.23	12.7	Present study
Coronation Garden forest (M-Made F)	Tribhuvan university	146	48.7	Present study
Lower Tropical Sal forest(NF)	Trisuli Watershed area	370.16	70.31	Dhungana Ishwari (2004)
Lower Tropical Sal forest(DF)	Trisuli watershed area	240.91	29.26	Dhungana Ishwari (2004)
Natural forest	Karne forest	264	59.6	Shrestha et al. (2000)
Degraded forest	Chitrepani Leasehold forest	23	11.4	Shrestha et al. (2000)
Sal regenerating forest	Chitrepani Community forest	57	52.2	Shrestha et al. (2000).

A comparison of Vegetation characteristics of present study with different forests of world.

The value of mean stand density 323.23 trees/ha and mean basal area 12.7 m^2/ha for the natural forest was well within the range of dry tropical forest. Jha and Singh (1990) reported the stand density and the mean basal area of the dry tropical forest of Vidhyan region to be 294 – 559 trees/ha and 7 – 23 m^2/ha respectively. Similarly those values of stand density and basal areas were more or less similar to those of dry evergreen forest.

Hubbel and Foster (1983) reported the stand density of 152 trees/ha for the tropical rain forest of Barra Colarado Island, Panama. Campbell et al. (1986) reported the basal area of 18 – 68 m^2/ha for the tropical rain forest of Amazonia. Thus, the stand density (146 trees/ha) and the basal area (48.7 m^2/ha) of the man-made forest were closer to the values reported for the tropical rain forests.

6.2 Litter fall production

The trend of litter fall of different components was: leaves greater than twigs. Among the different litter components viz., leaves and twigs, the contribution of leaves was maximum in both forest types. For example, 79.8 % was contributed by leaves and 22.2% by twigs in the natural forest whereas 76.5% was contributed by leaves and 23.5% by twig in the man-made forest. The above pattern of litter production agreed with the findings of Bray and Gorham (1964) and Garg (1997). The values for leaves were toward the upper side of the range (40-84%) reported for temperate forests (Rodin and Bazilevich 1967). The values for twigs felled within the range, 10-36%, reported for different forests of the world (Bray and Gorham 1964).

Significantly higher annual litter production in the natural forest than in the man-made forest was attributed to the nature and extent of the canopy growth of the former forest. Because yearly litter yield was known to be a function of the annual synthesis of fresh organic matter as foliage and other components in forests as reported by Bray and Gorham 1964.

The total litter fall did not indicate seasonal equability (Table 5.8). However, the litter fall in autumn accounted for a major fraction of the annual litter yield in both forests. More than 32% of the annual litter production was obtained during autumn in both forest types.

Maximum litter fall during the autumn months in these forests was characteristic of both forest types.

Pandey and Singh (1981) recorded maximum litter fall during summer for a mixed Oak-Conifer forest of Kumanu Himalaya. Pant and Tiwari (1992) recorded the maximum litter fall in summer, which was followed by winter and rainy season in a Montane Oak forest of Garhwal Himalaya. These findings differed from the findings of the present study. This might be due to the variation of climatic factors and topographical differences. But they also reported that the distribution of rain fall and litter fall has an inverse relationship i.e. low rain fall period and high litter fall and vice versa.

Table 6.2. A Comparison of Total litter fall and leaf litter fall in various forests.

Forest Type	Location	Total litter fall (t/ha/yr)	Leaf litter fall (t/ha/yr)	Reference
Oak – Rhododendron forest (NF)	Shivapuri national park	5.04	4.02	Present study
Coronation Garden forest (M-MF)	Tribhuvan University	4.25	3.50	Present study
Moist deciduous forest	UP – Dehra Dun	4.54 – 11.2	5.1 – 8.3	Seth and Yadav (1960)
Dry evergreen forest	PO - Coromandal	4.3 – 12.2	3.43 – 9.49	Visalakshi (1995)
Montane temperate forest	UP-C. Himalaya	4.26 – 7.81	2.57 – 5.90	Saxsena et at. (1978)
Montane sub- tropical forest	TN - Gundar	5.5	3.9	Blasco and Tassy (1975)

The present values of total litter fall (5.04 t/ha/yr in the natural forest and 4.25 t/ha/yr in the man-made forest) were higher than the mean litter fall of 3.5 t/ha/yr reported for the Oak forests of world (Rodin and Bazilevich 1967) and 4.12 t/ha/yr litter production recorded for a mixed Oak – Conifer of Kumanu Himalaya (Pandey and Singh 1981).

