

**“HABITAT HETEROGENEITY AND ITS IMPACT ON
ORGANIC MATTER, NUTRIENT POOL AND NITROGEN
MINERALIZATION IN TROPICAL DRY
DECIDUOUS FOREST”**

M. Sc. (Forestry) THESIS

By

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INDIRA GANDHI AGRICULTURAL UNIVERSITY
RAIPUR (C.G.)**

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By

SAJIWAN KUMAR

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CERTIFICATE – I

This is to certify that the thesis entitled “**Habitat Heterogeneity and Its Impact on Organic Matter, Nutrient Pool and Nitrogen Mineralization in Tropical Dry Deciduous Forest**” submitted in partial fulfillment of the requirements for the degree of “**MASTER OF SCIENCE FORESTRY**” of the Indira Gandhi Agricultural University, Raipur, is a record of the bonafide research work carried out by **Mr. Sajiwan Kumar** under my guidance and supervision. The subject of the thesis has been approved by the Student’s Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma (certificate awarded etc.) or has been published/published part has been fully acknowledged. All the assistance and help received during the course of the investigations have been duly acknowledged by him.

Dr. Lalji Singh
Chairman
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THESIS APPROVED BY THE STUDENT’S ADVISORY COMMITTEE

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Member	(Dr. K. Tedia)	_____
Member	(Dr. A. K. Singh)	_____

CERTIFICATE – II

This is to certify that the thesis entitled “**Habitat Heterogeneity and Its Impact on Organic Matter, Nutrient Pool and Nitrogen Mineralization in Tropical Dry Deciduous Forest**” submitted in partial fulfilment of the requirements for the degree of “**M.Sc. in Forestry**” submitted by **Mr. Sajiwan Kumar** to the Indira Gandhi Agricultural University, Raipur, in partial fulfillment of the requirements for the degree of M.Sc. (Forestry) in the **Department of Forestry** has been approved by the Student’s Advisory Committee after oral examination in collaboration with the external examiner.

EXTERNAL EXAMINER

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Major Advisor

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LIST OF ABBREVIATIONS

NOTATION	DESCRIPTION
%	Percent
<	Less than
>	Greater than
⁰ C	Degree Celsius
C	Carbon
CD	Critical differences
CG	Chhattisgarh
E	East longitude
e.g.	For example
<i>et al.</i>	Others
Fig.	Figure
g	Gram
ha	Hectare
K	Potassium
Kg	Kilogram
Kg ha ⁻¹	Kilogram per hectare
M	Meter
mg ha ⁻¹ yr ⁻¹	Milligram per hectare per year
mm	Millimeter
MSL	Mean Sea level
N	Nitrogen
P	Phosphorus
<i>viz.,</i>	Namely
µg g ⁻¹	Microgram per gram
µg g ⁻¹ mo ⁻¹	Microgram per gram per month

CHAPTER - I

INTRODUCTION

The biological cycle of nutrient is one of the principal processes, which support organic productivity (Singh *et al.*, 1992). Both quantity and quality of organic matter interact with soil microclimate and thus influence biogeochemical cycling particularly in relatively dry ecosystem (Burke 1989). The functioning of these ecosystems is typically influenced by the availability of nutrients and water. Approximately one-half of the dry tropical forest in the world occurs on nutrient poor soil (Sanchez 1976, Singh *et al.*, 1989) and in a climate characterized by marked seasonality.

The primary production in most ecosystems is influenced by the availability of nutrients (Cole and Rapp 1980; Chaturvedi and Singh, 1987). The proportion of available forms of nutrients in the soil is generally low and not more than about 1-2% of the total quantity of most mineral nutrients in a soil is readily available for plant uptake (Brady 1984). Nitrogen is an essential plant nutrient, which to a large extent governs the uptake of P, K and others mineral nutrients also and being limited in many plant communities. N deserves special attention on the study of nutrient cycling (Melillo, 1981; Vitousek *et al.*, 1982). The plant available N is produced through N-mineralization.

Soil organic matter influences physico-chemical properties such as water retention, erodibility, cation exchange capacity and nutrient availability (Johnston 1985). It supplies energy and body building

constituents for most of the microorganisms (Allison 1973) and is a critical factor in soil fertility (Brady 1984). Soil organic matter contributes to the soil fertility in a number of ways.

It increases the cation exchange capacity (Johnston 1986), water holding capacity (Salter and William, 1969) and availability of nutrient (Schnitzer and Khan 1978). Influence of temperature and rainfall is dominant on the amount of organic matter in soil (Jenny, 1941). Soil in the cooler climates generally has more soil organic matter than in warm climates (Brady 1984). Soil moisture also exert a positive control upon accumulation of organic matter in soil. Among the soil nutrients, macronutrient viz., nitrogen, phosphorus and potassium, play a key role in influencing the growth of plant. Balanced nutrition is essential for producing good saturated timber.

Addition of organic matter to the soil varies from one ecosystem to other ecosystem and from species to species, within same ecosystems it may vary from one microsites to the other microsites i.e. from depressions to adjoining non-depressions or flats microsites.

The composition and productivity of an ecosystem is markedly affected by physical and chemical properties of soil. Soil properties vary across the landscape due to the modifying effects of topography on soil forming and geomorphic processes (Coleman *et al.*, 1983).

Nitrogen cycling within forest ecosystem is regulated by a complex interrelationship among plant uptake, the quality and quantity of plant litter returned to the soil and mineralization of organic N through the activities of soil microorganisms. The rate at which N is made available for plant growth

is dependent on the process of mineralization. In turn, the rate at which plant material is mineralized is related to the amount of litter returned to the forest floor and its chemical composition.

Nitrogen mineralization is the microbial conversion of soil organic nitrogen to ammonium nitrogen and which in turn may be oxidized to nitrate nitrogen (Vitousek *et al.*, 1982). Ammonium-N and nitrate-N represent the available inorganic forms of nitrogen in the soil. The total amount of N liberated from the organic matter is gross mineralization and the quantity remaining after subtraction *In-situ* microbial immobilization (uptake microbes) is net mineralization. Nitrogen mineralization is of crucial importance in natural forest ecosystem where nitrogen (N) has been reported to be a limiting nutrient for plant growth. Soil moisture and temperature regimes are of paramount importance in determining N-mineralization rates. Major pulses of N-mineralization occur as a result of increase in microbial activity caused by alternate wetting drying (Birch, 1958; Cabrera and Kissel, 1988).

Release of nutrient by biological mineralization is crucial in maintaining cycling of essential nutrients immobilized in dead plant material and vital for continued productivity of terrestrial ecosystems. Increased understanding of factors influencing mineralization may lead to management practices which enhance microbial nutrient mineralization without addition of fertilizers (Elliott and Coleman 1988).

Although plants take up the inorganic $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$, they produce organic N compounds and return there to the soil through litter fall. The plant available N is produced through N-mineralization. As a result of

enzymatic digestion the more complex protein and allied compound of the organic matter are simplified and hydrolyzed to NH^+ .

Topographic situation is known to influence greatly the N-mineralization rate in dry tropical forest (Raghubanshi, 1992). Nitrogen is undoubtedly the most intensively studied plant nutrient in both natural and managed ecosystem. Despite its importance to plant growth and ecosystem productivity there is still no reliable soil test for nitrogen availability. In natural ecosystems nitrogen losses are generally assumed to be small because of efficient nutrient cycling, mineralization occurring in synchrony with plant uptake on managed system however this synchrony may be disrupted leading to the build up of mineral nitrogen in soil. This nitrogen is susceptible to losses *via* various pathways. Leaching losses can be large especially in the humid tropics where rainfall is high and a majority of the soils have little retention capacity for cations or anions. Losses of nitrogen through denitrification may be as large or larger than through leaching in disturbed or managed system. Little is known however, about denitrification in tropical ecosystem, natural or managed.

Phosphorus occurs naturally on the earth's surface principally as orthophosphate (PO_4^{3-}) but under reducing conditions, such as those that occur in lake sediments. Soil organic matter content and composition is related to the availability of phosphorus in soil; Walker and Adams (1958, 1959). Walker *et al.* (1959) and Smeck (1973) suggested that the phosphorus content of the parent material ultimately controlled the organic carbon, phosphorus, nitrogen and sulphur contents of soil. Walker (1965) and Walker and Syers (1976) have suggested that phosphorus availability to

organism would control nitrogen fixation and that in turn would ultimately control organic matter accumulation.

Considerable progress has taken place (Cole *et al.*, 1977) in the elucidation of specific parts of phosphorus reaction but progress has been limited by the extreme reactivity of phosphorus and its existence as part of a large number of inorganic and organic compounds.

Habitat heterogeneity in terms of patchy availability of nutrients in a dry tropical forest is characteristic features. The forest floor is characterized by the presence of topographic depressions, litter accumulation in these troughs gives rise to patchy microsites, which are different in appearance from the adjoining non-patchy milieu flats.

The troughs are characterized by higher available nutrient pool size, these microsites, richer in nutrients furnish pockets of nutrient reserves in otherwise nutrient poor soil to be exploited by the plants. Microsites richer in available plant nutrients have been found to be an important source of mineral nutrient for plants in a variety of environment (Chapin 1980; Bloom *et al.*, 1985, Robinson and Rorison 1983; Grime *et al.*, 1986). Hence it is expected that in dry tropical deciduous forest under study the soil properties such as texture, bulk density, water holding capacity, nutrient pool, total N available N, inorganic P organic C and N-mineralization will be higher in troughs than flat microsites.

The present study entitled “**Habitat Heterogeneity and Its Impact on Organic Matter, Nutrient Pool and N-mineralization in Tropical Dry Deciduous Forest**” was carried out at Barnawapara wildlife sanctuary Raipur (C.G.) during 2005-2006 with following objectives:

1. To assess the effect of habitat heterogeneity on organic matter and nutrient pool in three different seasons.
2. To study the effect of habitat heterogeneity on nitrogen mineralization.

CHAPTER – II

REVIEW OF LITERATURE

In this chapter an attempt has been made to review the work done on organic matter, nutrient pool, nitrification and nitrogen mineralization. However, little work has been done on nitrogen mineralization in tropical forest in sub humid and dry deciduous forest, but there is a total lack of information or only little work has been done on nitrogen mineralization and nutrient pool on the physio-graphically distinct microsites on the forest floor of the tropical dry deciduous forest of India. The literature related to organic matter, nutrient pool and nitrogen mineralization are broadly reviewed under the following heads.

2.1 Organic matter, nutrient pool in relation to habitat heterogeneity

Organic matter influences physical and chemical properties of soils, out of proportion to their small quantities present (Allison, 1973). Carbon is a common constituent of all organic matter and is involved essentially in all life processes. Consequently, by the transformation of this element, termed the carbon cycle is in reality a bio-cycle that makes possible the continuity of life on earth.

Soil microorganisms play a key role in the decomposition of residues and cycling of plant nutrient (Hutchinson and King, 1982). Microbial biomass a labile fraction of soil organic matter (Jenkinson and Ladd, 1981) is both a major sink for plant-available nutrients (immobilization) and source (mineralization) (Singh *et al*; 1989).

Brams-E (1973) has reported soil organic matter and phosphorus relationship under tropical forest. A positive correlation was detected between organic C and acid-extractable inorganic P (Bray P_i) in the surface soil (0.15 cm deep), but not in the sub soil (32-60 cm), in soils of the humid tropics under secondary forest in Sierra Leone. The concentration of Bray P_i was 1-20 kg/ha in the surface soil and about 1/5 of this in the sub soil. This finding is briefly discussed in relation to the simultaneous decline in soil organic matter and P contents after clearing in a shifting cultivation system.

Paul and Juma (1981) recognized the difficulty in demonstrating mineralization relationship in natural ecosystems. Generally, mineral-N does not accumulate in undisturbed grassland or forest sites since carbon input is high and nitrogen is the element limiting decomposition. Organic matter is positively related to cation exchange capacity and moisture retention. Moreover, it can provide a stable storage mechanism for retaining the N fixed by alder until subsequent crops can use it. In addition Harvey *et al.* (1979) showed that increased soil organic matter leads to greater ectomycorrhizal development.

During forest development forest floor materials accrete in mass and nutrient become progressively less available (Vogt *et al.*, 1986, Bonan 1990, Viereck *et al.*, 1993). It seems that in addition to the general slowing down of microbial activity at the lower temperature in montane forest (reflected in the slower decay of the litter) (Edwards, 1977) there is a complexation of organic matter by soil colloids (Edwards and Grubb, 1982), so that nitrogen continuously accumulates and is relatively unavailable to plants.

Singh (1989) studied the mineral nutrient in tropical dry deciduous forest and Savanna ecosystem in India and found that the forest (including soils) contained 1.5 times more nitrogen and phosphorus and over 3-5 times more potassium than Savanna. The larger part of the mass of all nutrients are held in the soil in both ecosystem. The mean concentrations (biomass weighted) of nitrogen, phosphorus and potassium in the Savanna vegetation as a whole were 77,100 and 105% greater than the corresponding concentration in forest. The annual nitrogen and phosphorus uptake and return through litter fall were similar in both ecosystems. The Savanna however, showed a greater uptake and return of potassium. The annual below ground nutrient return in the savanna was about 1-5 times greater than in the forest relative to their low share (<2%) in the nutrient content of the forest vegetation. Herbs accounts for 15-24% of annual uptake of the major nutrients.

Burke *et al.* (1989) have reported that the highest total and available N and P in topographic depression in a sagebrush steppe landscapes on Wyoming.

Prasad and Gupta (1990) have reported the heterogeneity in soil properties in seven soil pedons exposed on one quadrat in each of three forest types—southern tropical dry deciduous forest in coimbatore division Tamil Nadu, Southern moist mixed deciduous forest in Palghat division Kerala and West coast tropical evergreen forest Gudalur division Tamil Nadu. They found the maximum variation in the evergreen forest with less variation in moist and dry deciduous forest (in that order). The most pronounced heterogeneity was in terms of clay, silt, P₂O₅, organic carbon,

cation exchange capacity and base saturation. The data suggested that besides exposing a single pedon on or adjacent to a vegetation quadrat auger samples should also be collected to take account of soil heterogeneity.

Raghubanshi, (1991) studied on dynamics of biomass C, N and P in dry tropical forest in India and reported that the texture was sandy loam with bulk density ranging from 1.37 to 1.68 g cm⁻³. The soil from the foot slope site had the highest bulk density and that from the hill top site the lowest. Organic carbon, total N and total P ranged from 0.47 to 2.0, 0.05 to 0.16 and 0.021 to 0.031%, respectively. In these forest soils, the highest concentration of soil organic C, total N and total P occurred in hill top site followed by the mid slope site. The pool sizes for inorganic N (NO₃⁻ - N + NH₄⁺ - N) and NaHCO₃-P were highest in the dry periods of the annual cycle.

Jha and Dimir (1991) studied on soil nutrients and forest productivity in four natural stands. The stands were: (I) at 1800 m altitude, dominated by *Pinus roxburghii*, (II) at 2100 m altitude, dominated by *Cedrus deodara* and *Pinus wallichiana*, (III) at 2400 m altitude dominated by *Quercus leucotrichophora* and *Quercus floribunda* and (IV) at 2700 m altitude, dominated by *Abies pindrow* and *Picea smithiana* and they reported that the total nutrient pool (TNP) of NPK was in order K > N > P and the available nutrient pool (ANP) in the order N > K > P. The ANP was only a fraction of the TNP particularly for P. The ANP for N increased from 200 to 310 kg/ha in stand (I) to (IV), but for K was greatest in stand (I) and least in stand (IV), ANP for P was slightly higher in stand (I) than in others. Soil organic matter increased from 2.44 to 6.26% in stand (I) to (IV).

Srivastava and Singh (1991) studied the effect of land use (Forests, Savanna crop field and mine spoil) on microbial C, N and P in dry tropical forest soil and they found that the mean microbial C, N and P on the four major system, ranged from 250 to 609 $\mu\text{g C/g}$, 27 to 67 $\mu\text{g N/g}$ and 12 to 26 $\mu\text{g P/g}$. The microbial biomass in these systems was characterized by a mean C: N: P ratio of 23.2%. Microbial C, N and P were positively related to root biomass and total decline in the amounts of soil nutrients and microbial C, N and P. The calculated annual flux of N and P through microbial biomass ranged from 27 to 64 kg N/ha and 13 to 26 kg P/ha. Thus in dry tropical environment the microbial biomass contributes substantially to the N and P requirements of higher plants.

Ojo-L-O (2001) studied the soil vegetation relation of four locations (Obom, Omo, Owan and Sapoba) in the reserved rain forest of southern Nigeria and results of soil analysis indicated that the mean value of the soil variable for all the four sites were: 4.25% organic matter, 1.35% organic carbon, 79%, sand 15.8%, clay, 0.08% total nitrogen and 80.0 C mol kg^{-1} CEC. Exchangeable Na, K, Mg and Ca, respectively were 1-4, 2.89, 3.47 and 8.83 C mol kg^{-1} while available phosphorus was 6.61 ppm while pH in water and pH in CaCl_2 was 4.44 and 3.66, respectively. The result also showed that sites are significantly different in their contents of organic matter, organic carbon, sand, clay, magnesium, phosphorus and pH indicating high variability between sites for these soil properties however, values for nitrogen, CEC, exchangeable Na and K are not significantly different.

