FERTILITY STATUS OF SOILS UNDER DIFFERENT LAND USES IN PANCHRUKHI BLOCK OF HIMACHAL PRADESH

THESIS

By

POONAM GOGOI
(A-2010-30-46)

Submitted to

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in

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TO

MAMMA PAPA

Who taught me the only thing that should be total and all encompassing-LOVE

Dr. V K Sharma
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CERTIFICATE – I

This is to certify that the thesis entitled **"Fertility status of soils under different land uses in Panchrukhi block of Himachal Pradesh"** submitted in partial fulfillment of the requirements for the award of the degree of **Master of Science (Agriculture)** in the discipline of **Soil Science** of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur is a bonafide research work carried out by **Ms. Poonam Gogoi (A-2010-30-46)** daughter of **Shri Mahendra Nath Gogoi** under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been fully acknowledged.

(Dr. V K Sharma)
Major Advisor

Place: Palampur
Dated: 19 July, 2011

CERTIFICATE- II

This is to certify that the thesis entitled **"Fertility status of soils under different land uses in Panchrukhi block of Himachal Pradesh"** submitted by **Ms. Poonam Gogoi (A-2010-30-46)** daughter of **Shri Mahendra Nath Gogoi** to the CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur in partial fulfilment of the requirements for the degree of **Master of Science (Agriculture)** in the discipline of **Soil Science** has been approved by the Advisory Committee after an oral examination of the student in collaboration with an External Examiner.

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I owe entire responsibility for all the errors and omissions that may remain in this work.

Place: Palampur

Dated: 19 July, 2011

(Poonam Gogoi)

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LIST OF ABBREVIATIONS USED

Sr. no.	Abbreviation	Meaning
1.	°C	Degree celcius
2.	%	Per cent
3.	BS	Base satuaration
4.	CEC	Cation exchange capacity
5.	cl	Clay loam
6.	cmol (p^+) kg^{-1}	Centi mol proton per kilogram
7.	Ca	Calcium
8.	Cu	Copper
9.	DTPA	Diethylene Triamine Penta Acetic acid
10.	*et al.*	*etalii (and others)*
11.	etc.	Etcetra
12.	e.g.	Example
13.	EC	Electrical Conductivity
14.	Fe	Iron
15.	Fig	Figure
16.	i.e.	That is
17.	K	Potassium
18.	kg ha^{-1}	Kilogram per hectare
19.	l	Loam
20.	ls	Loamy sand
21.	M	Moist
22.	m	Meter
23.	mm	Milli Metre
24.	mg kg^{-1}	Milligram per kilogram
25.	Mg	Magnesium
26.	*Mn*	*Manganese*
27.	mt	Million tones
28.	N	Nitrogen
29.	N	North
30.	OC	Organic Carbon
31.	P	Phosphorus
32.	S	Sulphur
33.	sl	sandy loam
34.	sicl	silty clay loam
35.	*via.,*	Through
36.	*viz.,*	vi delicet (namely)
37.	Zn	Zinc

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ABSTRACT

Present study aims at determining fertility status of soils under different land uses in Panchrukhi block of Himachal Pradesh. Panchrukhi block lies between 76°31'17" E to 76°40'35" E longitude and 32°07'15" N to 31°55'54" N latitude and comprises of 37 panchayats. Per cent of the total area of 6, 159 ha under cropland, tea garden, forest and grass/ scrub land is 27, 3, 54 and 16, respectively. Soils of the study area belong to *Typic Dystrudepts, Typic Eutrudepts, Typic Hapludalfs, Typic Paleudalfs and Lithic Udorthents* and are strongly acidic to neutral in reaction, low in EC, low to high in organic carbon and moderately-coarse to moderately-fine in particle size class. Surface soils had higher OC and lower soil pH, EC, sand, and base saturation than subsurface layers. However, clay and CEC values in surface layers were comparatively lower in *Alfisols* and *Inceptisols*. There was a considerable spatial variation in available nutrient contents within and between land uses and panchayats. Agricultural lands had higher amounts than non-agricultural lands. Per cent panchayats rating high, medium and low in Panchrukhi block were 16, 52 and 32 in available N; nil, 52 and 48 in available P; 16, 54 and 30 in available K and 8, 57 and 35 in available S, respectively. Soils of all panchayats were sufficient in available Ca, Mg and Fe. Per cent panchayats deficient in Mn, Zn and Cu were 30, 84 and 38, respectively. Irrespective of the soil taxa and land use, all the nutrients decreased with increasing depth in *Entisols*. Available N, P, S, Zn and Cu decreased with increasing soil depth whereas K, Ca, Mg, Fe and Mn exhibited an irregular trend of distribution with depth in *Inceptisols and Alfisols*. Further, it was observed that total nutrient content, soil organic carbon, clay and base saturation proved to be better soil fertility indicators in the study area.

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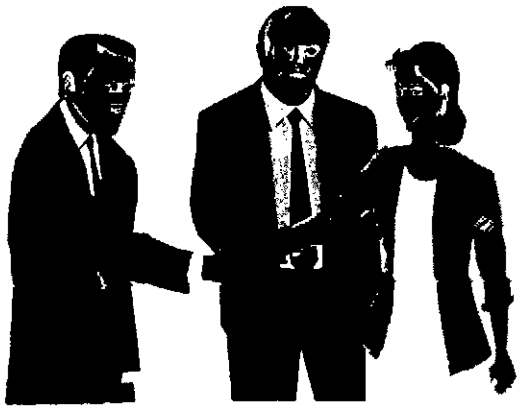


INTRODUCTION

1. INTRODUCTION

Sustainable agriculture aims at meeting the needs of the present without endangering the resource base of the future generations. According to FAO (1989), it is necessary to manage agricultural resources judiciously for changing human needs while maintaining or enhancing the quality of environment and conserving natural resources. In India, sustainability of agro-ecosystems has also become a major concern in order to feed the burgeoning population and maintaining environmental quality. More than 57 per cent of total geographical area of India is suffering from different kinds of soil degradation problems (Sehgal and Abrol 1998). Further, India needs 350 million tonnes (mt) of food grains to feed the projected population of 1.48 billion by 2030 (Reddy 2011).

Sustainable agricultural productivity is affected by a number of factors viz., climate, soils, agricultural input availability, size of holding, technical know-how, irrigation facilities, population pressure on land, land tenure system etc. Among all, soil is the critical component of the earth system, functioning not only for the production of food, fodder and fiber but also in the maintenance of local, regional and global environmental quality (Pathak 2010). The soil characteristics and properties always define sustainable land use practices to harness the potential of different agro-ecoregions for commercial agriculture. Warren and Agnew (1998) described that of all the threats to sustainability, the threat due to soil fertility depletion is most serious. As long as agriculture remains a soil-based industry, major increase in productivity are unlikely to be attained without ensuring an adequate and balanced supply of nutrients. The estimates by Biswas *et al.* (1996) showed that there is depletion of about 25 mt of nutrients annually through various crops in India. It is hardly returning about 14 mt in the form of fertilizers and manures, thus leaving a negative balance of 11 mt. According to them, soil-test based fertilizer recommendations are key to sustain agricultural productivity in India.

Soil fertility refers to the inherent capacity of a soil to supply essential nutrients to plants in adequate amount, in correct proportion and at right time for their optimum growth. Soil fertility of an area is controlled by pedogenic (climate, parent material, topography, organisms and time) as well as artificial (land use and management practices) factors. There exists a close relationship between landforms and soil fertility status of an area (Meena *et al.* 2010). The interactions between soil properties like soil texture, soil reaction, organic carbon, cation exchange capacity with available nutrient concentration were also used as clue to indicate soil fertility status (Richter and Markewitz 2001).

A proper evaluation of the fertility of the soil before planting a crop helps in adopting appropriate measures to make up for the shortcomings and ensuring a good crop production (Sekhon *et al.* 2009). Soil testing provides a base for optimum fertilizer use at farm levels and soil fertility maps to guide planners and fertilizer manufacturers/distributors to devise nutrient management strategies. Soil fertility maps in India are usually prepared on the basis of available nutrient status of surface soils (Motsara 2002). Limited attention is usually given on soil fertility characterization of sub-surface soils and non-agricultural lands, which are important factors that ultimately affect the fertility status of soils.

Nowadays, various agencies and departments of private and public sectors are planning and implementing developmental programmes by involving people at a panchayat level. Because of the limited availability of soil database at a panchayat level, such plans are usually based on available soil data at block or district levels.

Himachal Pradesh, a hilly state, has a deep dissected topography with mosaic of mountain ranges (Greater, Lesser and Outer Himalayas) and valleys of varying slopes and sizes at different altitudes, complex geological formations and diversity of flora. It has twelve districts. Kangra district of Himachal Pradesh represents almost all the agro-climatic conditions of the State *viz.*, low-hills subtropical, mid-hills sub-humid, high-hills wet temperate and high-hills dry temperate conditions. The district is further divided into fifteen developmental blocks. Panchrukhi block represents the socio-economic and mid-hills-cum-low-hills agro-situations of Kangra district to a large extent.

Keeping in view the above-mentioned facts and figures, present investigation entitled "Fertility status of soils under different land uses in Panchrukhi block of Himachal Pradesh" was carried out with the following objectives:

i) to determine available macro- and micro-nutrient status of surface soils under different land uses in each panchayat of Panchrukhi block and

ii) to study the horizon-wise distribution of available nutrients and of soil properties affecting nutrient availability in soils representing different land uses of Panchrukhi block.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

It is evident from early writings of Xenophon (434-355 B.C.), Theophrastus (372-287 B.C.), Cato (234-149 B.C.) and Virgil (70-19 B.C.) that even before the advent of Christian era, the Greeks and Romans realized the impact of soil on growth of plants. These writings have made a mention of increase in the productivity of soil as a result of the application of manures, decaying organic matter, ash and inorganic salts like saltpetre. Since then, scientific research on soil fertility assessment continued and are still continuing. The period from the middle of nineteenth century to the beginning of twentieth century marks an era during which much progress was made in the evaluation of soil fertility and its improvement with addition of manures and fertilizers. In 1843, JB Lawes and JH Gilbert established an agricultural experiment station at Rothamsted, England and by 1855, they settled the concept that soil fertility can be maintained by means of chemical fertilization. Thereafter, soil testing programmes became popular throughout the world for fertilizer applications to crops.

In India, soil testing programme is relatively young and was started in 1955-56. This chapter reviews the work done by various workers on soil fertility characterization particularly in India under the following heads:

2.1 Soil fertility status in India with special reference to Himachal Pradesh

2.2 Soil characteristics/properties affecting soil fertility

2.1 Soil fertility status in India with special reference to Himachal Pradesh

Soil chemists judge a soil's nutrient status by estimating the "plant-available" fraction of the total nutrient present in it using an established method which must be accurate, reproducible (precise) and rapid. Based on the estimated available nutrient status, the soils are then categorized into low, medium and high categories. It is accepted that the soils testing low or medium cannot support optimum crop yields on their own and require fertilizer application. Lower the soil's fertility (greater a nutrient's deficiency), higher will be the rate of nutrient application to meet crop needs. Fertility in soils is the result of presence of essential plant nutrients in adequate amounts and in available forms to the plant. The work done on soil fertility evaluation should be a continuous one so that the changes in fertility status of soils can be assessed periodically for making more scientific recommendations on soil fertility management.

Ramamoorthy and Bajaj (1969) reported that the soils of India were low in available N and P and medium in available K. Thakur *et al.* (1971) found that the cultivated soils of Seeraj and Karsog blocks in Mandi district of Himachal Pradesh were medium in available N and low in available P and K. Ghosh and Hasan (1976) rated majority of Indian soils as medium, high and low in available K to the extent of 42, 38 and 20 per cent, respectively.

Verma *et al.* (1976) reported that the cultivated soils of Kangra region of Himachal Pradesh were low in available N, P and K. Ghosh and Hasan (1979) reported that available P status in Indian soils was medium, low and high to the extent of 52, 46 and 2 per cent, respectively.

Ghosh and Hasan (1980) prepared a map of nitrogen status of Indian soils and found that many soils of hill regions including Himachal Pradesh were high in available N, while those of plains were low to medium in N status. Takkar and Nayyar (1981) observed Fe and Mn deficiencies in cultivated alluvial plains of Punjab.

Sekhon *et al.* (1982) observed that the lateritic soils occurring on the summits of hills in the central, southern and eastern India were relatively less fertile and tended to be deficient in all the macronutrients *viz.,* N, P and K. Verma and Tripathi (1982) reported that available nitrogen content in Una and Hamirpur districts varied from 113 to 228 kg ha^{-1} while it ranged from 295 to 503 kg ha^{-1} in Kangra, Mandi, Bilaspur, Shimla and Sirmour districts of Himachal Pradesh.

Patiram *et al.* (1984) found more than 50 per cent soils from the district East Khasi Hills of Meghalaya as low in available Zn. However, it was high in West Khasi hills, probably due to high organic matter. Verma *et al.* (1985) characterized the soils of Kangra, Kullu, Mandi and Sirmour areas of Himachal Pradesh and found the contents of both available P and K ranging from 2.69 to 28.22 kg ha^{-1} and 4.26 to 1507 kg ha^{-1}, respectively.

Raina (1988) studied the citrus growing soils of Paonta valley in Himachal Pradesh and reported the soils as low in available N, medium to high in available P and medium in available K. Gupta and Tripathi (1989) observed that exchangeable calcium in the soils of North-West Himalayas were medium to high in status (2.2 to 10.5 cmol (p^+) kg^{-1}).

Available P status was found to be low Dehra, Nurpur, Lambagaon, Badsar and Sundernagar blocks of Himachal Pradesh. Available N and K were rated as medium in these blocks (Anonymous 1993).

Kaistha and Gupta (1993) reported that exchangeable Ca and Mg in sub-humid temperate highlands of Himachal Pradesh varied from 3.7 to 15.3 and 0.1 to 4.2 cmol (p^+) kg^{-1}, respectively. Masih *et al.* (1995) found that the agriculturally developed soils of semi-arid plain zones of Rajasthan were sufficient in available Cu and Mn and deficient in available Fe and Zn.

Gupta and Tripathi (1996) reported that exchangeable Mg contents in the soils of North-West Himalayas ranged from 0.7 to 10.5 cmol (p^+) kg^{-1}. Brar (1998) reported that soils of Punjab were deficient in available N, P, K, S, Zn, Fe, Cu and Mn to the extent of 78.2, 47.5, 8.2, 24.9, 49.0, 17.0, 2.0 and 3.0 per cent, respectively. Sharma *et al.* (1998) found the soils of Loon watershed of Kangra district as medium in available N, P and K status.

According to Anonymous (2001), 51, 36 and 59 per cent of Indian soils were high, medium and low in available N; 6, 45 and 49 per cent in available P and 52, 39 and 9 per cent in available K. Further, 20 to 25 and 35 to 40 per cent of soil samples studied were deficient in available S and Zn, respectively.

Mahajan (2001) reported the soils of Mandi district in Himachal Pradesh as medium in available N (384 to 492 kg ha^{-1}), P (17 to 22 kg ha^{-1}) and K (231 to 235 kg ha^{-1}), high in exchangeable Ca (4.0 to 5.1 cmol (p^+) kg^{-1}) and Mg (1.7 to 2.4 cmol (p^+) kg^{-1}) and high in DTPA extractable Fe (91 to 129 ppm), Mn (1.3 to 3.5 ppm), Zn (5.5 to 8.3 ppm) and Cu (1.7 to 2.8 ppm). Sharma *et al.* (2001) reported that majority of soils of Himachal Pradesh were deficient in P, S, Ca and Mg.

Singh (2001) revealed that 12, 5, 49 and 3 per cent soils of India were deficient in available Fe, Mn, Zn and Cu, respectively. Out of 3,650,004 samples of Indian soils, per cent soil samples which fell in low, medium and high categories were 63, 26, and 11 in case of available N; 42, 38, 20 in case of available P; 13, 37 and 50 in case of available K and 40, 35 and 25 percent in case of available S, respectively (Motsara 2002).

Sharma *et al.* (2002) reported that soils of Fatehpur block in Himachal Pradesh were low to high in available N and P and low to medium in available K, *sufficient in exchangeable Ca and Mg and deficient to sufficient in available* micronutrient cations. Sharma and Kumar (2003) reported that soils of agricultural lands of mid-hills zone were medium to high in available N, low to medium in available P and low to high in available K.

Tondon (2004) reported that about 63, 44, 21 and 37 per cent of Indian soils were low in available N, P, K and S, respectively. CSK Himachal Pradesh Agricultural University, Palampur prepared a soil fertility map of Himachal Pradesh at a block level. Available N, P and K status were low to medium in majority of the blocks (Anonymous 2005).

Kumar and Verma (2005) studied the fertility status of rice growing soils of Palam valley of Himachal Pradesh and reported that the soils were low to medium in available N and P and low to high available K. Laxminarayana (2006) observed medium to high potassium content (149 to 268 kg ha^{-1}) in rice growing soils of Mizoram. Bhaskar *et al.* (2007) reported that many soils of Assam were high to medium in available N and K and low in available P, Zn and Mn.

According to Mondal *et al.* (2007), soils of Chattha area of Jammu were low in available N, P and K and sufficient in exchangeable Ca, Mg and S and micronutrient cations. Agricultural lands had better soil fertility status as compared to that in non-agricultural lands. Sarkar *et al.* (2007) found low level of available S (0.8 to 7.6 mg kg^{-1}) in benchmark soils of West Bengal.

Sharma *et al.* (2008) assessed the croplands of Amritsar district of Punjab for macronutrient status and rated the soils as low, high, medium and high in available N, P, K and S status, respectively. Shetty *et al.* (2008) reported that majority of Karnataka soils were medium in available nitrogen and potassium and high in available phosphorus.

Singh (2008) revealed that soils of seven states *viz.*, Bihar, Punjab, Haryana, Maharashtra, Madhya Pradesh, Tamil Nadu and Uttar Pradesh were deficient in available Fe, Mn, Zn and Cu to the extent of 18.6, 10.5, 35 and 3.6 per cent, respectively. As regards Indian soils, deficiency of available Fe, Mn, Zn and Cu was to the extent 12.6, 1.9. 48.8 and 3.1 per cent, respectively. In Himachal Pradesh; 5, 42 and 27 per cent of the samples studied were deficient in available Mn, Zn and Cu.

Rattan *et al.* (2008) found that the contents of Fe, Mn, Zn and Cu in Indian soils varied from 3.4 to 68.1, 4.0 to 102.0, 0.1 to 2.8 and 0.2 to 5.0 mg kg^{-1}, respectively. Thus, Mn and Cu were sufficient in all soils; however, Fe and Zn were deficient in few soils.

Vara Prasad Rao *et al.* (2008) characterized the grassland soils of Andhra Pradesh as low in available N, S, Zn and Fe, low to medium in available P and medium to high in available K and sufficient in available Cu and Mn. Dhale and Prasad (2009) found higher status of exchangeable Ca and Mg in orange growing soils of Maharashtra.

Shekhar (2009) observed that exchangeable magnesium content in surface soils of forest, grassland and cultivated lands of high rainfall areas in Kangra, Chamba and Mandi districts of Himachal Pradesh fell in low category. Singh (2009) reported a deficiency of about 41, 12, 5 and 4 per cent of available S, Fe, Mn, Zn and Cu, respectively in soils of India and predicted that Zn deficiency is further expected to increase from 48 to 63 per cent by the year 2025 as most of the marginal soils are brought under cultivation.

Sood et al. (2009) found that 39, 7, 8 and 34 per cent *cropland soils of* Muktsar district of Punjab were deficient in available Zn, Cu, Mn and Fe, respectively. Tiwary (2009) reported that available P status varied from low (4.1 kg ha^{-1}) to medium (56.4 kg ha^{-1}) in major soils of India. Kumar and Prasad (2010) characterized the sugarcane growing soils of Maharashtra and found the soils as medium in available N, low in available P, medium to high in potassium and deficient in available Mn, Cu, Zn and Fe contents.

Sahoo *et al.* (2010) characterized the fertility status of agricultural lands of Manipur and rated the soils as medium to high in available N (503 to 1078 kg ha^{-1}), *low in available* P *(0.4 to 3* kg ha^{-1}) *and low to high in available* K *(79 to 441* kg ha^{-1}). Available micronutrients *viz.*, Fe, Mn, Zn and Cu were sufficient and ranged from 57.5 to 244.5, 36.0 to 85.5, 0.58 to 1.52 and 0.74 to 3.06 ppm, respectively. Shilpashree *et al.* (2011) revealed that soils of arecanut gardens in Karnataka were medium in available N, P and K and sufficient in Ca, Mg, Fe, Mn, Zn and Cu.

The review of literature reveals that soils differ considerably in nutrient availability. Soil fertility characterization is mainly focused on cultivated lands and at macro-levels. Grasslands and pastures are usually placed under neglected side. There is limited information on available nutrient status at a micro-watershed/ *panchayat level*.

2.2 Soil characteristics/ properties affecting soil fertility

Soil fertility has been considered, in the past, as a physico-chemical phenomenon taking place in the soil system. Soil characteristics and properties are the outcome of the interplay of pedogenic processes prevailing in an area and are very much needed in the interpretation of soils for evaluating their fertility. The interrelationship of soil nutrients with these properties decides the supplying power of respective nutrients by the soil. The hilly and mountainous regions are endowed with a wide range of factors that exert an influence on spatial variability of soils. A review on interrelationships between soil properties and soil fertility is necessary for better prediction of nutrient supplying power of soils.

2.2.1 Soil depth/ horizonation

Plants derive their nutrition from surface and subsurface soils in different amounts and proportions. Deep rooted plants draw more nutrients from sub-soils as compared to surface soils during their growth. Soil nutrients follow a definite trend of distribution with depth in a given landscape. Horizons are formed due to a particular set of pedogenic processes. Basic soil forming processes *viz*., gains, losses, translocation and transformation of soil materials within a soil which ultimately may affect total and available nutrient contents.

Zonn (1950) made comparisons between a natural oak-hornbeam brown soil and a similar former forest soil that had been under cultivation for over 100 years. There was, in general, more even distribution of nutrient elements in the cultivated profile. Higher degree of leaching of bases and a lower degree of leaching of P were also observed. Gupta *et al.* (1974) studied the properties of seven typical forest profiles of Kangra district of Himachal Pradesh and reported that the soil horizons were rich in total nitrogen status.

Singh and Raman (1982) studied some soil profiles of North Eastern Himalayas and reported a decreasing order of exchangeable Ca and Mg content with depth. It might be due to mild leaching of calcium and magnesium from upper to lower horizons. Singh *et al.* (1988) found decrease in available nitrogen with increase in profile depth. The higher amount organic carbon in the surface layers was responsible for higher nitrogen contents.

Jalali *et al.* (1989) studied the distribution of micronutrients in benchmark soils of Kashmir at different altitudes and reported that available Fe, Mn, Zn, Cu contents of soils decreased with increase in profile depth. Tapesh Lahiri and Chakravarti (1989) evaluated the soils of Sikkim at various altitudes and reported that high altitudes soils were high in available Fe than low altitude soils due to low soil pH and high organic matter content.

Singh *et al.* (1990) found higher available Fe content surface soils. That might be due to the regular addition of Fe through plant residues on the surface followed by suitable moisture regimes that accelerates the reduction process causing more availability of Fe. Sharma and Mahajan (1990) found that available macro-nutrients and micro-nutrient cations except for available Ca and Mg showed a decreasing trend with depth in orchard soils in Indora-Nurpur areas of Himachal Pradesh.

Sangwan and Singh (1993) reported an irregular trend of distribution of Fe, Mn, Zn and Cu with increasing depth. Chahal and Saini (1995) assessed the distribution of available Fe in arid zones of Punjab and indicated its decreasing pattern with increasing depth. The variation with depth was due to lower amount of organic matter in lower depths. Pannu *et al.* (1995) observed that surface horizons of cultivated soils of Haryana had higher amounts of available Zn, Fe, Cu and Mn, which decreased with increasing soil depth.

Walia and Rao (1996) observed an increase in exchangeable Ca as well as Mg content with soil depth in red soils of Bundel Khand region of Uttar Pradesh. Tripathi *et al.* (2000) found an irregular trend of distribution of available S in grasslands. Nayak et al. (2002) reported a medium range of available N, P and K in less cultivated areas of Bhubaneswar, which showed a decreasing trend with increasing depth of the profiles.

Singh and Singh (2007) analyzed the available N and S status in cultivated profiles of Uttar Pradesh and reported that both nutrients showed a distinct declining trend with increasing depths in all the pedons. Sarade and Prasad (2008) observed lower available Zn and Cu than Fe and Mn in surface soils, which showed a decreasing trend down the profiles.

Rajeswar *et al.* (2009) studied the vertical distribution of available macro- and micro-nutrients in soil profiles of Andhra Pradesh and indicated that soils were low in available N, medium to high in available P and available K and sufficient in available Zn, Cu, Mn and Fe in the surface soils, all showed a decreasing trend with increasing depth, except for an irregular distribution of available Cu and Mn, which might be due to their presence in reduced forms.

Trivedi *et al.* (2010) observed that available P showed a decreasing trend with increasing depth in cultivated alluvial soils of Madhya Pradesh, which might be attributed to a decrease in organic matter content down the profiles. The highest P level in surface soils might be due to continuous addition of manure and fertilizers in this layer.

2.2.2 Total nutrient content

Available nutrient content may depend upon the total mineral reserves in the soil.

Kanwar (1976) reported that mean total P in soils of Uttar Pradesh and Punjab were 0.08 and 0.20 per cent, respectively, and it deccreased with soil depth in profiles of mature and increased with soil depth in immature soils of Indo-Gangetic plains.

Kaistha *et al.* (1990) observed that total N content in the forest soils of North-Western Himalayan Region varied from 3200 ppm in surface horizons to 250 ppm in sub-surface horizons and found that available N had a positive relationship with total N in some profile soils of northern Himalayas.

Sood *et al.* (1991) reported that total P content varied from 260 to 770 ppm in the soils of Himachal Pradesh. Tripathi and Singh (1992) reported that total S varied from 160 to 325 ppm in the soils of Himachal Pradesh. Kher and Singh (1993) reported that total S of the soils were in the range of 139 to 226 ppm with an average of 183 ppm in different parts of North Kashmir.

Patgiri and Datta (1993) found total P ranged from 810 to 1162 ppm in tea growing soils of Assam. Bhogal *et al.* (1996) reported a positive correlation between available S and total S in the soils of Bihar and Karanataka, respectively. Ghosh and Mukhopadhyay (1996) reported a positive and significant correlation of available K with total K in Jagannathpur and Barakunda soil series of West Bengal.