These values of total litter fall and the values of leaf litter fall (4.02 t/ha/yr in the natural forest and 3.50 t/ha/yr in the man-made forest) felled within the range of Dry Evergreen forest (Total litter fall of 4.3–12.2 t/ha/yr and leaf litter fall of 3.43 – 9.49 t/ha/yr) of Coromandal (Visalakshi 1995).

Bray and Gorham (1964) found the total litter production in world forests averages 1t/ha/yr in arctic alpine forests, 3.5 t/ha/yr in cool temperate forests, 5.5 t/ha/yr in warm temperate forests and 11 t/ha/yr in equatorial forests. However, the range in litter production within different major climatic zones was rather wide. So, the results reviewed by Jenson (1974) indicated a range in total annual litter production of 1.5 – 9.9 t/ha/yr in tropical region. The value of total litter fall recorded for the present natural forest (5.04 t/ha/yr) and the man-made forest (4.25 t/ha/yr) was lower than the tropical region forests. However, it felled within the range of cool temperate region (Jenson 1974).

The average annual woody litter fall (twigs) recorded in this study for the natural forest (1.02 t/ha/yr) was slightly higher than the world mean of 0.9 t/ha/yr for Cool temperate forests whereas it was slightly lower for the man-made forest (0.77 t/ha/yr) studied at present. Similarly, both values for natural forest and the man-made forest were slightly lower than 1.1 t/ha/yr for mixed Oak – Conifer forest of Kumanu Himalaya (Pandey and Singh 1981) and 1.3 t/ha/yr reported for an Oak – hickory forest in central Missouri (Rochow 1974) and Tropical humid montane forest of southern India (Blasco and Tassy 1975).

The comparison in the rates of litter fall between the natural and the man-made forest at 5% level of significance indicated that there is no significant difference between the rates of litter fall of the natural and the man-made forests (Table 5.12). It may be due to the undisturbed nature of the man-made forest. As being a garden forest there is no such human activities like firewood, fodder collection, timber etc.

6.3 Rate of Litter decomposition:

The pattern of litter decomposition indicated most rapid weight loss during summer season and the minimum during the winter season in both natural and man-made forests. The high rate of decomposition in summer season could be ascribed to the suitable temperature and moisture condition for the activity of decomposers (microorganisms). Environmental conditions, mainly temperature and moisture played a role in litter decomposition in terrestrial environment. The lower rate of decomposition in winter was due to average low winter temperature. The decomposition during winter (21.4% in the natural forest and 19.0% in the man-made forest) estimated in this study (Table 5.9) was higher than over-winter 9% loss of weight reported for Jeffrey Pine needles under snow (Stark 1971) and lower than over-winter 30 – 50% loss recorded for grasses and ferbs under snow (Bleak 1970), 25% loss of weight during winter for Aspean leaves in Northeastern Minnesota (Grigal and McColl 1977), 27% loss of *Qleucotrichophora* leaf litter during winter in Naini Tal hills, Kumanu Himalaya (Saxsena et al. 1978).

The rate of litter decomposition was higher in the natural forest than in the man-made forest (Table 5.9). It may be due to less canopy cover that reduces the moisture content of soil in the man-made forest. Organic matter dynamics is an important aspect of the decomposer sub-system in the forest ecosystems. In the forest ecosystem the rate of litter decomposition is mainly governed by the nature of substrate, soil oxygen availability, soil salinity, and micro-organism and scavenger activity. Due to all these differences between the natural and man-made forests, the decomposition rate was also different.