Abha, chhabra *et al.* (2003) studied the soil organic carbon pool in Indian forests. They estimated soil organic carbon densities for various forest

types for two depth classes (0-50 and 0-100 cm). The mean soil organic carbon density estimates for top 50 cm based on 175 observations ranged from 37.5 t ha⁻¹ in tropical dry deciduous forest to 92.1 t ha⁻¹ in littoral and swamp forest. The mean soil carbon density estimates based on 136 observations ranged from 70 t ha⁻¹ in tropical dry deciduous forest to 162 t ha⁻¹ in montane temperate forest for top 1 m soil depth, and the total soil organic carbon pools in Indian forest have been estimated as 4.13 Pg C in top 50 cm and 6.81 Pg C in top 1 m soil depth.

Campo-Alves-J (2003) studied the nutrient availability and fluxes along a toposequence in tropical dry forest in Mexico and found that the P, K, Ca and Mg availability in the soil and their fluxes from the canopy to the forest floor and to assess the relationship among productivity availability and losses of nutrient, in relation to the slope. Significant variation in soil nutrient pools and nutrient fluxes along slope were observed but not in all cases. Availability of P (range 0.292 to 0.088 gm⁻²), Ca (1.178 to 0.797 gm⁻²) and Mg (0.187 to 0.106 gm⁻²) in the soil (top 5 cm) decreased with altitudinal variation also, through fall P, K and Mg fluxes and litter fall P, K and Ca fluxes were lower at upper slope sites, indicating that the altitudinal sequence of the sites reflect a decreasing magnitude of nutrient up slope

Regis *et al.* (1993) concluded that the total amount of mineralized N was closely related to total quantities of organic C and N and the clay content also significantly contributed to total variation in mineralized N. These results indicate that a long term N availability is found in clayey soil groups that contain large contents of total C.

The microbial demand for N is stoichiometrically related to the C metabolism, and N and C are incorporated into the microbial biomass (Parna, 1975). Knops *et al.* (2000) found that the rate of carbon accumulation was controlled by the rate of nitrogen accumulation that in turn depends on atmospheric nitrogen deposition and symbiotic nitrogen fixation by leguminous plants. C4 grasses which increased the C: N ratio of the soil organic matter and thereby increased the rate of carbon accumulation, but not nitrogen accumulation. Singh *et al.* (1991) found that mean annual microbial C varied from 361 to 466 $\mu\text{g g}^{-1}$, microbial N from 35 to 44 $\mu\text{g g}^{-1}$ and microbial P from 16 to 23 $\mu\text{g g}^{-1}$ dry soil. The mean annual microbial C, N and P were positively related to each other. Accumulation of soil N closely follows that of soil organic matter because, on average, about 99 % of N in terrestrial ecosystem is organically bound (Rosswall, 1976). Microbial N uptake and turnover has been proposed as important pathway for N sequestration in forest floor or organic matter (Magill *et al.*, 1997).

Jackson *et al.* (1993) worked on the small-scale nutrient heterogeneity around individual plants and reported that the pronounced small-scale heterogeneity in nitrogen in the soil around plants.

Roy and Singh (1994) have studied the consequences of habitat heterogeneity for availability of nutrient in a dry tropical forest and evaluated that in terms of the patchy availability of nutrients in a trough and flats micro-sites on forest floor. The concentration of organic carbon, total nitrogen, total P and total K were 2.45, 0.173, 0.033, 0.656% in troughs, which are more than adjoining flats 1.14, 0.076, 0.024, 0.497 organic carbon, total nitrogen, total phosphorus and total potassium, respectively.

2.2 Nitrogen mineralization in relation to habitat heterogeneity

The primary production in most ecosystems is influenced by the availability of nutrients (Curlin, 1970; Cole and Rapp, 1980; Chaturvedi and Singh, 1987). The proportion of available forms of nutrients in the soil is generally low. Not more than about 1-2% of the total quantity of most mineral nutrients in a soil is readily available for plant uptake (Brady, 1984). Nitrogen is an essential plant nutrient which, to a large extent, governs also the uptake of N, P and other mineral elements and being limiting in many plant communities, N deserves special attention in the study of nutrient cycling (Ellenberg, 1977; Melillo, 1981; Vitousek *et al.*, 1982). The plant available N is produced through N-mineralization.

Plants take up the inorganic $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$. It produces organic N compounds and returns to the soil through litter fall. Vegetation therefore, influences N-mineralization and nitrification through competition with microbes for nutrients (Rommel, 1935, Vitousek *et al.*, 1982) and through litter quality and quantity (Berg and staff, 1981; Paul and Juna, 1981; Staaf and Berg, 1981; Vitousek *et al.*, 1982).

Vitousek and Matson (1988) reported that the rate of N-mineralization ranged from 36 to 48 $\mu\text{g g}^{-1}$ for the Amazonian forest of Brazil and Semi deciduous forest of Panama and from 78 to 204 $\mu\text{g g}^{-1}$ for old growth tropical forest of Costa Rica old field and repeatedly disturbed experiment plots of Costa Rica also showed very high mineralization rates of 30-99 $\mu\text{g g}^{-1} \text{ m}^{-1}$.

Singh *et al.* (1989) have reported that on microbial biomass acts as a source of plant nutrient in dry tropical forest and savanna. Roy and Singh

(1994) have reported that the greater rates of Nitrogen mineralization in troughs than in adjoining flats indicated a greater nutrient supply potential of troughs. Higher rates of nitrogen mineralization in the troughs also reflects a greater amount of soil microbial biomass which acts both as a sink and source of nutrient.

Singh *et al.* (1991) reported that rate of nitrification varied from 0.8 to 15 $\mu\text{gg}^{-1} \text{m}^{-1}$. The rate of N-mineralization range from 0.38 to 17 $\mu\text{gg}^{-1} \text{m}^{-1}$ for dry tropical forest (Raghubansi 1992). The rate of N-mineralization was closely related to root decomposition. During rainy season the rate of decomposition was maximum and rate of N-mineralization was also maximum (Usman 1993). Marion and Muller (1982) reported that the potential mineralized nitrogen was positively correlated to total soil nitrogen and negatively with carbon/nitrogen ratio.

Donald *et al.* (1991) worked on topographic influences on nitrogen cycling on upland pin Oak ecosystem, and found that the annual rates of mineralization among the four stands ranged from 3.0 to 6.7 $\text{g N m}^{-2} \text{yr}^{-1}$ but were not significantly influenced by aspect or slope position. Although aspect had no effect on nitrification, bottom slope positions had significantly lower (0.3 $\text{g N m}^{-2} \text{yr}^{-1}$) nitrification rates compared to middle (1.3 $\text{g N m}^{-2} \text{yr}^{-1}$) and top (1.4 $\text{g N m}^{-2} \text{yr}^{-1}$) slope positions. Annual N mineralization and nitrification increased with stand age, slope position and aspect had little influence on N cycling rates within the subtle topography of East Central Minnesota.

Raghubanshi (1992) found that the net N-mineralization and nitrification rates ranged from 0 to 32 $\mu\text{gg}^{-1} \text{month}^{-1}$ and 0 to 19 μgg^{-1}

month⁻¹, respectively within the annual cycle and among the topographic position for dry tropical forest. Annual mineralization increased from 125 $\mu\text{g g}^{-1}$ at the hill base to 203 $\mu\text{g g}^{-1}$ at the hill top. For nearby savanna soils, Singh *et al.*, 1991 reported 0-18-15 $\mu\text{g N g}^{-1}$ month⁻¹ nitrification rates. For Serengeti grasslands of Tanzania, Ruess and McNaughton (1987) reported N-mineralization rates from 1.04 to 64 $\mu\text{g N g}^{-1}$ 20 day⁻¹.

In tropical forests of Brazil Panama and Costa Rica nitrification rates were very high from 6 to 54 $\mu\text{g N g}^{-1}$ 10 day⁻¹ (Vitousek and Mutson, 1988). Nitrification and N-mineralization rates were maximum in rainy season and minimum in summer season. (Burk, 1989), Livingston *et al.* (1988) found N-mineralization rates increased from 7.6 $\mu\text{g N g}^{-1}$ 10 day⁻¹ at the hill bottom to 19.3 $\mu\text{g N g}^{-1}$ 10 day⁻¹ at ridge.

Roy and Singh (1994) worked on consequences of habitat heterogeneity for availability of nutrient in dry tropical forest and reported Net nitrogen mineralization rates were greater in the troughs than in the flats, with maximum of 47.0 $\mu\text{g g}^{-1}$ month⁻¹ and 23.6 $\mu\text{g g}^{-1}$ month⁻¹, respectively and also reported that the relative to the flats, the troughs had a greater microbial biomass, available nutrients pool and N-mineralization rates. Microbial C, N and P concentration were positively correlated with N-mineralization rates only when data for the flats and troughs were pooled.

Kim-Choosing (1995) studied the rate of N-mineralization on clear cut and uncut oak and pine stands and found that the net N-mineralization in oak stands over the course of both growing seasons was 67 kg ha^{-1} in the clear cut and 30 kg ha^{-1} in the uncut stands. In contrast net nitrogen mineralization in pine stands was 27 kg ha^{-1} and 13 kg ha^{-1} for the same

treatments. Total net nitrogen mineralization rates were always higher in oak stands than pine stands.

Hirobe *et al.* (1998) have investigated the spatial variability of soil nitrogen (N) transformation patterns along a slope of a *Cryptomeria japonica* plantation. The controlling factors of the soil transformation pattern were examined by multivariate analysis. Net N-mineralization showed no clear gradient along the slope while net nitrification and percent nitrification were high in the lowest part and very low in the upper part of the slope. The middle part was the transition zone corresponding to the patchiness of the lower and upper soils. Soil properties e.g. C/N ratio and pH except total N were significantly correlated with slope position.

Chen-Xiangwer *et al.* (1999) studied on soil nitrogen mineralization in different forest soil. They analyzed by studying ammonium nitrogen ($\text{NH}_4^+\text{-N}$) and nitrate nitrogen ($\text{NO}_3\text{-N}$) using the method of field incubation. They reported that the $\text{NH}_4\text{-N}$ was much higher than those of $\text{NO}_3\text{-N}$ and both increased with increasing tube incubation time. The increases in $\text{NO}_3\text{-N}$ and $\text{NH}_4\text{-N}$, the quantity of nitrogen mineralization and nitrogen mineralization ratio were different for different forest soils, from June 5 to October 5, the increases in $\text{NH}_4\text{-N}$ were 114.5, 108.9, 97.0 and 81.0 micro gg^{-1} and those in $\text{NO}_3\text{-N}$ were 46.0, 39.5, 33.8 and 30.1 micro gg^{-1} , respectively in the four forest soil types. During the same period, the quantity of N-mineralization was 160.5, 148.4, 130.8 and 111.3 micro gg^{-1} and nitrogen mineralization ratio was 2.40, 12.32, 2.17 and 2.06%, respectively.

Ellingson *et al.* (2000) have studied on soil N dynamics associated with deforestation, biomass and pasture conversion in a Mexican tropical dry

forest. Soil nitrogen dynamics were measured before and after slash burning in two different fire severity treatment and they found that the N-mineralization was higher in the burned plot, than in the adjacent disturbed forest. Potential nitrification was $> 9.5 \text{ micro g NO}_3\text{-N g}^{-1} \text{ soil day}^{-1}$ in the slash and burns plots and $3.9 \text{ micro g NO}_3\text{-N g}^{-1} \text{ soil day}^{-1}$ in adjacent reference forest. Potential nitrification was significantly higher in the high severity treatment than in the low severity treatment.

Carlyle and Nambiar (2001) reported that net N-mineralization ranged between 1.1 and $9.7 \text{ Mg kg}^{-1} \text{ day}^{-1}$ in forest floor and between 0.02 and $0.53 \text{ Mg kg}^{-1} \text{ day}^{-1}$ in mineral soil about their study on relationship between the N-mineralization properties of the forest floor and mineral soil.

Hi Shiqing *et al.* (2003) investigated the change of soil non-exchangeable nitrogen during the aerobic and water logged incubation and their effects on quantity of mineralization of soil organic nitrogen and microbial biomass nitrogen. The results showed that $\text{NH}_4^+\text{-N}$ produced during water logged incubation could be fixed by clay mineral, leading to the increase of non-exchangeable nitrogen from 30.0 to $142.4 \text{ micro gg}^{-1}$, thus, the mineralization quantity of organic nitrogen was lower than the actual quantity.

Pajuste and Frey (2003) found that the rate of nitrification was very low and most of the annual net nitrification occurred during just one or two month (May-June, October) depending on site and year. Measured annual net N-mineralization was 29.2 kg ha^{-1} for the spruce stand and 23.6 kg ha^{-1} for the pine stand. Stump and Binkley (1993) reported a negative correlation between lignin/N of litter and total net N-mineralization in the forest floor of

aspen, spruce and pine. Scott and Binkley (1997) found a negative correlation between lignin/N of foliar litter and rate of net mineralization in forest across the United States. Prescott and Preston (1994) found that the rate of N-mineralization in the forest floor of three conifers was related to initial N, C/N, lignin percent, lignin/N and Calkyl C content of foliar litter. The annual mean net mineralization was 29.24 kg N ha⁻¹ in the spruce and 23.58 kg N ha⁻¹ in pine stand. The rates were on the lower end for conifer forests (Nadelhoffer *et al.*, 1984, Persson and Wiren, 1995, Popovic, 1980, Williams, 1992).

Neilfoster *et al.* (2005) have studied on topographic position regulation of N dynamics in soil within Canadian Shield headwater, located in calibrated catchments containing mature tolerant hard wood forest. They examined as how N pool, mineralization, nitrification and leaching in soil relate to N export in drainage water. A uniformly high net N mineralization and nitrification potential for perfficial soil layers rich in organic N was demonstrated for ridge, upper, middle slope and lower slope, foot slope topographic positions. Result from plot scale studies revealed that NO₃-concentrations in soil water from well-drained soils were highly variable through the catchments, ranging from 25 to 175 μ mol/l with a medium of 80 μ mol/l. The isotopic effects of denitrification were not detected in soil water collected from lower foot slope and In situ rates of N₂O production from soils on lower food slope, slopes and valley bottoms were very low and highly variable. Higher N exports from soils, than from streams were not explained by differences in soil water N with topographic position or denitrification in lower landscape topographic positions.

2.3 The effect of seasonality on organic matter and nutrient pool

The biological cycle of nutrients is one of the principal processes supporting organic productivity (Singh *et al.*, 1992). Both quantity and quality of organic matter interact with soil microclimate and thus influence biogeochemical cycling, particularly in relatively dry ecosystems (Burke, 1989). The functioning of these ecosystems is typically influenced by the availability of nutrients and water. Approximately one-half of the dry tropical forest in the world occurs on nutrient poor soils (Sanchez 1976, Singh *et al.*, 1989) and in a climate characterized by marked seasonality.

For tropical soils, Sanchez (1976) found a slow nitrate build up in the top layer during the dry season, followed by a large but short-lived increases at the onset of rainy season and rapid decrease as rainy season progressed during August and minimum in January. Singh (1991) reported that plant available N range from 2.8 to 10.6 $\mu\text{g g}^{-1}$ with maximum value in dry period (Summer season) and minimum value in the wet period (rainy season). The trend of nitrogen mineralization was opposite to that of the size of available N pool. The seasonal pattern of N-mineralization was similar to nitrifications, being maximum in the rainy season and minimum in summer season.

Paster *et al.* (1984) found that mean daily rates of mineralization and nitrification per gram of organic matter were highest in spring or summer and very low in autumn or winter.

Burk (1989) reported that higher soil moisture and temperature favoured N-mineralization in the sagebrush steppe landscape.

Theodore and Bowen (1983) showed that in *Pinus radiata* forest soils of Australia a strong season effect on the N-mineralization prevails due to the dynamic nature of moisture as well as temperature. Seronsen (1974) and Birch (1958, 1960) reported that N-mineralization increases when dry soil is rewetted with water. Birch (1960) observed that the extent of flush of N-mineralization of East African soils once rewetted was correlated with the extent of the previous dry season and predicted that mineralization was maximum during the rainy season. Menaut *et al.* (1985) opined that in slightly acidic soil the high stock of nutrient is rapidly released during wet season.

Hairston *et al.* (1991) while working on topographic influences on soils and trees within single mapping units on a sandy landscape reported that the differences in soil water were highly significant among slope positions ($P < 0.01$) in part influenced by the shallow water table at the lower slope positions. Organic matter and total N of the forest floor and N-released by anaerobes incubation from the surface mineral soil differed among aspects ($P < 0.1$). Twenty year radial growth rate of site-index trees was significantly different among both slope positions and aspects ($P < 0.1$) but total wood volume, basal area and site index did not differ significantly with topography.

Mainthani *et al.* (1998) found that inorganic N (ammonium + nitrate) was highest during winter and lowest during rainy season in three stands whereas ammonification, nitrification and N-mineralization rates showed reverse seasonal trend. Pajuste and Frey (2003) have reported that the amount of mineral nitrogen formed during monthly incubation period in

vegetation were considerably (0.4-3.7 kg ha⁻¹) low. Ammonium was the dominant form of mineral nitrogen, which is typical for more humus. The rates of nitrification was very low and most of the annual nitrification occurred just in one or two month during May–June and October depending on site. Measured annual net N-mineralization was 29.2 kg ha⁻¹ for spruce stand and 23.6 kg ha⁻¹ for pine stand.