Rahman (1996) found a non-significant correlation between available and total N contents in the soils under paddy cultivation in Netherlands. Khan *et al.* (1997) showed significant and positive correlation of available micronutrients *viz.,* Fe, Mn, Zn and Cu with total micronutrients *viz.,* Fe, Mn, Zn and Cu in the some benchmark soils of Bangladesh.

Minhas *et al.* (1997) found that total nitrogen decreased systematically with increasing depth in forests of Northern Himalayas. Sharma *et al.* (1999) reported that total Fe, Mn, Zn and Cu content in the soils of Shivalik hills of the semi arid tract of Punjab varied from 1.31 to 3.60 per cent, 310 to 880 mg kg^{-1}, 32 to 118 mg kg^{-1} and 11 to 29 mg kg^{-1}, respectively.

Jalali *et al.* (2000) observed that the total Fe, Mn, Zn and Cu contents varied from 1.02 to 4.10 per cent, 500 to 900 mg kg^{-1}, 170 to 270 mg kg^{-1} and 10 to 29 mg kg^{-1}, respectively, in the Ladakh soils. Contents of total Fe decreased with depth, whereas others did not showed any specific trend with increasing depth.

Prabhuraj *et al.* (2001) studied mulberry growing soils of Karnataka and reported a positive and significant correlation between available Cu and total Cu and indicated the genetic richness of these soils in Cu. For other micronutrients *viz.,* Fe, Mn and Zn, a non- significant correlation was observed.

Samanta *et al.* (2002) reported that total Fe and Cu contents in cultivated soils of West Bengal varied from 0.65 to 8.78 per cent and 8.0 to 136.8 mg kg^{-1}, respectively. Deb *et al.* (2009) found that total content of micronutrients is a poor predictor of their supplying power to the plants and total Fe, Mn, Zn and Cu in Indian soils varied from 4000 to 273000, 37 to 11,500, 7 to 1000 and 1.8 to 960 ppm, respectively.

Mohanty *et al.* (2009) reported that total N content in Indian soils varied from 0.02 to 0.44 per cent and decreased with increasing soil depth. Pasricha and Sarkar (2009) found that total S in forest soils of hilly regions varied from 300 to 580 ppm. Tiwari (2009) reported that total P in the soils of India and Himachal Pradesh ranged from 120 to 2166 ppm and 732 to 2166 ppm, respectively.

Sharma and Kanwar (2010) reported that total Cu contents varied from 4 to 92 mg kg^{-1} with an average value of 43 mg kg^{-1} in the soils of high hills dry temperate zone of Himachal Pradesh.

2.2.3 Soil pH

Soil pH is considered as the driver of soil fertility because of its direct impact on nutrient availability and plant growth. A pH range of 6 to 7 seems to promote the most ready availability of nutrients.

Katyal and Agarwala (1982) depicted an inverse relationship of soil pH with available micronutrient cations *viz.*, Fe, Mn, Zn and Cu. Mishra *et al.* (1990) observed a positive relationship of soil pH with available P, Cu and Mn in foot hill soils of Himalayas. Rajkumar *et al.* (1990) reported that available Fe, Mn and Zn in hills and hill ridges of Bundelkhand were negatively correlated with soil pH.

According to Tiwary and Mishra (1990), available Zn and Mn were negatively correlated with pH, however, available Cu as well as Fe were positively correlated with pH. Shukla and Lyngdoh (1990) did not found any relationship of soil pH with available Zn in cultivated soils of Meghalaya.

Walia and Chamuah (1990) reported that soil pH values of soils ranged from 4.3 to 9.9 in different regions of the country. Kaistha and Gupta (1993) reported that soil pH varied from 6.7 to 7.7 in the Central Himalayas of Himachal Pradesh whereas, Singh *et al.* (1991) reported that it ranged from 6.5 to 8.4 in the mid altitude of outer Himalayas and Walia and Rao (1996) reported that it ranged from 5.1 to 9.8 in the soils of North-Western Himalayas.

Minhas *et al.* (1997) observed that soil pH under forest cover ranged from 5.0 to 5.8 in the wet temperate zone of Himachal Pradesh, whereas, it varied from 5.3 to 6.5 in the cultivated soils of Kangra and Mandi districts. The soils were less acidic at relatively lower altitude because of their lower organic carbon content.

Gangopadhyay *et al.* (1998) found that paddy growing soils of Assam were moderately acidic at the surface (pH 4.7 to 5.7) and slightly acidic to nearly neutral in the sub-surface (pH 5.0 to 6.8). Brady and Weil (2002) indicated that the solubility, availability and plant uptake of micronutrient cations (Cu, Fe, Mn and Zn) are more under acidic conditions (pH of 5.0 to 6.5). Patil and Prasad (2004) reported that the pH of the soils ranged from 5.6 to 6.8 in Sal supporting soils of Madhya Pradesh.

Chaudhary *et al.* (2005) categorized soils of Himachal Pradesh as slightly acidic (pH 6.0) to mildly alkaline (pH 8.3). Soil pH increased with depth, which might be due to the decrease in organic carbon content.

Meena *et al.* (2006) observed a positive correlation of soil pH with available N, P, Zn, Fe, Mn and Cu in soils of Rajasthan, but with available K, it showed no correlation. Sharma *et al.* (2006) revealed that all the micronutrients showed no effect with pH, except for Zn, which increased with increasing pH.

Sharma *et al.* (2006) reported that soils of Ladakh had a positive correlation between available phosphorus and potassium with pH, whereas available micronutrients had non-significant positive correlation with pH. Dhale and Prasad (2009) found soil pH ranging from 8.2 to 8.9 in different soils of Maharashtra.

Sharma and Kanwar (2010) reported that in the soils of dry temperate zone of Himachal Pradesh, soil pH ranged from 6.2 to 10.3 with a mean value of 7.6. Bacchewar and Gajbhiye (2011) found that exchangeable Ca showed non-significant correlation with soil pH. However, exchangeable Mg showed positive *significant correlation with soil pH. Sharma and Kanwar (2011) studied the Mn* status in pea growing soils of Himachal Pradesh and found a negative and significant correlation with soil pH.

2.2.4 Electrical Conductivity (EC)

EC is a measure of soluble salt concentration in the soil solution. When a soil solution containing a relatively large amount of dissolved salts is brought into contact with a plant cell, it will cause shrinkage of the protoplasmic lining. This action, called plasmolysis, increases with the concentration of the salt solution. Higher concentration of dissolved salts in any soil affects plant growth adversely.

Arora and Takkar (1988) reported that available S showed a positive and significant relationship with EC in different soils. Singh and Choudhary (1990) observed a negative and non-significant relationship between available Cu and EC.

Ramana Murthy and Srivastava (1994) observed a positive and significant correlation of EC with available P, K and Fe in the soils of Lower Shivaliks.

Available Cu had a positive and non-significant relation, while available Mn showed a negative and non-significant relation with it.

Chattopadhyay *et al.* (1996) revealed that micronutrients were significantly and negatively correlated with EC in the cultivated soils of hills and hill ridges of Rajasthan. Yadav *et al.* (1999) found that soil EC varied from 0.34 to 0.59 dS m^{-1} in surface soils and from 0.16 to 0.57 dS m^{-1} in subsurface soils of Madhya Pradesh. In some profiles, it showed an increasing trend as well as an irregular trend with increasing depth.

Singh *et al.* (2005) found that EC varied from 0.16 to 0.35 dS m^{-1} in surface and from 0.09 to 0.22 dS m^{-1} in subsurface soils of Uttaranchal and decreased with increasing depth. Sitanggang *et al.* (2006) reported that EC varied from 1.05 to 1.30 in the soils of Haryana and showed an increasing trend with soil depth.

Verma *et al.* (2007) revealed that EC showed a negative correlation with available Mn, but a positive relation with available Zn, Cu and Fe in the soils of Punjab. Athokpam *et al.* (2010) observed that EC had a positive relation with available K in Manipur soils.

Trivedi *et al.* (2010) found a negative and highly significant relation of EC with available P in the soils of Madhya Pradesh. Bhanwaria *et al.* (2011) reported a negative and non-significant correlation between available micronutrients and EC in the soils of Rajasthan.

2.2.5 Soil Organic Carbon

Soil organic carbon content is recognized as a key indicator of soil fertility and also of sustainability of agricultural systems. It has long been recognized as a source of plant nutrients, principally N, and substantially P, S and micronutrients, besides being promoter of a range of soil physical characteristics. According to Hodgson (1963), the presence of organic carbon may promote the availability of certain elements by supplying soluble complexing agents that interfere with their fixation.

Sauchelli (1969) reported a negative correlation between organic carbon and Cu as organic matter fixes Cu. Since Fe is held in the chelate as a soluble complex, there was a positive relation between organic carbon and Fe.

Ruhal and Paliwal (1980) found that available S had a significant correlation with organic carbon in the soils of Rajasthan.

Sharma *et al.* (1981) suggested soil organic carbon as a common index of availability of both phosphorus and potassium in acid brown soils of Shimla. Singh and Datta (1988) indicated an increase in organic carbon content with an increase in elevation. It was high in surface horizons which sharply decreased in sub-surface horizons of some benchmark soils of India.

Kaistha *et al.* (1990) reported that organic carbon content varied from 0.30 to 8.33 per cent in the soils of different regions of Himachal Pradesh. Moderately high amount of organic carbon was recorded in mid-altitude soils of Outer Himalayas. They also observed significantly positive relationship of available N and organic carbon in some forest soil profiles of Himalayan region.

Mandal *et al.* (1990) while studying the hill forest soils of Eastern Himalayas reported a positive correlation between organic carbon and exchangeable bases. Available N and K were highly correlated with organic carbon but available P showed negative relation.

Kanthalia and Bhatt (1991) reported a close relation between soil organic carbon and available nitrogen due to the association of nitrogen with organic matter and the adsorption of ammonical N by humus complex in the soil. Relationship with available phosphorus was not significant possibly due to the fact that available phosphorus included mostly inorganic P and oragnic P is low. A positive non-significant relation with available potassium might be attributed to the release of potassium from organic complexes.

Mongia and Bandopadhyay (1992) studied the soils of tropical forests and reported that organic carbon had a positive relation with available N, P and K. Kaistha and Gupta (1994) reported that organic carbon content decreased with increasing soil depth. The increase in organic matter content with increase in altitude was due to continuous addition of leaf litter and slow decomposition of organic residues under low temperature.

Ramesh *et al.* (1994) studied the soils of Guntur district of Andhra Pradesh and indicated that organic carbon content had a high degree of positive correlation with available nitrogen and negative correlation with all micronutrients. Sud *et al.* (1995) analyzed phosphorus status in soils of Himachal Pradesh and found that among all soil properties, organic carbon had a close relationship with available P, thereby indicating that the major part of P was associated with organic matter content of the soil.

Minhas *et al.* (1997) reported lower amounts of organic carbon in cultivated soils of Kangra district of Himachal Pradesh. Gangopadhyay *et al.* (1998) observed high organic carbon content in the paddy soils of Assam at the surface which decreased gradually with increasing soil depth.

Bharambe *et al.* (1999) reported that organic carbon content in Maharashtra soils ranged from 0.23 to 0.81 per cent in the surface layers and exhibited a decreasing trend with soil depth. Sarkar and Sahoo (2000) found that organic carbon content in the soils of Indo-Gangetic Plains of Bihar varied from 0.08 to 0.86 per cent. It decreased gradually with depth.

Sharma and Jaggi (2001) showed that available S was significantly and positively correlated with organic carbon. Kumar *et al.* (2006) studied the soils of Himachal Pradesh and found a positive correlation between soil organic carbon and available N, P and K in forest, grassland and wasteland soils.

Sharma *et al.* (2006) revealed that micronutrients showed a positive correlation with organic carbon. The contents of Cu, Fe and Mn increased from 0.81 to 2.52, 18.96 to 22.25 and 5.97 to 6.93, respectively, with an increase in soil organic carbon from 0.4 to 0.75 per cent. Singh *et al.* (2006) reported a significant positive correlation between DTPA-extractable Fe and soil organic matter content under different land uses

Saha *et al.* (2008) reported that organic carbon content of the soils varied significantly among the various land uses. Sharma and Kanwar (2010) stated that the soils of dry temperate zone of Himachal Pradesh contained 0.42 to 4.08 per cent organic carbon. Kumar *et al.* (2011) indicated a significant positive correlation of micronutrients *viz.*, Fe, Mn, Zn and Cu with organic carbon due to formation of chelate complexes in arid soils of Rajasthan.

2.2.6 Soil Texture

The relative proportion of the various soil separates in a soil *i.e.* soil texture has a great bearing on its fertility. A soil with good physical condition has satisfactory water holding capacity. If there is no proper circulation of air and water in the soil, it is not suitable for plant growth. Soils with large particles have larger inter-pores. In such soils water moves down very fast to the lower layers of soils. Whereas soils with smaller particles such as silt or clay have better nutrient retaining capacity and thus are highly fertile.

Katyal and Vlek (1985) found a positive and significant effect of clay content on the availability of available Cu and this was attributed to the presence of soil organic matter, which released soil bounded Cu. Bharambe *et al.* (1990) reported that available Fe was positively and significantly correlated with silt content.

Sahu *et al.* (1990) observed that the clay content had a significant negative correlation with available Fe and significant positive correlation with available Cu and Mn, whereas silt showed positive correlation with Cu only. Clay along with silt had significant positive correlation with available Cu.

Shukla and Lyngdoh (1990) reported a positive correlation with Zn and clay content in the hill soils of Meghalaya. Basumatary and Bordoloi (1992) found a positive relationship with clay and silt but a negative correlation with sand.

Ramana Murthy and Srivastava (1994) observed that in the soils of Lower Shivaliks, available P and K showed a positive and non-significant relation with sand and clay, and a significant and negative correlation with silt. Available micronutrients showed a significant and negative, positive and positive relation with sand, silt and clay, respectively. However, available Fe had a non-significant relation with sand, silt and clay.

Chahal and Saini (1995) observed a positive correlation of available Fe with clay and silt contents and a negative correlation with sand in arid zones of Punjab. Tisdale *et al.* (1995) stated that micronutrients had positive relation with the fine mineral fractions like clay and silt in many soils, while negative relations with coarser sand particles.

Sharma and Jaggi (2001) observed a positive correlation of available S with silt and clay contents which revealed that S supplying power of soils depended largely upon soil texture. Nazif *et al.* (2006) reported a negative, positive and positive relation for all the nutrients with sand, silt and clay content, respectively in the hill ecosystem of Jammu and Kashmir except for Mn, which showed a negative relation with clay content.

Hundal *et al.* (2006) revealed that the contents of available P in cultivated soils of Punjab was significantly and positively correlated with sand, but significantly and negatively correlated with silt content. Available Mg was found to be significantly and negatively correlated with clay content.

Singh *et al.* (2009) reported a positive and significant relation of clay content with available N, K and S and a negative and non-significant correlation with available P in Punjab soils. Singh *et al.* (2009) reported that silt and clay were positively correlated but sand showed a negative correlation with available S in all the soils.

Athokpam *et al.* (2010) analyzed the soils of Manipur for correlation studies between soil texture and soil potassium and observed a highly positive correlation of available K with clay but with silt and sand fractions, it showed a negative correlation. Prasad (2010) reported that exchangeable K had a positive correlation with clay and a negative with sand content in soils under different land uses.

Trivedi *et al.* (2010) reported that sand, silt and clay possessed a negative, positive and negative relation, respectively, with available P in alluvial soils of Madhya Pradesh.

2.2.7 Cation Exchange Capacity (CEC)

CEC is sum total of exchangeable cations that a soil can absorb. It gives an indication of the type of clay minerals present in the soil, its capacity to retain nutrients against leaching and assessing their fertility. A high CEC means more nutrient availability and that fewer cations will be lost through leaching out of the root zone.

Nair and Chamuah (1988) reported a decrease in CEC with depth in pine forests of Meghalaya. Gangopadhyay *et al.* (1990) reported an increase in CEC values with increase in altitude. Kaistha *et al.* (1990) found that the CEC values did not follow any definite distribution trend with depth in many soils of India. Mandal *et al.* (1990) reported that the CEC values ranged from 2.9 to 43.9 cmol (p^+) kg^{-1} in different regions of the country.

Hasan (1991) studied the soils of Bangladesh and found that CEC is significantly and positively correlated with available N, K, Mg, Fe, Mn and Zn. Singh *et al.* (1991) found that the CEC values ranged from 9.1 to 25.6 cmol (p^+) kg^{-1} in the mid-altitude soils of Outer Himalayas. Ramana Murthy and Srivastava (1994) studied the soils of Lower Shivaliks and reported a positive and non-significant relation of CEC with available P, K and Zn. A negative and non-significant relation with available Cu and Fe and a negative and significant correlation with available Mn were observed.

Elahi *et al.* (1996) found an increase in CEC values from surface to sub-surface horizons. Khan *et al.* (1997) observed a positive relationship between micronutrient cations and CEC in the soils of Bangladesh. Minhas *et al.* (1997) observed that while studying soils of zone of Himachal Pradesh under forest vegetation, CEC was higher in soils under blue pine-silver fir due to higher organic matter and clay contents.

Mahapatra *et al.* (2000) revealed that the CEC of soils in sub-humid ecosystem of Kashmir region ranged from 6 to 22 cmol (p^+) kg^{-1}. Kumar *et al.* (2002) found a positive correlation between available S and CEC in acidic soils of Jharkhand. Sarkar and Sahoo (2000) found CEC varying from 8.1 to 35 cmol (p^+) kg^{-1} in the Indo-Gangetic Plains of Bihar.

Chaudhary *et al.* (2005) ascribed low values of CEC varying from 9.0 to 11.5 cmol (p^+) kg^{-1} to the predominance of low CEC minerals especially illite in Solan district of Himachal Pradesh. Kour and Jalali (2008) reported that CEC was positively correlated with both total and available S in soils of Jammu and Kashmir.

Sharma *et al.* (2008) reported a positive and significant correlation of CEC with available N, K and S in soils of Punjab but with available P, there was a positive and non-significant correlation. Najar *et al.* (2009) found that the CEC of the North facing soils were higher {17.20 to 22.6 cmol (p^+) kg^{-1}} than that of South facing soils {9.80 to 21.0 cmol (p^+) kg^{-1}} in the apple growing soils of Kashmir valley.

Talukdar *et al.* (2009) observed that irrespective of land uses, available Fe was positively and significantly correlated with CEC in the soils of Assam. Sharma and Kanwar (2010) reported that CEC of the soils of pea growing areas of dry temperate zone of Himachal Pradesh varied from 3.5 to 62.0 cmol (p^+) kg^{-1} with an average value of 18.4 cmol (p^+) kg^{-1}. Bhanwaria *et al.* (2011) obtained a positive and highly significant relation of CEC with all available micronutrient cations in Mokala soil series of Rajasthan.

2.2.8 Base saturation

The extent to which the adsorption complex of a soil is saturated with exchangeable cations other than hydrogen and aluminum is known as base saturation. It represents the relative availability of many positively charged nutrients (cations) such as Ca, Mg and K.

Kaistha *et al.* (1990) established a negative correlation between available N and base saturation on the basis of studies conducted in some forest profiles of North-western Himalayan region. Mandal *et al.* (1990) studied forest soil of eastern Himalayas and found that base saturation showed an irregular trend with increase in soil depth.

Sarkar *et al.* (1997) characterized the soils of West Bengal under varied altitude and found that base saturation was low in surface soils and it increased with increasing depth. Sen *et al.* (1997) studied the soils of Assam and established an increasing trend of base saturation in all soil profiles.

Swarnam *et al.* (2004) characterized the soils of Haryana and Delhi and found that the exchange complex was dominated by Ca followed Mg and K and contributed to a high base saturation value of the soils which ranged from 75.9 to 94.3 per cent.

Mondal *et al.* (2006) studied Tarai soils of West Bengal under different land uses and found that base saturation was higher in cultivated as compared to forest soils, followed by orchard and tea garden and varied from 48.4, 28.4, 12.6 and 9 per cent, respectively.

Sitanggang *et al.* (2006) found base saturation in Himachal Pradesh that ranging from 3.40 to 70.1 per cent. Sharma *et al.* (2007) studied the correlation between base saturation and available Mn in the soils of Himachal Pradesh and concluded that per cent base saturation is a crucial factor in deciding the availability of Mn. Borkotoki and Das (2008) found a positive and significant correlation of available S with base saturation in soils of Assam.

It may be inferred from the available literature that effect of soil properties on soil fertility is dependent upon the environmental conditions and therefore, vary from place to place.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present chapter has been covered under the following sections:

3.1 General description of the study area

3.2 Soil sampling and analysis

3.3 Determination of available nutrient status

3.4 Statistical analysis

3.1 Description of the study area

3.1.1 Location and extent

Panchrukhi block is situated between 76°31'17"E to 76°40'35"E longitude and 32°07'15"N to 31°55'54"N latitude in foot hills of Lesser Himalayas of Himachal Pradesh. It is covered by two Survey of India topographical sheets *viz.*, 52 D/12 and 53 A/9 and has an altitude ranging from 660 to 1438 m above mean sea level. It comprises of 37 panchayats with an areal extent of 6,159 ha. National Highway from Pathankot to Mandi (NH-20) and narrow-gauge railway line from Pathankot to Jogindernagar pass through the block (Fig. 3.1). Abbreviations used in figure 3.1 have been presented in table 3.1.

3.1.2 Geology

The soils of Panchrukhi block are mainly derived from fluvio-glacial deposits and Shivalik formations. Fluvio-glacial deposits are mainly produced by the action of glaciers on Lesser Himalayas (Dhauladhar range). The important rocks of Lesser Himalayas are gneiss, granite, phyllite, shale, slate, sandstone, quartzite etc. (Wadia 1960). Shivalik formations are dominated by lower and upper Shivaliks. The upper Shivaliks comprise of conglomeratic beds and sandstone, while lower Shivaliks include shales and sandstones (Dey 1968). Geological formations of the Lesser Himalayas are older than those of Shivalik formations.

3.1.3 Geomorphology

Broadly, Panchrukhi block was divided into two soil zones *viz.*, mid- hill soil zone (910 to 1517 m above mean sea level) and low-hill soil zone (< 910 m above

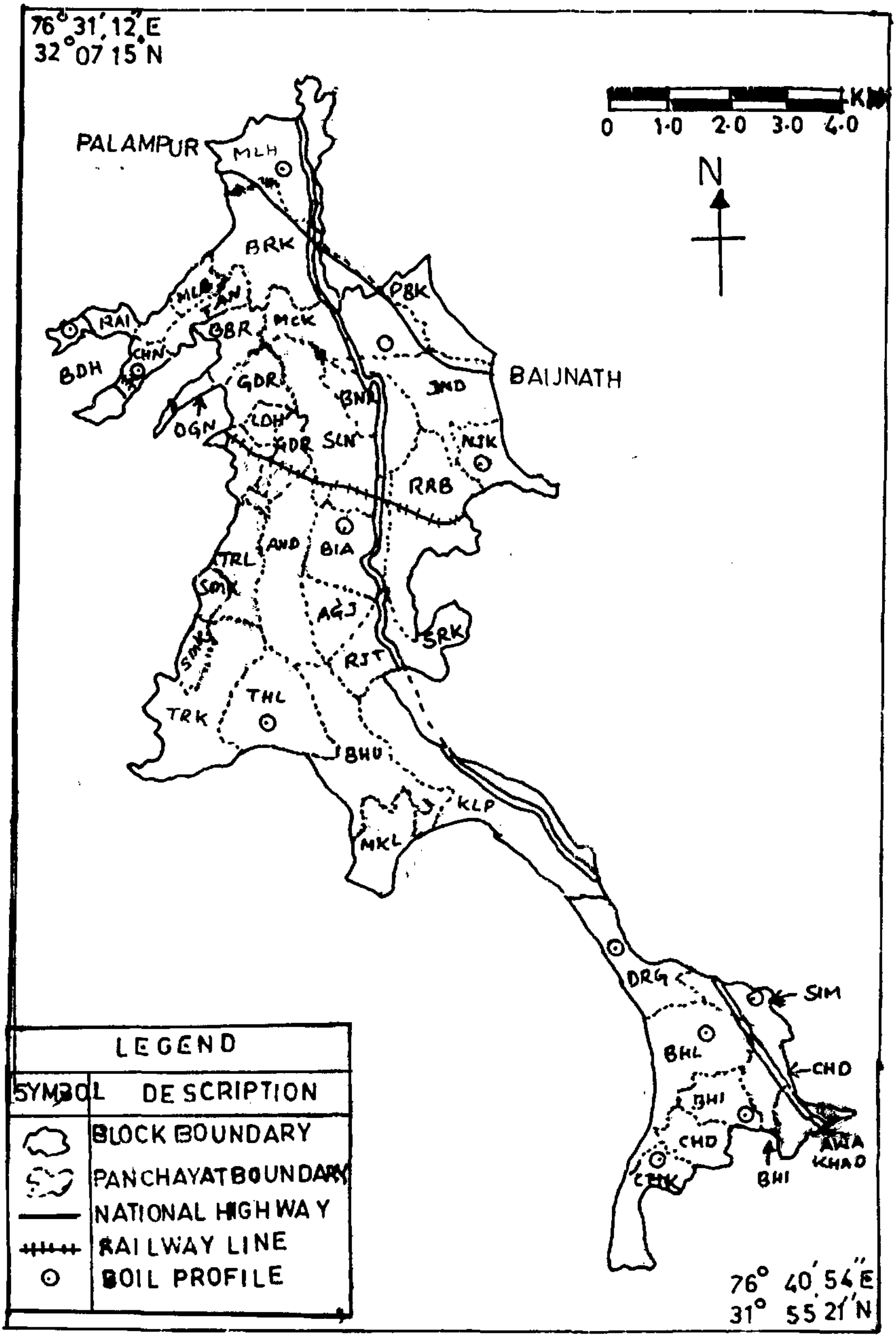


Fig. 3.1 Panchayat map of Panchrukhi block

mean sea level) by Tiwari and Awasthi (1978). Mid-hill soil zone comprises of very gently to steeply sloping fluvio-glacial terraces, whereas low-hill soil zone is dominated with moderately sloping to extremely steep side slopes (Plates 3.1 and 3.2). Mid- and low-hill soil zone occupies 65 and 35 per cent of the total area of the block, respectively.