The initial chemical constituents of the litter, physical structure of tissues and their proportionate variation in plant organs like leaves, twigs, fruit, seeds etc. have profound effect on the decay rate (Swift 1979). The rate of decomposition of leaves and twigs are correlative to the number of initial chemical constituents. These correlations are obviously due to the wide chemical as well as structural differences in litter components viz. leaf and twigs. Nitrogen and magnesium are said to have positive relation with decay rate. During the decomposition process, carbon is used as energy source by decomposers, while nitrogen is assimilated into cell proteins and other components. The role of magnesium has not been defined in the decomposition process however it is assumed that this nutrient is required by the decomposer organisms for their metabolic activities because substantial amount of this element was found in the element composition of the decomposer organisms (Swift 1979).

Table 6.3. A Comparison of seasonal variation in leaf litter Decomposition of different forests (%/season).

Season	*Quercus leucotrichophora* Forest.	Oak-Rhododendron forest (N-F)	Coronation Garden forest (M-made- F)
Summer	2.2	23.27	22.06
Autumn	52.9	18.24	19.40
Winter	19.4	26.08	25.33
Spring	1.4	32.39	33.20

The correlation coefficient between the rate of litter fall and the rate of leaf litter decomposition in both natural (r = 0.716) and man-made forests (r = 0.535) were positive. The accumulation of large amount of organic matter in the soil due to high litter fall resulted the high rate of litter decomposition (Table 5.9). But there was no significance difference between the means of the rate of litter decomposition between the natural and the man-made forest at 5% level of significance, which may be due to a)similar pattern of physiographic features b) no any human disturbances like fodder collection, firewood and c) similarity between soil nutrients (Table 5.12).

6.4 Soil

The soils of both natural and man-made forests were acidic in reaction and PH ranged from 4.31 – 5.92. Very high status of organic matter and total nitrogen was maintained in these soils whereas, available phosphorus and available potassium showed a medium to very high and medium to high range respectively. The organic matter and nutrients were high especially in upper layers because of the fall of huge amount of litter on the soil surface and its rapid decomposition due to favorable conditions of moisture and temperature.

Organic matter differed significantly among seasons in both the forest types. At both the natural and man-made forests, organic matter decreased in summer season and was high during winter season. With the sparse plant cover, resulting lower litter falls, organic matter content of the soil decreases (Forth 1984).

Total nitrogen content differed slightly among seasons but it did not show a great variation as did available phosphorus and available potassium. However, it decreased in summer season and was high during winter season. This result showed a similarity with the results obtained by Forth (1984), Shrestha (1979) and Black (1968). Forth 1984 proved a direct relation between organic matter content and available nitrogen of the soil, i.e. as the organic matter increases the available nitrogen also increases and vice-versa. Shrestha (1979) suggested that nitrogen was obtained from organic matter and showed variation with seasons. Similarly Black (1968) emphasized on the dominant role of climate in determining nitrogen content of the soil through the influence of temperature and water supply on the activities of plants and microorganisms.

Available phosphorus content for both the natural and man-made forests was low in spring and high in summer season. Sah (1983), Read and Mitchell (1983) also found similar results.

Available potassium content for both the natural and man-made forests was low in winter and high in summer season. Potassium concentration was lower in natural forest than in man-made forest, it may be due to mobile nature of potassium which leaches out most rapidly from canopy and the leaf litter by rain as suggested by Sah (1983).

Table 6.4. Mean values of various soil constituents in different forest types.

Soil character	Natural forest (ShNP)	Man-made forest (Coronation garden)	Moist-deciduous forest (Dandeli)	Semi-evergreen forest (Yellapur)	Wet-evergreen forest (Siddapur)	Scrub forest (Jog)
PH	4.62	5.6	6.3	6.2	6.4	5.3
Total Nitrogen(%)	0.47	0.33	0.27	0.4	0.28	0.2

The PH of the man-made forest was similar to some extent with that of Scrub forest whereas it was lower than the moist-deciduous forest and wet-evergreen forest type studied by Singh (1968). The total nitrogen of the man-made forest was lower that the total nitrogen recorded for all those forest types. Similarly the Ph of the natural forest was little lower than those records for moist-deciduous, semi-evergreen, wet-evergreen and scrub forest types but total nitrogen content was some what similar to that of semi-evergreen forest type and higher than that of the others.