Usman *et al.* (1999) reported in his study that total available inorganic N pool was 27-35 µgg⁻¹ during rainy season to 20-31 µgg⁻¹ during winter season. The proportion of nitrates N and mineral-N in soil followed the pattern summer > rainy > winter while total N showed the following pattern summer > winter > rainy.

Usman *et al.* (1999) reported that the rate of nitrification among different seasons was in the order rain > winter > summer in broad leaf forest of Central Himalayas while, that of ammonification followed the order rainy > summer > winter, because conditions in rainy season was more favorable for N-mineralization. The available nitrogen pool ranged from 10.00 µgg⁻¹ (winter) to 35.8 µgg⁻¹ (March). The trend for N-mineralization rates was opposite to that of the size of the available N, the value of inorganic-N uptake of July and ranged between 0 and 25 µgg⁻¹ across different month. The highest rate of N-mineralization measured using *in-situ* soil incubation technique in temperate forest typically occurs in spring or early summer with a secondary peak, late in the growing season (Melillo, 1977; Nadelhoffer *et al.*, 1983).

Jha *et al.* (1999) studied the seasonal changes in soil organic matter (SOM) content under fifteen (15) year old stand of *Pinus roxburghii*,

Tectona grandis, *Dalbergia sissoo*, *Eucalyptus hybrid*, *Acacia catechu* and also in natural *Shorea robusta* forest and barren land in Mussorie Forest Division U.P. India. The result showed the SOM content was higher under natural *S. robusta* forest followed by *D. sissoo*, *Eucalyptus hybrid*, *T. grandis*, *Acacia catechu* and *Pinus roxburghii* plantation in pre-monsoon, while the SOM was lowest in barren land. After the monsoon, SOM was found to be higher only under Eucalyptus plantation at top (0-10 cm) soil profile, however the overall content of SOM was highest in natural *S. robusta* forest and lowest on barren land.

Moisture-limited seasonality in N-mineralization has been reported by Singh *et al.* (1991) in dry tropical savanna. Several workers (Birch, 1958; Rorensen, 1974) have shown that rewetting of dry soil increases N-mineralization. Ammonification rates increased, whereas nitrification rates declined within the stand age. Montangini *et al.* (1986) attributed decrease in nitrification rates to allelopathic inhibition by organic compound in soil or plant extract.

Singh *et al.* (2000) have studied the seasonal variation in organic carbon and nutrient availability in arid zone agroforestry system. They reported that the temporal variations in soil organic carbon (SOC) extractable P, soil available N were significant ($P < 0.01$). Increased SOC coincided with the periods of litter production and the harvest of agricultural crop. The levels of $PO_4\text{-P}$, $NO_3\text{-N}$ and $NH_4\text{-N}$ increased during summer but the increased in the concentration of some nutrients was also observed in winter months.

Singh *et al.* (2000) have studied on fine root biomass and tree species effects on potential N-mineralization in afforested sodic soils and they found that nitrogen was maximum in summer season and decreased with soil depth. Nitrogen mineralization during anaerobic incubation of 14 days could not be differentiated by tree species but the monsoon season favoured the process and winter season retarded it. Mineralization decreased with soil depth corresponding to fine roots. There was a reduction in bush density of soil, pH and EC in forested soil compared to a similar but non forested soil, whereas, organic C and total N increased in forested soils. Nitrogen mineralization was affected significantly by the fine root biomass and available N content in the soils, whereas negative relations of mineralized N with pH and EC were noticed though these were not significantly different in this study.

Paul *et al.* (2004) studied the effects of topography and reestablishment of N-fixing Koa (*Acacia kar*, *A. gracy*) trees in 100 year old mantane grassland on surface soil properties, N pools and N transformations. They assessed using standard and ^{15}N -isotope pool dilution methods and found that the topographic position affected pH and concentration of total C, total N and extractable P. After ten years, Koa trees were re-introduced to grassland and it was observed that the concentration of soil $\text{NH}_4^+\text{-N}$ had increased above levels though the $\text{NO}_3^-\text{-N}$ was intermediate between forest and grassland.

Ammonium dominated the inorganic N pools in grassland soil and NO_3^- - dominated in forest soils. Under planted Koa, NH_4^+ domination was beginning to give way to NO_3^- - domination.

Erica *et al.* (2005) studied on spatial heterogeneity and soil nitrogen dynamics in a burned black spruce forest stand, distinct controls at different scales and evaluated spatial pattern of soil N mineralization, microbial community composition and local site characteristics (plant/forest floor, cover, soil pH, soil % C and % N) in a 0.25 ha burned black spruce forest stand in interior Alaska. Results indicating that factors governing soil N varied at two different scales. *In-situ* net N-mineralization was auto correlated with microbial community composition at relatively broad scale (0.8 m) and with local site characteristics at relatively fine scale (2-4 m). At the scale of the individual core soil moisture was the best predictor of *In-situ* net N-mineralization.

CHAPTER - III

MATERIALS AND METHODS

The present investigation entitled “**Habitat Heterogeneity and Its Impact on Organic Matter, Nutrient Pool and Nitrogen Mineralization in Tropical Dry Deciduous Forest**” was carried out during 2005-06. The details of study site, climate, geology, soil, forest types and other land use figures are described below:

3.1 Study area

The study was conducted in Barnawapara wildlife sanctuary comprising an area of 224.66 km², which is located on the North-Eastern corner of Raipur district of Chhattisgarh.

The study was carried out on hill site under the core zone of Sanctuary near Nuchha Petro Camp of Kothari Road. The geographical location, climate and physiographic features of the study area are given below.

3.2 Geographical location and physiography

The Barnawapara wildlife sanctuary is located between 21⁰18' to 21⁰30' North latitudes and 80⁰ 22' to 82⁰ 37' East longitudes is named after Bar and Nawapara forest villages which are in the heart of the sanctuary. It is situated about 23 km away from Patewa on Raipur, Sambalpur, National Highway No-6 just on the border of Chhattisgarh and Orissa. The tributaries of Mahanadi are the sources of water, River Balmdehi forms the Western

boundary and Jonk River forms the North–Eastern boundary of the sanctuary.

The general topography of Barnawapara sanctuary reveals that the area is mostly undulating with varying degree of slopes, which is found especially in the Southern and Eastern aspects. The North-Western aspects are predominantly covered with different mountain ranges. The highest peak of 470 m in Northern aspect is located in Mundapathar hill range. In Western aspect, the highest peak of 458 m is located in Kansa Pathar hill range. The study area is surrounded by dry deciduous forests, grassland, agriculture lands and human habitations. All villages in the sanctuary area are categorized, as forest villages and majority of them are accessible through Kachha roads, network is absent in few hilly tracts, which are inaccessible due to steep slopes and forest.

3.3 Climate and weather

The climate of Barnawapara sanctuary is dry humid tropical with an average annual rainfall of 1200 to 1350 mm. It gradually decreases from South–East direction to North–West direction. About 80 per cent of annual rainfall is received from South–West monsoon, during June to August. Number of rainy days varies from 90-100 days.

The mean monthly maximum temperature ranges from 27.3⁰C in January to 41.8⁰C in May and mean monthly minimum temperature range from 12.7⁰C in December to 27.3⁰C in May. The mean annual maximum and minimum temperature of study area are 33.1⁰C and 20.5⁰C, respectively. The weather conditions of Raipur district in 2005-2006 are presented in Figure 3.1.

3.4 Humidity

Relative humidity of Barnawapara sanctuary area increase with the onset of South–West monsoon and it generally becomes more than 80 per cent in July. In the post monsoon and winter seasons, the relative humidity lies between 50 to 65 per cent.

3.5 Geology

The Barnawapara sanctuary area has three distinct geological formations viz., Chhattisgarh super group, Late Precambrian and Early Precambrian. Litho logically, the area is divided into seven groups namely Raipur shale and limestone, Khairagarh sandstone, Gunderdehi shale, Cuddapahas charmur limestone, Chandrapur sand grit, Dharwar rocks, Granite and gneiss.

3.6 Physico–chemical properties of the soil

Soils of Barnawapara area are grouped in to three classes viz., *Inceptisols*, *Alfisols* and *Vertisols*. The *Inceptisols* are immature soils mostly sandy loam having light texture and shallow to moderate depth. They are low in organic matter and available nutrients, which support mainly grassland and degraded forests, these soils are commonly found in Eastern and Southern aspects. *Alfisols* occur in midland situation, which are moderately deep and hence have good water holding capacity and bear luxuriant vegetation on the other hand *Vertisols* are deep clayey soils having good water holding capacity and are supporting rich vegetation. Some of these lands are utilized for cultivation of agricultural crops. The physico-chemical properties of different soils of study area are given in Table.3.1.

Table 3.1: Important physical and chemical properties of soils in study area (0.20 cm depth)

Properties	Soil type		
	<i>Inceptisols</i>	<i>Alfisols</i>	Vertisols
A. Physical properties			
Biochemical composition			
Coarse sand	5.50%	2.9%	7.8%
Fine sand	28.12%	22.7%	11.0%
(%) Silt	35.80%	29.8%	22.8%
(%) Clay	28.50%	41.4%	50.6%
CaCO ₃ (%)	0.39%	0.5%	Nil
B. Chemical properties			
pH	6.10	7.60	7.30
E.C. inch Mhos/cm. 25 ⁰ C	0.20	0.65	0.20
Average nutrient kg ha ⁻¹			
P ₂ O ₅	33.60	10.00	26.40
K ₂ O	82.40	220.00	280.00
N Total	132.44	182.62	211.22
Water holding capacity %	40.06	50.50	61.01

Source: Working plan of Raipur division period 1986-1996.

3.7 Forest types and flora

According to Champion and Seth (1968) the forests of the study area are classified in to four major forest types viz., (1) Southern tropical dry deciduous teak forest (5A/G₆), (2) Northern tropical dry peninsular deciduous Sal forest (5B/G₆), (3) Northern tropical mixed deciduous Sal forest (5B/C₂); (4) Dry bamboo brakes (5/E₉).

The predominant wood flora found in these forests are *Tectona grandis*, *Terminalia tomentosa*, *Buchnanian lanzan*, *Madhuca indica*, *Boswellia serrata*, *Acacia catechu*, *Dalbergia paniculata*, *Chloroxylam*

pavriflora, *Shorea robusta*, *Dalbergia latifolia*, *Deistanthus collinus* etc. In degraded forests, *Butea monosperma*, *Lagerstoemia lanceolata*, *Deistanthus collinus*, *Bauhinia vahlii*, etc. are commonly found in under storey shrub layer, *Woodfordia fruticosa*, *Dudonia viscosa*, *Ziziphus* spp., *Phoenix* spp., *Nyctanthes arboristis* are commonly found. Among the bamboos, *Dendrocalamus strictus* is most predominant bamboo, while *Bambusa bamboos* also occasionally occurs in these forests. The important grasses like *Cynodon dactylon*, *Heteropogen centrotus*, *Fragrostis tenella*, *Sehima dicanthium* and *Dicanthium annulatum* etc. are also found in the study area.

3.8 Details of experiment

The study site is located under the core zone of Barnawapara wild life sanctuary. The present investigation is carried out on hill near the Nuchha Petro Camp Kothari Road under core zone. The forest floor of hill base, mid slope, hill top is characterized by a variety of topographic depressions leading to the matrix of flats and troughs. The flats and troughs are identified as two distinct microsites. The area covered by troughs and flats was estimated by three 30 meters random transects on topographic floor. The total area covered by troughs is 11.83 per cent and by flats 87.86 per cent.

3.9 Method

3.9.1 Soil sampling

Soil sampling was done from the upper 10 cm soil layer every season for one annual cycle (2005-06) and 10 sample sites are located randomly in each environment (troughs and flats) at hill base, mid slope and hill top sites. Each sample was thoroughly mixed, air dried and sieved through a 2 mm

mesh screen for different chemical analysis. Soil sample for determining bulk density collected with the help of metal tube (5.0 cm) diameter.

3.9.2 Soil analysis

Soil pH was measured with glass electrode (1:2 soil: water ratio), particle size distribution (texture analysis) by pipette titration method (Piper 1950). Organic carbon of the soil was determined by Walkley and Black's method and available phosphorus was determined following by Olsen's method (Olsen *et al.*, 1954). Inorganic potassium determined by using flame photometer. Total N and available N were measured by Kelplus (Pelican equipment) based on micro Kjeldhal principle. For the analysis of mineral N ($\text{NO}_3\text{-N}$ and NH_4) soil sample were collected as described above for every season. After thorough mixing of sample from a particular distance large pieces of plant materials were hand picked. The soils were sieved through 2 mm mesh screen, fine root were removed and the samples transported to the laboratory. The sample were kept field moist. Field moist samples were used for analysis of $\text{NO}_3\text{-N}$ and $\text{NH}_4\text{-N}$ within 24th hrs. of sampling. Nitrate nitrogen ($\text{NO}_3\text{-N}$) was measured by the Phenoldisulphonic acid method (Jackson 1958) using a nitrate extract. Ammonium nitrogen ($\text{NH}_4\text{-N}$) was estimated by the phenate method (Wetzel and Likens, 1979) in an extract of 2 m – KCl.

3.9.3 N-mineralization

Nitrogen-mineralization was measured by *in-situ* buried bag technique (Eno, 1960). A portion of fresh soil sample (150 gm) was incubated in soil at the depth of 20 cm using polyethylene bag, coarse roots and large fragments of organic debris were removed from the soil through

sieving in order to avoid any marked immobilization during incubation (Ross *et al.*, 1985, Schimel and Pasrton, 1988). NO₃-N and NH₄-N were determined at time zero and after 30 days of field incubation. The increase in the concentration of NH₄-N plus NO₃-N during the course of field incubation is defined as net N-mineralization (Melillo *et al.*, 1982 and Pastor *et al.*, 1984). The increase in NO₃-N during exposure is referred to as nitrification. Rates of N-mineralization were calculated using the equation represented by Nadelhoffer *et al.* (1984), i.e.

$$\Delta \text{NH}_4^+ \text{-N} = \text{NH}_4^+ \text{-Na (t+1)} - \text{NH}_4^+ \text{-Ni (t)}$$

$$\Delta \text{NO}_3 \text{-N} = \text{NO}_3 \text{-Na (t+1)} - \text{NO}_3 \text{-Ni (t)}$$

$$\Delta \text{Min} = \Delta \text{NH}_4^+ \text{-N} + \Delta \text{NO}_3 \text{-N}$$

Where,

NH₄⁺ - Ni (t) = Mean NH₄⁺ - N content of initial non incubated soil sample at the start of time t

NH₄⁺ - Na (t+1) = Mean NH₄⁺ - N content accumulated in incubated soil sample at the end of time t + 1

Δ NH₄⁺ - N = Net ammonification during incubation.

NO₃- Ni (t) = Mean NO₃-N content of initial non incubated soil samples at the start of time t

NO₃- Na (t+1) = Mean NO₃-N accumulated in incubated soil samples at the end of time t + 1

Δ NO₃-N = Net nitrification in incubation

Δ Min / N-min = Net N-mineralization in incubations

All results are expressed on oven dry soil (105°C, 24 hr) basis, the nutrient pool and organic matter data were analyzed statistically through window based SPSS programme.

3.10 Statistical analysis

3.10.1 Analysis for organic matter and nutrient pool

Design of experiment: *Nested factor experiment within CRD:* Analysis of variance of three habitat factors along with two nested microsite factors crossed with three season factors under the setup of Completely Randomized Design having three soil samples within each cell.

Factor 1: Habitat

- (a) Hill top (0.0 meter on 30 meter transect line)
- (b) Mid slope (15 meter in 30 meter transect line)
- (c) Hill base (30 meter in 30 meter transect line)

Factor 2: Microsites

- (a) Depression (Troughs)
- (b) Non depression (flats)

Factor 3: Season

- (a) Winter
- (b) Summer
- (c) Rainy

Replication: 03 (Soil sample)

3.10.2 Analysis for N-mineralization

The analysis for N-mineralization were done by comparing the average effects between different habitats and the same between different

microsites within each habitat for the rainy season using the statistical technique of t-test.