3.1.4 Drainage

The study area is mainly characterized by dendritic drainage system (Fig. 3.2). The study area ultimately drains to Beas river through five main streams *viz.*, Maul, Mandh, Awa, Haroti and Gununu *khads*. Majority of the streams of mid-hill and low-hill soil zone are perennial and ephemeral, respectively. These streams are very active during rainy season as shown in figure 3.2.

3.1.5 Climate

Panchrukhi block is represented by wet temperate climate with an annual rainfall ranging from 1937 mm to 2612 mm. The mean maximum and minimum temperature ranges were from 23.16°C to 26.85°C and 12.98°C to 13.60°C, respectively. A bulk of precipitation is received during the monsoon period. Generally, the period from 31st April to 21st June and 18th October to 10th December remains dry (Fig. 3.3). The soil moisture and temperature regimes of the study area are udic and thermic, respectively (Sidhu *et al.* 1997).

3.1.6 Natural Vegetation

The important vegetation types found in the study area are:

i. Tree species

Albizia chinensis (Ohi), *Bambusa arundinacea* (Magar), *Bambusa nutans* (Nal), *Bauhinia vahlii* (Taur), *Bauhinia variegata* (Kachnar), *Bombax ceiba* (Simbal), *Celtis australis* (Khirak), *Ficus religiosa* (Pipal), *Ficus roxburgii* (Trembal), *Grewia optiva* (Biul), *Mangifera indica* (Amb), *Morus alba* (Tut), *Pinus roxburgii* (Chir), *Prunus padus* (Pajah), *Pyrus pashia* (Kainth), *Rhododendron arboreum* (Bras), *Syzgium cumini* (Jamun), *Terminalia belerica* (Bahera), *Toona ciliata* (Tuni).

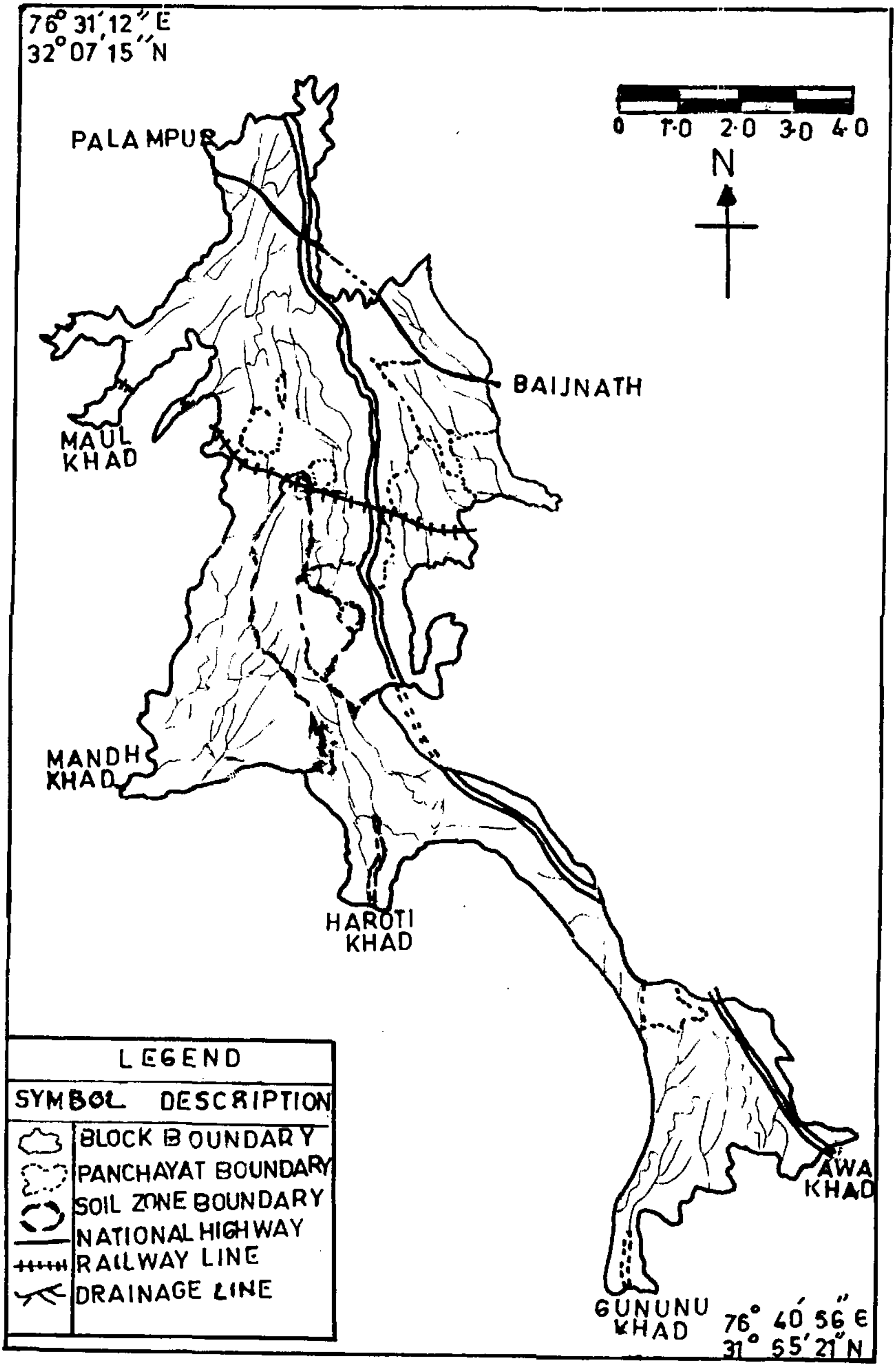


Fig. 3.2 Drainage map of study area

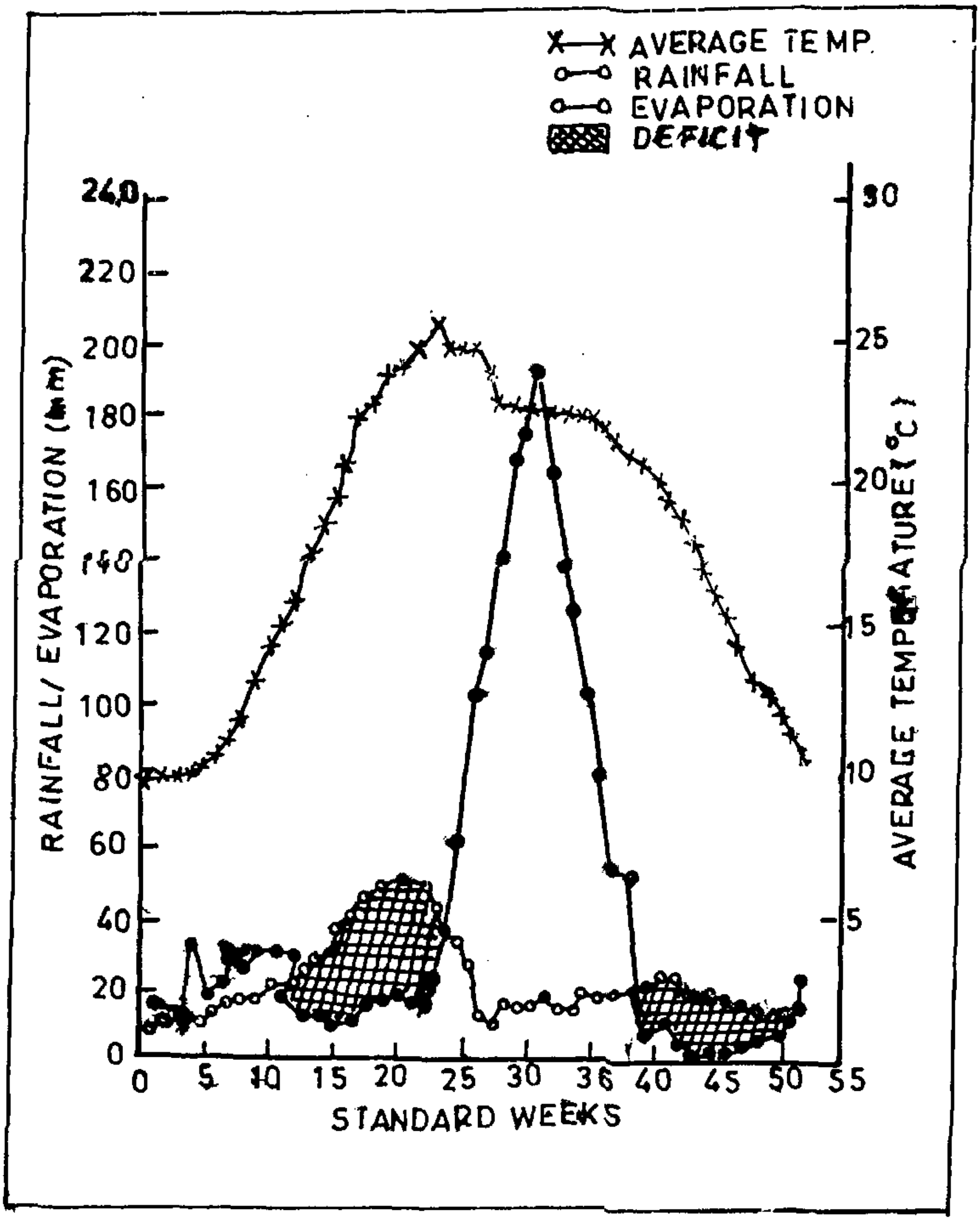


Fig. 3.3 Weekly rainfall, evaporation and temperature distribution in the study area

ii. **Shrubs and grasses**

Ageratum conizoides (Neela phulna), *Berberis asiatica* (Kasmal), *Cannabis sativa* (Bhang), *Carissa spinarum* (Garna), *Cynodon dactylon* (Dhoob), *Eupatorium adenophorum* (Basuti), *Euphorbia thymifolia* (Dhudhli), *Imperata cylindrica* (Chiz), *Lantana camara* (Phulnu), *Murraya exotica* (Gandla), *Panicum maximum* (Guinea grass), *Parthenium hysterophorus* (Congress grass), *Paspalum notatum* (Kodri), *Rubus paniculatus* (Akha), *Saccharum munja* (Baggad), *Vitex negundo* (Banah), *Zanthoxylum alatum* (Tirmar), *Zizyphus jujuba* (Ber).

3.1.7 Land use

As per land use/ cover classification by CSKHPKV (Anonymous 2010), per cent of total area of Panchrukhi block under crop land, tea garden, forest and grass/ scrub land was 27, 3, 54 and 16, respectively. Distribution of land uses in various panchayats of Panchrukhi block has been presented in table 3.1.

3.2 Soil sampling and analysis

To fulfill the first objective of the present investigation i.e. to determine the available nutrient status of surface soils, three hundred forty six surface (0-15 cm) soil samples representing different land uses (crop land, tea garden, forest and grass/ scrub land) were collected at a rate varying from 2 to 4 per land use and 8 to 10 per panchayat after crop harvests during *kharif* 2010 (Table 3.2). About 10 to 15 cores per acre in a zig-zag pattern were used to draw one composite sample from the sampling site. The soil samples were processed and analyzed for pH, electrical conductivity (EC), organic carbon (OC) and texture (feel method) and available macro- and micro-nutrients (N, P, K, Ca, Mg, S, Fe, Mn, Zn and Cu) using standard methods (Table 3.3).

To meet out the second objective i.e. to study horizon-wise distribution of available nutrients and soil properties affecting soil fertility (total nutrient content, pH, EC, OC, mechanical separates, CEC and base saturation), fourteen soil profiles representing major soils and land uses of the study area were exposed and horizon-wise soil samples were drawn. According to Sharma *et al.* (2002) and Sharma and Kumar (2003), majority of the soils of mid-hill soil zone belong to *Alfisols* and *Inceptisols* while those of low-hill soil zone to *Entisols* and *Inceptisols*.

Soils of forest and grass/ scrub lands in both zones belong mainly to *Entisols*. Eight and six profiles were dug out in mid- and low-hill soil zones of Panchrukhi block, respectively, to fulfil the objective of the present investigation.

3.3 Determination of available nutrient status

Soils were categorized as low, medium and high in available macro-nutrient status by using the limits as adopted by State Soil Testing Laboratories. A soil having available content ranging from 280 to 560 kg N ha^{-1}, 10 to 25 kg P ha^{-1},118 to 280 kg K ha^{-1}, 1.5 to 2.5 cmol (p+) Ca kg^{-1}, 1.0 to 2.0 cmol (p+) Mg kg^{-1} and 10 to 20 mg S kg^{-1} is rated as medium in respective nutrient status. Using 4.5 mg Fe kg^{-1}, 1.0 mg Mn kg^{-1}, 0.6 mg Zn kg^{-1} and 0.2 mg Cu kg^{-1} as critical limits, soils may be rated as deficient or sufficient in the respective nutrient.

Soil nutrient indices (SNI) were also worked out to depict the available status of each macro-nutrient at a panchayat/ block level by using the formula proposed by Parker *et al.* (1951) as given below:

$$SNI = \frac{(N_l * 1) + (N_m * 2) + (N_h * 3)}{N_t}$$

where, Nt = total number of samples analyzed for a nutrient in any given area

N_l = number of samples falling in low category of nutrient status

N_m = number of samples falling in medium category of nutrient status

N_h = number of samples falling in category of nutrient status

A SNI value less than 1.67, between 1.67 to 2.33 and more than 2.33 indicate low, medium and high fertility of soil, respectively.

3.4 Statistical analysis

Simple correlation coefficients between available nutrient contents and soil properties affecting soil fertility *viz.*, total nutrient contents, pH, EC, OC, mechanical separates, CEC and base saturation were worked out at soil zone/ block level by using the standard procedure (Gomez and Gomez 1984).

Table 3.1 Distribution of land uses in mid- and low-hill soil zones

Panchayat	Area (ha)			
	Crop land	Tea garden	Forest	Grass/ scrub land
Mid- hill soil zone				
1.Badehar (BDH)	10 (16)	5 (8)	16 (62)	9 (14)
2.Bandbihar (BBR)	49 (56)	-	26 (30)	13 (14)
3.Banuri Khas (BRK)	107 (38)	20 (7)	105 (37)	51 (18)
4.Bharwana (BHR)	95 (57)	4 (2)	37 (22)	31 (19)
5.Biara (BIA)	43 (21)	6 (3)	116 (57)	39 (19)
6.Chandropa (CHN)	15 (20)	7 (9)	41 (54)	14 (17)
7.Deogran (DGN)	14 (23)	4 (6)	33 (54)	11 (17)
8.Gadiara (GDR)	61 (37)	15 (9)	31 (19)	58 (35)
9.Jandpur (JND)	113 (51)	9 (4)	39 (18)	59 (27)
10.Ladoh (LDH)	52 (39)	8 (6)	37 (28)	25 (17)
11.Mahal Banuri(MLB)	15 (18)	12 (15)	45 (56)	9 (11)
12.Mahal Holta (MLH)	73 (26)	11 (4)	139 (49)	59 (21)
13.Moulichak (MCK)	56 (51)	7 (6)	25 (23)	21 (20)
14.Nouri Jhikli (NJK)	61 (61)	-	16 (16)	24 (23)
15.Padiharkhar (PDK)	74 (56)	-	16 (12)	42 (32)
16.Rajpur (RAJ)	34 (33)	14 (14)	35 (34)	20 (19)
17.Rajot (RJT)	17 (12)	-	118 (84)	6 (4)
18.Rakkar Bheri (RKB)	106 (39)	-	38 (14)	128 (47)
19.Sagoor Khas (SRK)	19 (29)	-	36 (53)	12 (18)
20.Saliana (SLN)	*104 (43)*	*5 (2)*	*56 (24)*	*71 (31)*
21.Simbal Khola (SMK)	29 (31)	-	37 (39)	28 (30)
22.Sungal (SNG)	86 (58)	9 (6)	28 (19)	25 (17)
23.Tanda (TAN)	36 (35)	18 (19)	36 (35)	12 (11)
24.Tikkar Khas (TRK)	79 (27)	-	177(60)	39 (13)
25.Tarhail (TRL)	59 (41)	-	16 (11)	68 (48)
26.Tatahail(THL)	48 (20)	-	169 (71)	22 (9)
Total	**1455 (36)**	**154 (4)**	**1493 (37)**	**907 (23)**
Low-hill soil zone				
1.Andretta (AND)	49 (19)	-	199 (78)	8 (3)
2.Agojar (AGJ)	6 (2)	-	259 (97)	3 (1)
3.Bhirdi (BHI)	18 (9)	-	171 (81)	7 (4)
4.Bhulana (BHL)	11(5)	-	193 (85)	23 (10)
5.Bhuana(BHU)	13 (5)	-	219 (81)	26 (10)
6.Chadiar (CHD)	13 (8)	-	134 (83)	14 (9)
7.Check (CHK)	16 (12)	-	112 (82)	9 (6)
8.Darug (DRG)	14 (6)	-	206 (88)	14 (6)
9.Kailaspur (KLP)	26 (15)	-	139 (83)	3 (2)
10.Makol (MKL)	9 (8)	-	104 (87)	6 (5)
11.Simbal (SIM)	6 (4)	-	121 (95)	1 (1)
Total	**181 (8)**	**-**	**1856 (86)**	**113 (5)**
Panchrukhi block	**1636 (27)**	**154 (3)**	**3349 (54)**	**1020 (16)**

Parenthesis indicate per cent of total area of Panchrukhi block
Note: "-" indicate non-existence

Table 3.2 Number of surface soil samples collected under different land uses

Panchayat	Number of soil samples taken			
	Crop land	Tea garden	Forest	Grass/ scrub land
Mid-hill soil zone				
1.Badehar	3	2	2	3
2.Bandbihar	4	-	3	2
3.Banuri Khas	3	2	3	2
4.Bharwana	4	2	2	2
5.Biara	2	2	3	3
6.Chandropa	4	2	2	2
7.Deogran	2	2	3	3
8.Gadiara	3	2	2	3
9.Jandpur	4	2	2	2
10.Ladoh	4	2	2	2
11.Mahal Banuri	3	2	2	3
12.Mahal Holta	2	2	3	3
13.Moulichak	3	2	2	3
14.Nouri Jhikli	4	-	3	3
15.Padiharkhar	4	-	3	3
16.Rajpur	4	2	2	2
17.Rajot	3	-	3	2
18.Rakkar Bheri	4	-	2	3
19.Sagoor Khas	3	-	3	2
20.Saliana	3	2	2	3
21.Simbal Khola	4	-	3	3
22.Sungal	4	2	2	2
23.Tanda	3	2	3	3
24.Tikkar Khas	3	-	3	2
25.Tarhail	4	-	3	3
26.Tatahail	3	-	3	3
Total	**87**	**32**	**66**	**67**
Low-hill soil zone				
1.Andretta	2	-	4	2
2.Agojar	2	-	4	2
3.Bhirdi	3	-	4	2
4.Bhulana	3	-	4	3
5.Bhuana	3	-	4	3
6.Chadiar	2	-	4	2
7.Check	3	-	4	2
8.Darug	2	-	4	2
9.Kailaspur	2	-	4	2
10.Makol	2	-	4	2
11.Simbal	2	-	4	2
Total	**26**	**-**	**44**	**24**
Panchrukhi block	**113**	**32**	**110**	**91**

Note: "-" indicate non-existence

Table 3.3 Methods used for chemical analysis of soil samples

Sr. no	Parameter	Method	Reference(s)
1.	Mechanical separates	Feel method, International Pipette	Piper 1966
2.	Organic carbon (OC)	Rapid titration	Walkley and Black 1934
3.	Soil pH (1:2.5)	Potentiometric	Jackson 1973
4.	Electrical conductivity (EC)	Conductimetric	Jackson 1973
5.	Cation exchange capacity (CEC)	Distillation (1N NH_4OAc extractable)	Jackson 1973
6.	Available macro-nutrients		
	N	Alkaline potassium permanganate method	Subhiah and Asija 1956
	P	Colorimetric (0.5N $NaHCO_3$ extractable)	Olsen *et al.* 1954
	K	Flame-photometric (1N NH_4OAc extractable)	Merwin and Peech 1950
	Ca and Mg	Atomic Absorption Spectrophotometric (1 N NH_4OAc extractable)	Sarma *et al.* 1987
	S	Turbidimetric (0.15% $CaCl_2$ extractable)	Jackson 1973
	Available micro-nutrient cations	AAS (DTPA extractable)	Lindsay and Norvell 1978
7.	Total N	Digestion mixture -cum-Distillation	Page *et al.* 1982
8.	Total P	Tri-acid digestion-cum-Colorimetric	Piper 1966
9.	Total S	Di-acid digestion-cum-Turbidimetric	Johnson and Nishita 1952
10.	Total K	Tri-acid digestion-cum-Flame-photometric	Piper 1966
11.	Total Ca and Mg	Tri-acid digestion-cum-AAS	Piper 1966
12.	Total micro-nutrients	Tri-acid digestion-cum- AAS	Jackson 1973

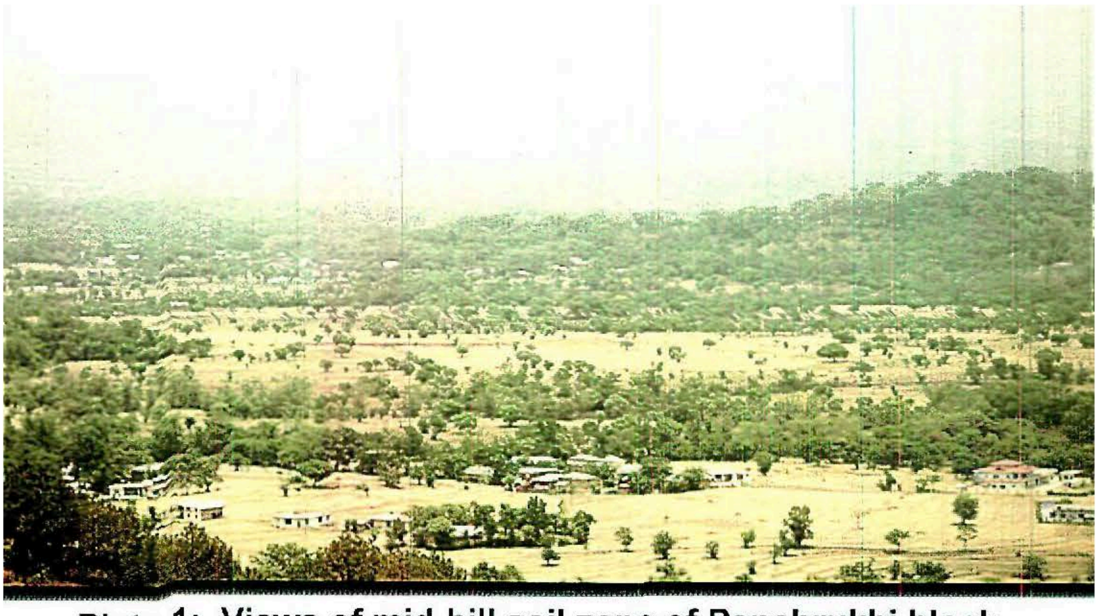


Plate 1: Views of mid-hill soil zone of Panchrukhi block

Plate 2: Views of low-hill soil zone of Panchrukhi block

RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

The results pertaining to the present investigation have been presented and discussed under the following heads and sub heads:

4.1 Soil pH, EC, OC and texture of surface soils

4.2 Available nutrient contents in surface soils

- 4.2.1 Primary nutrients
- 4.2.2 Secondary nutrients
- 4.2.3 Micro-nutrient cations

4.3 Available nutrient status in surface soils

- 4.3.1 Macro-nutrients
- 4.3.2 Micro-nutrient cations

4.4 Soil properties in representative soil profiles:

- 4.4.1 Available nutrient contents
- 4.4.2 Soil properties affecting soil fertility
- 4.4.3 Interrelationship between available nutrients and soil properties

4.1 Soil pH, EC, OC and texture of surface soils

Soil pH (1:2.5), EC (dS m^{-1}), OC (g kg^{-1}) and texture of surface soils in mid-hill soil zone ranged from 5.2 to 6.4, 0.21 to 0.32, 3.6 to 15.8 and loamy sand to silty clay loam, respectively (Tables 4.1 and 4.3). Mean soil pH, EC and OC values were highest in Nouri Jhikli (6.2), Gadiara (0.28 dS m^{-1}) and Banuri Khas (9.9 g kg^{-1}) panchayats and lowest in Mahal Holta (5.6), Simbal Khola (0.23 dS m^{-1}) and Simbal Khola (5.5 g kg^{-1}) panchayats, respectively. While comparing different land uses, mean values of soil pH, EC and OC were highest in grass/ scrubland, teagarden and teagarden and lowest in teagarden, grass/ scrubland and grass/ scrubland, respectively.

Soil pH (1:2.5), EC (dS m^{-1}), OC (g kg^{-1}) and texture of surface soils in low-hill soil zone ranged from 6.1 to 7.0, 0.27 to 0.34, 3.6 to 8.7, and loamy sand to sandy loam, respectively (Tables 4.2 and 4.4). Mean soil pH, EC and OC values were highest in Simbal (6.8), Makol (0.31 dS m^{-1}) and Bhirdi (7.5 g kg^{-1}) and lowest in Bhuana (6.5), Darug (0.28 dS m^{-1}) and Makol (5.3 g kg^{-1}), respectively. While comparing different land uses, mean values of soil pH, EC and OC were highest in grass/ scrubland, cropland and forest and lowest in forest, grass/ scrubland and grass/ scrubland, respectively. While comparing soil pH, EC and OC values averaged for all the land uses as well as panchayats in both the zones, it was observed that OC in mid-hill soil zone was greater than low-hill soil zone, whereas pH and EC were comparatively higher in low-hill soil zone.

Soil pH (1:2.5), EC (dS m^{-1}), OC (g kg^{-1}) and texture of surface soils in Panchrukhi block as a whole ranged from 5.2 to 7.0, 0.21 to 0.34 and 3.6 to 15.8 and loamy sand to silty clay loam (Tables 4.1 to 4.4). While comparing different land uses, mean values of soil pH, EC and OC were highest in grass/ scrubland, teagarden and teagarden and lowest in teagarden, grass/ scrub land and grass/ scrub land, respectively.