The chemical composition of soils had been influenced to a great extent by drainage condition, differential transport or eroded material, leaching, translocation and redeposition of mobile soil constituents. Chemical composition of the soil indicates trend in laterisation process with release of bases, oxidation of organic matter and breakdown of parental material.

6.5 Wildlife and soil organisms

Isopods, diplopoda, coleopteran, formicidae and oligochaeta played a major role in decomposition process Burghouts et al. (1992). Soil arthropods as a whole were less prominent in decomposition processes but termites were primary because the ability of termites to breakdown wood and other plant litter is greatly enhanced by the presence of symbiotic protozoa in their digestive tract. Gurung (2002) estimated the major ground vegetative loss were due to the presence of animals like Wild boar (*Sus Scrofa*), Porcupine (*Hystix indica*), Monkey (*Macaca mulatta*), Beer (*Selenarctos thibetanus*), Deer(*Muntiacus muntijak*) and various types of birds. Wild boar was very frequent all over the ShNp and monkey was very frequent in Sundarijal which were the major organisms for crop depredation (Bajracharya 2005). Thus wild animals like wild boar, leopards, langur, jungle cat, barking deer played a significant role in litter decomposition. They scratch the ground surface so that the litter is partially buried beneath the soil which helps in faster decomposition and they also make the litter partially degraded. Plowman (1983) recorded pigs bury leaves beneath the soil promoting decomposition process. He also added that Oligochaeta were the main burrowing animals whereas Rootlets and fungi invaded the fragmenting litter.

7. CONCLUSION AND RECOMMENDATIONS

I studied the main aspects of nutrient cycling like litter fall, litter decomposition rate, major soil nutrients (N, P and K), organic matter and PH in the Shivapuri National park and taken as a reference in Coronation Garden of T.U. The study area was divided into three stations. Density, frequency and basal area of the tree species were measured and the important plant species existing were identified. Field observation showed that there were eleven tree species belonging to six families. The result of vegetation showed that *Quercus glauca* was the densest species and the most frequent species was *Castonopsis indica*. In the man-made forest *Salix babylonica* was the densest species and *Lagerstroemia indica* was most frequent.

The maximum litter falls were recorded during autumn and summer season respectively (Table 5.8). The annual litter fall and rate of litter decomposition were slightly lower in the man-made forest than the natural forest (Table 5.8 and 5.9) which suggested that litter fall and decomposition were governed by the strength of canopy cover.

The soil was rich in nutrient content and was acidic in nature. PH, organic matter, total nitrogen, available phosphorus and available potassium showed fluctuations with seasons. The organic matter, PH and total nitrogen were highest in winter season due to the suitable temperature and moisture content whereas available phosphorus and potassium were highest in summer season in both forests (Table 5.10).

The group of organisms like oligochaeta, isopoda, araneae, blattodea, coleoptera, rootlets, fungi, wild boar, porcupine, monkey, beer, and deer played a major role in the litter decomposition process, thus contributing to soil nutrient (Table 5.11).

The positive correlation between litter fall and litter decomposition and between organic matter and litter decomposition suggested that soil nutrients depended largely on the rate of litter fall and decomposition, leading to a strong relationship between soil nutrients and the forest status that determined the nutrient cycling.

Based on the present study and data, some recommendations have been derived as:

a) Most of the researchers have been concentrated in the low land or high mountain areas leaving a big gap of research in the middle mountain. This gap should be narrowed by developing a long-term research program.

b) The study of nutrient cycling in a land ecosystem may lead to a public support in the enrichment of fertility of soil in any agricultural land.

c) By the study of major soil organisms and wildlife contributing to nutrient cycling can lead to the awareness of wildlife and soil organisms.

d) Man-made forest is similar to the natural forest in respect of nutrient accumulation and cycling. So, plantation programme in different places might prove to be one of the best methods of nutrient conservation.

e) Although nutrient cycling is very important topic in ecological studies, it has been neglected. So more of the research works should be concentrated in this topic.

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