Table 3.2: The Skeleton of ANOVA used for statistical analysis

	S.V.	D.F.	SS	MSS	F
1.	Habitat (H)	$3-1 = 2$			
2.	Microsites within H(m) habitat	$3(2-1) = 3$			
	Microsite at Hill Top $H_1(m)$	$(2-1) = 1$			
	Microsite at Hill Middle $H_2(m)$	$(2-1) = 1$			
	Microsite at Hill Base $H_3(m)$	$(2-1) = 1$			
3.	Season (S)	$(3-1) = 2$			
4.	Habitat and season (H x S)	$(2 \times 2) = 4$			
5.	Microsites within habitat x Season [H(m) x S]	$3(2-1) \times (3-1) = 6$			
	Microsite at Hill Top x Season [$H_1(m) \times S$]	$1 \times 2 = 2$			
	Microsite at Hill Middle x Season [$H_2(m) \times S$]	$1 \times 2 = 2$			
	Microsite at Hill Base x Season [$H_3(m) \times S$]	$1 \times 2 = 2$			
6.	Error	$3 \times 2 \times 3(3-1) = 36$			
	Total	$3 \times 2 \times 3 \times 3-1 = 53$			

Table 3.3: Plant species found in study site

S.No.	Botanical name	Local name	Family	Habit
1.	<i>Aegle marmelos</i>	Bel	Rutaceae	Tree
2.	<i>Andrographis paniculata</i>	Bhuineem	Acanthoaceae	Herb (Annual)
3.	<i>Anogeissus latifolia</i>	Dhaora	Combretaceae	Tree
4.	<i>Azodiraeha indica</i>	Neem	Mediaceae	Tree
5.	<i>Bauhinia vahlii</i>	Siyal	Caesalpinaceae	Climber
6.	<i>Boswellia serrata</i>	Salai	Burceraceae	Tree
7.	<i>Butea monosperma</i>	Palas	Fabaceae	Tree
8.	<i>Careya arborea</i>	Kumbhi	Lecythidaceae	Tree
9.	<i>Cassia fistula</i>	Danbehar	Rutaceae	Tree
10.	<i>Cassia tora</i>	Charota	Caesalpinaceae	Herb (Annual)
11.	<i>Chloroxylon swietenia</i>	Bhirra	Rutaceae	Tree
12.	<i>Cleistanthus collinus</i>	Karra	Euphorbiaceae	Tree
13.	<i>Dalbergia paniculata</i>	Dhobni	Fabaceae	Tree
14.	<i>Diospyros melanoxylon</i>	Tendu	Ebenaceae	Tree
15.	<i>Emblica officinalis</i>	Aonla	Euphorbiaceae	Tree
16.	<i>Mucuna pruriens</i>	Kewanch	Fabaceae	Climber
17.	<i>Pongamia pinnata</i>	Karanj	Fabaceae	Tree
18.	<i>Pterocarpus marsupium</i>	Beeja	Fabaceae	Tree
19.	<i>Salmalia malabarica</i>	Semhar	Stereuliaceae	Tree
20.	<i>Semicarpus anacardiom</i>	Bhilwa	Anacardiaceae	Tree
21.	<i>Terminalia chebula</i>	Harra	Eomloretaceae	Tree
22.	<i>Woodfordia fruticosa</i>	Dhawai	Lythraceae	Shrub

CHAPTER - IV

RESULTS AND DISCUSSION

The results obtained on present investigation entitled “**Habitat heterogeneity and its impact on organic matter, nutrient pool and nitrogen mineralization in Tropical dry deciduous forest**” is described and discussed in this chapter under the following sections:

- 4.1 Effect of habitat heterogeneity on physicochemical properties.
- 4.2 Effect of habitat heterogeneity on organic matter.
- 4.3 Effect of habitat heterogeneity on nutrient pool.
- 4.4 Effect of seasonality on organic matter.
- 4.5 Effect of seasonality on Nutrient pool.
- 4.6 Effect of habitat heterogeneity on mineral N, nitrification, ammonification and N-mineralization.

4.1 Effect of habitat heterogeneity on physicochemical properties

The physico-chemical properties of soil in depression and non-depression microsites under three different habitats, hill base, mid slope and hill top is given in Table 4.1. The soil pH under hill base depression, hill base non-depression, mid slope depression, mid slope non-depression, hill top depression, hill top non-depression was 6.35, 6.40, 6.73, 6.58, 6.85 and 6.80, respectively.

The soil texture in the entire three habitats was silt loam. The soil of hill base depression contained 30% clay, 26% silt and 44% sand. Soil under hill base non-depression was comprised of 46% clay, 20% silt and 34% sand.

The soil of mid slope depression contained 22% clay, 44% silt and 34% sand. Soil under mid slope non-depression was comprised of 18% clay, 54% silt and 28% sand. The soil of hill top depression contained 44% clay, 18% silt and 38% sand. Soil under hill top non-depression comprised of 46% clay, 18% silt and 36% sand.

The bulk density was 1.02, 1.25, 0.86, 0.95, 0.70 and 0.82 g cm⁻³ respectively under hill base depression, non-depression, mid slope depression, non-depression and hill top depression, non-depression.

The organic carbon content in soil of hill base depression and non-depression were 1.34% and 0.91%. Soil under mid slope depression and non-depression contained 2.02% and 1.72% organic C and the soil of hill top depression, non-depression contained 2.45% and 2.06% respectively.

Available N observed under soil of hill base depression and non depression comprised of 153.33 kg ha⁻¹ and 110.79kg ha⁻¹.soil of mid slope depression comprised of 195.71 kg ha⁻¹ and 169.10 kg ha⁻¹ and under the hill top depression and non depression have 256.44 kg ha⁻¹ and 219.43 kg ha⁻¹ respectively. Total nitrogen were 0.13%, 0.12%, 0.16%, 0.14%, 0.20% and 0.18% under hill base depression, non depression, mid slope depression, non depression and hill top depression, non depression, respectively. Available phosphorus under the soil of hill base depression, non-depression was 10.86 and 9.58 kg ha⁻¹. In soil of mid slope depression, non-depression were 15.71 kg ha⁻¹ and 13.34 kg ha⁻¹. Soil under hill top depression and non-depression contained 26.24 kg ha⁻¹ and 22.31 kg ha⁻¹ available P, respectively.

Available potassium were 213.65 kg ha⁻¹, 193.27 kg ha⁻¹, 300.91 kg ha⁻¹, 240.60 kg ha⁻¹, 384.54 kg ha⁻¹ and 349.76 kg ha⁻¹ under hill base

depression, non-depression, mid slope depression, non-depression and hill top depression, non depression, respectively.

The concentration of organic carbon, total nitrogen, total P and total K were highest in troughs (depression) and were found more than adjoining flats, Roy and Singh 1994 have reported that the troughs, which accumulate litter and trapped the nutrients in the dynamics microbial biomass, were characterized by higher amounts of organic matter, total and mineral N, available P and nutrient supply potential. Burke *et al.* (1989) have reported similar result where the highest total and available N and P were found in topographic depression in a sagebrush steppe landscape in Wyoming.

4.2 Effect of habitat heterogeneity on organic matter

Organic matter contains not only carbon but comprised of various nutrients required for growth and development of plant. Organic carbon present in soil and organic matter of soil is directly related to vegetation.

It was observed that soil of hilltop comprised of organic carbon (2.25%) as compared to mid slope 1.87% and hill base 1.12%. It was lowest in rainy season across three season and microsities (Table 4.2a)

Along topographic depression the value of organic carbon (1.93%) was maximum in depression compared to non-depression (1.56%) under all the three habitat across three seasons (Table 4.2c).

The differences in organic carbon due to interaction of habitat and microsite found statistically significant ($P < 0.05\%$). It ranged from 0.91% to 2.45%. Highest was found under hill top depression whereas lowest in hill base non depression. Highest was found under hill top depression (2.45%)

followed by hill top non depression (2.06%), mid slope depression (2.02%), mid slope non depression (1.72%), hill base depression (1.34%) and hill base non depression (0.91%) across all seasons (Table 4.2a).

Roy and Singh (1994) have reported similar result where more organic carbon in topographic depression than adjoining flats were observed. Raghubanshi (1991) reported the concentration of soil organics carbon from 0.47 to 2.0% from foot hill to slope soil to hill top in dry tropical forest. The effect of topography on soil fertility may depend on water balances, which change in varying climate (Clark 1990b).

Accumulation of organic C in soil is affected by climate, the productivity of vegetation and age of site (Fileheva *et al.*, 2002). With soil development accumulation of organic matter and N take place in the mined soil surface (Chichester and Haceser, 1991).

In present study, soil organic carbon was highest in hill top habitat as compared to mid slope and hill base. All depression microsite have higher organic carbon content compared to non-depression across all the habitats.

The soil organic matter contributes to the soil fertility in a number of ways. It increases cation exchange capacity, (Johnston 1986) water holding capacity, (Salter and Williams, 1969) and availability of nutrients (Schnitzel and Khom, 1978). Organic carbon is important for the sustainability of vegetation (Dragonich and Patterson, 1995). During oxidation organic matter release N, P and other trace element. Soil organic C and N are present in several distinct forms in soil such as proteins, peptides, carbohydrates, lignin, organic acids and amino sugars (Mc Gill and Cole, 1981; Cononova, 1966).

Organic C and N are generally influenced by climate, natural vegetation, texture cropping and crop sequences (Brady 1984). Temperature and rainfall extent a dominant influence on the amount of organic matter in soil (Jehny 1941). Soil in the cooler climates generally has more soil organic matter than in warmer climates (Brady, 1984), soil moisture also exerts a positive control upon accumulation of organic matter in soils.

4.3 Effect of habitat heterogeneity on nutrient pool

Nutrient pool viz., available P, available K, available N and total N greatly influenced by habitat heterogeneity. The result of available P is given in Table 4.3a. Available P observed in soil at hill top was 24.27 kg ha⁻¹ and it was highest as compared to mid slope and hill base microsites. It was maximum in summer and minimum in rainy season. In topographic depression microsite the value of available phosphorus was maximum (17.60 kg ha⁻¹) as compared to non-depression microsite (15.07 kg ha⁻¹) under all habitats across three season (Table 4.3c).

The differences in available P due to interaction of habitat and microsite were statistically significant ($P < 0.05\%$). It ranged from 9.58 to 26.24 kg ha⁻¹. Highest available phosphorus was observed at hill top depression (26.24 kg ha⁻¹) followed by hill top non depression (22.31 kg ha⁻¹), mid slope depression (15.71 kg ha⁻¹), mid slope non depression (13.34 kg ha⁻¹), hill base depression (10.86 kg ha⁻¹) and hill base non depression (9.58 kg ha⁻¹). It was observed lowest across the all season (Table 4.3a).

The result of available K is given in Table 4.4a. Differences due to microsite was statistically significant ($P < 0.05\%$). Highest available K was

observed at hill top (367.15 kg ha⁻¹) followed mid slope (270.78 kg ha⁻¹), while on hill base (203.45 kg ha⁻¹) it was observed lowest across three seasons.

At topographic depression, (microsite) the value of available K was maximum (299.70 kg ha⁻¹) as compared to non-depression microsite. It was 261.21 kg ha⁻¹ under all habitats across three season (Table 4.4c).

The differences in available K due to interaction of habitat and microsite were statistically significant (P<0.05%). It ranged from 193.27 to 384.50 kg ha⁻¹. Highest available K was observed at hill top depression (384.54 kg ha⁻¹) followed by hill top non depression (349.76 kg ha⁻¹), mid slope depression (300.91 kg ha⁻¹) mid slope non depression (240.66 kg ha⁻¹), hill base depression (213.64 kg ha⁻¹) and lowest at hill base non depression (193.27 kg ha⁻¹) across the three season (Table 4.4a).

The results of available N is given in Table 4.5a. Differences in available N were statistically significant (P<0.05%). Available N in soil observed at hill top was 237.94 kg ha⁻¹ and it was highest as compared to mid slope (182.41 kg ha⁻¹) and hill base (130.06 kg ha⁻¹) microsites across three season.

At topographic depression the mean value of available N was maximum (201.83 kg ha⁻¹) as compared to non-depression (166.50 kg ha⁻¹) under all habitat across three season (Table 4.5c).

The differences in available N due to interaction of habitat and microsite were statistically significant (P<0.05%). It ranged between 110.79 to 256.45 kg ha⁻¹. Highest value of available N was observed at hill top depression (256.45 kg ha⁻¹) followed by hill top non depression (219.43 kg

ha⁻¹), mid slope depression (195.10 kg ha⁻¹), hill base depression (153.34 kg ha⁻¹) and hill base non depression (110.79 kg ha⁻¹) across all the season (Table 4.5a).

The result of total N is given in Table 4.6a. Differences in results were statistically significant. Highest total N observed in soil at hill top. It was 0.19% on hill top followed by mid slope 0.15% and hill base 0.13% across three seasons.

At topographic depression the value of total N was observed maximum. It was 0.16% as compared to non-depression 0.14% under all habitats across three seasons (Table 5.6c).

The differences in total N due to interaction of habitat and microsite were statistically significant ($P < 0.05\%$). It ranged from 0.12 to 0.20%. Highest available total N was recorded at hill top depression (0.20%) followed by hill top non depression (0.18%), mid slope depression (0.16%), mid slope non depression (0.14%), hill base depression (0.13%) and lowest at hill base non depression, it was 0.12% across all the seasons (Table 4.6a).

Nutrient pool values were recorded highest in hill top as compared to mid slope and hill base in present study. Raghubanshi (1991) reported similar result in dry tropical forest. The highest concentration of soil organic C, total N and total P occurred were reported hill top site followed by the mid slope site by above author have studied the effect of habitat heterogeneity for availability of nutrient in a dry tropical forest and evaluated that in terms of the patchy availability of nutrient in a trough (depression) and flats (non-depression) microsite on forest floor. Roy and Singh (1994). Their results were similar to the present observations.

Burke *et al.* (1989) found similar type result, highest total and available N and P in topographic depression in a sagebrush steppe landscape in Wyoming.

Paul *et al.* (2003) reported topographic position affected pH and concentration of total C, total N and extractable P. soil microorganism were potentially strong competitors for inorganic N on grassland slope, where they immobilized nearly all the inorganic N that was produced during short and medium term field incubation thus leaving little for plant growth.

Montagnini and Sancho (1990) found that within 2.5year of planting soils under N fixing species had greater organic matter content, total N and exchangeable K and Mg than pasture soils.

4.4 Effect of seasonality on organic matter

Fig 4.1a. shows the seasonal pattern of organic carbon in three habitats. The value of organic carbon was highest in summer and lowest in rainy season. The value of organic carbon across the season followed the pattern summer > winter > rainy. In summer it was 2.14%, while in case of winter it was 1.80% and in rainy season it was 1.31% organic carbon across three habitats.

In summer organic carbon was 2.69%, 2.18% and 1.55% under hill top, mid slope and hill base, respectively. In winter, it was 2.34%, 1.99% and 1.09% at hill top, mid slope and hill base, respectively. In case of rainy season it was 1.74%, 1.45% and 0.74% at hill top, mid slope and hill base, respectively. The maximum organic carbon content was observed at hill top

(2.67%) in summer season and it was minimum 0.74% at base hill. (Fig 4.1b.)

Interaction effect of microsite and season on organic matter showed statistically significant result ($P < 0.05$). It ranged from 1.11% to 2.25%. The value of organic carbon was highest at depression in summer season, while lowest at non-depression in rainy season across all habitats. (Fig 4.1c)

Difference in organic carbon due to interaction of habitat, microsite and season were statistically significant ($P < 0.05$). It ranged from 0.60% to 2.72%. Maximum value was observed under hill top depression in summer, while in case of base hill non-depression in rainy season it was observed minimum (0.60%).

The biological cycle of nutrients is one of the principle processes supporting organic productivity (Singh *et al.*, 1992) both quantity and quality of organic matter interact with soil micro climate and thus influence biogeochemical cycling particularly in relatively dry ecosystem (Burke 1989). The functioning of this ecosystem is tropically influenced by the availability of nutrient and water. Singh *et al.* (2000) reported that temporal variation in soil organic carbon, increased soil organic carbon, and coincided with the periods of litter production and the harvest of agricultural crop.

Organic matter was higher in summer across all the microsite under three habitats. Water availability is one of the important abiotic controls on ecosystem processes, affecting carbon and nutrient cycle both directly through carbon fixation, mineralization and uptake as well as controlling inputs and outputs of nutrients. Austin *et al.* (2002) found that both ecosystem carbon and nutrient availability are largely constrained by the

magnitude and seasonality of precipitation in arid and semi-arid ecosystem and also suggesting a direct control of precipitation on nitrogen turnover and interaction with nitrogen availability in controlling carbon gain.

4.5 Effect of seasonality on nutrient pool

Nutrient pool viz., available P, available K, available N and total N too found to be influenced by change in season, Fig 4.2a showed the seasonal changes on quantity of available P. The value of available P across the season followed the pattern summer > winter > rainy. Mean value of P in summer was 18.42 kg ha⁻¹ whereas in winter it was 16.23 kg ha⁻¹ and in rainy it was 14.36 kg ha⁻¹, across three habitats.

The value of available P across habitat was maximum under hill top (26.39 kg ha⁻¹) in summer, while in case of hill base it was minimum 7.94 kg ha⁻¹ in rainy season. Statistically the value of P in mid slope in rainy season (12.91 kg ha⁻¹) was at par with hill base (12.86 kg ha⁻¹) in summer season (Fig. 4.2b).

Interaction effect of microsite x season on available P is shown in Fig. 4.2c. It ranged from 13.27 kg ha⁻¹ to 19.93 kg ha⁻¹. The value of available P was highest at depression microsite (19.93 kg ha⁻¹) under summer season, whereas lowest at non-depression microsite (13.27 kg ha⁻¹) under rainy season.

Differences due to habitat, microsite and season were statistically significant ($P < 0.05\%$). It ranged from 7.48 kg ha⁻¹ to 28.67 kg ha⁻¹. The higher mean value observed in case of hill top depression (28.67 kg ha⁻¹) in summer season followed by top depression (26.16 kg ha⁻¹) in winter. Hill top

non-depression (24.11 kg ha^{-1}) in summer, hill top depression (23.89 kg ha^{-1}) in rainy, hill top non-depression (22.23 kg ha^{-1}) in winter and lowest mean value observed at hill base non-depression (7.48 kg ha^{-1}) in rainy season. Statistically the value of P in mid slope depression (14.10 kg ha^{-1}) in rainy season was at par with hill base depression (13.96 kg ha^{-1}) in summer season. Similarly hill base non-depression (11.76 kg ha^{-1}) in summer season at par with mid slope non-depression (11.73 kg ha^{-1}) in rainy season (Fig. 4.2a).