4.2 Available nutrient contents in surface soils

4.2.1 Primary nutrients

Available N (kg ha^{-1}), P (kg ha^{-1}) and K (kg ha^{-1}) of surface soils in mid-hill soil zone ranged from 121 to 746, 4.2 to 18.2 and 97 to 395, respectively (Table 4.5 and 4.7). Mean N, P and K values were highest in Mahal Holta (561 kg ha^{-1}), Mahal Banuri (15.6 kg ha^{-1}) and Tanda (320 kg ha^{-1}) panchayats and lowest in Rajot (229 kg ha^{-1}), Tatahail (7.9 kg ha^{-1}) and Simbal Khola (104 kg ha^{-1}) panchayats, respectively. While comparing different land uses, mean values of N, P and K were highest in tea garden, cropland and tea garden, respectively. Grass/ scrub lands showed lowest values for all these nutrients.

Available N (kg ha^{-1}), P (kg ha^{-1}) and K (kg ha^{-1}) of surface soils in low-hill soil zone ranged from 105 to 618, 3.3 to 12.6 and 75 to 269, respectively (Tables 4.6 and 4.8). Mean N, P and K values were highest in Agojar (315 kg ha^{-1}), Bhulana (9.6 kg ha^{-1}) and Bhirdi (186 kg ha^{-1}) panchayats and lowest in Makol (121 kg ha^{-1}), Makol (7.5 kg ha^{-1}) and Check (105 kg ha^{-1}) panchayats, respectively. While comparing different land uses, mean values of N, P and K were highest in forest, cropland and cropland, respectively. Grass/ scrubland showed lowest values for all these nutrients.

Available N (kg ha^{-1}), P (kg ha^{-1}) and K (kg ha^{-1}) in surface soils of Panchrukhi block as a whole ranged from 105 to 746, 3.3 to 18.2, 75 to 395,

Table 4.1 Distribution of soil pH and organic carbon (OC) under different land uses in mid-hill soil zone

Panchayat	pH					OC (g kg^{-1})				
	Cropland	Tea garden	Forest	Grass/scrub land	Overall	Cropland	Tea garden	Forest	Grass/scrub land	Overall
1.Baderlar	6.0-6.2 (6.1)	5.7-5.8 (5.8)	6.1-6.3 (6.2)	6.1-6.3 (6.2)	5.7-6.3 (6.0)	5.4-7.2 (6.5)	9.9-10.9 (10.4)	8.1-8.9 (8.5)	5.2-5.7 (5.5)	5.2-10.9 (7.9)
2.Bandbihar	5.9-6.1 (6.0)	-	5.9-6.2 (5.8)	6.1-6.2 (6.2)	5.9-6.2 (6.0)	6.9-7.8 (7.3)	-	7.7-8.4 (8.0)	5.6-5.8 (5.7)	5.6-8.4 (7.3)
3.Banuri Khas	5.7-5.9 (5.8)	5.5-5.6 (5.6)	5.6-5.8 (5.7)	5.9-6.1 (5.8)	5.5-6.1 (5.7)	7.9-10.1 (8.7)	12.9-14.4 (13.5)	10.2-11.9 (11.1)	6.3-6.9 (6.6)	6.3-14.4 (9.9)
4.Bharwana	5.8-6.1 (5.9)	5.5-5.8 (5.7)	5.9-6.2 (6.1)	6.1-6.3 (6.2)	5.5-6.3 (5.9)	6.6-7.3 (7.0)	10.1-11.7 (10.9)	7.9-8.8 (8.4)	5.5-6.3 (5.9)	5.5-11.7 (8.2)
5.Biara	5.7-5.9 (5.8)	5.2-5.4 (5.3)	5.9-6.2 (6.1)	6.0-6.3 (6.1)	5.2-6.3 (5.8)	5.7-6.2 (6.0)	8.7-10.2 (9.5)	7.4-7.9 (7.6)	5.2-5.8 (5.5)	5.2-10.2 (7.3)
6.Chandropa	5.9-6.2 (6.1)	5.3-5.5 (5.4)	6.0-6.2 (6.1)	6.1-6.3 (6.2)	5.3-6.3 (6.0)	6.9-8.2 (7.5)	11.7-13.1 (12.4)	10.3-11.7 (11.0)	4.9-6.8 (5.9)	4.9-13.1 (9.2)
7.Deogran	6.0-6.2 (6.1)	5.6-5.8 (5.7)	5.9-6.2 (6.0)	6.1-6.4 (6.2)	5.6-6.4 (6.0)	7.4-8.5 (8.0)	7.9-9.4 (8.7)	7.4-7.7 (7.5)	3.9-5.6 (4.7)	3.9-9.4 (7.5)
8.Gadiara	5.8-6.1 (5.9)	5.5-5.7 (5.6)	5.9-6.1 (6.0)	6.0-6.4 (6.2)	5.5-6.4 (5.9)	7.0-8.1 (7.6)	10.9-12.5 (11.7)	8.1-9.5 (8.8)	5.4-6.2 (5.8)	5.4-12.5 (8.6)
9.Jandpur	5.8-6.2 (5.9)	5.5-5.8 (5.7)	5.7-6.0 (5.9)	6.0-6.2 (6.1)	5.5-6.2 (5.9)	6.5-7.6 (7.1)	11.9-13.6 (12.8)	7.1-8.6 (7.8)	5.9-6.7 (6.3)	5.9-13.6 (8.8)
10.Ladoh	5.6-5.9 (5.8)	5.6-5.7 (5.7)	6.1-6.4 (6.3)	6.3-6.5 (6.4)	5.6-6.5 (6.0)	7.4-8.1 (7.8)	12.2-13.6 (12.9)	8.8-10.1 (9.1)	5.7-6.3 (6.0)	5.7-13.6 (9.1)
11.Mahal Banuri	5.7-5.9 (5.8)	5.5-5.7 (5.6)	5.6-5.8 (5.7)	6.0-6.2 (6.1)	5.5-6.2 (5.8)	7.4- 8.6 (7.9)	12.9-14.5 (13.7)	9.9-10.6 (10.3)	6.2-6.5 (6.4)	6.2-14.5 (9.7)
12.Mahal Holta	5.6-5.8 (5.7)	5.2-5.3 (5.3)	5.4-5.7 (5.5)	5.8-6.1 (5.9)	5.2-6.1 (5.6)	9.0-11.9 (10.5)	13.9-14.5 (14.2)	11.5-13.6 (12.6)	5.9-8.2 (6.6)	5.9-14.5 (10.9)
13.Moulichak	5.8-6.0 (5.9)	5.6-5.8 (5.7)	5.9-6.1 (6.0)	6.0-6.3 (6.1)	5.6-6.3 (5.9)	7.9-9.1 (8.5)	11.2-12.9 (12.5)	8.9-9.3 (9.1)	5.5-6.8 (6.2)	5.5-12.9 (9.1)

Panchayat	pH					OC (g kg^{-1})				
	Cropland	Tea garden	Forest	Grass/scrub land	Overall	Cropland	Tea garden	Forest	Grass/scrub land	Overall
14.Nouri Jhikli	5.9-6.1 (6.0)	-	6.0-6.3 (6.2)	6.1-6.4 (6.2)	5.9-6.4 (6.2)	6.2-8.2 (7.5)	-	8.1-8.8 (8.5)	5.7-6.0 (5.8)	5.7-8.8 (6.9)
15.Padiharkhar	5.9-6.1 (6.0)	-	6.0-6.1 (6.1)	6.1-6.3 (6.2)	5.9-6.3 (6.1)	6.3-8.2 (7.2)	-	7.4-7.9 (7.7)	5.8-6.4 (6.1)	5.8-8.2 (6.0)
16.Rajpur	5.9-6.1 (6.0)	5.7-5.9 (5.8)	5.8-6.1 (6.0)	6.0-6.2 (6.2)	5.7-6.2 (5.9)	6.1-7.3 (6.8)	10.3-11.2 (10.8)	8.8-9.5 (9.2)	5.8-6.1 (6.0)	5.8-11.2 (7.3)
17.Rajot	5.8-6.3 (6.1)	-	6.0-6.2 (6.1)	6.2-6.4 (6.3)	5.8-6.4 (5.9)	5.6-5.9 (5.8)	-	7.4-7.8 (7.6)	5.3-6.3 (5.8)	5.3-7.8 (5.7)
18.Rakkar Bheri	6.0-6.3 (6.1)	-	6.0-6.4 (6.2)	6.1-6.4 (6.3)	6.0-6.4 (6.2)	6.3-7.5 (7.1)	-	8.4-9.1 (8.8)	5.3-5.7 (5.5)	5.3-9.1 (6.6)
19.Sagoor Khas	6.1-6.3 (6.2)	-	6.2-6.4 (6.3)	6.1-6.4 (6.3)	6.1-6.4 (6.2)	7.3-8.2 (7.5)	-	8.2-9.4 (8.7)	5.2-5.7 (5.5)	5.2-9.4 (6.7)
20.Saliana	5.7-6.0 (5.9)	5.5-5.7 (5.6)	6.0-6.4 (6.2)	6.1-6.4 (6.3)	5.5-6.4 (5.9)	6.8-7.8 (7.4)	9.9-12.1 (10.9)	9.6-10.1 (9.9)	6.0-6.2 (6.1)	6.0-12.1 (7.8)
21.Simbal Khola	6.1-6.3 (6.2)	-	6.0-6.3 (6.1)	6.1-6.3 (6.2)	6.0-6.3 (6.2)	5.4-5.8 (5.6)	-	7.5-8.3 (7.9)	4.9-5.2 (5.1)	4.9-8.3 (5.5)
22.Sungal	5.7-5.9 (5.8)	5.5-5.8 (5.7)	5.9-6.2 (6.1)	6.0-6.4 (6.2)	5.5-6.4 (5.9)	7.4-8.9 (8.2)	10.8-11.8 (11.3)	8.3-9.5 (8.9)	5.9-6.7 (6.3)	5.9-11.8 (8.3)
23.Tanda	5.6-5.9 (5.8)	5.5-5.7 (5.6)	5.7-6.0 (5.9)	5.8-6.0 (5.9)	5.5-6.0 (5.7)	7.9-8.9 (8.4)	12.2-15.8 (14.0)	10.1-11.2 (10.6)	6.2-6.5 (6.4)	6.2-15.8 (9.4)
24.Tikkar Khas	6.0-6.3 (6.2)	-	5.9-6.1 (6.0)	6.1-6.3 (6.2)	5.9-6.3 (6.1)	5.4-5.9 (5.7)	-	7.7-9.2 (8.5)	5.2-5.6 (5.4)	5.2-9.2 (5.7)
25.Tarhail	5.8-6.2 (5.9)	-	5.9-6.1 (6.0)	6.0-6.3 (6.1)	5.8-6.3 (6.0)	6.9-7.9 (7.1)	-	7.9-8.3 (8.1)	5.8-6.1 (5.9)	5.8-8.3 (6.9)
26.Tatahail	5.9-6.2 (6.0)	-	6.0-6.2 (6.2)	6.1-6.4 (6.3)	5.9-6.4 (6.1)	5.7-5.9 (5.8)	-	7.6-8.3 (7.9)	5.1-5.5 (5.3)	5.1-8.3 (6.4)
Mid-hill soil zone	**5.6-6.3 (6.0)**	**5.2-5.9 (5.6)**	**5.6-6.4 (5.9)**	**5.8-6.4 (6.2)**	**5.2-6.4 (6.0)**	**6.8-11.9 (7.6)**	**7.9-15.8 (11.9)**	**7.4-13.6 (8.8)**	**3.6-6.8 (6.1)**	**3.6-15.8 (8.5)**

Values in parentheses indicate mean values
"-" indicate non-existence

Table 4.2 Distribution of soil pH and organic carbon (OC) under different land uses in low-hill soil zone

Panchayat	pH					OC (g kg^{-1})				
	Cropland	Tea garden	Forest	Grass/scrubland	Overall	Cropland	Tea garden	Forest	Grass/scrub land	Overall
1.Andretta	6.4-6.5 (6.5)	-	6.1-6.5 (6.3)	6.7-6.8 (6.8)	6.1-6.8 (6.5)	7.4-8.3 (7.9)	-	7.4-8.5 (8.0)	5.9-6.8 (6.4)	5.9-8.5 (7.3)
2.Agojar	6.4-6.5 (6.5)	-	6.5-6.7 (6.6)	6.7-6.9 (6.8)	6.4-6.9 (6.7)	7.7-8.0 (8.1)	-	7.5-8.7 (7.9)	6.1-6.9 (6.5)	6.1-8.7 (7.1)
3.Bhirdi	6.5-6.6 (6.6)	-	6.3-6.6 (6.5)	6.8-6.9 (6.9)	6.3-6.9 (6.6)	7.1-8.0 (7.6)	-	7.2-8.7 (7.8)	6.2-6.9 (6.6)	6.2-8.7 (7.5)
4.Bhulana	6.5-6.7 (6.6)	-	6.2-6.5 (6.4)	6.6-6.7 (6.7)	6.2-6.7 (6.6)	7.0-7.2 (7.1)	-	6.6-7.4 (6.9)	4.8-5.4 (5.2)	4.8-7.4 (6.6)
5.Bhuana	6.4-6.5 (6.5)	-	6.1-6.5 (6.3)	6.5-6.7 (6.7)	6.1-6.7 (6.5)	6.5-7.1 (6.8)	-	7.0-8.1 (7.6)	4.5-5.4 (5.0)	4.5-8.1 (6.6)
6.Chadiar	6.5-6.6 (6.5)	-	6.4-6.7 (6.5)	6.6-6.9 (6.8)	6.4-6.9 (6.8)	6.9-7.4 (7.2)	-	7.2-8.3 (7.8)	5.4-6.2 (5.8)	5.4-8.3 (7.1)
7.Check	6.4-6.5 (6.5)	-	6.5-6.7 (6.6)	6.8-7.0 (6.9)	6.4-7.0 (6.6)	5.0-6.1 (5.5)	-	6.3-7.3 (6.6)	4.5-5.1 (4.8)	4.5-7.3 (5.9)
8.Darug	6.3-6.4 (6.3)	-	6.3-6.5 (6.4)	6.6-6.8 (6.7)	6.3-6.8 (6.5)	4.9-5.4 (5.1)	-	6.5-7.2 (6.9)	4.6-5.1 (4.9)	4.6-7.2 (6.0)
9.Kailaspur	6.4-6.5 (6.5)	-	6.4-6.6 (6.5)	6.7-6.8 (6.8)	6.4-6.8 (6.6)	5.4-6.2 (5.8)	-	6.9-8.1 (7.4)	4.4-5.2 (4.8)	4.4-8.1 (6.3)
10.Makol	6.5-6.6 (6.6)	-	6.4-6.7 (6.6)	6.6-6.8 (6.7)	6.4-6.8 (6.6)	4.7-5.3 (5.0)	-	6.6-7.1 (6.8)	4.0-4.4 (4.1)	4.0-7.1 (5.3)
11.Simbal	6.7-6.9 (6.8)	-	6.5-6.7 (6.6)	6.8-6.9 (6.9)	6.5-6.9 (6.8)	5.3-6.6 (6.0)	-	7.2-7.9 (7.5)	3.6-4.2 (3.9)	3.6-7.9 (6.2)
Low-hill soil zone	**6.3-6.9 (6.6)**	-	**6.1-6.7 (6.5)**	**6.5-7.0 (6.8)**	**6.1-7.0 (6.7)**	**4.7-8.3 (6.7)**	-	**6.6-8.7 (7.3)**	**3.6-6.9 (5.5)**	**3.6-8.7 (6.8)**
Panchrukhi block	**5.6-6.9 (6.1)**	**5.2-5.9 (5.6)**	**5.6-6.7 (6.2)**	**5.8-7.0 (6.2)**	**5.2-7.0 (5.9)**	**4.7-11.9 (6.9)**	**7.9-15.8 (11.9)**	**6.6-13.6 (7.9)**	**3.6-6.9 (5.7)**	**3.6-15.8 (7.5)**

Values in parentheses indicate mean values

"-" indicate non-existence

Table 4.3 Distribution of soil EC and texture under different land uses in mid-hill soil zone

Panchayat	EC (dS m^{-1})					Texture (Feel method)				
	Cropland	Tea garden	Forest	Grass/scrub land	Overall	Cropland	Tea garden	Forest	Grass/scrub land	Overall
1.Badehar	0.28-0.31 (0.30)	0.25-0.27 (0.26)	0.22 - 0.24 (0.23)	0.22 - 0.24 (0.23)	0.22-0.31 (0.27)	sl-l	sl-l	ls-sl	ls-sl	ls-sl
2.Bandbihar	0.26-0.29 (0.28)	-	0.23 - 0.25 (0.24)	0.23 - 0.25 (0.24)	0.23-0.29 (0.25)	sl-l	-	ls-sl	ls-sl	ls-sl
3.Banuri Khas	0.29-0.32 (0.31)	0.25 - 0.27 (0.26)	0.21 - 0.24 (0.23)	0.22 - 0.25 (0.24)	0.21-0.32 (0.27)	l-cl	l-cl	sl-l	sl-l	sl-cl
4.Bharwana	0.27-0.29 (0.28)	0.27 - 0.29 (0.28)	0.22 - 0.25 (0.24)	0.21 - 0.22 (0.22)	0.21-0.29 (0.27)	sl-l	sl-l	ls-sl	ls-sl	ls-sl
5.Biara	0.30-0.32 (0.31)	0.26 - 0.30 (0.28)	0.22 - 0.24 (0.23)	0.21 - 0.23 (0.22)	0.21-0.32 (0.26)	l-cl	l-cl	sl-l	sl-l	sl-cl
6.Chandropa	0.29-0.32 (0.30)	0.25 - 0.27 (0.26)	0.23 - 0.25 (0.24)	0.23- 0.24 (0.24)	0.23-0.32 (0.27)	sl-l	sl-l	sl-l	ls-sl	ls-sl
7.Deogran	0.27-0.31 (0.28)	0.26 - 0.29 (0.27)	0.22-0.24 (0.23)	0.22 - 0.24 (0.23)	0.22-0.31 (0.25)	sl-l	sl-l	ls-sl	ls-sl	ls-sl
8.Gadiara	0.30-0.32 (0.31)	0.25 - 0.28 (0.27)	0.22-0.26 (0.24)	0.21 - 0.23 (0.23)	0.21-0.32 (0.28)	sl-l	sl-l	ls-sl	ls-sl	ls-sl
9.Jandpur	0.26-0.29 (0.28)	0.27 - 0.29 (0.28)	0.23-0.25 (0.24)	0.21 - 0.23 (0.22)	0.23-0.29 (0.26)	sl-l	sl-l	ls-sl	ls-sl	ls-sl
10.Ladoh	0.23- 0.27 (0.25)	0.25 - 0.28 (0.27)	0.23-0.24 (0.24)	0.22 - 0.24 (0.23)	0.22-0.28 (0.25)	ls-sl	ls-sl	ls-sl	ls-sl	ls-sl
11.Mahal Banuri	0.29-0.31 (0.30)	0.30 - 0.31 (0.31)	0.25-0.27 (0.26)	0.21 – 0.23 (0.22)	0.21-0.31 (0.27)	si-sicl	si-sicl	l-cl	sl-l	sl-sicl
12.Mahal Holta	0.27-0.31 (0.29)	0.30 – 0.31 (0.31)	0.23-0.26 (0.25)	0.23 – 0.25 (0.24)	0.23-0.31 (0.28)	l-cl	l-cl	l-cl	sl-l	sl-cl
13.Moulichak	0.25-0.29 (0.27)	0.25 – 0.27 (0.26)	0.23-0.25 (0.24)	0.23 – 0.24 (0.24)	0.23-0.29 (0.25)	sl-l	sl-l	sl-l	ls-sl	ls-sl

Panchayat	EC (dS m^{-1})					Texture (Feel method)				
	Cropland	Tea garden			Overall	Cropland	Tea garden	Forest	Grass/ scrub land	Overall
14.Nouri Jhikli	0.25 -0.29 (0.27)	-	0.23-0.28 (0.26)	0.21-0.22 (0.22)	0.21-0.29 (0.25)	sl-l	-	ls-sl	ls-sl	ls-sl
15.Padiharkhar	0.23- 0.29 (0.26)	-	0.24-0.27 (0.26)	0.21 -0.23 (0.22)	0.21-0.29 (0.24)	sl-l	-	ls-sl	ls-sl	ls-sl
16.Rajpur	0.25 -0.28 (0.27)	0.26-0.27 (0.27)	0.23-0.25 (0.24)	0.22-0.24 (0.24)	0.22-0.28 (0.25)	sl-l	sl-l	sl-l	ls-sl	ls-sl
17.Rajot	0.24 -0.26 (0.25)	-	0.23-0.26 (0.25)	0.22-0.23 (0.23)	0.22-0.26 (0.25)	sl	-	ls-sl	ls-sl	ls-sl
18.Rakkar Bheri	0.27-0.30 (0.28)	-	0.23-0.25 (0.24)	0.21-0.23 (0.22)	0.21-0.30 (0.25)	l	-	sl-l	ls-sl	ls-l
19.Sagoor Khas	0.27-0.31 (0.29)	-	0.24-0.27 (0.25)	0.22-0.24 (0.23)	0.22-0.31 (0.27)	sl	-	ls-sl	ls-sl	ls-sl
20.Saliana	0.24-0.28 (0.26)	0.26-0.29 (0.28)	0.25-0.27 (0.26)	0.21-0.23 (0.22)	0.21-0.29 (0.27)	sl-l	sl-l	ls-sl	ls	ls-sl
21.Simbal Khola	0.23-0.25 (0.24)	-	0.23-0.25 (0.24)	0.21-0.23 (0.22)	0.21-0.25 (0.23)	ls-sl	-	ls-sl	ls	ls-sl
22.Sungal	0.29-0.31 (0.29)	0.25-0.26 (0.26)	0.23-0.24 (0.24)	0.23-0.24 (0.24)	0.23-0.31 (0.26)	sl-l	sl-l	ls-sl	ls-sl	ls-sl
23.Tanda	0.31-0.32 (0.31)	0.26-0.29 (0.28)	0.24-0.25 (0.25)	0.21-0.23 (0.22)	0.21-0.32 (0.26)	l-cl	l-cl	sl-l	ls-sl	ls-cl
24.Tikkar Khas	0.23-0.27 (0.26)	-	0.24 -0.26 (0.25)	0.21-0.23 (0.22)	0.21-0.27 (0.24)	ls-sl	-	ls	ls	ls-sl
25.Tarhail	0.25 -0.27 (0.26)	-	0.23-0.24 (0.24)	0.23- 0.24 (0.24)	0.23-0.27 (0.25)	sl-l	-	ls-l	ls-sl	ls-sl
26.Tatahail	0.26 -0.29 (0.28)	-	0.24- 0.28 (0.26)	0.22-0.23 (0.23)	0.22-0.29 (0.26)	sl	-	ls-sl	ls-sl	ls-sl
Mid-hill soil zone	**0.23-0.32 (0.26)**	**0.25-0.31 (0.28)**	**0.21-0.27 (0.24)**	**0.21-0.25 (0.22)**	**0.21-0.32 (0.26)**	**ls-sicl**	**ls-cl**	**ls-l**	**ls-sl**	**ls-sicl**

Parentheses indicate mean values
Note: ls=loamy sand sl=sandy loam, l=loam, cl=clay loam, sicl=silty clay loam
"-" indicate non-existence

Table 4.4 Distribution of soil EC and texture under different land uses in low-hill soil zone

Panchayat	EC (dS m^{-1})					Texture (Feel method)				
	Cropland	Tea garden	Forest	Grass/scrub land	Overall	Cropland	Tea garden	Forest	Grass/scrub land	Overall
1.Andretta	0.29-0.31 (0.30)	-	0.31-0.32 (0.32)	0.28-0.31 (0.29)	0.29-0.31 (0.30)	si	-	is-si	is-si	is-si
2.Agojar	0.28-0.31 (0.30)	-	0.29-0.31 (0.30)	0.29-0.30 (0.30)	0.29-0.31 (0.30)	sl	-	ls-sl	ls-sl	ls-sl
3.Bhirdi	0.31-0.34 (0.32)	-	0.29-0.31 (0.30)	0.28-0.31 (0.29)	0.28-0.34 (0.31)	sl	-	sl	sl	sl-sl
4.Bhulana	0.31-0.32 (0.32)	-	0.28-0.31 (0.29)	0.27-0.29 (0.28)	0.27-0.32 (0.28)	sl	-	sl	ls-sl	ls-sl
5.Bhuana	0.28-0.31 (0.30)	-	0.28-0.29 (0.29)	0.27-0.28 (0.28)	0.27-0.31 (0.29)	sl	-	sl	ls	ls-sl
6.Chadiar	0.29-0.32 (0.31)	-	0.28-0.31 (0.29)	0.27-0.29 (0.28)	0.27-0.32 (0.29)	sl	-	ls-sl	ls-sl	ls-sl
7.Check	0.32-0.33 (0.33)	-	0.29-0.31 (0.30)	0.28-0.29 (0.29)	0.28-0.33 (0.30)	sl	-	sl	sl	sl
8.Darug	0.28-0.29 (0.29)	-	0.28-0.31 (0.29)	0.27-0.29 (0.28)	0.27-0.31 (0.28)	sl	-	sl	sl	sl
9.Kailaspur	0.28-0.31 (0.30)	-	0.28-0.32 (0.30)	0.29-0.31 (0.30)	0.28-0.32 (0.30)	sl	-	sl	ls	ls-sl
10.Makol	0.31-0.33 (0.32)	-	0.31-0.32 (0.32)	0.28-0.30 (0.29)	0.28-0.33 (0.31)	ls-sl	-	ls	ls	ls-sl
11.Simbal	0.28-0.29 (0.29)	-	0.31-0.32 (0.32)	0.29-0.30 (0.29)	0.28-0.32 (0.29)	sl	-	sl	sl	sl
Low-hill soil zone	**0.28-0.34 (0.32)**	-	**0.28-0.32 (0.30)**	**0.27-0.30 (0.28)**	**0.27-0.34 (0.30)**	**sl-ls**	-	**sl**	**sl**	**ls-sl**
Panchrukhi block	**0.23-0.34 (0.27)**	**0.25-0.31 (0.28)**	**0.21-0.32 (0.25)**	**0.21-0.30 (0.23)**	**0.21-0.34 (0.27)**	**ls-sicl**	**ls-cl**	**ls-l**	**ls-sl**	**ls-sicl**

Values in parentheses indicate mean values
***Soils with slight to moderate gravelliness**
Note: ls=loamy sand sl=sandy loam, l=loam, cl=clay loam, sicl=silty clay loam
"-" indicate non-existence

respectively (Tables 4.5 to 4.8). While comparing different land uses, mean values of N, P and K were highest in teagarden, cropland and teagarden, respectively. The lowest values were found in grass/ scrubland.