Fig. 4.3a shows the seasonal change in quantity of available K. The mean value of available K across the season followed pattern. summer > winter > rainy. In summer season, it was $304.70 \text{ kg ha}^{-1}$ followed by winter season ($270.02 \text{ kg ha}^{-1}$) and rainy season ($261.08 \text{ kg ha}^{-1}$) across three habitats.

Seasonal changes across habitat ranged from 190.45 to $405.22 \text{ kg ha}^{-1}$. Hill top in summer had maximum ($405.22 \text{ kg ha}^{-1}$) while in case of hill base it was minimum $190.45 \text{ kg ha}^{-1}$ in rainy season, (Fig. 4.3b).

Seasonal changes across microsite in available K is shown in Fig. 4.2c. It ranged from 246.64 to $331.37 \text{ kg ha}^{-1}$. Highest value of available K was observed at hill depression ($331.37 \text{ kg ha}^{-1}$) in summer season, whereas lowest at non-depression in rainy season; ($246.64 \text{ kg ha}^{-1}$). Statistically the value of K in non-depression ($278.03 \text{ kg ha}^{-1}$) in summer season was at par with depression ($275.52 \text{ kg ha}^{-1}$) in rainy season across three habitats.

Seasonal changes across habitat and microsite found statistically significant ($P < 0.05\%$). It ranged from 183.56 to $436.64 \text{ kg ha}^{-1}$. Maximum was recorded at hill top depression in summer, while minimum in case of hill base non-depression in rainy season.

Seasonal effect due to habitat and microsite and season were statistically significant ($P < 0.05\%$). It ranged from $183.56 \text{ kg ha}^{-1}$ to $436.64 \text{ kg ha}^{-1}$. The highest mean value was observed at hill top depression ($436.64 \text{ kg ha}^{-1}$) in summer season followed by hill top non depression ($373.81 \text{ kg ha}^{-1}$) in summer season, hill top depression ($370.68 \text{ kg ha}^{-1}$) in winter season, hill top depression ($346.30 \text{ kg ha}^{-1}$) in rainy season, whereas lowest available K observed at hill base non depression ($183.56 \text{ kg ha}^{-1}$) in rainy season. Statistically the value of K in hill base depression ($210.78 \text{ kg ha}^{-1}$) in winter season was at par with hill base non-depression ($2045.59 \text{ kg ha}^{-1}$) in summer season. Similarly mid slope non-depression ($235.75 \text{ kg ha}^{-1}$) in winter season at par with hill base depression ($232.62 \text{ kg ha}^{-1}$) in summer season and mid slope non-depression ($231.35 \text{ kg ha}^{-1}$) in winter season (Fig. 4.3a).

Fig. 4.4a shows the changes of concentration in available nitrogen with habitat and microsite. The available N across season followed the same pattern as in case of organic C, P and K followed the pattern: summer > winter > rainy. Mean value of N were 234.41 , 181.78 and $136.22 \text{ kg ha}^{-1}$ in summer, winter and rainy seasons, respectively.

The mean value of N across habitat with season ranged from 107.35 to $301.83 \text{ kg ha}^{-1}$. Maximum mean value observed under hilltop in summer season. It was $301.83 \text{ kg ha}^{-1}$, whereas minimum $107.35 \text{ kg ha}^{-1}$ was observed under hill base in rainy season. Statistically hill top ($242.12 \text{ kg ha}^{-1}$) in winter season at par with mid slope ($236.76 \text{ kg ha}^{-1}$) in summer season. Similarly mid slope ($179.47 \text{ kg ha}^{-1}$) in winter season at par. Hill top ($170.13 \text{ kg ha}^{-1}$) in rainy season, also at par with hill base ($123.74 \text{ kg ha}^{-1}$) in winter season (Fig. 4.4b).

Seasonal changes in N across microsite are shown in Fig. 4.3c. It ranged from 127.35 to 256.97 kg ha⁻¹. Highest mean value observed under depression (256.97 kg ha⁻¹) in summer season, while lowest value from non-depression (127.35 kg ha⁻¹) in rainy season.

Seasonal changes of available N across habitat and microsite are shown in Fig. 4.4a. It ranged from 96.16 to 318.29 kg ha⁻¹. Maximum quantity of N in hill top depression was found in summer. It was 318.29 kg ha⁻¹ whereas minimum (96.16 kg ha⁻¹) under hill base non depression in rainy season.

Mid slope non-depression (120.53 kg ha⁻¹) in summer season and hill top non depression (214.55 kg ha⁻¹) in winter season were statistically at par. Similarly hill base depression (199.65 kg ha⁻¹) in summer season at par with mid slope depression (199.18 kg ha⁻¹) in winter season and also hill base depression (140.91 kg ha⁻¹) in winter at par with mid slope depression (135.01 kg ha⁻¹) in rainy season and hill base non depression (129.61 kg ha⁻¹) in summer season.

Seasonal pattern of total nitrogen is given in Fig. 4.5a. It followed the pattern: summer > winter > rainy. It ranged from 0.12% in rainy season to 0.17% in summer season, in winter it was 0.16%.

Seasonal change of total N across habitat ranged from 0.08% to 0.21%. it was higher under hill top in summer (0.21%), while lower (0.08%) in case of hill base in rainy season (Fig. 4.5b).

Seasonal changes of total N across microsite was highest from depression (0.18%) in summer season followed, depression in winter, non

depression in summer, non depression in winter, depression in rainy, and non depression in rainy season (Fig. 4.5c).

Seasonal changes due to the interaction of habitat, microsite and season were statistically significant ($P < 0.05\%$). It ranged between 0.07% to 0.23%. The highest total N was observed at hill top depression (0.23%) in summer season followed by hill top depression (0.21%) in winter season, hill top non depression (0.19%) in summer season mid slope depression (0.18%) in summer season, mid slope depression (0.17%) in winter season, whereas lowest value of total N observed at hill base non depression (0.07%) in rainy season. Statistically the value of N in hill top non-depression (0.18%) in rainy season was at par with hill base depression (0.15%) in summer season. similarly mid slope depression (0.12%) in rainy season at par with hill base non-depression (0.13%) in summer season (Fig. 4.5a).

Nutrients such as available P, available K, available N and total N followed the pattern: summer > winter > rainy across all the habitats and microsites. The temporal variation in available N, P, K and total N are controlled by soil water potential (directly by rainfall distribution) and plant uptake dynamics. Massive uptake of nutrient by vegetation from soil during the active growth season lowered the soil nutrient pool during the wet period of year; leaching and runoff also contribute to the reduction of nutrient pool. Vitousek and Matson (1985) showed that in intact forest soils relatively rapid biological uptake of available N is one of the reasons for the meagre size of the available N pool.

The value of nitrate N, ammonical N and inorganic N pool were maximum in early summer season and minimum during late rainy season.

Singh *et al.* (1989) have argued that increase in nitrate – N and ammonical N during the dry summer and winters, reflect the low demand of available nutrient by higher plants and upward movement of soil solution.

Burke *et al.* (1989) suggested that nutrient accumulation is a dynamic ecosystem property and is influenced by slowly changing landscape pattern in semi-arid ecosystem; nutrient dynamics are closely linked to seasonal variation in temperature and moisture. Temperature is seldom limiting for these biological processes in this region but moisture drops substantially after the end of rainy season and during summer it become dry.

Birch (1958) suggested that during the dry spring season the soil starts drying due to increased evaporation thereby enhancing the upward movement of nitrate and release of free ammonia and amino acid from the dry soil. Firestone (1982) reported that the rate of N-loss from soil due to denitrification, it increased by factors that increase the extent of anaerobic microsite in soil. Heavy rainfall and the increase in soil moisture in the part of India may lead to the development of anaerobic microsite by decreasing the rate of oxygen diffusion through soil matrix. Phosphorus is derived by weathering from parent material and is present in very low quantity in highly weathered soils. Vitousek and Sanford (1986) argued that the P cycle is more complex than the N cycle.

4.6 Effect of habitat heterogeneity on mineral N, nitrification, ammonification and N-mineralization

The value of mineral N viz., NO₃-N and NH₄-N was observed highest at hill top followed by mid slope and hill base. Depression microsite had

mineral-N maximum as compared to non depression microsite across all three habitat. The mean value of $\text{NO}_3\text{-N}$ is given in Table 4.7a. It ranged from 4.18 to $6.85 \mu\text{gg}^{-1}$. Higher mean value was observed at hill top ($6.85 \mu\text{gg}^{-1}$), followed by mid slope ($5.64 \mu\text{gg}^{-1}$) and lower in case of hill base ($2.18 \mu\text{gg}^{-1}$). The mean value of depression was $5.90 \mu\text{gg}^{-1}$ recorded as compared to non-depression $5.21 \mu\text{gg}^{-1}$ across all habitats.

Within habitat all combination of microsite showed statistically significant variation ($P < 0.025\%$) using t test. t values are given in Table 4.7b. Mean value of $\text{NO}_3\text{-N}$ were 7.38, 6.33, 5.86, 5.42, 4.46 and $3.90 \mu\text{gg}^{-1}$ at hill top depression, hill top non depression, mid slope depression, mid slope non depression, hill base depression and hill base non depression, respectively.

The pool of $\text{NH}_4\text{-N}$ follows similar trend i.e. the value of $\text{NH}_4\text{-N}$ was highest at hill top $6.00 \mu\text{g g}^{-1}$ followed by mid slope $4.35 \mu\text{g g}^{-1}$ and hill base $2.97 \mu\text{gg}^{-1}$ (Table 4.8a). The maximum value was observed in depression as $4.85 \mu\text{gg}^{-1}$ compared to non depression ($4.02 \mu\text{gg}^{-1}$) across the entire three habitats for $\text{NH}_4\text{-N}$. All combination of microsite showed statistically significant variation ($P < 0.025\%$) using t test (Table 4.8b).

Maximum mean value of $\text{NH}_4\text{-N}$ was $6.50 \mu\text{gg}^{-1}$ at hill top depression and it was followed 5.49, 4.56, 4.14, 3.50 and $2.45 \mu\text{gg}^{-1}$ at hill top non-depression, mid slope depression and mid slope non-depression, hill base depression and hill base non-depression, respectively.

The rate of nitrification was higher at hill top ($31.39 \mu\text{gg}^{-1} \text{ month}^{-1}$) followed, mid slope ($30.20 \mu\text{gg}^{-1} \text{ month}^{-1}$) and was lower in case of hill base ($27.48 \mu\text{gg}^{-1} \text{ month}^{-1}$). The higher rate of nitrification was observed under

depression ($30.79 \mu\text{g g}^{-1} \text{ month}^{-1}$) compared to non-depression ($28.59 \mu\text{g g}^{-1} \text{ month}^{-1}$) across the entire three habitat (Table 4.9a). The rate of nitrification, microsite within habitat all combination showed statistically significant results ($P < 0.025\%$), except combination of hill base depression with mid slope non depression ($t = 0.55$) and mid slope depression with hill top non depression ($t = 0.33$). The t values of all combination are given in table 4.9b. The rate of nitrification ranged from 25.29 to $31.78 \mu\text{g g}^{-1} \text{ month}^{-1}$. Maximum rate was found at hill top depression ($31.78 \mu\text{g g}^{-1} \text{ month}^{-1}$) followed by 31.03, 30.93, 29.68, 29.47 and $25.29 \mu\text{g g}^{-1} \text{ month}^{-1}$ at hill top non depression, mid slope depression, hill base depression, mid slope non depression and hill base non depression, respectively.

Table 4.10a shows the rate of ammonification. Highest was observed at hill top ($6.32 \mu\text{g g}^{-1} \text{ month}^{-1}$) followed by mid slope ($5.54 \mu\text{g g}^{-1} \text{ month}^{-1}$) and hill base ($4.49 \mu\text{g g}^{-1} \text{ month}^{-1}$).

The rate of ammonification was higher at depression ($5.77 \mu\text{g g}^{-1} \text{ month}^{-1}$) as compared to non-depression ($5.12 \mu\text{g g}^{-1} \text{ month}^{-1}$) across all the three habitats.

All combination of microsite within habitat showed statistically ($P < 0.025\%$) significant differences except the combination of mid slope depression with hill top non-depression ($t = 0.34$) showed at par result. The rate of ammonification ranged from 4.38 to $6.75 \mu\text{g g}^{-1} \text{ month}^{-1}$. Maximum rate was observed under hill top depression ($6.75 \mu\text{g g}^{-1} \text{ month}^{-1}$), followed by mid slope depression ($5.97 \mu\text{g g}^{-1} \text{ month}^{-1}$), hill top non depression ($5.89 \mu\text{g g}^{-1} \text{ month}^{-1}$), mid slope non-depression ($5.11 \mu\text{g g}^{-1} \text{ month}^{-1}$), hill base

depression ($4.59 \mu\text{gg}^{-1} \text{ month}^{-1}$) and hill base non-depression ($4.38 \mu\text{gg}^{-1} \text{ month}^{-1}$).

The similar trend was also observed for nitrogen mineralization. The highest mean value of N-mineralization was observed at hill top ($37.71 \mu\text{gg}^{-1} \text{ month}^{-1}$). Followed by mid slope ($35.74 \mu\text{gg}^{-1} \text{ month}^{-1}$) and lowest at hill base ($31.97 \mu\text{gg}^{-1} \text{ month}^{-1}$) (Table 4.11a).

The effect of microsite across all habitats on N-mineralization at depression was $36.89 \mu\text{gg}^{-1} \text{ month}^{-1}$ which was higher compared to non-depression $33.72 \mu\text{gg}^{-1} \text{ month}^{-1}$.

Table 4.11b shows that the t values of N-mineralization. Statistically all combination of microsite were significant ($P < 0.025\%$), except combination of mid slope depression with hill top non-depression ($t = 0.06$) and hill base depression with mid slope non-depression ($t = 0.80$) showed at par results. The higher value of N-mineralization were observed at hill top depression $38.50 \mu\text{gg}^{-1} \text{ month}^{-1}$ followed by 36.92 , 36.90 , 34.58 , 34.27 and $29.69 \mu\text{gg}^{-1} \text{ month}^{-1}$ at hill top non depression, mid slope depression, mid slope non depression, hill base depression and hill base non depression, respectively. Lower value observed at hill base non-depression, which was $29.69 \mu\text{gg}^{-1} \text{ month}^{-1}$.

Roy and Singh (1994) have reported similar result in dry tropical forest, the rates of net nitrogen mineralization were greater in the troughs (depression) than in the flats (non depression) with a maximum of $47.0 \mu\text{gg}^{-1} \text{ month}^{-1}$ and $23.6 \mu\text{gg}^{-1} \text{ month}^{-1}$ respectively, indicated a greater nutrient supply potential of troughs due to accumulation of higher quantity of organic matter inputs through litter in troughs than flats.

Carlyle and Nambiar (2001) reported that net N-mineralization ranged between 1.1 and 9.7 Mg kg⁻¹ day⁻¹ in forest floor and between 0.02 and 0.53 Mg kg⁻¹ day⁻¹ in mineral soil in their study on relationship between the N-mineralization properties of forest floor and mineral soil.

Raghubanshi (1992) found that the net N-mineralization and nitrification rates ranged from 0 to 32 µgg⁻¹ month⁻¹ and 0 to 19 µgg⁻¹ month⁻¹ respectively, with in the annual cycle and among the topographic position for dry tropical forest. Annual mineralization incident from 125 µgg⁻¹ at hill base to 203 µgg⁻¹ at hilltop for nearby Savanna soils. Singh *et al.* (1991) reported the rate of nitrification between 0.8 and 15 µgg⁻¹ month⁻¹. The rate of N-mineralization was closely related to root decomposition during rainy season, the rate of decomposition was maximum and rate of N-mineralization was also maximum (Usman 1993).

Vitousek and Matson (1988) reported that the rate of N-mineralization ranged from 36 to 48 µgg⁻¹ month⁻¹ for the Amazonian forest of Brazil and Semi-arid deciduous forest of Panama and from 78 to 204 µgg⁻¹ month⁻¹ for old growth tropical forest of Costa Rico.

Roy and Singh (1994) reported same result, the greater rates of N-mineralization in troughs (depression) than in adjoining flats indicated a greater nutrient supply potential of troughs. Higher rate of nitrogen mineralization in troughs also reflects a greater amount of soil microbial biomass, which acts both as a sink and source of nutrient (Singh *et al.*, 1989)

Burke (1989) reported higher soil moisture and temperature favored N-mineralization in Sagebrush steppe landscape. Moreover, the higher values of mineral N inorganic P and soil physical properties close to trees

could be attributed to higher amount of organic matter inputs through litter fall, root mortality and herbaceous biomass as reported by Kele (2002).

Higher soil moisture was also observed in the depression microsite than in flats during present study and hence could be possible reason for increase in N-mineralization and nitrification in troughs

Fire (Debano and Conrad 1978), tree fall (Mladenoff 1987, Vitousek and Denslow 1986) and forest practices (Bormann and Likens 1979, Vitousek and Matson 1985), for example, produce patchy landscapes and they have important immediate consequences for cycling of N as a consequence of volatilization, transfer of organic matter from aboveground biomass to the forest floor, reduce uptake by plant, altered rates of solution transport through the soil profile and elevated mineralization with changed forest floor temperatures and soil moisture.

At regional scales, these effects are often modified by physiographic and edaphic factors and several studies have shown distinct pattern of N cycling along topographic and edaphic gradients (Pastor *et al.*, 1984, Schimel *et al.*, 1985, Burke 1989). In addition to biotic factors, species composition and its effect on litter fall chemistry play an important role in regulating rates of N cycling at scale of an individual forest ecosystem (Aber and Melillo, 1982).

CHAPTER – V

SUMMARY, CONCLUSIONS AND SUGGESTION FOR FUTURE RESEARCH WORK

The present study was carried out to evaluate the effect of habitat heterogeneity on organic matter, nutrient pool and nitrogen mineralization under two microsites (depression, non depression) within three habitats i.e. hill top, mid slope, hill base in Dry Tropical Forest habitat. Study was conducted in Barnawapara wild life sanctuary comprising an area of 224.66 km² and is located on the North-Eastern corner of Raipur district of Chhattisgarh. Sanctuary is located between 21⁰18' to 21⁰30' North latitudes and 80⁰22' to 82⁰37' East longitudes and is named after Bar and Nawapara forest villages, which are in heart of sanctuary. This region comes under dry humid tropical climate.

Major finding are:

1. The soil pH ranged between 6.73 to 6.85 at depression and 6.40 to 6.80 at non-depression across all the habitats.
2. The soil texture in all habitats was silt loam. The value of sand ranged from 34 to 44% at depression and 28 to 36% at non-depression. The value of silt ranged from 18 to 44% at depression and 18 to 54 at non-depression whereas clay ranged 22 to 44 % at depression and 18 to 46 % at non-depression across the entire habitat.

3. Bulk density of soil ranged from 0.70 to 1.08 g cm⁻³ at depression, whereas 0.82 to 1.25 g cm⁻³ at non-depression across the three habitats.
4. Organic carbon content at depression microsite ranged between 1.34 and 2.45 per cent and at non-depression it from 0.91 to 2.06 per cent.
5. Available phosphorus in soil at depression ranged from 10.86 to 26.24 kg ha⁻¹ and at non-depression it ranged from 9.58 to 22.31 kg ha⁻¹.
6. Available potassium in soil at depression ranged between 213.64 and 384.54 kg ha⁻¹ and at non-depression from 193.27 to 367.15 kg ha⁻¹.
7. Available nitrogen in soil at depression ranged between 153.33 and 256.44 kg ha⁻¹ and at non-depression from 110.79 to 219.43 kg ha⁻¹ across all the habitat.
8. Total nitrogen ranged between 0.13 and 0.20 per cent at depression and 0.12 to 0.18 per cent at non-depression across the entire habitat.
9. Mineral nitrogen viz., NO₃-N at depression ranged from 4.46 to 7.38 µg g⁻¹ and at non-depression from 3.90 to 6.33 µg g⁻¹ across the entire habitat.
10. The value of NH₄-N ranged between 3.50 to 6.50 µgg⁻¹ at depression and 2.45 to 5.95 µgg⁻¹ at non-depression across the entire habitat.
11. The rate of nitrification ranged between 29.68 and 31.78 µgg⁻¹ mo⁻¹ at depression and 25.29 to 31.03 µgg⁻¹mo⁻¹ at non-depression across the entire habitat.

12. The rate of ammonification ranged from 4.59 to 6.75 $\mu\text{gg}^{-1} \text{mo}^{-1}$ at depression and 4.38 to 5.89 $\mu\text{gg}^{-1} \text{mo}^{-1}$ at non-depression across three habitats.
13. The rate of nitrogen mineralization ranged from 34.27 to 38.50 $\mu\text{gg}^{-1} \text{mo}^{-1}$ at depression and at non-depression it ranged between 29.67 and 36.92 μgg^{-1} across the entire habitat.
14. The seasonal value of organic carbon in summer ranged between 1.55 and 2.69 per cent; winter from 1.09 to 2.34 per cent and rainy season it from 0.74 to 1.74 per cent across all habitats.
15. The seasonal value of available Phosphorus in summer ranged from 12.86 to 26.39 kg ha^{-1} . In winter, it ranged between 9.87 and 24.19 kg ha^{-1} . In rainy season, it ranged from 7.48 to 20.25 kg ha^{-1} across all habitats.
16. The seasonal values of available potassium in summer ranged between 219.11 to 405.23 kg ha^{-1} . In winter, it ranged from 200.72 to 360.57 kg ha^{-1} . In rainy season, it ranged between 190.54 and 335.66 kg ha^{-1} across all habitats.
17. The seasonal value of available nitrogen in summer ranged between 164.63 kg ha^{-1} to 301.33 kg ha^{-1} . In winter, it ranged from 123.76 to 242.12 kg ha^{-1} . In rainy season, it ranged from 107.80 to 169.86 kg ha^{-1} across all habitats.
18. The seasonal value of total nitrogen in summer ranged from 0.14 to 0.21 per cent. In winter, it ranged from 0.11 to 0.20 per cent. In rainy season, it ranged between 0.08 and 0.16 per cent.

19. The seasonal value of organic matter at depression ranged from 1.79 to 2.72 per cent and at non-depression from 1.31 to 2.66 per cent in summer. In winter, it ranged from 1.35 to 2.62 per cent and 0.83 to 2.06 per cent. In rainy season, it ranged from 0.89 to 2.02 per cent and 0.60 to 1.47 per cent across the entire habitat.
20. The seasonal value of phosphorus at depression was 13.96 to 28.67 kg ha⁻¹ and at non depression it was 11.76 to 24.11 kg ha⁻¹ in summer, in winter it ranged from 10.23 to 26.16 kg ha⁻¹ in depression and 9.51 to 22.23 kg ha⁻¹ in non depression, whereas in rainy it was 8.40 to 23.89 kg ha⁻¹ in depression and 7.48 to 20.61 kg ha⁻¹ in non depression across all the habitats.
21. Seasonal value of available potassium at depression ranged from 232.64 to 436.64 kg ha⁻¹ and at non-depression it was 205.59 to 373.81 kg ha⁻¹ in summer season. In winter, it ranged 210.78 to 370.68 kg ha⁻¹ in depression and from 190.66 to 350.41 kg ha⁻¹ in non-depression however, in case of rainy season, it ranged from 197.52 to 346.30 kg ha⁻¹ across the entire habitat.
22. Seasonal value of available nitrogen at depression ranged from 199.65 to 318.29 kg ha⁻¹ and at non-depression from 129.61 to 285.37 kg ha⁻¹ in summer. In winter, it ranged from 140.91 to 269.69 kg ha⁻¹ in depression and 106.61 to 214.53 kg ha⁻¹ in non-depression however, in case of rainy season, it ranged from 119.45 to 181.36 kg ha⁻¹ in depression and 96.16 to 158.36 kg ha⁻¹ in non depression across the entire habitat.

23. Seasonal values of total nitrogen at depression ranged from 0.15 to 0.23 per cent and at non depression ranged from 0.13 to 0.19 per cent in summer. In winter, it ranged from 0.13 to 0.21 per cent in depression and 0.11 to 0.19 per cent in non depression. In rainy season, it ranged from 0.10 to 0.18 per cent in depression and 0.07 to 0.15 per cent in non depression across the entire habitat.

Conclusion

The following conclusions could be drawn on the basis of the present study:

1. Depression microsites having greater impact on organic matter as compared to non depression microsite under all the habitat across three seasons.
2. Depression microsite having greater impact on nutrient pool as compared to non depression microsites under all the habitat across three season.
3. Nitrification, ammonification and nitrogen mineralization was high at depression microsite as compared to non depression microsite across habitat.
4. The seasonal variation of organic carbon and nutrient pool viz., available P, available K, available N and total N followed the pattern : summer > winter > rainy across all the habitat.

Suggestion for future work

Present study clearly indicate the marked effect of habitat on soil properties. Depression microsite hold more quantity of leaf litter, micro organism and optimum soil moisture and temperature and more favourable conditions for activities of microorganism compared to non depression. However, there is need to continue this study for revalidation and conformations of results.

**“HABITAT HETEROGENEITY AND ITS IMPACT ON ORGANIC
MATTER, NUTRIENT POOL AND NITROGEN MINERALIZATION
IN TROPICAL DRY DECIDUOUS FOREST”**

By
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ABSTRACT

Study entitled “**Habitat Heterogeneity and Its Impact on Organic Matter, Nutrient Pool and N-mineralization in Tropical Dry Deciduous Forest**” was conducted during 2005-2006. Two microsite (Depression and non depression) under three habitat (hill base, mid slope, hill top) were under taken for the present study. The soil samples were collected from two microsite along the topographic gradients e.g. hill base, hill slope and hill top in three seasons to quantity organic matter, nutrient pool and nitrogen mineralization.

The major findings of this study are as follows:

Soil pH under three habitats (hill base, mid slope, hill top) ranged between 6.40 and 6.85. The soil texture under the e three habitats was silt loam. Bulk density of soil ranged between 0.70 and 1.25 g cm⁻³. The organic carbon content in soil was 1.12 to 2.25%. Nutrient pool viz., available P ranged between 10.22 and 24.27 kg ha⁻¹, available K ranged between 203.45 and 367.15 kg ha⁻¹, available N ranged between 132.06 and 273.94 kg ha⁻¹, total N ranged between 0.13 and 0.19 per cent. Mineral N viz., NO₃-N ranged from 4.18 to 6.85 µgg⁻¹ while NH₄-N ranged between 2.45 and 6.50 µgg⁻¹. The rate of nitrification ranged between 27.48 and 31.39 µgg⁻¹ mo⁻¹. The rate of ammonification ranged between 4.49 and 6.32 µgg⁻¹ mo⁻¹. The value of nitrogen mineralization ranged between 31.97 and 37.71µgg⁻¹ mo⁻¹. Among the three habitats the effect of hill top was greater on physico-chemical properties, nutrient pool, nitrification rates and rate of nitrogen mineralization. Study showed marked influence of microsite on all soil parameters studied. Organic carbon content at depression was 1.34 to 2.45 per cent and at non-depression it was 0.91 to 2.06 per cent. Available P was 10.86 to 26.24 kg ha⁻¹ in depression and 9.58 to 22.31 kg ha⁻¹ in non-depression. Available K ranged between 213.64 and 384.54 kg ha⁻¹ in depression and 193.27 to 367.15 kg ha⁻¹ in non-depression. Available N at depression ranged between 153.33 and 256.44 kg ha⁻¹ and at non-depression between 110.79 and 219.43 kg ha⁻¹. Total N ranged between 0.13 and 0.20 per cent in depression and between 0.12 and 0.18 per cent in non depression, respectively. Mineral N viz., NO₃-N at depression ranged between 4.46 and 7.38 µgg⁻¹ and at non-depression it ranged between 3.90 and 6.33 µgg⁻¹. NH₄-N ranged between 3.50 and 6.50 µgg⁻¹ at depression and 2.45 to 5.95 µgg⁻¹ in non-depression, respectively.

The rate of nitrification ranged between 29.68 and 31.78 $\mu\text{gg}^{-1}\text{mo}^{-1}$ at depression and between 25.29 and 31.03 $\mu\text{gg}^{-1}\text{mo}^{-1}$ at non-depression. Ammonification ranged between 4.59 and 6.75 $\mu\text{gg}^{-1}\text{mo}^{-1}$ and between 4.38 and 5.89 $\mu\text{gg}^{-1}\text{mo}^{-1}$, respectively. The rates of nitrogen mineralization at depression it ranged between 34.27 and 38.50 $\mu\text{gg}^{-1}\text{mo}^{-1}$ and between 29.67 and 36.92 $\mu\text{gg}^{-1}\text{mo}^{-1}$ at non-depression.

There was a marked effect of seasonality on organic matter and nutrient pool. Seasonality plays an important role in dry tropical forest. The seasonal value of organic matter at depression ranged between 1.79 and 2.72 per cent and at non-depression it was 1.31 to 2.66 per cent in summer season and in winter it was 1.35 to 2.62 per cent in depression and 0.83 to 2.06 per cent in non-depression microsite. In rainy season it was 0.89 to 2.02 per cent and 0.60 to 1.47 per cent, respectively in depression and non-depression.

Available P at depression ranged between 13.96 and 28.67 kg ha^{-1} and at non-depression between 11.76 and 24.11 kg ha^{-1} in summer season. In winter it ranged between 10.23 and 26.16 kg ha^{-1} and 9.51 to 22.23 $\mu\text{g ha}^{-1}$, respectively in depression and non-depression microsite. In rainy season it was 8.40 to 23.89 kg ha^{-1} and 7.48 to 20.61 kg ha^{-1} , respectively in depression and non-depression microsite. Available K at depression was 232.64 to 436.64 kg ha^{-1} and at non-depression it was 205.59 to 373.81 kg ha^{-1} in summer season. In winter it was 210.78 to 370.68 kg ha^{-1} and 190.66 to 350.41 kg ha^{-1} , respectively in depression and non-depression microsite. In rainy season it was 197.52 to 346.30 kg ha^{-1} and 183.56 to 325.02 kg ha^{-1} , respectively in depression and non-depression microsite.

Available N at depression ranged between 199.65 and 31.29 kg ha^{-1} and at non-depression between 129.61 and 285.37 kg ha^{-1} in summer. In winter it ranged between 140.91 and 269.69 kg ha^{-1} and 106.61 to 214.53 kg ha^{-1} , respectively in depression and non-depression microsite. In rainy season it ranged between 119.45 and 181.36 kg ha^{-1} and 96.16 to 158.36 kg ha^{-1} , respectively in depression and non-depression microsite. Total N at depression ranged between 0.15 and 0.213 per cent and at non-depression from 0.13 to 0.19 per cent in summer. In winter it ranged between 0.13 and 0.21 per cent and 0.11 to 0.19 per cent, respectively in depression and non depression microsite. In rainy season it was 0.10 to 0.18 per cent and 0.07 to 0.10%, respectively in depression and non-depression microsite.

Study revealed the marked influence of habitat microsite on organic matter, nutrient pool and N mineralization in dry tropical forest.

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Table 4.2b: Effect of season x habitat on (%) organic carbon

Season	Hill base	Mid slope	Hill top
Winter	1.09f (6.02)	1.99c (8.13)	2.34b (8.72)
Summer	1.55d (7.04)	2.18b (8.53)	2.69a (9.40)
Rainy	0.74g (4.93)	1.45e (6.80)	1.74d (7.13)

CD for S x H at 5% = 0.22

In bracket arc sign value

Table4.2c: Effect of season x microsite on (%) organic carbon

Season	Depression	Non depression
Winter	2.05b (8.33)	1.56d (7.04)
Summer	2.25a (8.53)	2.02c (8.13)
Rainy	1.51d (7.04)	1.11e (6.02)
Mean	1.93 (7.92)	1.56 (7.04)

C.D. for M x S at 5% = 0.17

C.D. for M at 5% = 0.10

In bracket arc sign value

Table 4.3b: Effect of season x habitat on available phosphorus (kg ha⁻¹)

Season	Hill base	Mid slope	Hill top
Winter	9.87a	14.65e	24.19b
Summer	12.86f	16.01d	26.39a
Rainy	7.94h	12.91f	22.25c

CD for S x H at 5% = 0.235

Table 4.3c: Effect of season x microsite on available phosphorus (kg ha⁻¹)

Season	Depression	Non-depression
Winter	17.42b	15.06e
Summer	19.93a	16.90c
Rainy	15.46d	13.27f
Mean	17.60	15.07

CD for M x S at 5% = 0.19
CD for M at 5% = 0.11

Table4.4b: Effect of season x habitat on available potassium (kg ha⁻¹)

Season	Hill base	Mid slope	Hill top
Winter	200.72h	265.44e	360.57b
Summer	219.11g	289.77d	405.22a
Rainy	190.54i	257.05f	335.66c

CD for S x H at 5% = 5.81

Table4.4c: Effect of season x microsite on available potassium (kg ha⁻¹)

Season	Depression	Non-depression
Winter	292.20b	258.95d
Summer	331.37a	278.03c
Rainy	275.52c	246.64e
Mean	299.70	261.21

CD for S x M at 5% = 4.74
CD for M at 5 % = 3.26

Table4.5b: Effect of season x habitat on available Nitrogen (kg ha⁻¹)

Season	Hill base	Mid slope	Hill top
Winter	123.74e	179.47c	242.12b
Summer	164.63d	236.76b	301.83a
Rainy	107.81f	131.00e	170.13c

CD for S x H at 5% = 9.43

Table4.5c: Effect of season x microsite on available Nitrogen (kg ha⁻¹)

Season	Depression	Non-depression
Winter	203.26c	160.31d
Summer	256.97a	211.84b
Rainy	145.27e	127.35f
Mean	201.83	166.50

CD for S x M at 5% = 7.70
CD for M at 5% = 4.44

Table4.6b: Effect of season x habitat on (%) total nitrogen

Season	Hill base	Mid slope	Hill top
Winter	0.11d (2.05)	0.16b (2.31)	0.20a (2.56)
Summer	0.14cd (2.14)	0.17b (2.36)	0.21a (2.63)
Rainy	0.08e (1.64)	0.11d (2.07)	0.16bc (2.29)

CD for S x H at 5% = 0.16

In bracket arc sign value

Table 4.6c: Effect of season x microsite on (%) total nitrogen

Season	Depression	Non depression
Winter	0.17ab (2.36)	0.15bc (2.22)
Summer	0.18a (2.43)	0.16ab (2.29)
Rainy	0.13c (2.07)	0.10d (1.81)
Mean	0.16 (2.29)	0.14 (2.14)

C.D. for M x S at 5% = 0.13

C.D. for M at 5% = 0.09

In bracket arc sign value

Table 4.7a: Effect of habitat x microsite on NO₃ - N (µg g⁻¹)