4.2.2 Secondary nutrients

Available Ca {cmol (p+) kg^{-1}}, Mg {cmol (p+) kg^{-1}} and S (mg kg^{-1}) of surface soils in mid-hill soil zone ranged from 1.7 to 2.9, 0.9 to 1.6 and 3.9 to 26.1, respectively (Tables 4.7 and 4.9). Mean Ca {cmol (p+) kg^{-1}}, Mg {cmol (p+) kg^{-1}} and S (mg kg^{-1}) values were highest in Sagoor Khas (2.7), Tarhail (1.4) and Mahal Holta (18.8) panchayats and lowest in Tanda (2.1), Sagoor Khas (1.0) and Simbal Khola (8.5) panchayats, respectively. While comparing different land uses, mean values of Ca, Mg and S were highest in grass/ scrublands, grass/ scrub land and tea garden and lowest in tea garden, tea garden and grass/ scrublands, respectively.

Available Ca {cmol (p+) kg^{-1}}, Mg {cmol (p+) kg^{-1}} and S (mg kg^{-1}) of surface soils in low-hill zone ranged from 2.8 to 3.8, 1.0 to 1.8 and 3.3 to 17.3, respectively (Tables 4.8 and 4.10). Mean Ca {cmol (p+) kg^{-1}}, Mg {cmol (p+) kg^{-1}} and S (mg kg^{-1}) values were highest in Simbal (3.5), Bhirdi (1.5) and Andretta (13.5) panchayats and lowest in Bhuana (3.1), Makol (1.1) and Makol (8.9) panchayats, respectively. While comparing different land uses, mean values of Ca, Mg and S were highest in grass/ scrub land, grass/ scrub land and forest and lowest in cropland, cropland and grass/ scrub land, respectively.

Available Ca {cmol (p+) kg^{-1}}, Mg {cmol (p+) kg^{-1}} and S (mg kg^{-1}) of surface soils in Panchrukhi block as a whole ranged from 1.7 to 3.8, 0.9 to 1.8 and 3.3 to 26.1, respectively (Tables 4.7 to 4.10). While comparing different land uses, mean values of Ca, Mg and S were highest in grass/ scrub land, grass/ scrub land and tea garden and lowest in cropland, cropland and grass/ scrub lands, respectively.

4.2.3 Micro-nutrient cations

Available Fe (mg kg^{-1}), Mn (mg kg^{-1}), Zn (mg kg^{-1}) and Cu (mg kg^{-1}) of surface soils in mid-hill soil zone ranged from 5 to 82, 0.3 to 24.1, 0.3 to 2.6 and 0.1 to 0.6, respectively (Tables 4.11 and 4.13). Mean Fe, Mn, Zn and Cu values were highest in Banuri Khas (59 mg kg^{-1}), Tanda (11.4 mg kg^{-1}), Banuri Khas (1.4

Table 4.5 Distribution of available N and P under different land uses in mid-hill soil zone

Panchayat	Available N ($kg\ ha^{-1}$)					Available P ($kg\ ha^{-1}$)				
	Cropland	Tea garden	Forest	Grass/scrub land	Overall	Cropland	Tea garden	Forest	Grass/scrub land	Overall
1.Badehar	235-347 (283)	427-554 (491)	267-363 (315)	153-219 (186)	153-347 (320)	9.1-12.1 (10.5)	9.5-10.3 (9.9)	10.1-10.3 (10.2)	6.7-7.2 (7.0)	6.7-12.1 (9.4)
2.Bandbihar	347-507 (423)	-	363-443 (609)	315-347 (331)	315-507 (451)	11.8-13.5 (12.6)	-	10.1-10.3 (10.2)	6.8-7.4 (7.1)	6.8-13.5 (9.9)
3.Banuri Khas	491-602 (554)	682-746 (714)	570-618 (597)	299-363 (331)	299-746 (554)	13.9-15.5 (14.7)	9.8-11.1 (10.5)	10.2-10.3 (10.3)	5.9-6.3 (6.1)	5.9-15.5 (13.9)
4.Bharwana	331-443 (391)	475-586 (531)	395-459 (427)	251-331 (291)	251-586 (406)	9.7-13.2 (11.5)	9.4-10.9 (9.7)	10.3-10.4 (10.4)	6.2-7.1 (6.7)	6.2-13.2 (9.6)
5.Biara	363-539 (448)	586-666 (626)	395-491 (438)	235-331 (294)	235-666 (458)	15.7-17.9 (16.9)	10.4-11.3 (10.9)	10.3-10.5 (10.4)	8.1-8.5 (8.3)	8.1-17.9 (15.1)
6.Chandropa	411-570 (495)	570-650 (610)	554-618 (586)	235-379 (309)	235-650 (459)	12.8-15.1 (13.4)	9.9-11.1 (10.5)	10.2-10.4 (10.3)	7.3-7.9 (7.6)	7.3-15.1 (10.5)
7.Deogran	427-491 (459)	459-539 (499)	331-437 (379)	121-283 (186)	121-539 (361)	11.8-13.3 (12.6)	9.6-10.7 (10.1)	7.9-10.2 (9.1)	6.7-7.2 (7.0)	6.7-13.3 (9.7)
8.Gadiara	363-491 (427)	539-634 (587)	347-411 (379)	219-331 (278)	219-634 (499)	11.8-13.9 (13.0)	8.5-9.9 (9.2)	6.9-10.1 (8.1)	6.8-7.7 (7.3)	6.8-13.9 (9.4)
9.Jandpur	363-443 (403)	550-680 (615)	411-554 (483)	299-331 (315)	299-680 (459)	11.9-14.8 (13.6)	8.4-10.1 (9.3)	9.7-10.4 (10.0)	5.6-6.3 (6.0)	5.6-14.8 (12.9)
10.Ladoh	395-507 (438)	650-746 (698)	523-583 (553)	299-363 (331)	299-746 (498)	9.3-12.5 (10.6)	7.9-9.1 (8.5)	7.5-10.2 (8.9)	4.9-6.3 (5.6)	4.9-12.5 (8.5)
11.Mahal Banuri	395-491 (438)	634-714 (674)	427-491 (459)	331-363 (352)	331-714 (481)	16.9-18.2 (17.5)	10.8-11.4 (11.1)	10.1-10.5 (10.3)	7.7-8.6 (8.2)	7.7-18.2 (15.6)
12.Mahal Holta	539-618 (579)	666-714 (690)	602-698 (650)	331-379 (377)	331-714 (561)	16.9-18.1 (17.4)	10.1-10.9 (10.5)	10.1-10.3 (10.2)	6.8-7.8 (7.3)	6.8-18.1 (11.4)
13.Moulichak	363-507 (432)	570-634 (602)	379-443 (411)	267-395 (331)	267-634 (432)	13.6-15.1 (14.1)	9.6-10.4 (9.9)	10.2-10.3 (10.3)	6.5-6.7 (6.6)	6.5-15.1 (10.2)

Panchayat	Available N (kg ha^{-1})					Available P (kg ha^{-1})				
	Cropland	Tea garden	Forest	Grass/scrub land	Overall	Cropland	Tea garden	Forest	Grass/scrub land	Overall
14.Nouri Jhikli	363-570 (415)	-	427-554 (480)	235-315 (267)	235-554 (379)	12.8-15.1 (13.9)	-	8.9-10.1 (9.1)	4.8-5.2 (5.0)	4.8-15.1 (9.3)
15.Padiharkhar	347-491 (411)	-	379-443 (411)	283-379 (331)	283-491 (387)	12.7-14.2 (13.5)	-	8.2-10.2 (9.2)	5.1-6.4 (5.7)	5.1-14.2 (9.5)
16.Rajpur	331-427 (375)	570-618 (594)	347-521 (434)	315-459 (387)	315-618 (457)	13.1-15.1 (14.0)	8.9-10.7 (9.8)	10.1-10.3 (10.2)	6.9-7.3 (7.1)	6.9-15.1 (10.3)
17.Rajot	267-331 (272)	-	169-299 (245)	105-153 (129)	105-331 (229)	9.7-12.3 (10.6)	-	9.1-10.1 (9.5)	4.2-4.9 (4.6)	4.2-12.3 (8.2)
18.Rakkar Bheri	342-554 (474)	-	379-427 (403)	235-299 (267)	235-554 (391)	14.4-17.9 (16.2)	-	10.2-10.4 (10.3)	4.8-5.3 (5.0)	4.8-17.9 (10.6)
19.Sagoor Khas	379-491 (438)	-	363-459 (411)	235-315 (275)	235-491 (387)	9.7-11.9 (10.8)	-	9.7-10.1 (9.9)	5.1-5.7 (5.4)	5.1-11.9 (8.8)
20.Saliana	395-459 (427)	491-583 (537)	395-443 (419)	299-379 (336)	299-583 (436)	8.8-10.3 (9.8)	9.1-10.7 (9.9)	8.8-9.8 (9.3)	4.3-4.5 (4.4)	4.3-10.7 (8.4)
21.Simbal Khola	187-363 (251)	-	235-347 (288)	121-169 (142)	121-347 (231)	9.6-10.8 (10.1)	-	6.6-8.2 (7.4)	5.6-7.3 (6.9)	5.6-10.8 (8.2)
22.Sungal	427-602 (383)	570-602 (586)	331-554 (443)	299-315 (306)	299-602 (423)	12.9-15.1 (14.0)	9.3-10.8 (10.1)	10.1-10.3 (10.2)	7.2-7.8 (7.5)	7.2-15.1 (10.6)
23.Tanda	443-521 (486)	634-714 (674)	427-634 (510)	315-363 (339)	315-714 (523)	17.2-18.8 (17.9)	11.1-11.4 (11.3)	10.2-10.4 (10.3)	7.5-8.1 (7.9)	7.5-18.8 (11.9)
24.Tikkar Khas	251-347 (288)	-	235-395 (299)	137-187 (159)	137-395 (312)	8.8-10.9 (9.3)	-	7.7-9.2 (8.1)	6.3-7.1 (6.7)	6.3-10.9 (8.4)
25.Tarhail	235-347 (287)	-	251-395 (304)	121-169 (148)	121-395 (321)	12.9-14.6 (13.9)	-	8.6-10.3 (9.4)	5.5-5.9 (5.7)	5.5-14.6 (9.9)
26.Tatahail	331-443 (390)	-	331-459 (384)	219-327 (276)	219-459 (356)	8.9-11.5 (10.3)	-	8.2-10.1 (9.1)	4.2-4.7 (4.4)	4.2-11.5 (7.9)
Mid-hill soil zone	**169-618 (379)**	**459-746 (617)**	**315-698 (441)**	**121-411 (285)**	**121-746 (459)**	**8.8-18.2 (13.4)**	**7.8.-11.4 (10.3)**	**5.6-10.5 (9.4)**	**4.2-8.8 (7.9)**	**4.2-18.2 (10.4)**

Values in parentheses indicate mean values
"-" indicate non-existence

Table 4.6 Distribution of available N and P under different land uses in low-hill soil zone

Panchayat	Available N ($kg\ ha^{-1}$)					Available P ($kg\ ha^{-1}$)				
	Cropland	Tea garden	Forest	Grass/scrub land	Overall	Cropland	Tea garden	Forest	Grass/scrub land	Overall
1.Andretta	443-521 (517)	-	411-618 (515)	283-315 (299)	283-618 (451)	11.3-12.4 (11.9)	-	4.4-6.1 (5.5)	3.8-4.8 (4.3)	3.8-12.4 (7.5)
2.Agojar	523-570 (547)	-	331-618 (483)	299-331 (315)	299-618 (448)	11.5-12.6 (12.1)	-	7.5-8.3 (7.9)	3.3-4.9 (4.1)	3.3-12.6 (7.9)
3.Bhirdi	411-459 (438)	-	459-618 (554)	283-311 (298)	283-618 (428)	10.2-12.1 (11.1)	-	8.3-9.8 (9.1)	5.1-7.7 (6.4)	5.1-12.1 (9.1)
4.Bhulana	331-379 (331)	-	235-363 (303)	89-187 (138)	89-379 (267)	11.8-12.6 (12.1)	-	8.9-9.5 (9.3)	7.7-8.1 (7.9)	7.7-12.6 (9.6)
5.Bhuana	315-427 (379)	-	379-602 (487)	121-267 (202)	121-602 (373)	9.6-11.9 (10.5)	-	8.7-9.2 (8.9)	7.6-8.1 (7.9)	7.6-11.9 (9.1)
6.Chadiar	299-427 (356)	-	523-602 (560)	267-313 (290)	267-602 (412)	10.1-12.3 (11.2)	-	9.7-9.9 (9.8)	6.7-7.5 (7.1)	6.7-12.3 (9.2)
7.Check	203-313 (256)	-	315-395 (359)	169-251 (210)	169-395 (291)	8.1-11.2 (10.4)	-	9.8-10.1 (9.9)	4.4-7.1 (5.8)	4.4-11.2 (8.6)
8.Darug	219-251 (235)	-	251-443 (371)	105-153 (129)	105-443 (278)	7.7-9.1 (8.3)	-	9.9-10.1 (9.9)	4.8-5.6 (5.2)	4.8-10.1 (7.5)
9.Kailaspur	267-347 (307)	-	427-523 (467)	169-251 (210)	169-523 (363)	10.8-11.7 (11.2)	-	9.4-9.9 (9.7)	5.6-7.7 (7.2)	5.6-11.7 (9.2)
10.Makol	153-267 (210)	-	299-395 (343)	105-137 (121)	105-395 (224)	7.8-9.7 (8.6)	-	9.7-10.0 (9.8)	4.1-5.3 (4.7)	3.9-10.0 (7.5)
11.Simbal	267-353 (315)		331-507 (435)	105-187 (146)	105-507 (323)	10.3-12.5 (11.1)	-	9.5-9.9 (9.7)	7.1-7.9 (7.5)	8.4-12.5 (9.2)
Low-hill soil zone	**153-570 (358)**	-	**219-618 (493)**	**105-313 (191)**	**105-618 (437)**	**7.7-12.6 (11.1)**	-	**4.4-10.1 (9.2)**	**3.3-8.1 (6.5)**	**3.3-12.6 (8.2)**
Panchrukhi block	**153-618 (399)**	**459-746 (617)**	**219-698 (477)**	**105-411 (178)**	**105-746 (389)**	**8.8-18.2 (11.9)**	**7.8-11.4 (8.6)**	**4.4-10.5 (9.3)**	**3.3-8.8 (7.5)**	**3.3-18.2 (10.9)**

Values in parentheses indicate mean values
"-" indicate non-existence

Table 4.7 Distribution of available K and S under different land uses in mid-hill soil zone

Panchayat	Available K (kg ha^{-1})					Available S (mg kg^{-1})				
	Cropland	Tea garden	Forest	Grass/scrub land	Overall	Cropland	Tea garden	Forest	Grass/scrub land	Overall
1.Badehar	248-283 (266)	256-334 (295)	186-195 (191)	132-148 (140)	132-334 (228)	9.8-12.1 (10.6)	17.5-19.3 (18.4)	9.8-13.1 (11.5)	7.3-9.4 (8.4)	7.3-19.3 (12.2)
2.Bandbihar	243-302 (277)	-	141-163 (152)	125-143 (134)	125-302 (204)	14.3-17.9 (16.3)	-	13.2-16.6 (15.1)	10.8-12.1 (11.4)	10.8-17.9 (14.5)
3.Banuri Khas	305-338 (323)	365-391 (378)	143-176 (159)	139-152 (146)	139-391 (249)	11.3-14.9 (12.8)	21.7-24.8 (23.2)	12.1-19.6 (15.1)	11.6-12.2 (11.9)	11.6-24.8 (15.9)
4.Bharwana	256-289 (271)	259-272 (266)	149-172 (161)	137-162 (150)	137-289 (223)	13.9-17.3 (15.3)	19.4-21.6 (20.5)	17.3-18.2 (17.8)	7.6-11.2 (9.4)	7.6-21.6 (15.9)
5.Biara	298-336 (317)	352-386 (369)	238-262 (252)	185-218 (205)	185-386 (274)	17.8-21.1 (19.5)	21.2-24.3 (22.3)	12.3-17.3 (14.6)	8.0-10.1 (9.2)	8.0-24.3 (16.6)
6.Chandropa	248-301 (259)	268-272 (270)	242-263 (251)	125-139 (132)	125-301 (234)	11.4-16.8 (13.9)	19.6-23.6 (21.6)	17.3-20.2 (18.8)	5.2-10.2 (7.7)	5.2-23.6 (15.3)
7.Deogran	221-273 (247)	247-279 (263)	162-204 (185)	113-165 (134)	113-279 (213)	18.1-19.6 (18.9)	18.3-21.6 (19.9)	9.7-13.2 (11.9)	3.9-10.2 (6.2)	3.9-21.6 (14.1)
8.Gadiara	235-287 (259)	278-302 (290)	148-181 (165)	138-156 (147)	138-302 (220)	14.2-18.9 (16.6)	19.9-22.2 (21.3)	12.9-16.2 (14.6)	8.6-11.1 (9.5)	8.6-22.2 (15.2)
9.Jandpur	182-273 (229)	238-252 (245)	148-216 (182)	125-132 (129)	125-273 (203)	14.1-18.5 (16.6)	21.3-23.3 (22.3)	16.2-18.5 (17.3)	10.5-11.7 (11.1)	10.5-23.3 (16.9)
10.Ladoh	187-235 (186)	213-248 (231)	119-151 (135)	116-141 (129)	116-248 (166)	12.6-14.0 (13.5)	18.2-20.1 (19.1)	14.2-16.9 (15.6)	11.2-11.8 (11.6)	11.2-20.1 (14.7)
11.Mahal Banuri	315-348 (301)	336-385 (361)	246-298 (271)	203-215 (219)	203-385 (282)	16.5-18.8 (17.5)	23.5-25.5 (24.4)	18.8-19.8 (19.0)	11.2-12.4 (11.8)	11.2-25.5 (18.6)
12.Mahal Holta	342-368 (355)	361-379 (372)	281-313 (297)	195-231 (214)	195-379 (299)	19.9-21.6 (20.8)	23.4-26.1 (24.8)	18.6-20.2 (19.4)	11.2-12.6 (11.9)	11.2-26.1 (19.4)
13.Moulichak	225-381 (309)	324-382 (353)	251-285 (268)	127-165 (217)	127-382 (260)	18.2-21.1 (19.6)	21.7-23.6 (22.7)	11.8-16.9 (14.4)	9.7-11.6 (10.7)	9.7-23.6 (16.5)

Panchayat	Available K (kg ha^{-1})					Available S (mg kg^{-1})				
	Cropland	Tea garden	Forest	Grass/scrub land	Overall	Cropland	Tea garden	Forest	Grass/scrub land	Overall
14.Nouri Jhikli	235-310 (256)	-	112-135 (122)	89-123 (108)	89-310 (165)	11.3-17.1 (13.9)	-	17.3-19.3 (18.4)	9.6-10.9 (10.1)	9.6-19.3 (14.3)
15.Padiharkhar	241-284 (254)	-	136-186 (155)	128-146 (143)	128-284 (191)	12.1-19.2 (15.6)	-	15.2-16.9 (16.2)	10.2-11.2 (10.8)	10.2-19.2 (14.3)
16.Rajpur	235-295 (282)	297-346 (322)	255-273 (264)	112-143 (128)	112-346 (243)	13.2-16.2 (14.8)	20.6-22.1 (21.4)	11.9-12.8 (12.4)	11.2-12.7 (12.0)	11.2-22.1 (15.3)
17.Rajot	218-242 (231)	-	117-135 (121)	104-122 (113)	104-242 (156)	9.5-11.3 (10.2)	-	10.4-11.8 (10.9)	8.2-9.1 (8.7)	8.2-11.8 (9.9)
18.Rakkar Bheri	258-305 (279)	-	254-276 (265)	132-162 (147)	132-305 (242)	12.2-18.2 (16.1)	-	10.3-12.2 (10.9)	9.2-10.5 (9.8)	9.2-18.2 (12.1)
19.Sagoor Khas	228-265 (245)	-	185-251 (220)	121-154 (138)	121-265 (209)	14.6-18.2 (16.7)	-	10.9-17.4 (14.9)	8.6-10.6 (9.6)	8.6-18.2 (13.2)
20.Saliana	218-297 (256)	242-289 (266)	119-159 (135)	107-149 (124)	107-297 (191)	13.8-16.9 (15.7)	19.8-23.4 (21.6)	17.3-19.6 (18.5)	11.5-12.6 (12.0)	11.5-23.4 (14.5)
21.Simbal Khola	112-175 (135)	-	97-135 (114)	89-127 (104)	89-127 (104)	8.5-9.9 (9.4)	-	10.1-10.3 (10.2)	6.5-8.1 (7.5)	6.5-10.3 (8.5)
22.Sungal	255-298 (272)	268-317 (293)	245-261 (251)	127-155 (141)	127-298 (235)	18.1-21.1 (19.9)	20.1-21.8 (21.0)	17.6-19.9 (18.8)	11.4-12.6 (12.0)	11.4-21.8 (17.5)
23.Tanda	278-336 (310)	371-395 (383)	252-284 (267)	198-232 (324)	198-395 (320)	18.1-19.2 (18.7)	22.1-23.6 (22.9)	19.2-20.2 (19.7)	10.2-12.1 (11.2)	10.2-23.6 (17.3)
24.Tikkar Khas	107-142 (128)	-	122-168 (146)	105-136 (122)	105-148 (132)	9.7-12.2 (10.4)	-	10.6-11.9 (11.1)	6.3-8.7 (7.6)	6.3-12.2 (11.7)
25. Tarhail	221-295 (253)	-	157-210 (187)	132-175 (154)	132-295 (204)	11.2-17.5 (13.6)	-	13.2-17.7 (15.4)	10.6-12.3 (11.4)	10.6-17.7 (13.4)
26.Tatahail	221-295 (228)	-	157-210 (184)	132-175 (116)	132-210 (158)	10.7-14.5 (12.4)	-	10.1-12.3 (10.5)	5.4-7.3 (6.5)	5.4-14.5 (13.2)
Mid-hill soil zone	**107-368 (254)**	**213-395 (310)**	**122-313 (192)**	**97-233 (149)**	**97-395 (217)**	**9.5-21.6 (19.5)**	**17.5-26.1 (21.6)**	**10.1-20.2 (14.2)**	**3.9-12.7 (9.8)**	**3.9-26.1 (14.7)**

Values in parentheses indicate mean values
"-" indicate non-existence

Table 4.8 Distribution of available K and S under different land uses in low-hill soil zone

Panchayat	Available K (kg ha^{-1})					Available S (mg kg^{-1})				
	Cropland	Tea garden	Forest	Grass/scrub land	Overall	Cropland	Tea garden	Forest	Grass/scrub land	Overall
1.Andretta	248-269 (254)	-	125-181 (148)	121-134 (128)	121-269 (181)	12.3-17.1 (14.3)	-	13.9-17.3 (15.6)	10.3-11.2 (10.8)	10.3-17.3 (13.5)
2.Agojar	233-261 (251)	-	118-152 (134)	125-133 (129)	118-261 (175)	14.2-16.8 (15.5)	-	11.2-15.3 (14.6)	10.6-11.3 (10.9)	10.6-16.8 (13.1)
3.Bhirdi	198-272 (239)	-	165-203 (187)	97-114 (106)	97-272 (186)	12.8-14.7 (13.5)	-	12.9-17.2 (14.8)	10.3-11.2 (10.8)	10.3-17.2 (13.4)
4.Bhulana	215-239 (227)	-	115-169 (121)	113-131 (123)	113-239 (154)	12.9-14.1 (13.5)	-	9.7-13.6 (11.3)	7.2-9.5 (8.3)	7.2-14.1 (11.7)
5.Bhuana	197-223 (209)	-	168-196 (175)	85-121 (106)	85-223 (164)	9.7-13.7 (11.1)	-	14.2-17.2 (15.8)	7.6-9.8 (8.6)	7.6-17.2 (12.8)
6.Chadiar	218-265 (239)	-	125-168 (106)	107-132 (120)	107-265 (172)	11.9-13.5 (12.5)	-	13.3-16.5 (14.7)	8.7-11.4 (10.0)	8.7-16.5 (12.9)
7.Check	103-116 (110)	-	98-114 (112)	75-97 (86)	75-116 (105)	8.6-12.3 (10.2)	-	10.9-13.8 (12.4)	3.3-5.4 (4.4)	3.3-13.8 (9.9)
8.Darug	115-184 (149)	-	117-161 (144)	87-106 (97)	87-184 (134)	8.7-9.2 (9.0)	-	11.7-14.1 (13.0)	4.7-6.9 (5.8)	4.7-14.1 (10.2)
9.Kailaspur	119-149 (134)	-	109-124 (119)	98-117 (108)	98-149 (115)	9.5-12.8 (11.1)	-	12.6-16.6 (4.1)	7.3-9.6 (8.4)	7.3-16.6 (11.9)
10.Makol	105-118 (112)	-	97-131 (142)	86-93 (108)	86-131 (126)	7.7-9.2 (8.4)	-	10.2-11.7 (11.2)	3.9-5.4 (4.7)	3.9-11.7 (8.9)
11.Simbal	198-253 (226)	-	115-167 (138)	95-112 (104)	95-253 (151)	9.7-12.1 (10.9)	-	11.5-16.3 (14.8)	5.6-7.9 (7.8)	5.6-16.3 (11.8)
Low-hill soil zone	**103-269 (212)**	-	**98-203 (146)**	**75-145 (110)**	**75-269 (166)**	**7.7-17.1 (15.8)**	-	**10.2-17.3 (16.6)**	**3.3-11.4 (7.4)**	**3.3-17.3 (11.5)**
Panchrukhi block	**103-368 (267)**	**213-395 (310)**	**98-313 (167)**	**75-233 (132)**	**75-395 (276)**	**6.0-21.6 (17.6)**	**18.3-26.1 (21.3)**	**10.2-20.2 (17.4)**	**3.3-12.6 (10.4)**	**3.3-26.1 (19.5)**

Values in parentheses indicate mean values
"-" indicate non-existence

Table 4.9 Distribution of available Ca and Mg under different land uses in mid-hill soil zone