Habitat	Depression	Non-depression	Mean
Hill base	4.46	3.90	4.18
Mid slope	5.86	5.42	5.64
Hill top	7.38	6.33	6.85
Mean	5.90	5.21	

Table 4.7b: t-value for NO₃ - N (µg g⁻¹)

	Base non- depression	Base depression	Mid non- depression	Mid - depression	Top non- depression
Top depression	10.72*	8.77*	5.91*	4.49*	2.99*
Top non- depression	10.70*	7.74*	3.81*	1.88*	
Mid depression	9.78*	6.42*	2.04*		
Mid non- depression	8.27*	4.70*			
Base depression	2.97*				

t-table value (0.025%), 18 df = 1.05

* = Significant

Table 4.8a: Effect of habitat x microsite on NH₄ - N (µg g⁻¹)

Habitat	Depression	Non-depression	Mean
Hill base	3.50	2.45	2.97
Mid slope	4.56	4.14	4.35
Hill top	6.50	5.49	6.00
Mean	4.85	4.02	

Table 4.8b: t-value for NH₄ - N (µg g⁻¹)

	Base non-depression	Base depression	Mid non-depression	Mid - depression	Top non-depression
Top depression	17.55*	13.31*	10.74*	8.98*	4.36*
Top non-depression	16.34*	11.21*	8.42*	5.00*	
Mid depression	11.41*	6.01*	2.52*		
Mid non-depression	10.12*	4.11*			
Base depression	5.94*				

t-table value (0.025%), 18 df = 1.05

* = Significant

Table4.9a: Effect of habitat x microsite on Nitrification ($\mu\text{g g}^{-1} \text{ month}^{-1}$)

Habitat	Depression	Non-depression	Mean
Hill base	29.68	25.29	27.48
Mid slope	30.93	29.47	30.20
Hill top	31.78	31.03	31.39
Mean	30.79	28.59	

Table4.9b: t-value for Nitrification ($\mu\text{g g}^{-1} \text{ month}^{-1}$)

	Base non- depression	Base depression	Mid non- depression	Mid - depression	Top non- depression
Top depression	14.53*	5.33*	6.10*	2.71*	2.18*
Top non- depression	14.27*	4.01*	4.90*	0.33 NS	
Mid depression	13.21*	3.40*	4.15*		
Mid non- depression	9.56*	0.55NS			
Base depression	9.77*				

t-table value (0.025%), 18 df = 1.05

* = Significant

NS = Non-significant

Table 4.10a: Effect of habitat x microsite on Ammonification ($\mu\text{g g}^{-1}$ month⁻¹)

Habitat	Depression	Non-depression	Mean
Hill base	4.59	4.38	4.49
Mid slope	5.97	5.11	5.54
Hill top	6.75	5.89	6.32
Mean	5.77	5.12	

Table4.10b: t-value for Ammonification ($\mu\text{g g}^{-1}$ month⁻¹)

	Base non- depression	Base depression	Mid non- depression	Mid - depression	Top non- depression
Top depression	9.87*	8.76*	7.35*	3.86*	3.59*
Top non- depression	6.42*	5.37*	3.58*	0.34 NS	
Mid depression	6.89*	5.89*	4.04*		
Mid non- depression	3.33*	2.29*			
Base depression	0.86				

t-table value (0.025%), 18 df = 1.05

* = Significant

NS = Non-significant

Table4.11a: Effect of habitat x microsite on Nitrogen mineralization ($\mu\text{g g}^{-1} \text{ month}^{-1}$)

Habitat	Depression	Non-depression	Mean
Hill base	34.27	29.67	31.97
Mid slope	36.90	34.58	35.74
Hill top	38.50	36.92	37.71
Mean	36.89	33.72	

Table4.11b: t-value for Nitrogen mineralization ($\mu\text{g g}^{-1} \text{ month}^{-1}$)

	Base non- depression	Base depression	Mid non- depression	Mid - depression	Top non- depression
Top depression	17.85*	10.05*	9.44*	3.98*	4.11*
Top non- depression	16.45*	7.53*	6.79*	0.06 NS	
Mid depression	15.86*	7.07*	6.35*		
Mid non- depression	10.50*	0.80 NS			
Base depression	9.74*				

t-table value (0.025%), 18 df = 1.05

* = Significant

NS = Non-significant

Table4.3a: Effect of habitat, microsite and season on available phosphorus (kg ha⁻¹)

Season	Hill base			Mid slope			Hill top			Over all Mean
	Depression	Non-depression	Mean	Depression	Non-depression	Mean	Depression	Non-depression	Mean	
Winter	10.23l	9.51m	9.87	15.87g	13.44j	14.65	26.16b	22.23d	24.19	16.23
Summer	13.96i	11.76k	12.86	17.17f	14.85h	16.01	28.67a	24.11c	26.39	18.42
Rainy	8.40n	7.48o	7.94	14.10i	11.73k	12.01	23.89c	20.61e	22.25	14.36
Mean	10.86	9.58	10.22	15.71	13.34	14.52	26.24	22.31	24.27	

CD for H at 5% = 0.16

CD for S at 5% = 0.16

CD for H x M at 5% = 0.19

CD for H x M x S at 5% = 0.33

Table 4.4a: Effect of habitat, microsite and season on available potassium (kg ha⁻¹)

Season	Hill base			Mid slope			Hill top			Over all Mean
	Depression	Non-depression	Mean	Depression	Non-depression	Mean	Depression	Non-depression	Mean	
Winter	210.78i	190.66jk	200.72	295.14e	235.75h	265.44	370.68b	350.46c	360.57	270.02
Summer	232.64h	205.59ij	219.11	324.83d	254.71g	289.77	436.64a	373.81b	405.23	304.70
Rainy	197.52j	183.56k	190.54	282.76f	231.35h	257.05	346.30c	325.02d	335.66	261.08
Mean	213.64	193.27	203.455	300.91	240.66	270.78	384.54	349.76	367.15	-

CD for H at 5% = 3.99

CD for S at 5% = 3.99

CD for H x M at 5% = 4.74

CD for H x M x S at 5% = 8.22

Table 4.5a: Effect of habitat, microsite and season on available Nitrogen (kg ha⁻¹)

Season	Hill base			Mid slope			Hill top			Over all Mean
	Depression	Non-depression	Mean	Depression	Non-depression	Mean	Depression	Non-depression	Mean	
Winter	140.91i	106.61l	123.76	199.18f	159.76h	179.47	269.69c	214.55e	242.12	181.78
Summer	199.65f	129.61ij	164.63	252.96d	220.56e	236.76	318.29a	285.37b	301.83	234.41
Rainy	119.45kl	96.16l	107.80	135.01ij	126.99jk	131.00	181.36g	158.36h	169.86	136.22
Mean	153.34	110.79	132.06	195.72	169.10	182.41	256.45	219.43	237.94	184.14

CD for H at 5% = 5.44

CD for S at 5% = 5.44

CD for H x M at 5% = 7.70

CD for H x M x S at 5% = 13.33

Table 4.6a. Effect of habitat, microsite and season on (%) total Nitrogen (arc sign Transformation used)

Season	Hill base			Mid slope			Hill top			Over all Mean
	Depression	Non-depression	Mean	Depression	Non-depression	Mean	Depression	Non-depression	Mean	
Winter	0.13ghi (2.00)	0.11hi (1.95)	0.11 (2.05)	0.17bed (2.38)	0.15def (2.24)	0.16 (2.31)	0.21ab (2.62)	0.19abc (2.52)	0.20 (2.56)	0.16 (2.30)
Summer	0.15def (2.25)	0.13ghi (2.03)	0.14 (2.14)	0.18abc (2.45)	0.16cde (2.29)	0.17 (2.37)	0.23a (2.75)	0.19abc (2.52)	0.21 (2.65)	0.17 (2.38)
Rainy	0.10i (1.84)	0.07j (1.55)	0.08 (1.69)	0.13fgh (2.11)	0.10hi (1.80)	0.11 (2.07)	0.18bcd (2.40)	0.15efg (2.18)	0.16 (2.29)	0.12 (1.99)
Mean	0.13 (2.07)	0.12 (1.84)	0.13 (1.96)	0.16 (2.31)	0.14 (2.14)	0.15 (2.22)	0.20 (2.59)	0.18 (2.40)	0.19 (2.49)	

CD for H at 5% = 0.09

CD for S at 5% = 0.07

CD for H x M at 5% = 0.13

CD for H x M x S at 5% = 0.22

In bracket arc sign value

Table4.2a: Effect of habitat, microsite and season on (%) organic carbon (arc sign Transformation used)

Season	Hill base			Mid slope			Hill top			Over all Mean
	Depression	Non-depression	Mean	Depression	Non-depression	Mean	Depression	Non-depression	Mean	
Winter	1.35g (6.55)	0.83h (5.44)	1.09 (6.02)	2.19b (8.53)	1.79d (7.71)	1.99 (8.13)	2.62a (9.28)	2.06c (8.13)	2.34 (8.72)	1.80 (7.71)
Summer	1.79d (7.71)	1.31g (6.55)	1.55 (7.04)	2.25b (8.59)	2.11c (8.19)	2.18 (8.53)	2.72a (9.45)	2.66a (9.40)	2.69 (13.31)	2.14 (8.33)
Rainy	0.89h (5.41)	0.60i (4.45)	0.74 (4.93)	1.64e (7.34)	1.26g (6.46)	1.45 (6.80)	2.02c (8.12)	1.47f (6.95)	1.74 (9.46)	1.31 (6.55)
Mean	1.34 (6.55)	0.91 (5.44)	1.12 (6.02)	2.02 (8.13)	1.72 (7.49)	1.87 (7.92)	2.45 (8.95)	2.06 (8.16)	2.25 (10.14)	

CD for H at 5% = 0.12

CD for S at 5% = 0.12

CD for H x M at 5% = 0.17

CD for H x M x S at 5% = 0.31

In bracket arc sign value

Table 4.1: Physicochemical properties of soil in Dry Tropical Forest

Characteristic	Hill base		Mid slope		Hill top	
	Depression	Non depression	Depression	Non depression	Depression	Non depression
Soil pH	6.85	6.40	6.73	6.58	6.85	6.80
Soil Texture						
% Clay	30	46	22	18	44	46
% Silt	26	20	44	54	18	18
% Sand	44	34	34	28	38	36
Bulk density (g cm ⁻³)	1.08	1.25	0.86	0.95	0.70	0.82
% Organic carbon	1.34	0.91	2.02	1.72	2.45	2.06
Available N (kg ha ⁻¹)	153.33	110.79	195.71	169.10	256.44	219.43
Total N (%)	0.13	0.12	0.16	0.14	0.20	0.18
Available P (kg ha ⁻¹)	10.86	9.58	15.71	13.34	26.24	22.31
Available K (kg ha ⁻¹)	213.64	193.27	300.91	240.60	384.54	349.76
NO ₃ -N (µg g ⁻¹)	4.46	3.90	5.86	5.42	7.38	6.33
NH ₄ -N (µg g ⁻¹)	3.50	2.45	4.56	4.14	6.50	5.49

APPENDIX – I: Monthly meteorological details of Raipur District during study (2005-06)

Month	Temperature (⁰ C)		Rainfall (mm)	Rainy (day)	Relative humidity (%)		Evaporation (mm)	Wind velocity (kmph)	Sun shine (hr)
	Max.	Min.			I	II			
Sept. 2005	31.1	24.6	276.8	8	90	72	4.0	6.2	5.2
Oct. 2005	30.3	22.0	120.8	2	93	61	3.1	3.3	6.1
Nov. 2005	29.2	12.6	0.00	0	90	29	3.5	2.3	9.1
Dec. 2005	20.8	10.4	0.00	0	90	31	2.9	2.4	6.8
Jan. 2006	28.7	13.1	0.00	0	87	27	3.4	2.3	9.0
Feb. 2006	33.4	13.8	0.00	0	79	22	4.5	2.4	9.4
March 2006	33.2	18.3	45.2	7	75	33	6.0	4.0	8.1
April 2006	38.7	22.6	46.6	3	57	22	8.5	5.7	8.5
May 2006	40.1	26.5	62.2	3	59	29	10.2	8.0	7.1
June 2006	37.7	26.9	94.9	7	69	40	8.3	8.3	4.8
July 2006	30.5	24.5	550.9	20	92	77	3.5	8.7	2.3
Aug. 2006	29.5	24.5	360.1	13	93	76	3.1	9.0	2.5

APPENDIX – II: Organic carbon

Source	DF	SS	MSS	F cal.	F Table
Factor A	2	63.28	31.64	888.24*	3.26
Factor B	1	10.92	10.92	306.45*	4.11
AB	2	0.50	0.25	7.07*	3.26
Factor C	2	32.39	16.19	454.61*	3.26
AC	4	1.36	0.34	9.58*	2.63
BC	2	0.80	0.40	11.33*	3.26
ABC	4	0.66	0.16	4.65*	2.63
Error	36	1.28	0.04	-	-
Total	53	111.21			

APPENDIX – III: Available Phosphorus

Source	DF	SS	MSS	F cal.	F Table
Factor A	2	1870.91	935.45	1616.77*	3.26
Factor B	1	86.99	86.99	1503.56*	4.11
AB	2	15.47	7.73	27.16*	3.26
Factor C	2	149.34	74.67	1290.58*	3.26
AC	4	6.28	1.57	27.16*	2.63
BC	2	1.63	0.81	14.09*	3.26
ABC	4	1.42	0.35	6.13*	2.63
Error	36	2.08	0.06	-	-
Total	53	2134.15			

APPENDIX – IV: Available Potassium

Source	DF	SS	MSS	F cal.	F Table
Factor A	2	243664.96	121832.48	3492.41*	3.26
Factor B	1	19966.89	19966.89	572.36*	4.11
AB	2	3673.54	1836.77	52.65*	3.26
Factor C	2	17751.05	8875.53	254.42*	3.26
AC	4	3117.48	779.37	22.34*	2.63
BC	2	1527.24	763.62	21.88*	3.26
ABC	4	628.95	157.24	4.50*	2.63
Error	36	1255.85	34.88	-	-
Total	53	291585.99			

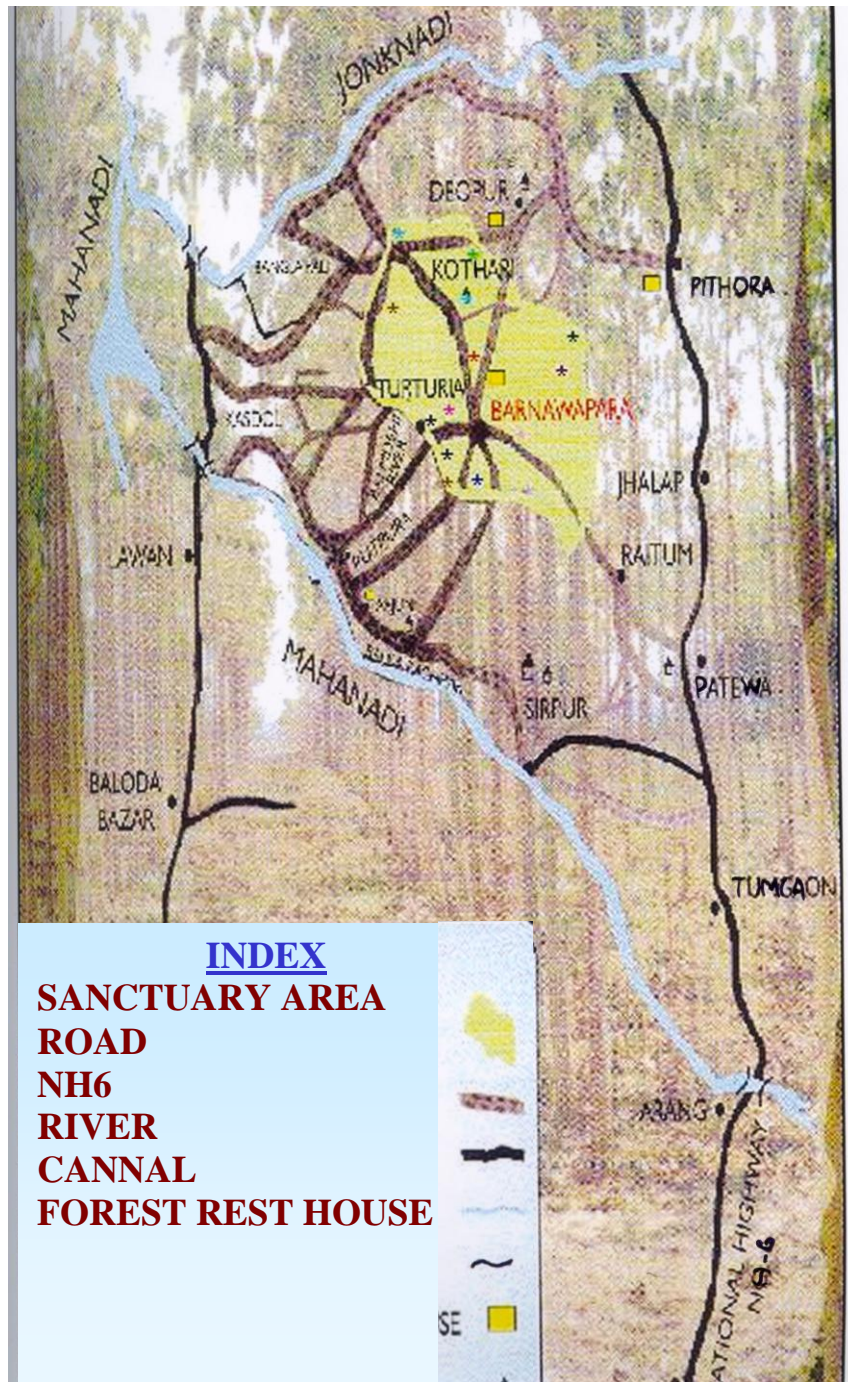
APPENDIX – V: Available nitrogen

Source	DF	SS	MSS	F cal.	F Table
Factor A	2	101144.59	50572.29	774.86*	3.26
Factor B	1	16847.99	16847.99	258.14*	4.11
AB	2	584.98	292.49	4.48*	3.26
Factor C	2	86755.04	43377.52	664.62*	3.26
AC	4	9370.92	2342.72	35.89*	2.63
BC	2	2055.55	1027.77	15.75*	3.26
ABC	4	1388.20	347.08	5.32*	2.63
Error	36	2349.58	65.26	-	-
Total	53	220496.88			

APPENDIX – VI: Total nitrogen

Source	DF	SS	MSS	F cal.	Prob.
Factor A	2	2.597	1.299	67.20*	0.00
Factor B	1	0.518	0.518	26.81*	0.00
AB	2	0.006	0.003	0.17*	-
Factor C	2	1.486	0.743	38.45*	0.00
AC	4	0.023	0.006	0.30*	-
BC	2	0.021	0.010	0.54*	-
ABC	4	0.005	0.001	0.06*	-
Error	36	0.696	0.019	-	-
Total	53	5.353			

Plate 3.1: Location map of Barnawapara



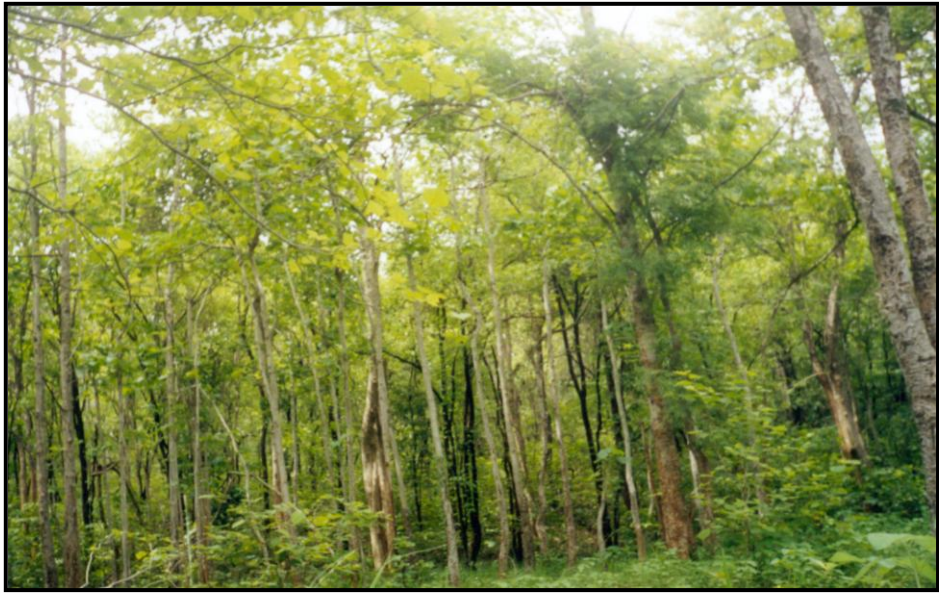


Plate 3.2: General view of experimental site



A. View of depression



B. View of non depression

Plate 3.3: View of microsites

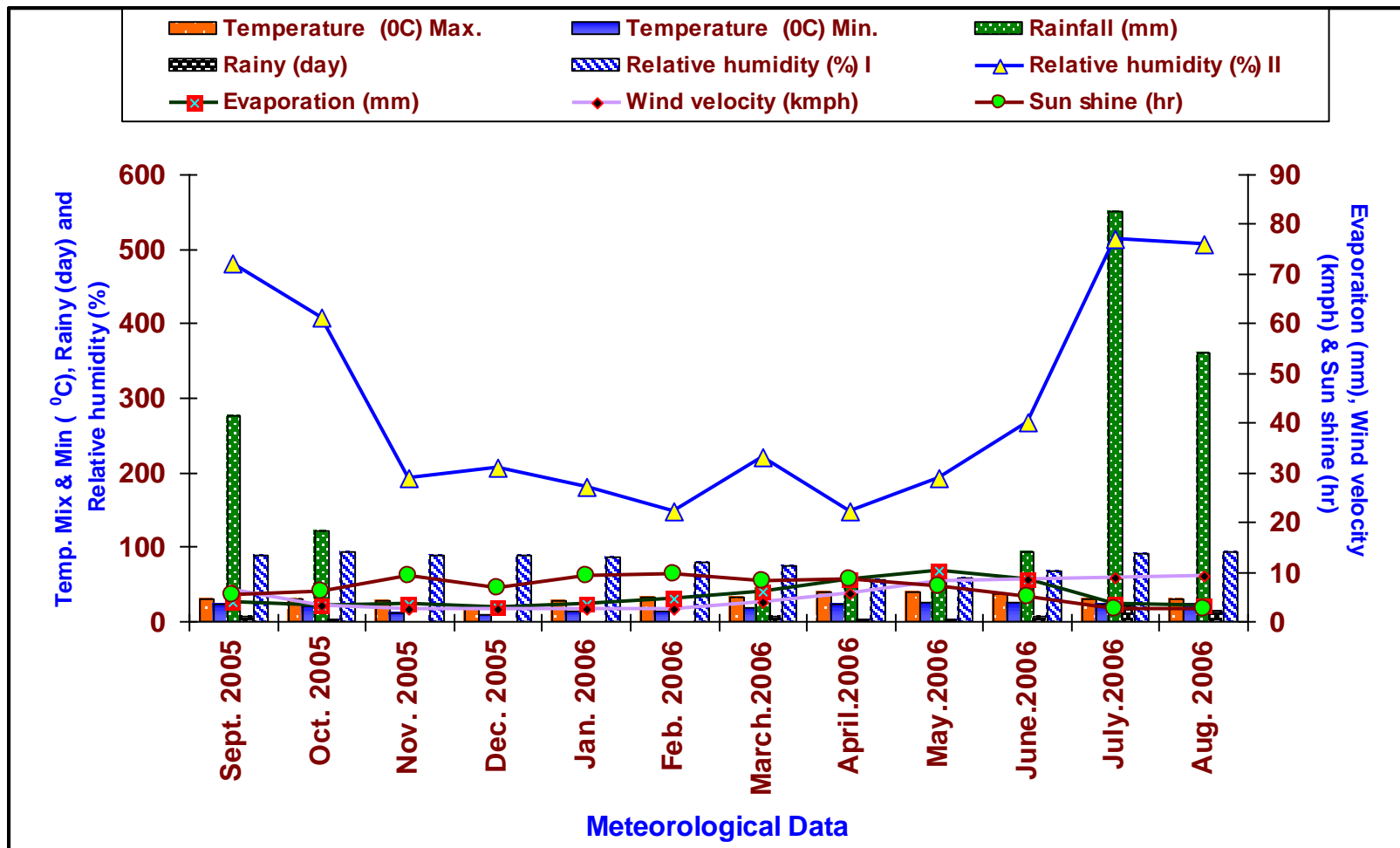


Fig. 3.1: Monthly meteorological details of Raipur District during study (2005-06)

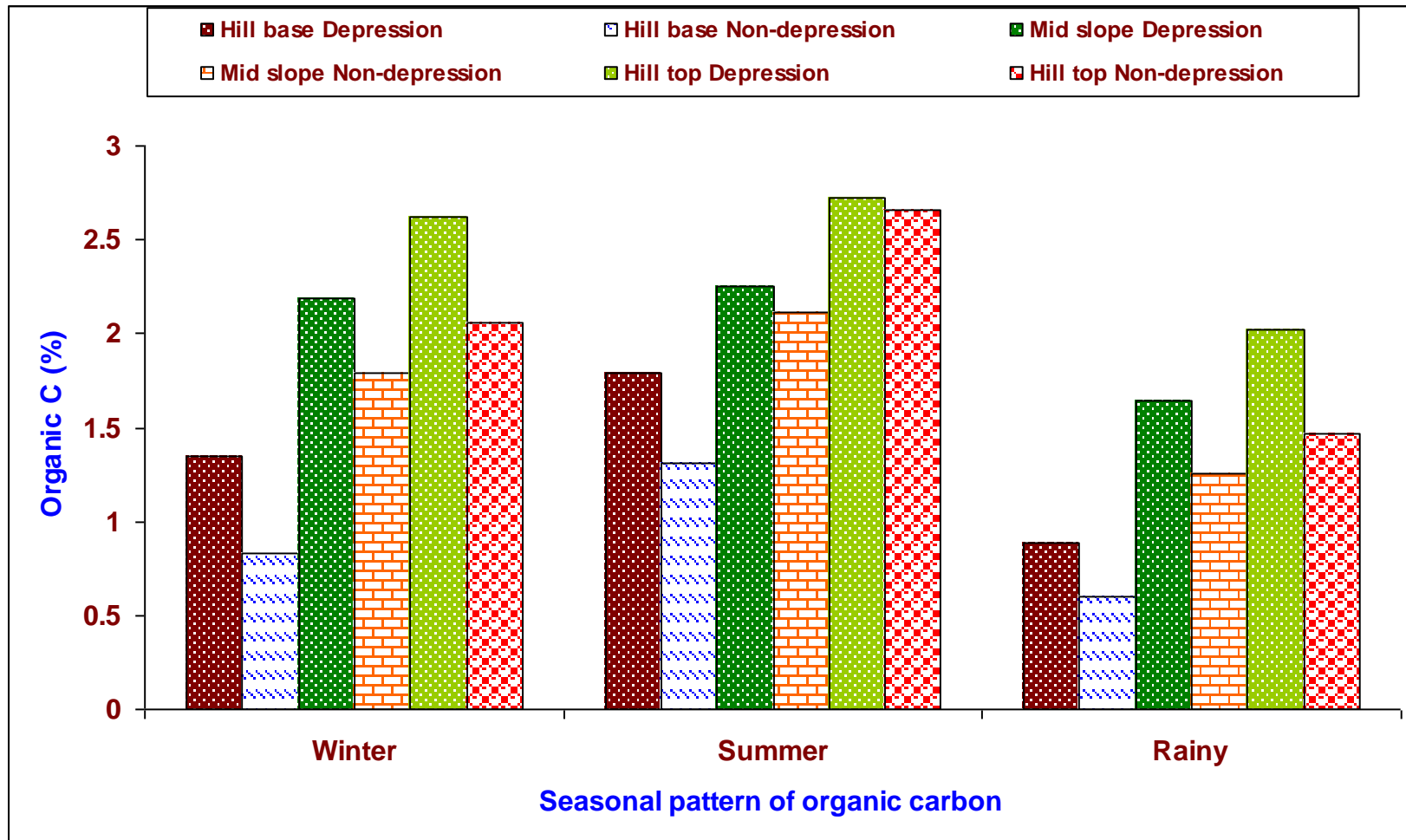


Fig. 4.1a: Effect of habitat, microsite and season on (%) organic carbon

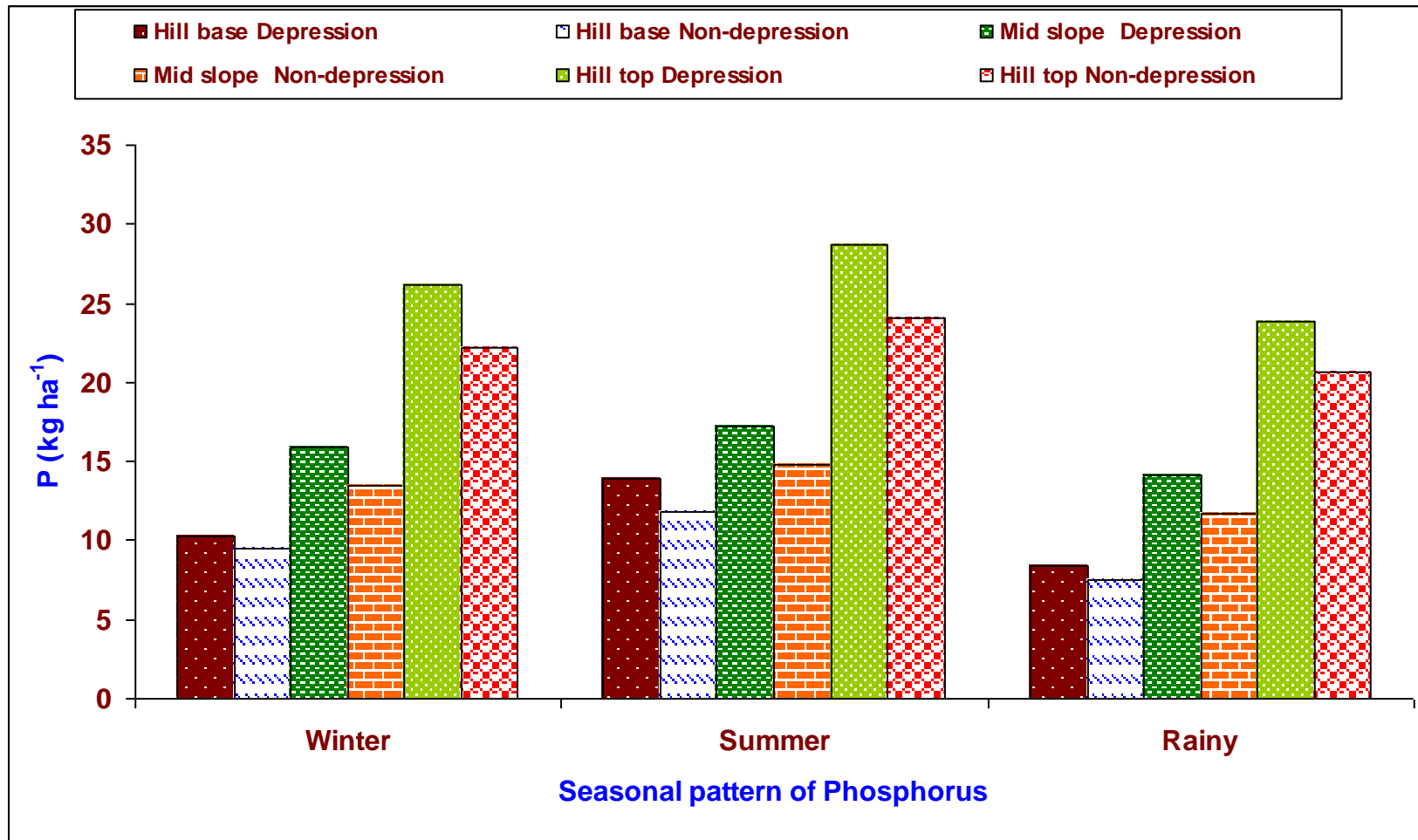


Fig. 4.2a: Effect of habitat, microsite and season on available phosphorus (kg ha⁻¹)

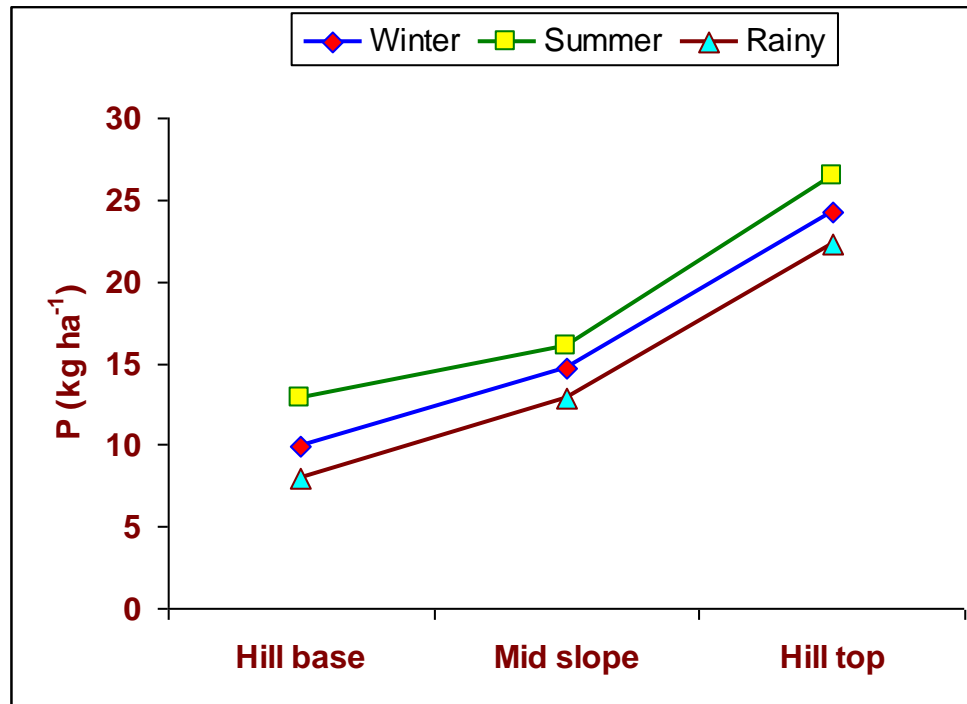


Fig. 4.2b: Effect of season x habitat on available phosphorus (kg ha-1)