Panchayat	Available Ca {cmol (p+) kg^{-1}}					Available Mg {cmol (p+) kg^{-1}}				
	Cropland	Tea garden	Forest	Grass/scrub land	Overall	Cropland	Tea garden	Forest	Grass/scrub land	Overall
1.Badehar	2.3-2.5 (2.4)	2.1-2.3 (2.2)	2.5-2.7 (2.6)	2.6-2.8 (2.7)	2.1-2.8 (2.5)	1.1-1.3 (1.2)	0.9-1.1 (1.0)	1.2-1.3 (1.3)	*1.2-1.5* (1.3)	*0.9-1.5* (1.2)
2.Bandbihar	2.2-2.3 (2.3)	-	2.3-2.6 (2.5)	2.6-2.7 (2.7)	2.2-2.7 (2.6)	1.0-1.2 (1.2)	-	1.0-1.1 (1.1)	1.1-1.3 (1.2)	1.0-1.3 (1.1)
3.Banuri Khas	2.1-2.2 (2.2)	1.8-2.0 (1.9)	2.0-2.2 (2.2)	2.2-2.5 (2.4)	1.8-2.5 (2.3)	1.3-1.4 (1.3)	0.9-1.0 (1.0)	1.2-1.3 (1.3)	1.3-1.4 (1.4)	0.9-1.4 (1.3)
4.Bharwana	2.2-2.5 (2.4)	1.9-2.2 (2.1)	2.3-2.6 (2.5)	2.5-2.8 (2.7)	1.9-2.8 (2.5)	1.1-1.4 (1.3)	0.9-1.0 (1.0)	1.1-1.2 (1.2)	1.1-1.2 (1.2)	0.9-1.4 (1.2)
5.Biara	2.1-2.3 (2.2)	1.7-1.9 (1.8)	2.4-2.6 (2.5)	2.3-2.7 (2.5)	1.7-2.7 (2.4)	1.2-1.4 (1.3)	1.0-1.2 (1.1)	1.2-1.3 (1.2)	1.3-1.4 (1.4)	1.1-1.4 (1.3)
6.Chandropa	2.2-2.5 (2.4)	1.8-1.9 (1.9)	2.5-2.6 (2.6)	2.5-2.7 (2.6)	1.8-2.7 (2.4)	1.2-1.3 (1.3)	0.9-1.1 (1.0)	1.1-1.3 (1.2)	1.0-1.2 (1.1)	0.9-1.3 (1.2)
7.Deogran	2.3-2.6 (2.4)	2.0-2.2 (2.1)	2.4-2.7 (2.6)	2.5-2.8 (2.7)	2.0-2.8 (2.5)	1.2-1.3 (1.2)	0.9-1.1 (1.0)	1.2-1.4 (1.3)	1.0-1.1 (1.1)	0.9-1.4 (1.2)
8.Gadiara	2.1-2.5 (2.3)	1.9-2.1 (2.0)	2.2-2.5 (2.4)	2.3-2.8 (2.6)	1.9-2.8 (2.4)	1.1-1.2 (1.2)	0.9-1.0 (1.0)	1.1-1.3 (1.2)	0.9-1.3 (1.2)	0.9-1.3 (1.0)
9.Jandpur	2.2-2.4 (2.3)	1.8-2.1 (2.0)	2.1-2.3 (2.2)	2.3-2.6 (2.5)	1.8-2.6 (2.4)	1.2-1.3 (1.3)	1.0-1.1 (1.1)	1.0-1.2 (1.2)	1.3-1.4 (1.3)	1.0-1.4 (1.2)
10.Ladoh	2.0-2.2 (2.1)	1.9-2.1 (2.0)	2.6-2.9 (2.8)	2.7-2.9 (2.8)	1.9-2.9 (2.5)	0.9-1.0 (1.0)	0.9-1.0 (0.9)	1.2-1.3 (1.3)	1.3-1.4 (1.4)	0.9-1.4 (1.2)
11.Mahal Banuri	2.1-2.4 (2.3)	1.9-2.1 (2.0)	2.0-2.3 (2.2)	2.3-2.5 (2.4)	1.9-2.5 (2.2)	1.3-1.5 (1.4)	1.0-1.3 (1.2)	1.1-1.4 (1.2)	1.3-1.4 (1.4)	1.0-1.5 (1.3)
12.Mahal Holta	2.0-2.2 (2.2)	1.7-1.9 (1.8)	1.9-2.1 (2.0)	2.2-2.5 (2.4)	1.7-2.5 (2.4)	1.2-1.4 (1.3)	1.0-1.1 (1.1)	1.2-1.4 (1.2)	1.3-1.4 (1.4)	1.0-1.4 (1.3)
13.Moulichak	2.2-2.4 (2.3)	2.1-2.2 (2.2)	2.2-2.5 (2.4)	2.3-2.7 (2.5)	2.1-2.7 (2.4)	1.2-1.5 (1.4)	1.1-1.2 (1.2)	1.1-1.3 (1.2)	1.2-1.3 (1.2)	1.1-1.5 (1.3)

Panchayat	Available Ca {cmol (p+) kg^-1^}					Available Mg {cmol (p+) kg^-1^}				
	Cropland	Tea garden	Forest	Grass/scrub land	Overall	Cropland	Tea garden	Forest	Grass/scrub land	Overall
14.Nouri Jhikli	2.2-2.5 (2.4)	-	2.3-2.7 (2.5)	2.5-2.9 (2.7)	2.2-2.9 (2.5)	0.9-1.1 (1.1)	-	1.0-1.1 (1.1)	1.1-1.4 (1.2)	0.9-1.4 (1.1)
15.Padiharkhar	2.3-2.5 (2.4)	-	2.3-2.5 (2.9)	2.4-2.7 (2.6)	2.3-2.7 (2.6)	1.0-1.2 (1.1)	-	0.9-1.1 (1.0)	1.1-1.2 (1.1)	0.9-1.2 (1.1)
16.Rajpur	2.4-2.6 (2.5)	1.9-2.1 (2.0)	2.2-2.5 (2.6)	2.3-2.6 (2.4)	2.0-2.6 (2.7)	1.0-1.1 (1.1)	0.9-1.1 (1.0)	0.9-1.2 (1.1)	1.1-1.2 (1.1)	0.9-1.2 (1.1)
17.Rajot	2.3-2.7 (2.5)	-	2.3-2.6 (2.5)	2.6-2.8 (2.7)	2.3-2.8 (2.7)	1.0-1.1 (1.1)	-	0.9-1.3 (1.1)	1.2-1.6 (1.4)	0.9-1.6 (1.2)
18.Rakkar Bheri	2.4-2.8 (2.6)	-	2.5-2.7 (2.6)	2.5-2.8 (2.6)	2.4-2.8 (2.6)	1.2-1.3 (1.3)	-	1.2-1.3 (1.2)	1.2-1.5 (1.3)	1.2-1.5 (1.3)
19.Sagoor Khas	2.6-2.7 (2.7)	-	2.6-2.8 (2.7)	2.6-2.9 (2.8)	2.6-2.9 (2.7)	1.1-1.2 (1.1)	-	0.9-1.2 (1.1)	1.0-1.1 (1.1)	0.9-1.2 (1.0)
20.Saliana	2.1-2.4 (2.3)	-	2.4-2.9 (2.7)	2.7-2.9 (2.8)	1.9-2.9 (2.5)	1.1-1.3 (1.2)	-	0.9-1.0 (1.0)	1.0-1.1 (1.1)	0.9-1.3 (1.1)
21.Simbal Khola	2.5-2.8 (2.7)	-	2.3-2.7 (2.6)	2.5-2.8 (2.6)	2.3-2.8 (2.5)	1.0-1.1 (1.1)	-	1.1-1.2 (1.2)	1.0-1.1 (1.1)	1.0-1.2 (1.1)
22.Sungal	2.1-2.3 (2.2)	1.9-2.1 (2.0)	2.2-2.6 (2.4)	2.2-2.6 (2.4)	1.9-2.8 (2.4)	1.0-1.2 (1.1)	0.9-1.0 (1.0)	0.9-1.0 (1.0)	1.2-1.3 (1.3)	0.9-1.3 (1.1)
23.Tanda	2.0-2.3 (2.2)	1.8-2.0 (1.9)	2.1-2.3 (2.2)	2.1-2.3 (2.2)	1.8-2.3 (2.1)	1.0-1.3 (1.2)	0.9-1.0 (1.0)	0.9-1.0 (1.0)	1.2-1.3 (1.3)	0.9-1.3 (1.1)
24.Tikkar Khas	2.3-2.7 (2.6)	-	2.3-2.5 (2.4)	2.3-2.5 (2.4)	2.3-2.8 (2.4)	1.4-1.5 (1.5)	-	0.9-1.2 (1.1)	1.1-1.4 (1.3)	0.9-1.5 (1.3)
25. Tarhail	2.2-2.6 (2.4)	-	2.2-2.5 (2.4)	2.2-2.5 (2.4)	2.2-2.7 (2.4)	1.2-1.3 (1.7)	-	1.0-1.3 (1.2)	1.3-1.5 (1.4)	1.0-1.5 (1.4)
26.Tatahail	2.3-2.5 (2.4)	-	2.3-2.6 (2.5)	2.3-2.6 (2.5)	2.3-2.8 (2.5)	1.1-1.3 (1.4)	-	0.9-1.1 (1.1)	1.1-1.3 (1.2)	0.9-1.3 (1.2)
Mid-hill soil zone	**2.0-2.7 (2.5)**	**1.7-2.3 (1.9)**	**1.9-2.9 (2.2)**	**2.1-2.9 (2.7)**	**1.7-2.9 (2.5)**	**0.9-1.5 (1.2)**	**0.9-1.3 (1.1)**	**0.9-1.4 (1.2)**	**0.9-1.6 (1.3)**	**0.9-1.6 (1.3)**

Values in parentheses indicate mean values
"-" indicate non-existence

Table 4.10 Distribution of available Ca and Mg under different land uses in low-hill soil zone

Panchayat	Available Ca {cmol (p+) kg^{-1}}					Available Mg {cmol (p+) kg^{-1}}				
	Cropland	Tea garden	Forest	Grass/scrub land	Overall	Cropland	Tea garden	Forest	Grass/scrub land	Overall
1.Andretta	2.9-3.2 (3.0)	-	3.0-3.3 (3.2)	3.3-3.6 (3.4)	2.9-3.6 (3.3)	1.2-1.3 (1.3)	-	1.1-1.2 (1.2)	1.3-1.5 (1.4)	1.1-1.5 (1.2)
2.Agojar	2.8-3.2 (3.1)	-	3.2-3.5 (3.4)	3.5-3.6 (3.6)	2.8-3.6 (3.4)	1.3-1.4 (1.4)	-	1.1-1.2 (1.2)	1.3-1.6 (1.5)	1.1-1.6 (1.2)
3.Bhirdi	3.1-3.3 (3.2)	-	3.1-3.4 (3.3)	3.6-3.7 (3.6)	3.1-3.7 (3.4)	1.2-1.5 (1.4)	-	1.4-1.5 (1.4)	1.6-1.8 (1.7)	1.2-1.8 (1.5)
4.Bhulana	3.1-3.2 (3.2)	-	2.9-3.3 (3.1)	3.2-3.4 (3.3)	2.9-3.4 (3.2)	1.0-1.1 (1.1)	-	1.3-1.4 (1.3)	1.5-1.7 (1.6)	1.0-1.7 (1.2)
5.Bhuana	2.9-3.1 (3.0)	-	2.8-3.1 (3.0)	3.1-3.3 (3.2)	2.8-3.3 (3.1)	1.1-1.2 (1.2)	-	1.1-1.2 (1.1)	1.5-1.8 (1.7)	1.1-1.8 (1.2)
6.Chadiar	3.1-3.2 (3.2)	-	3.2-3.4 (3.3)	3.2-3.5 (3.4)	3.1-3.5 (3.4)	1.3-1.4 (1.4)	-	1.2-1.5 (1.4)	1.4-1.5 (1.5)	1.2-1.5 (1.3)
7.Check	2.9-3.1 (3.0)	-	3.1-3.4 (3.3)	3.4-3.8 (3.6)	2.9-3.8 (3.4)	1.4-1.5 (1.4)	-	1.2-1.3 (1.3)	1.5-1.8 (1.7)	1.2-1.8 (1.3)
8.Darug	2.8-3.1 (2.9)	-	2.9-3.2 (3.1)	3.4-3.6 (3.5)	2.8-3.6 (3.2)	1.1-1.3 (1.2)	-	1.1-1.2 (1.2)	1.4-1.6 (1.5)	1.1-1.6 (1.2)
9.Kailaspur	3.0-3.2 (3.3)	-	2.9-3.4 (3.2)	3.4-3.6 (3.5)	2.9-3.6 (3.3)	1.2-1.3 (1.3)	-	1.1-1.2 (1.2)	1.6-1.7 (1.7)	1.1-1.7 (1.2)
10.Makol	3.1-3.3 (3.2)	-	3.0-3.4 (3.3)	3.3-3.6 (3.5)	3.0-3.6 (3.5)	1.1-1.2 (1.2)	-	1.1-1.2 (1.2)	1.5-1.8 (1.6)	1.1-1.8 (1.1)
11.Simbal	3.2-3.4 (3.3)	-	3.4-3.6 (3.5)	3.5-3.8 (3.7)	3.2-3.8 (3.5)	1.2-1.5 (1.4)	-	1.2-1.4 (1.3)	1.6-1.8 (1.7)	1.2-1.8 (1.3)
Low-hill soil zone	**2.8-3.4 (3.1)**	-	**2.8-3.6 (3.2)**	**3.1-3.8 (3.6)**	**2.8-3.8 (3.2)**	**1.0-1.5 (1.3)**	-	**1.1-1.5 (1.4)**	**1.4-1.8 (1.6)**	**1.0-1.8 (1.5)**
Panchrukhi block	**2.0-3.4 (2.6)**	**1.7-2.3 (1.9)**	**1.9-3.6 (2.8)**	**2.1-3.8 (3.1)**	**1.7-3.8 (2.4)**	**0.9-1.5 (1.2)**	**0.9-1.3 (1.1)**	**0.9-1.5 (1.2)**	**0.9-1.8 (1.3)**	**0.9-1.8 (1.3)**

Values in parentheses indicate mean values
"-" indicate non-existence

mg kg^{-1}) and Mahal Banuri (0.5 mg kg^{-1}) panchayats and lowest in Bandbihar (21 mg kg^{-1}), Sagoor Khas (3.1 mg kg^{-1}), Rakkar Bheri (0.5 mg kg^{-1}) and Bandbihar (0.2 mg kg^{-1}) panchayats, respectively. While comparing different land uses, mean values of micronutrient cations were highest in teagarden and lowest in grass/ scrubland, respectively.

Available Fe (mg kg^{-1}), Mn (mg kg^{-1}), Zn (mg kg^{-1}) and Cu (mg kg^{-1}) of surface soils in low-hill soil zone of Panchrukhi block ranged from 5 to 22, 0.4 to 7.8, 0.2 to 1.3 and 0.1 to 0.5, respectively (Tables 4.12 and 4.14). Mean Fe, Mn, Zn and Cu values were highest in Bhirdi (18 mg kg^{-1}); Bhuana (5.1 mg kg^{-1}); Andretta (0.8 mg kg^{-1}) and Agojar (0.3 mg kg^{-1}) panchayats and lowest in Check (13 mg kg^{-1}), Simbal (1.2 mg kg^{-1}), Darug (0.4 mg kg^{-1}) and Darug (0.2 mg kg^{-1}) panchayats, respectively. While comparing different land uses, mean values of micronutrient cations were highest in forest and lowest in grass/ scrubland, respectively.

Available Fe (mg kg^{-1}), Mn (mg kg^{-1}), Zn (mg kg^{-1}) and Cu (mg kg^{-1}) of surface soils in Panchrukhi block as a whole ranged from 5 to 82, 0.3 to 24.1, 0.2 to 1.8 and 0.1 to 0.6 mg kg^{-1}, respectively (Tables 4.11 to 4.14). While comparing different land uses, mean values of micronutrient cations were highest in tea garden and lowest in grass/ scrub land.

The spatial soil variation in the study area with respect to above-mentioned physical and chemical attributes of a soil may be explained in the light of the pedological concept given by Jenny (1942). At any specific location on earth's surface, at least five factors *viz.*, parent material, climate, relief, biosphere and time or age are acting simultaneously to produce a soil. These factors are not of equal significance in the development of different soils. Although some of them may be more effective in determining nature of soils under a particular set of conditions, all of them are inter-related and complement one another and are expressed by the relationship of these five factors to the soil properties by the equation:

$S= f(cl, b, r, p, t....)$;

where, S= any soil property (pH, organic carbon, texture etc.), f= function of or dependent upon, cl=climate, b= biosphere (vegetation, organisms, man), r= relief or topography, p=parent material and t= time or age.

Table 4.11 Distribution of available Fe and Mn under different land uses in mid-hill soil zone

Panchayat	Fe (mg kg^{-1})					Mn (mg kg^{-1})				
	Cropland	Tea garden	Forest	Grass/scrub land	Overall	Cropland	Tea garden	Forest	Grass/scrub land	Overall
1.Badehar	39-52 (46)	62-71 (67)	47-51 (48)	9-12 (11)	9-71 (25)	0.8-2.3 (1.6)	11.2-17.2 (14.2)	5.2-8.8 (7.0)	0.7-1.4 (1.1)	0.7-17.2 (11.2)
2.Bandbihar	18-37 (29)	-	28-37 (32)	7-11 (10)	7-37 (21)	4.4-6.7 (5.1)	-	6.3-9.5 (4.9)	3.1-4.4 (3.8)	3.1-9.5 (4.6)
3.Banuri Khas	59-71 (65)	71-82 (77)	51-69 (59)	11-19 (15)	11-82 (59)	4.4-5.1 (4.7)	16.3-19.2 (17.8)	10.8-12.9 (11.8)	3.5-4.8 (4.2)	3.5-19.2 (9.5)
4.Bharwana	21-47 (32)	42-56 (49)	36-43 (38)	5-11 (8)	5-56 (29)	2.8-4.1 (3.4)	11.2-14.5 (12.9)	7.3-8.1 (7.7)	2.3-3.5 (2.9)	2.3-14.5 (6.8)
5.Biara	51-63 (38)	67-82 (75)	31-47 (39)	14-21 (16)	14-82 (43)	3.3-3.6 (3.5)	18.6-21.2 (19.9)	9.2-10.4 (9.8)	3.1-3.7 (3.4)	3.1-21.2 (9.3)
6.Chandropa	39-52 (46)	56-61 (59)	35-43 (39)	10-15 (13)	10-61 (40)	1.9-2.5 (2.2)	9.2-12.6 (10.9)	5.8-6.4 (6.1)	1.2-2.3 (1.6)	1.2-12.6 (5.7)
7.Deogran	18-24 (21)	33-49 (41)	31-44 (37)	7-12 (10)	7-49 (22)	4.9-6.5 (5.9)	11.3-15.7 (13.5)	7.3-8.3 (7.8)	0.6-1.8 (1.2)	0.6-15.7 (7.6)
8.Gadiara	16-25 (21)	35-42 (39)	34-39 (36)	8-12 (10)	8-42 (21)	5.5-6.3 (5.9)	9.5-14.3 (11.9)	7.7-8.5 (8.1)	0.5-3.3 (1.9)	0.5-14.3 (6.7)
9.Jandpur	32-61 (50)	56-78 (67)	39-52 (47)	8-13 (10)	8-78 (42)	5.7-6.8 (6.2)	8.3-12.5 (10.4)	7.9-8.6 (8.2)	0.8-1.5 (1.1)	0.8-12.5 (6.9)
10.Ladoh	21-42 (31)	36-51 (44)	37-49 (41)	9-16 (13)	9-51 (27)	6.3-7.8 (7.0)	12.9-17.1 (15.0)	5.9-8.3 (7.1)	1.1-1.3 (1.2)	1.1-17.1 (8.1)
11.Mahal Banuri	49-69 (59)	64-78 (71)	56-68 (61)	11-17 (14)	11-78 (47)	6.2-7.1 (6.7)	19.2-24.2 (21.7)	9.7-11.4 (10.0)	4.7-5.1 (4.9)	5.3-24.2 (11.2)
12.Mahal Holta	39-51 (45)	49-65 (57)	54-61 (57)	11-26 (19)	11-65 (42)	6.8-7.4 (7.1)	14.2-18.4 (16.3)	8.8-10.9 (9.8)	5.1-5.4 (5.2)	5.1-18.4 (10.1)
13.Moulichak	29-52 (42)	58-72 (65)	45-59 (51)	12-21 (16)	12-72 (39)	6.8-7.6 (7.2)	14.6-16.3 (15.5)	8.8-9.7 (9.3)	4.9-5.2 (5.1)	4.9-16.3 (9.6)

Panchayat	Fe (mg kg^{-1})					Mn (mg kg^{-1})				
	Cropland	Tea garden	Forest	Grass/scrub land	Overall	Cropland	Tea garden	Forest	Grass/scrub land	Overall
14.Nouri Jhikli	29-47 (32)	-	31-41 (36)	8-14 (11)	8-57 (29)	0.8-2.5 (1.7)	-	5.4-5.9 (5.7)	0.8-1.9 (1.4)	0.8-5.9 (3.3)
15.Padiharkhar	28-47 (36)	-	35-41 (38)	9-15 (12)	9-47 (26)	2.7-3.2 (3.0)	-	6.3-7.9 (7.1)	2.5-4.3 (3.3)	2.5-7.9 (4.7)
16.Rajpur	42-62 (53)	55-69 (62)	46-53 (50)	18-25 (21)	18-69 (45)	1.9-2.9 (2.4)	16.2-19.6 (17.9)	6.8-8.1 (7.7)	2.3-5.2 (3.5)	2.3-19.6 (8.1)
17.Rajot	27-42 (34)	-	38-48 (41)	7-10 (9)	7-48 (25)	0.9-3.2 (2.1)	-	5.3-6.8 (6.2)	0.3-0.7 (0.5)	0.3-6.8 (3.2)
18.Rakkar Bheri	23-41 (35)	-	37-46 (39)	9-13 (11)	9-46 (24)	3.1-3.6 (3.4)	-	5.7-6.2 (5.9)	1.3-2.1 (1.7)	1.3-6.2 (3.9)
19.Sagoor Khas	27-45 (36)	-	31-42 (36)	11-14 (13)	11-42 (27)	0.7-0.9 (0.8)	-	6.2-7.1 (6.9)	0.6-0.8 (0.7)	0.6-7.1 (3.1)
20.Saliana	25-42 (33)	47-65 (56)	38-41 (39)	5-11 (7)	5-65 (27)	3.6-4.3 (4.0)	17.6-21.3 (19.5)	7.3-8.4 (8.1)	2.3-4.4 (3.5)	2.3-21.3 (8.2)
21.Simbal Khola	25-51 (39)	-	37-43 (40)	5-13 (9)	5-51 (26)	2.4-3.9 (3.2)	-	5.9-6.5 (6.1)	0.8-4.3 (2.5)	0.8-6.5 (4.4)
22.Sungal	39-51 (50)	59-71 (65)	41-65 (51)	6-9 (8)	6-71 (41)	2.4-3.9 (3.2)	19.3-23.3 (21.3)	6.3-7.2 (6.9)	2.1-2.9 (2.5)	2.1-23.3 (8.8)
23.Tanda	56-78 (66)	69-82 (76)	48-65 (56)	12-17 (15)	12-82 (49)	5.7-6.9 (6.3)	21.7-24.1 (22.9)	9.6-12.4 (11.1)	4.6-5.1 (4.9)	4.6-24.1 (11.4)
24.Tikkar Khas	27-48 (37)	-	45-51 (48)	8-13 (10)	8-51 (29)	0.9-3.5 (2.2)	-	5.8-6.6 (6.2)	0.5-1.6 (1.0)	0.5-6.6 (3.8)
25. Tarhail	35-57 (46)	-	39-59 (45)	7-15 (12)	7-57 (32)	4.6-5.8 (5.2)	-	6.3-7.9 (7.4)	0.5-2.1 (1.3)	0.5-7.9 (4.9)
26.Tatahail	27-45 (34)	-	32-39 (34)	9-12 (11)	9-45 (24)	0.8-3.1 (1.9)	-	5.9-6.5 (6.3)	0.8-3.4 (2.1)	0.8-6.5 (3.6)
Mid-hill soil zone	**16-63 (45)**	**36-82 (63)**	**28-69 (49)**	**5-26 (15)**	**5-82 (49)**	**0.7-7.8 (4.4)**	**8.3-24.1 (16.9)**	**5.2-12.9 (8.1)**	**0.3-5.4 (2.9)**	**0.3-24.1 (9.1)**

Values in parentheses indicate mean values
"-" indicate non-existence

Table 4.12 Distribution of available Fe and Mn under different land uses in low-hill soil zone

Panchayat	Fe (mg kg^{-1})					Mn (mg kg^{-1})				
	Cropland	Tea garden	Forest	Grass/scrub land	Overall	Cropland	Tea garden	Forest	Grass/scrub land	Overall
1.Andretta	7-14 (10)	-	12-19 (16)	10-14 (12)	7-19 (15)	3.4-4.2 (3.9)	-	3.9-7.1 (4.7)	2.1-2.9 (2.6)	2.1-7.1 (3.9)
2.Agojar	9-15 (11)	-	9-16 (12)	7-10 (9)	7-16 (14)	5.8-6.7 (6.1)	-	4.8-6.4 (5.1)	2.7-3.4 (3.1)	2.7-6.7 (4.9)
3.Bhirdi	14-18 (16)	-	15-22 (19)	5-9 (7)	5-22 (18)	1.5-2.5 (1.9)	-	3.4-4.8 (4.1)	1.7-2.8 (2.3)	1.5-4.8 (2.9)
4.Bhulana	15-18 (17)	-	12-19 (16)	7-9 (8)	7-19 (16)	0.8-1.4 (1.1)	-	6.7-7.8 (7.1)	0.6-1.1 (0.9)	0.6-7.8 (3.5)
5.Bhuana	9-13 (11)	-	11-17 (10)	6-8 (7)	6-17 (15)	3.3-4.1 (3.6)	-	4.3-6.1 (5.7)	2.1-3.2 (6.1)	2.1-6.1 (5.1)
6.Chadiar	13-17 (15)	-	17-21 (18)	6-8 (7)	6-21 (16)	2.4-3.9 (3.1)	-	1.4-2.3 (1.9)	0.8-1.7 (1.3)	0.8-3.9 (2.4)
7.Check	8-12 (10)	-	9-16 (12)	5-8 (7)	5-16 (13)	0.9-1.2 (1.1)	-	1.9-2.8 (2.4)	0.4-1.7 (1.1)	0.4-2.8 (1.8)
8.[illegible]	11-14 (13)	-	11-16 (14)	6-8 (7)	6-16 (14)	0.8-2.2 (1.5)	-	1.7-2.6 (2.1)	0.5-1.1 (1.0)	0.5-2.6 (1.8)
9.Kailaspur	8-13 (10)	-	13-19 (16)	6-7 (7)	6-19 (15)	0.8-1.9 (1.4)	-	4.1-5.4 (4.9)	0.7-2.0 (1.5)	0.7-5.4 (2.9)
10.Makol	9-11 (10)	-	12-17 (15)	5-8 (7)	5-17 (15)	0.8-1.5 (1.3)	-	1.1-1.9 (1.6)	0.4-1.3 (1.1)	0.4-1.9 (1.5)
11.Simbal	8-11 (9)	-	13-18 (16)	6-11 (9)	6-18 (15)	0.8-1.8 (1.3)	-	1.2-2.1 (1.6)	0.5-1.4 (0.8)	0.5-2.1 (1.2)
Low-hill soil zone	**7-18 (12)**	-	**9-22 (17)**	**5-14 (8)**	**5-22 (15)**	**0.8-6.7 (2.7)**	-	**1.1 -7.8 (3.9)**	**0.4-3.4 (2.1)**	**0.4-7.8 (2.9)**
Panchrukhi block	**7-63 (22)**	**36-82 (61)**	**9-69 (29)**	**5-26 (9)**	**5-82 (33)**	**0.7-7.8 (3.6)**	**8.3-24.1 (16.9)**	**1.1-12.9 (5.7)**	**0.3-5.4 (2.4)**	**0.3-24.1 (6.9)**

Values in parentheses indicate mean values
"-" indicate non-existence

Table 4.13 Distribution of available Zn and Cu in soils under different land uses in mid-hill soil zone

Panchayat	Zn ($mg\ kg^{-1}$)					Cu ($mg\ kg^{-1}$)				
	Cropland	Tea garden	Forest	Grass/scrub land	Overall	Cropland	Tea garden	Forest	Grass/scrub land	Overall
1.Badehar	0.5-1.1 (0.7)	1.1-1.4 (1.3)	0.8-1.1 (0.9)	0.3-1.1 (0.7)	0.3-1.4 (1.0)	0.2-0.3 (0.3)	0.2-0.4 (0.3)	0.2-0.5 (0.4)	0.1-0.3 (0.2)	0.1-0.5 (0.3)
2.Bandbihar	1.0-1.2 (1.2)	-	0.9-1.4 (1.2)	0.5-1.1 (0.9)	0.5-1.4 (1.1)	0.1-0.3 (0.2)	-	0.2-0.3 (0.2)	0.1-0.2 (0.2)	0.1-0.3 (0.2)
3.Banuri Khas	1.2-1.3 (1.3)	1.5-1.8 (1.7)	1.2-1.4 (1.3)	0.9-1.2 (1.2)	0.9-1.8 (1.4)	0.2-0.3 (0.3)	0.3-0.5 (0.5)	0.3-0.5 (0.4)	0.1-0.3 (0.2)	0.1-0.5 (0.4)
4.Bharwana	0.8-1.2 (1.1)	1.3-1.6 (1.5)	0.9-1.1 (1.0)	0.5-1.1 (0.8)	0.5-1.6 (1.1)	0.2-0.3 (0.3)	0.4-0.5 (0.5)	0.2-0.3 (0.3)	0.2-0.3 (0.2)	0.2-0.5 (0.3)
5.Biara	1.1-1.2 (1.2)	1.1-1.3 (1.2)	0.7-0.9 (0.8)	0.5-0.9 (0.7)	0.5-1.3 (0.9)	0.2-0.3 (0.3)	0.3-0.4 (0.4)	0.2-0.3 (0.3)	0.1-0.2 (0.2)	0.1-0.4 (0.2)
6.Chandropa	0.5-1.1 (0.8)	0.9-1.2 (1.1)	0.4-0.6 (0.5)	0.4-0.9 (0.6)	0.4-1.1 (0.6)	0.2-0.3 (0.2)	0.5-0.6 (0.6)	0.3-0.4 (0.4)	0.2-0.3 (0.2)	0.2-0.6 (0.5)
7.Deogran	0.5-1.2 (0.9)	1.1-1.3 (1.2)	0.7-1.1 (0.9)	0.2-0.7 (0.4)	0.2-1.3 (0.8)	0.1-0.2 (0.2)	0.2-0.4 (0.3)	0.2-0.3 (0.3)	0.1-0.2 (0.2)	0.1-0.4 (0.3)
8.Gadiara	0.8-1.2 (1.0)	1.4-1.7 (1.6)	0.9-1.2 (1.1)	0.5-0.6 (0.6)	0.5-1.7 (1.3)	0.2-0.3 (0.3)	0.4-0.5 (0.5)	0.2-0.4 (0.3)	0.2-0.3 (0.3)	0.2-0.5 (0.4)
9.Jandpur	0.9-1.2 (1.1)	1.2-1.3 (1.3)	0.6-0.8 (1.0)	0.5-0.8 (0.7)	0.5-1.3 (1.1)	0.2-0.3 (0.3)	0.4-0.5 (0.5)	0.2-0.3 (0.3)	0.2-0.3 (0.2)	0.2-0.5 (0.4)
10.Ladoh	0.9-1.1 (1.0)	1.4-1.5 (1.5)	0.9-1.2 (1.1)	0.5-1.1 (0.8)	0.5-1.5 (1.1)	0.2-0.3 (0.2)	0.3-0.4 (0.4)	0.2-0.3 (0.3)	0.2-0.3 (0.2)	0.2-0.4 (0.2)
11.Mahal Banuri	1.1-1.3 (1.2)	1.4-1.6 (1.5)	1.2-1.4 (1.3)	1.1-1.2 (1.2)	1.1-1.6 (1.4)	0.2-0.3 (0.3)	0.4-0.6 (0.6)	0.3-0.5 (0.4)	0.2-0.3 (0.3)	0.2-0.6 (0.5)
12.Mahal Holta	1.2-1.3 (1.2)	1.4-1.6 (1.5)	0.8-1.1 (1.0)	1.1-1.2 (1.2)	0.8-1.6 (1.3)	0.2-0.3 (0.3)	0.4-0.6 (0.5)	0.3-0.5 (0.4)	0.2-0.3 (0.2)	0.2-0.6 (0.4)
13.Moulichak	1.1-1.3 (1.2)	0.9-1.5 (1.2)	0.7-0.9 (0.8)	0.4-0.9 (0.7)	0.4-1.5 (1.0)	0.2-0.3 (0.3)	0.4-0.5 (0.4)	0.2-0.3 (0.2)	0.2-0.3 (0.2)	0.2-0.5 (0.3)

Panchayat	Zn (mg kg^{-1})					Cu (mg kg^{-1})				
	Cropland	Tea garden	Forest	Grass/scrub land	Overall	Cropland	Tea garden	Forest	Grass/scrub land	Overall
14. Nouri Jhikli	0.4-0.9 (0.7)	-	0.5-0.7 (0.6)	0.3-0.7 (0.4)	0.4-0.9 (0.8)	0.2-0.3 (0.2)	-	0.2-0.3 (0.3)	0.1-0.2 (0.2)	0.1-0.3 (0.2)
15. Padiharkhar	0.5-1.1 (0.7)	-	0.6-0.7 (0.7)	0.6-0.8 (0.7)	0.5-1.1 (0.9)	0.2-0.3 (0.3)	-	0.2-0.3 (0.3)	0.2-0.3 (0.3)	0.2-0.3 (0.3)
16. Rajpur	1.1-1.3 (1.2)	1.2-1.5 (1.4)	0.4-0.8 (0.6)	0.3-0.7 (0.5)	0.3-1.5 (0.6)	0.2-0.3 (0.3)	0.3-0.5 (0.4)	0.2-0.3 (0.3)	0.2-0.3 (0.2)	0.2-0.5 (0.3)
17. Rajot	0.4-0.9 (0.7)	-	0.6-0.9 (0.7)	0.3-0.8 (0.6)	0.3-0.9 (0.5)	0.2-0.3 (0.3)	-	0.2-0.3 (0.3)	0.1-0.2 (0.2)	0.1-0.3 (0.3)
18. Rakkar Bheri	0.5-0.9 (0.6)	-	0.4-0.6 (0.5)	0.2-0.7 (0.4)	0.2-0.9 (0.8)	0.1-0.2 (0.2)	-	0.2-0.3 (0.3)	0.1-0.2 (0.2)	0.1-0.3 (0.2)
19. Sagoor Khas	0.5-0.7 (0.6)	-	0.5-0.8 (0.6)	0.3-0.7 (0.7)	0.3-0.8 (0.6)	0.2-0.3 (0.3)	-	0.2-0.3 (0.3)	0.1-0.2 (0.2)	0.1-0.3 (0.3)
20. Saliana	0.4-0.9 (0.6)	0.9-1.3 (1.1)	0.5-0.7 (0.6)	0.2-0.8 (0.5)	0.2-1.3 (0.7)	0.2-0.3 (0.3)	0.3-0.4 (0.4)	0.20.3 (0.3)	0.1-0.2 (0.1)	0.1-0.4 (0.3)
21. Simbal Khola	0.4-0.8 (0.6)	-	0.5-0.7 (0.6)	0.4-0.7 (0.5)	0.4-0.8 (0.6)	0.2-0.3 (0.3)	-	0.2-0.3 (0.3)	0.1-0.2 (0.2)	0.1-0.4 (0.3)
22. Sungal	1.2-1.3 (1.3)	1.5-1.7 (1.6)	0.9-1.3 (1.1)	0.7-0.8 (0.8)	0.7-1.7 (1.2)	0.2-0.3 (0.3)	0.3-0.5 (0.4)	0.2-0.3 (0.3)	0.2-0.3 (0.2)	0.2-0.5 (0.3)
23. Tanda	0.9-1.3 (1.2)	1.6-1.8 (1.7)	0.7-1.1 (0.9)	0.9-1.1 (1.0)	0.7-1.8 (1.2)	0.2-0.3 (0.3)	0.3-0.5 (0.4)	0.3-0.4 (0.4)	0.2-0.3 (0.3)	0.2-0.5 (0.4)
24. Tikkar Khas	0.5-0.8 (0.6)	-	1.2-1.4 (1.3)	0.3-0.7 (0.5)	0.3-1.4 (0.8)	0.1-0.2 (0.2)	-	0.2-0.3 (0.3)	0.1-0.2 (0.2)	0.1-0.3 (0.2)
25. Tarhail	0.7-1.1 (0.9)	-	0.5-0.7 (0.6)	0.3-0.7 (0.5)	0.3-1.1 (0.7)	0.2-0.3 (0.3)	-	0.2-0.3 (0.3)	0.1-0.2 (0.2)	0.1-0.3 (0.3)
26. Tatahail	0.9-1.2 (1.1)	-	0.4-0.7 (0.6)	0.3-0.7 (0.6)	0.3-1.2 (0.8)	0.1-0.3 (0.2)	-	0.2-0.3 (0.3)	0.1-0.2 (0.2)	0.1-0.3 (0.3)
Mid-hill soil zone	**0.3-1.3 (0.9)**	**0.9-1.8 (1.6)**	**0.4-1.4 (1.3)**	**0.2-1.2 (0.7)**	**0.3-2.6 (1.4)**	**0.1-0.3 (0.3)**	**0.2-0.6 (0.4)**	**0.2-0.5 (0.3)**	**0.1-0.3 (0.2)**	**0.1-0.6 (0.3)**

Values in parentheses indicate mean values
"-" indicate non-existence

Table 4.14 Distribution of available Zn and Cu in soils under different land uses in low-hill soil zone

Panchayat	Zn (mg kg^{-1})					Cu (mg kg^{-1})				
	Cropland	Tea garden	Forest	Grass/scrub land	Overall	Cropland	Tea garden	Forest	Grass/scrub land	Overall
1.Andretta	0.8-1.0 (0.9)	-	0.7-1.3 (1.0)	0.4-0.6 (0.5)	0.4-1.3 (0.8)	0.2-0.3 (0.3)	-	0.3-0.5 (0.3)	0.2-0.3 (0.3)	0.2-0.5 (0.3)
2.Agojar	0.9-1.0 (1.0)	-	0.8-1.1 (0.9)	0.2-0.5 (0.4)	0.2-1.1 (0.7)	0.2-0.4 (0.3)	-	0.3-0.5 (0.4)	0.2-0.3 (0.3)	0.2-0.5 (0.3)
3.Bhirdi	0.7-0.9 (0.7)	-	0.6-1.3 (1.0)	0.4-0.7 (0.6)	0.4-1.3 (0.7)	0.3-0.4 (0.4)	-	0.2-0.4 (0.3)	0.2-0.3 (0.3)	0.2-0.4 (0.3)
4.Bhulana	0.5-0.8 (0.6)	-	0.6-1.1 (0.9)	0.2-0.4 (0.3)	0.2-1.1 (0.7)	0.1-0.3 (0.3)	-	0.2-0.4 (0.3)	0.2-0.3 (0.2)	0.1-0.4 (0.3)
5.Bhuana	0.4-0.9 (0.6)	-	0.8-1.2 (1.0)	0.3-0.5 (0.4)	0.3-1.2 (0.6)	0.2-0.4 (0.3)	-	0.2-0.4 (0.3)	0.2-0.3 (0.2)	0.2-0.4 (0.3)
6.Chadiar	0.6-0.9 (0.7)	-	0.8-1.3 (1.1)	0.3-0.5 (0.4)	0.3-1.3 (0.7)	0.3-0.4 (0.4)	-	0.2-0.3 (0.3)	0.2-0.3 (0.2)	0.2-0.4 (0.3)
7.Check	0.2-0.7 (0.4)	-	0.4-0.9 (0.6)	0.2-0.4 (0.3)	0.2-0.9 (0.5)	0.1-0.3 (0.2)	-	0.1-0.3 (0.2)	0.1-0.2 (0.2)	0.1-0.3 (0.2)
8.Darug	0.3-0.5 (0.5)	-	0.3-0.7 (0.5)	0.2-0.5 (0.4)	0.2-0.7 (0.4)	0.1-0.2 (0.2)	-	0.1-0.3 (0.2)	0.1-0.2 (0.2)	0.1-0.3 (0.2)
9.Kailaspur	0.3-0.8 (0.5)	-	0.4-1.1 (0.7)	0.3-0.6 (0.5)	0.3-1.1 (0.7)	0.2-0.3 (0.3)	-	0.2-0.3 (0.3)	0.1-0.2 (0.2)	0.1-0.3 (0.3)
10.Makol	0.4-0.7 (0.6)		0.3-0.9 (0.7)	0.2-0.4 (0.3)	0.2-0.9 (0.5)	0.1-0.3 (0.2)	-	0.2-0.3 (0.3)	0.1-0.2 (0.2)	0.1-0.2 (0.2)
11.Simbal	0.4-0.6 (0.5)	-	0.4-0.7 (0.6)	0.3-0.4 (0.4)	0.3-0.7 (0.5)	0.1-0.2 (0.2)	-	0.2-0.3 (0.2)	0.1-0.2 (0.2)	0.1-0.3 (0.2)
Low-hill soil zone	**0.2-1.0 (0.7)**	-	**0.6-1.3 (0.9)**	**0.2-0.7 (0.4)**	**0.2-1.3 (0.6)**	**0.1-0.4 (0.3)**	-	**0.1-0.5 (0.3)**	**0.1-0.3 (0.2)**	**0.1-0.5 (0.3)**
Panchrukhi block	**0.2-1.3 (0.6)**	**0.9-1.8 (1.6)**	**0.4-1.4 (0.9)**	**0.2-1.2 (0.4)**	**0.2-1.8 (0.7)**	**0.1-0.4 (0.3)**	**0.2-0.6 (0.4)**	**0.2-0.5 (0.3)**	**0.1-0.3 (0.2)**	**0.1-0.6 (0.3)**

Values in parentheses indicate mean values
"-" indicate non-existence

Thus, any soil property is a function of the collective effects of all the five soil forming factors. These factors develop the soils by determining the rate and type of soil forming processes operating in an area. As evident from the Chapter 3, study area has different parent materials, topography, biosphere and time. The study area comprised of Shivalik hills and fluvio-glacial terraces and therefore differed in geological formations. Wadia *et al.* (1934) believed that fundamental character of Indian soil groups remained more or less the same as that of the geological formations from which they were derived. Soils of mid-hill soil zone are derived from fluvio-glacial terraces while those of low-hill soil zone from conglomerates. Similar type of results has also been obtained by many workers (Tiwari and Awasthi 1978; Verma and Tripathi 1982; Kaistha and Gupta 1993; Mahajan 2001 and Sharma and Kumar 2003). Though type of parent material within a soil zone is almost same, difference in soil properties may be attributed to spatial variation in topography and biosphere.

Higher exchangeable Ca and Mg and therefore, soil pH values in low hill as *compared to mid hill zone may be ascribed to the presence of higher amounts of* these nutrients in the parent material i.e. conglomeritic strata. Differences in soil and management practices within and between land uses also account for variation in available nutrient contents. Grass/ scrub and forest land in the study area are suffering from soil erosion problems. Majority of the forests are open and requires afforestation intervention.

4.3 Available nutrient status in surface soils

4.3.1 Macro-nutrients

On the basis of Soil Nutrient Index (SNI) values, available N, P, K and S status of surface soils in mid-hill soil zone ranged from low to high, low, medium to high and low to high, respectively (Appendices I and III). Soils of cropland, tea garden, forest and grass/ scrubland were medium, high, medium and low in available N; medium, low, low and low in available P; medium, high, medium and medium in available K and medium, high, medium and low in available S, respectively. Out of 26 panchayats, 5 (19%), 16 (62%) and 5 (19%) panchayats were low, medium and high in available N; 15 (58%) and 11 (42%) panchayats were low and medium in available P; 8 (31%), 12 (46%) and 6 (23%) panchayats were low, medium and high in available K and 6 (23%), 17 (65%) and 3 (12%) panchayats were low, medium and high in available S, respectively.

Available N, P, K and S status of surface soils in low-hill soil zone were low, low, low to medium and low, respectively (Appendices II and IV). Soils of cropland, forest and grass/ scrub land were low, low and low in available N; low, low and low in available P; medium, medium and low in available K and low, low and low in available S, respectively. Out of 11 panchayats, 6 (55%), 4 (36%) and 1 (9%) panchayats were low, medium and high in available N; 10 (91%) and 1 (9%) panchayats were low and medium in available P; 3 (27%) and 8 (73%) panchayats were low and medium in available K and 7 (64%) and 4 (36%) panchayats were low and medium in available S, respectively.

While comparing available N, P, K and S status under all the land uses as well as in panchayats of both the zones, it was observed that mid-hill soil zone has better nutrient status than low-hill soil zone.

Available N, P, K and S status of surface soils in Panchrukhi block were medium, low, medium and medium, respectively (Appendices I to IV). Out of 346 samples analysed, 55, 244 and 47 samples in available N; 107, 239 and 0 samples in available P; 53, 242 and 51 samples in available K and 72, 244 and 30 samples in available S, fell in the category low, medium and high, respectively (Appendix VII).

As regards available Ca and Mg, all the panchayats as well as soil samples analysed were sufficient in these nutrients (Appendix VII).

4.3.2 Micro-nutrient cations

Though available Fe was in sufficient amounts in all panchayats and under different land uses, available Mn, Zn and Cu were found to be deficient in different panchayats and land uses in mid-hill soil zone (Appendix V). Soils under cropland, tea garden, forest and grass/ scrub land were deficient, sufficient, sufficient and deficient in available Mn; deficient, sufficient, deficient and deficient in available Zn and deficient, sufficient, deficient and deficient in available Cu, respectively. Out of 26 panchayats, 11 (42%), 20 (77%) and 14 (54%) panchayats were deficient in available Mn, Zn and Cu, respectively.

Like mid-hill soil zone, available Fe was also in sufficient amounts in all panchayats and under different land uses in low-hill soil zone. However, deficiency of available Mn, Zn and Cu were observed under different panchayats and land uses (Appendix VI). Soils of cropland, forest and grass/ scrub land were deficient, sufficient and deficient in available Mn; deficient, deficient and deficient in available Zn and deficient, deficient and deficient in available Cu, respectively. Out of 11 panchayats, 7 (64%), 11 (100%) and 6 (55%) panchayats were deficient in available Mn, Zn and Cu, respectively.

While comparing available Fe, Mn, Zn and Cu status under all the land uses as well as in panchayats of both the zones, it was observed that mid-hill soil zone has better status than low-hill zone.

Irrespective of panchayat and land use, available Fe was found to be in sufficient content, however, a deficiency of available Mn, Zn and Cu were observed in Panchrukhi block as a whole (Appendices V and VI). Out of 346 samples analysed, 42, 83 and 23 samples fell in deficient category in available Mn, Zn and Cu contents, respectively (Appendix VIII).

A persual of results on available nutrient status revealed that soils differ considerably in soil fertility or available nutrient status from place to place. It is obvious because of the reason that soil fertility is controlled by pedogenic factors and land use/ management practices. The fertility of a soil depends, to a great extent, on the chemical composition of the parent material from which it has developed. Topography influences soil fertility through its effect on drainage, run-off, soil erosion and microclimate i.e. exposure of land surface to the sun and wind. The soils on the upper slope are less fertile than the soils on lower slope. It is because of high leaching and erosion of upper soils. The span of period from the inception of soil development to the present stage is termed as soil age. This may vary from a few years to several thousand years. Very old soils often become unfertile because of intensive crop raising for years which disrobes the soil of its capacity to provide nutrients. Similarly, very young soils on which soil formation process is still operative are also less fertile than mature soils. Climate includes precipitation, temperature, humidity and wind. These climatic factors influence soil fertility very much. In high rainfall areas, soluble nutrients leach down to the lower horizons of the soil and thus become unavailable to the crop plants. Similarly, temperature also influences soil fertility. In tropical or subtropical climate, decomposition of organic matter is faster and easier than in temperate climate.

Therefore, soils of tropical and subtropical regions are less fertile than those of temperate regions (Sehgal and Abrol 1994).

The micronutrient content of soil is determined by the chemical composition of its parent material. Both deficiency and toxicity of micronutrients in soil is related to the low or toxic content of the micronutrients in the parent materials and minerals from which the soils has developed. The distribution of micronutrient is not uniform in the soil and the spatial variation is very high, the natural sources of micronutrients in soil vary considerably from soil to soil. Besides inorganic minerals, organic matter also contributes substantially to the total content of micronutrients in the surface soils. Variability in total micronutrient content of the soils is a mirror of the diversity in parent materials from which these have originated. The total content of micronutrients is a poor predictor of their supplying power to the plants. It is the soil available pool that represents the native level (Tisdale *et al.* 1984).

In Panchrukhi block, mid-hill and low-hill soil zones are dominated by perennial and ephemeral streams, respectively. The cultivated areas of the block are dominated by paddy-wheat and maize-wheat cropping sequences. Farmers mostly grow local varieties of these crops using traditional methods of farming and are always eager to adopt scientific agro-technologies for obtaining higher yields. They apply about FYM @ 5 Mg ha^{-1} to both the crops, urea alone @ 3-5 kg per kanal to maize/ paddy and IFFCO 12:32:16/ urea @ 3 to 5 kg per kanal only to wheat. Very few farmers apply fertilizers on soil test basis. A few tea gardeners apply 60-70 kg N, 30-40 kg P_2O_5 and 30-40 kg K_2O ha^{-1} in the form of ammonium sulphate, single super sulphate and potassium sulphate, respectively. Majority of forests in the panchayats are open and are used for grazing animals. Soil and water management practices in forest and grass/ scrub lands are almost nil. None of farmers use fertilizers in non-arable lands. Non-arable lands are moderately to severely eroded.

4.4 Soil properties in representative soil profiles

On the basis of available soil survey reports, eight and six representative soil profiles were exposed in mid- and low-hill soil zone to fulfil the objectives of the present investigation. Taxonomic nomenclature has been defined on the basis istics and properties studied (Tables 4.15 and 4.16). Soils of mid-hill soil zone have been classified into four subgroups *viz.*, *Typic Dystrudepts, Typic Hapludalfs, Typic Paleudalfs and Lithic Udorthents*, whereas those of low-hill soil zone belong to *Typic Eutrudepts* and *Typic Udorthents.*

According to Sehgal and Abrol (1994), soils of the study area under agricultural and non-agricultural land uses belong to *Typic Dystrudept, Typic Hapludalf, Typic Paleudalfs, Lithic Udorthents, Typic Eutrudepts and Typic Udorthents.* There exists a soil-landform relationship in Panchrukhi block. Extremely to moderately steep lands have *Udorthents*, moderately sloping lands comprise of Dystrudepts and *Eutrudepts*, and gently to very gently lands have *Hapludalf* and *Paleudalfs.*

Soils also showed differences in horizon development on the basis of pedological time. There was a considerable homogeneity in horizonation in Sungal, Chandropa, Biara and Holta Bharmat soils under different land uses and are characterized by the presence of Ap/A and argillic (Bt1, Bt2...) horizons (Tables 4.15 and 4.16). Similarly, soils of Tatahail, Nouri Jhikli and Simbal belong to *Inceptisols* and have Ap and cambic (Bw1, Bw2...) horizons. There was no evidence of soil profile development in Kalu-di-Hatti, Badehar, Bhirdi, Bhuana, Bhulana, Darug and Check have Ap/A-CA-C horizons. The soils of Sungal, Chandropa, Biara and Holta Bharmat in mid-hill soil zone were very deep (150+). On the contrary, the soils of Tatahail, Nouri Jhikli in mid-hill soil zone and Simbal, Bhirdi and Check in low-hill soil zone were moderately deep (75 to 120 cm) while those of Bhuana, Bhulana and Darug were moderately shallow (50 to 75 cm). Soils of mid-hill soil zone comprise of brown to dark yellowish brown and sandy loam to loam surface horizons and strong brown to dark yellow brown and sandy loam to silty clay loam subsurface horizon, where as those of low-hill soil zone are characterized by the presence of dark brown to dark yellowish brown and sandy loam surface as well as subsurface horizons.

4.4.1 Available nutrient contents

Available N (kg ha^{-1}), P (kg ha^{-1}), K (kg ha^{-1}), Ca {cmol (p+) kg^{-1}}, Mg {cmol (p+) kg^{-1}}, S (mg kg^{-1}), Fe (mg kg^{-1}), Mn (mg kg^{-1}), Zn (mg kg^{-1}) and Cu (mg kg^{-1}) contents in mid-hill soil zone ranged from 299 to 650, 6.8 to 13.4, 143 to 349, 1.8 to 2.7, 1.0 to 1.4, 10.2 to 23.2, 12 to 71, 0.8 to 21.1, 0.6 to 1.6 and 0.2 to 0.6 in surface soils and 105 to 273, 1.9 to 7.0, 91 to 376, 1.7 to 3.0, 0.6 to 2.2, 3.2 to 8.5,

Table 4.15 Important site-soil characteristics of representative soil profiles of mid-hill soil zone

Profile name	Location	Land slope	Land use type	Horizons		Soil colour (M)	Soil texture
				Symbol	Depth (cm)		
1.Tatahail	76°33'57" 32°01'12"	Moderately sloping (5-10%)	Cropland	Ap	0-17	10YR 4/3 (DB)	sl
				Bw1	17-40	7.5YR 4/4 (DB)	sl
				Bw2	40-75	7.5YR 3.5/4 (DB)	sl
				R	75+		
2.Nouri Jhikli	76°36'13" 32°03'42"	Moderately sloping (5-10%)	Cropland	Ap	0-15	10YR 4/4 (DYB)	sl
				Bw1	15-35	10YR 4/4 (DYB)	sl
				Bw2	35-51	10YR 3.5/4(DYB)	sl
				Bw3	51-81	10YR 3.5/4(DYB)	sl
				R	81+	10YR 3.5/4(DYB)	-
3.Sungal	76°35'18" 32°04'36"	Gently sloping (3-5%)	Cropland	Ap	0-16	10YR 4/3 (DB)	l
				AB	16-37	10YR 4/4 (DB)	l
				Bt1	37-65	10YR 3/5 (DB)	cl
				Bt2	65-112	10YR 3/4 (DB)	cl
				Bt3	112-155	10YR 4/5 (DB)	cl
4.Chandropa	76°32'34" 32°04'30"	Gently sloping (3-5%)	Tea garden	Ap	0-16	10YR 4/3 (DB)	l
				AB	16-37	10YR 4/3 (DB)	l
				Bt1	37-65	10YR 4/3 (DB)	cl
				Bt2	65-112	10YR 3/5 (DYB)	cl
				Bt3	112-155		-
5. Biera	76°34'25" 32°02'45"	Very gently sloping (1-3%)	Tea garden	Ap	0-16	10YR 4/3 (DB)	cl
				AB	16-34	7.5YR 3/3 (DB)	cl
				Bt1	34-60	7.5YR 3/5 (SB)	sicl
				Bt2	60-92	7.5YR 3/4 (DB)	sicl
				Bt3	92-155	7.5YR 4/4 (DB)	sicl
6.Kalu-di-Hatti	76°32'0" 32°04'45"	Steeply sloping (25-33%)	Forest	A	0-14	10YR 4/3 (B)	l
				AC	14-30	10YR 4/4 (DYB)	l
				Cr	30+	10YR 4/6 (DYB)	-
7.Holta Bharmat	76°34'08" 32°05'54"	Very gently sloping (1-3%)	Forest	A	0-19	10YR 4/3 (B)	l
				Bt1	19-43	10YR 4/4 (DYB)	cl
				Bt2	43-75	10YR 4/4 (DYB)	sicl
				Bt3	75-113	7.5YR 4/4 (DB)	sicl
				Bt4	113-152	7.5YR 4/4 (DB)	sicl
8.Badehar	76°32'23" 76°32'0"	Steeply sloping (25-33%)	Grass/ scrub land	A	0-19	10YR 3/2.5(DB)	sl
				AC	19-35	10YR 4/3 (DB)	sl
				R	35+		-

Note : B=brown, DB=dark brown, DYB=dark yellowish brown

Table 4.16 Important site-soil characteristics of representative soil profiles of low-hill soil zone

Profile name	Location	Land slope	Land use type	Horizon	Soil depth (cm)	Soil colour (M)	Soil texture
1. Simbal	76°38'31" 31°58'30"	Moderately sloping (5-10%)	Crop land	Ap	0-18	10YR 4/3 (DB)	sl
				AB	18-45	10YR 4/4 (DYB)	sl
				Bw1	45-65	10YR 3.5/4(DYB)	sl
				Bw2	65-83	10YR 3.5/4(DYB)	sl
				Bw3	83-112	10YR 3.5/4(DYB)	sl
				Cr	112+	-	
2. Bhirdi	76°38'22" 31°57'15"	Strongly sloping (10-15%)	Crop land	Ap	0-26	10YR 4/4 (DB)	sl
				CA1	26-51	10YR 4/5 (DYB)	sl
				CA2	51-89	10YR 4/4(DYB)	sl
				Cr	89+	-	
3. Bhuana	76°35'28" 32°24"0"	Extremely steep (>50%)	Forest	Ap	0-19	10YR 4/4 (DYB)	sl
				AC	19-45	10YR 4/5(DYB)	sl
				Cr	45+	-	
4. Bhulana	76°38'12" 31°58'0"	Moderately steep (15-25%)	Forest	Ap	0-20	10YR 4/4 (DYB)	sl
				CA1	20-40	10YR 4/5(DYB)	sl
				CA2	40-64	10YR 4/5(DYB)	sl
				Cr	64+	-	
5. Darug	76°37'37" 31°59'0"	Extremely steep (>50%)	Grass/ scrub land	Ap	0-21	10YR 4/6 (DYB)	sl
				CA1	21-48	7.5YR 4/3(DB)	sl
				CA2	48+	-	
6.Check	76°37'55" 31°57'0"	Moderately steep (15-25%)	Grass/ scrub land	Ap	0-21	10YR 4/6 (DYB)	sl
				CA1	21-46	7.5YR 4/3(DB)	sl
				CA2	46-80	7.5YR 4/3(DB)	sl
				Cr	80+	-	

Note: DB=dark brown, DYB=dark yellowish brown

9 to 85, 0.3 to 31.3, 0.1 to 1.2 and 0.1 to 0.3 in subsurface soils, respectively (Tables 4.17 to 4.19) . On an average, available N (kg ha^{-1}), P (kg ha^{-1}), K (kg ha^{-1}), Ca {cmol (p+) kg^{-1}}, Mg {cmol (p+) kg^{-1}}, S (mg kg^{-1}), Fe (mg kg^{-1}), Mn (mg kg^{-1}), Zn (mg kg^{-1}) and Cu (mg kg^{-1}) contents in surface horizons were 419, 8.6, 209, 2.5, 1.8, 11.3, 25, 4.4, 0.7 and 0.3 in *Entisols*, 475, 12.2, 253, 2.5, 1.3, 13.5, 35, 2.7, 1.1 and 0.3 in *Inceptisols* and 618, 11.7, 294, 2.6, 1.1, 21.9, 54, 11.9, 1.5 and 0.4 in *Alfisols*, respectively. Respective values of these parameters in subsoils were 178, 3.9, 161, 1.8, 1.3, 5.4, 19, 2.9, 0.3 and 0.2 in *Entisols*, 169, 4.1, 289, 2.9, 1.4, 6.7, 33, 3.2, 0.6 and 0.2 in *Inceptisols* and 205, 4.4, 347, 2.7, 1.8, 6.8, 65, 15.7, 0.8 and 0.2 in *Alfisols*, respectively.

Available N (kg ha^{-1}), P (kg ha^{-1}), K (kg ha^{-1}), Ca {cmol (p+) kg^{-1}}, Mg {cmol (p+) kg^{-1}}, S (mg kg^{-1}), Fe (mg kg^{-1}), Mn (mg kg^{-1}), Zn (mg kg^{-1}) and Cu (mg kg^{-1}) contents in low-hill soil zone (Tables 4.20 to 4.22) ranged from 137 to 427, 5.1 to 12.1, 96 to 212, 2.9 to 3.6, 1.1 to 1.9, 4.9 to 14.9, 8 to 22, 0.9 to 7.8, 0.3 to 0.9 and 0.1 to 0.3 in surface soils and 72 to 167, 2.4 to 6.4, 59 to 182, 1.3 to 3.5, 0.6 to 1.4, 1.8 to 9.4, 5 to 17, 0.5 to 4.7, 0.2 to 0.4 and 0.1 to 0.2 in subsurface soils, respectively (Tables 4.20 to 4.22). On an average, available N (kg ha^{-1}), P (kg ha^{-1}), K (kg ha^{-1}), Ca {cmol (p+) kg^{-1}}, Mg {cmol (p+) kg^{-1}}, S (mg kg^{-1}), Fe (mg kg^{-1}), Mn (mg kg^{-1}), Zn (mg kg^{-1}) and Cu (mg kg^{-1}) contents in surface horizons were 299, 8.9, 152, 3.2, 1.4, 9.3, 14, 3.8, 0.6 and 0.2 in *Entisols* (A-C) and 283, 11.7, 162, 3.3, 1.3, 11.1, 11, 1.7, 0.5 and 0.2 in *Inceptisols* (A-Bw-C), respectively. Respective values of these parameters in subsoils were119, 3.9, 113, 2.2, 0.8, 4.8, 8, 2.1, 0.3 and 0.1 in *Entisols* and 149, 4.2, 182, 3.5, 1.4, 8.5, 16.8, 3.3, 0.3 and 0.1 in *Inceptisols*, respectively.

Available N (kg ha^{-1}), P (kg ha^{-1}), K (kg ha^{-1}), Ca {cmol (p+) kg^{-1}}, Mg {cmol (p+) kg^{-1}}, S (mg kg^{-1}), Fe (mg kg^{-1}), Mn (mg kg^{-1}), Zn (mg kg^{-1}) and Cu (mg kg^{-1}) contents in Panchrukhi block ranged from 137 to 650, 5.1 to 13.4, 96 to 349, 1.8 to 3.6, 1.0 to 1.9, 4.9 to 23.2, 8 to 71, 0.8 to 21.1, 0.3 to 1.6 and 0.1 to 0.6, respectively in surface soils and 72 to 273, 1.9 to 7.0, 59 to 376, 1.3 to 3.5, 0.6 to 2.2, 1.8 to 9.4, 5 to 85, 0.3 to 31.3, 0.1 to 1.2 and 0.1 to 0.3, respectively in subsurface soils (Tables 4.17 to 4.22).

On an average, surface horizons of *Entisols* had higher nutrient contents as compared to subsurface ones. Similar results were also observed with available N, P, S, Zn and Cu in *Inceptisols* and *Alfisols*. However, a reverse trend was obtained with available K, Ca, Mg, Fe and Mn.

Irrespective of the soil taxa and land use, all the nutrients decreased with increasing depth in *Entisols*. Available N, P, S, Zn and Cu in *Inceptisols and Alfisols,* decreased with increasing soil depth whereas K, Ca, Mg, Fe and Mn exhibited an irregular trend of distribution with depth. On an average, K, Ca, Mg, Fe and Mn were higher in subsoils as compared to surface soils.

4.4.2 Soil properties affecting soil fertility

Soil pH, EC (dS m^{-1}), OC (mg kg^{-1}), clay (%), silt (%),sand (%), CEC {cmol (p+) kg^{-1}} and base saturation (%) in mid-hill soil zone ranged from 5.3 to 6.0, 0.23 to 0.38, 5.3 to 11.9, 10.0 to 27.8, 10.3 to 45.8, 25.0 to 79.1, 5.4 to 15.7 and 46 to 58 in surface soils and from 5.6 to 6.1, 0.26 to 0.42, 3.3 to 5.5, 8.2 to 34.8, 10.7 to 47.1, 18.0 to 80.4, 4.2 to 16.7 and 50 to 59 in subsurface soils, respectively (Table 4.23). Average soil pH, EC (dS m^{-1}), OC (mg kg^{-1}), clay (%), silt (%),sand (%), CEC {cmol (p+) kg^{-1}} and base saturation (%) in surface horizons were 6.0, 0.24, 7.1, 10.5, 10.6, 78.8, 5.8 and 58 in *Entisols* (A-C),6.0, 0.27, 7.0, 16.3, 25.1, 58.6, 7.9 and 58 in *Inceptisols* (A-Bw-R) and 5.5, 0.30, 10.5, 21.9, 41.5, 36.3, 12.4 and 49 in *Alfisols* (A-Bt), respectively. Respective values of these parameters in subsoils were 6.1, 0.26, 5.0, 8.3, 11.1, 80.7, 5.4 and 59 in *Entisols*, 6.1, 0.30, 3.3, 17.4, 23.5, 59.2, 7.9 and 59 in *Inceptisols* and 5.7, 0.4, 4.3, 29.3, 41.4, 29.9, 14.6 and 53 in *Alfisols*, respectively.

Soil pH, EC (dS m^{-1}), OC (mg kg^{-1}), clay (%), silt (%), sand (%), CEC {cmol (p+) kg^{-1}} and base saturation (%) in low-hill soil zone ranged from 6.4 to 6.8, 0.28 to 0.33, 4.8 to 7.2, 9.7 to 12.3, 13.3 to 44.4, 45.4 to 76.5, 3.8 to 7.5 and 65 to 71 in surface soils and from 6.5 to7.0, 0.29 to 0.35, 2.8 to 3.7, 5.8 to 12.2, 15.1 to 47.3, 44.0 to 79.1, 2.4 to 5.5 and 67 to 75 in subsurface soils, respectively (Table 4.24). Average soil pH, EC (dS m^{-1}), OC (mg kg^{-1}), clay (%), silt (%),sand (%), CEC {cmol (p+) kg^{-1}} and base saturation (%) in surface horizons were 6.6, 0.29, 6.3, 10.8, 21.3, 67.9, 5.3 and 68 in *Entisols* (A-C) and 6.7, 0.29, 6.8, 11.3, 18.4, 70.3, 5.8 and 70 in *Inceptisols* (A-Bw-C), respectively. Respective values of these parameters in subsoils were 6.6, 0.31, 2.8, 8.5, 22.8, 68.8, 4.4 and 70 in *Entisols* and 6.8, 0.35, 3.2, 12.2, 16.9, 70.9, 5.5 and 72 in *Inceptisols,* respectively.

Soil pH, EC (dS m^{-1}), OC (mg kg^{-1}), clay (%), silt (%), sand (%), CEC {cmol (p+) kg^{-1}} and base saturation (%) in Panchrukhi block as a whole ranged 5.3 to 6.8, 0.23 to 0.38, 4.8 to 11.9, 9.7 to 27.8, 10.3 to 45.8, 25.0 to 79.1, 3.8 to 15.7 and 46 to 71 in surface soils and from 5.6 to 7.0, 0.26 to 0.42, 2.8 to 5.5, 5.8 to 34.8, 10.7 to 47.3, 18.0 to 80.4, 2.4 to 16.7 and 50 to 75 in subsurface soils, respectively (Tables 4.23 to 4.24).

On an average, surface soils had higher OC and lower soil pH, EC, sand and base saturation than subsurface layers. However, clay and CEC values in surface layers were comparatively lower in *Inceptisols and Alfisols.*

Irrespective of the soil taxa and land use, OC decreased with increasing soil depth, soil pH and base saturation increased with increasing depth whereas other properties namely EC, clay, silt, sand and CEC exhibited an irregular trend of distribution with depth.

Total N (%), P (%), K (%), Ca (%), Mg (%), S (mg kg^{-1}), Fe (mg kg^{-1}), Mn (mg kg^{-1}), Zn (mg kg^{-1}) and Cu (mg kg^{-1}) contents in mid-hill soil zone ranged from 0.041 to 0.089, 0.067 to 0.081, 2.23 to 2.34, 0.73 to 0.81, 0.23 to 0.34, 132 to 291, 7542 to 11132, 817 to 1557, 114 to 437 and 18.5 to 26.8 in surface soils and 0.018 to 0.049, 0.070 to 0.084, 2.20 to 2.37, 0.71 to 0.83, 0.19 to 0.35, 61 to 134, 8784 to 12362, 966 to 1446, 181 to 278 and 18.0 to 19.6 in subsurface soils, respectively (Tables 4.17 to 4.19). Average (%), P (%), K (%), Ca (%), Mg (%), S (mg kg^{-1}), Fe (mg kg^{-1}), Mn (mg kg^{-1}), Zn (mg kg^{-1}) and Cu (mg kg^{-1}) contents were 0.051, 0.083, 2.24, 1.2, 0.37, 176, 7725, 857, 127 and 18.6 in *Entisols* (A-C), 0.053, 0.069, 2.34, 0.75, 0.24, 170, 9125, 1003, 233 and 21.5 in *Inceptisols* (A-Bw-C) and 0.077, 0.076, 2.29, 0.78, 0.33, 110, 10283, 1202, 339 and 24 in *Alfisols* (A-Bt-C), respectively. Respective values of these parameters in subsoils were 0.036, 0.064, 2.21, 0.71, 0.20, 123, 7180, 813, 93 and 17.3 in *Entisols*, 0.024, 0.071, 2.29, 0.76, 0.26, 81, 9224, 1005, 170 and 18.3 in *Inceptisols* and 0.032, 0.081, 2.33, 0.080, 0.33, 110, 11335, 1294, 242 and 17.9 in *Alfisols*, respectively.

Total N (%), P (%), K (%), Ca (%), Mg (%), S (mg kg^{-1}), Fe (mg kg^{-1}), Mn (mg kg^{-1}), Zn (mg kg^{-1}) and Cu (mg kg^{-1}) contents in low-hill soil zone ranged from 0.037 to 0.059, 0.086 to 0.092, 2.34 to 2.43, 1.21 to 1.29, 0.37 to 0.39, 119 to 183, 5298 to 6479, 456 to 537, 112 to168 and 16.1 to 17.9 in surface soils and 0.017 to 0.039, 0.078 to 0.092, 2.23 to 2.38, 1.11 to 1.28, 0.36 to 0.39, 51 to 106, 4921 to

6160, 419 to 523, 59 to 124 and 15.1 to 16.2 in subsurface soils, respectively (Tables 4.20 to 4.22). Average (%), P (%), K (%), Ca (%), Mg (%), S (mg kg^{-1}), Fe (mg kg^{-1}), Mn (mg kg^{-1}), Zn (mg kg^{-1}) and Cu (mg kg^{-1}) contents in surface horizons were 0.050, 0.089, 2.37, 1.24, 0.38, 157, 5875, 502, 137 and 16.9 in *Entisols* (A-C) and 0.056, 0.089, 2.40, 1.28, 0.39, 79, 5912, 519, 137 and 17.4 in *Inceptisols* (A-Bw-C), respectively. Respective values of these parameters in subsoils were 0.025, 0.083, 2.3, 1.2, 0.37, 72, 5290, 447, 97 and 15.6 in *Entisols* (A-C) and 0.025, 0.092, 2.34, 1.3, 0.39, 79, 6160, 523, 112 and 15.7 in *Inceptisols* (A-Bw-C), respectively.

Total N (%), P (%), K (%), Ca (%), Mg (%), S (mg kg^{-1}), Fe (mg kg^{-1}), Mn (mg kg^{-1}), Zn (mg kg^{-1}) and Cu (mg kg^{-1}) contents in Panchrukhi block as a whole ranged from 0.037 to 0.089, 0.067 to 0.092, 2.23 to 2.43, 0.73 to 1.29, 0.23 to 0.39, 119 to 291, 5298 to 11132, 456 to 1557, 112 to 437 and 16.1 to 26.8 in surface soils and 0.017 to 0.049, 0.070 to 0.092, 2.22 to 2.38, 0.71 to 1.28, 0.19 to 0.39, 51 to 134, 4921 to 12362, 419 to 1446, 59 to 278 and 15.1 to 19.6 in subsurface soils, respectively (Tables 4.17 to 4.22).

On an average, surface soils of *Entisols* had higher contents of all nutrients than subsurface soils. Similar results were also observed with total N, S, Zn and Cu in *Inceptisols*. However, a reverse trend was obtained with total P, K, Ca, Mg, Fe and Mn.

Irrespective of the soil taxa and land use, total amounts of all nutrients decreased with increasing depth in Entisols, where as an irregular trend of distribution with depth was observed with nutrients except N, S and Cu in *Inceptisols* and *Alfisols*.

The variation in soil properties within and between soils may be attributed to the differences in soil make up, soil management practices, land use types, pedogenic processes (gains, losses, transformation and translocation of materials), plant nutrient recycling processes, etc. As soils form, nutrients are being continually removed from and added to the soil with time. The conditions that are present during soil formation ultimately determine how much and what kind of nutrients the soil can naturally supply and hold (Kanwar 1979).

The process of soil formation is a complex of or sequence of events, including both complicated reactions and comparatively simple rearrangement of matter that intimately affects the soils in which it operates. The specific

Table 4.17 Distribution of total and available contents of primary nutrients in representative soil profiles of mid-hill soil zone

Profile	Horizon	Depth (cm)	Total contents (%)			Available contents (kg ha^{-1})		
			N	P	K	N	P	K
1. *Tatahail*	Ap	0-17	0.044	0.069	2.33	395	11.4	257
	Bw1	17-40	0.032	0.070	2.31	299	6.1	284
	Bw2	40-75	0.009	0.071	2.35	105	2.2	274
	R	75+	-	-	-	-	-	-
2. *Nouri Jhikli*	Ap	0-15	0.061	0.069	2.25	554	12.9	249
	AB	15-35	0.044	0.070	2.26	283	7.1	278
	Bw1	35-51	0.036	0.071	2.27	121	5.1	321
	Bw2	51-81	0.018	0.070	2.26	89	2.4	293
	R	81+	-	-	-	-	-	-
3. *Sungal*	Ap	0-16	0.066	0.074	2.27	586	13.4	274
	AB	16-37	0.060	0.073	2.26	313	10.0	345
	Bt1	37-65	0.050	0.082	2.36	251	5.9	395
	Bt2	65-112	0.026	0.081	2.35	105	3.3	353
	Bt3	112-155	0.013	0.081	2.34	73	2.2	339
4. *Chandropa*	Ap	0-16	0.089	0.071	2.25	650	10. 9	251
	AB	16-38	0.074	0.072	2.27	379	7.4	286
	Bt1	38-69	0.039	0.077	2.29	169	3.3	359
	Bt2	69-105	0.025	0.075	2.28	125	2.3	302
	R	105+	-	-	-	-	-	-
5. *Biara*	Ap	0-16	0.066	0.081	2.34	618	11.2	301
	AB	16-34	0.039	0.083	2.32	379	5.2	348
	Bt1	34-60	0.027	0.084	2.36	283	3.0	367
	Bt2	60-92	0.024	0.084	2.39	169	1.3	388
	Bt3	92-155	0.016	0.084	2.39	89	0.7	382
6. *Kalu-di-Hatti*	A	0-14	0.062	0.068	2.24	539	10.3	274
	AC	14-30	0.049	0.064	2.21	251	5.3	231
	Cr	30+	-	-	-	-	-	-
7. *Holta Bharmat*	A	0-19	0.087	0.077	2.31	618	11.4	349
	Bt1	19-43	0.054	0.082	2.35	475	8.7	311
	Bt2	43-75	0.046	0.085	2.41	331	7.6	375
	Bt3	75-113	0.028	0.084	2.39	251	6.3	357
	Bt4	113-152	0.025	0.083	2.37	121	6.3	294
8. *Badehar*	A	0-18	0.041	0.067	2.23	299	6.8	143
	AC	18-35	0.023	0.064	2.20	105	2.6	91
	R	35+	-	-	-	-	-	-

Table 4.18 Distribution of total and available contents of secondary nutrients in representative soil profiles of mid-hill soil zone

Profile	Horizon	Depth (cm)	Total contents			Available contents		
			Ca (%)	Mg (%)	S (mg kg^{-1})	Ca (cmol (p+) kg^{-1})	Mg (cmol(p+) kg^{-1})	S (mg kg^{-1})
1. *Tatahail*	Ap	0-17	0.75	0.24	151	2.5	1.4	14.7
	Bw1	17-40	0.76	0.27	107	2.8	1.6	9.2
	Bw2	40-75	0.76	0.25	31	2.7	1.3	5.1
	R	75+	-	-	-	-	-	-
2. *Nouri Jhikli*	Ap	0-15	0.75	0.24	201	2.4	1.1	12.2
	AB	15-35	0.76	0.25	149	3.1	1.1	11.2
	Bw1	35-51	0.77	0.27	119	3.1	1.1	7.3
	Bw2	51-81	0.76	0.26	59	2.9	1.1	3.1
	R	81+	-	-	-	-	-	-
3. *Sungal*	Ap	0-16	0.77	0.30	217	2.3	1.2	21.0
	AB	16-37	0.76	0.29	109	1.9	1.5	12.1
	Bt1	37-65	0.82	0.33	131	3.5	2.3	8.3
	Bt2	65-112	0.81	0.31	71	2.8	2.2	5.7
	Bt3	112-155	0.80	0.33	57	2.7	1.9	2.1
4. *Chandropa*	Ap	0-16	0.75	0.27	291	1.8	1.0	22
	AB	16-38	0.76	0.28	239	1.6	1.3	12
	Bw1	38-69	0.79	0.32	127	2.8	1.5	4
	Bw2	69-105	0.77	0.30	76	2.4	1.2	3
	R	105+	-	-	-	-	-	-
5. *Biara*	Ap	0-16	0.81	0.34	234	1.9	1.1	23.2
	AB	16-34	0.80	0.33	131	1.6	0.9	18.3
	Bt1	34-60	0.83	0.34	86	2.7	1.7	13.6
	Bt2	60-92	0.84	0.35	83	2.6	1.6	7.1
	Bt3	92-155	0.82	0.35	53	2.4	1.4	4.4
6. *Kalu-di-Hatti*	A	0-14	0.74	0.23	219	2.3	2.2	12.3
	AC	14-30	0.71	0.22	165	1.7	1.9	7.6
	Cr	30+	-	-	-	-	-	-
7. *Holta Bharmat*	A	0-19	0.79	0.32	289	2.1	1.2	21.3
	Bt1	19-43	0.81	0.33	178	2.7	1.7	12.1
	Bt2	43-75	0.84	0.35	146	3.4	2.1	9.3
	Bt3	75-113	0.83	0.34	98	2.6	2.7	6.1
	Bt4	113-152	0.82	0.34	94	3.1	2.1.	2.4
8. *Badehar*	A	0-18	0.73	0.23	132	2.7	1.3	10.2
	AC	18-35	0.71	0.21	81	1.9	0.6	3.2

Table 4.19 Distribution of total and available contents of micro- nutrients in representative soil profiles of mid-hill soil zone

Profile	Horizon	Depth (cm)	Total contents (mg kg^{-1})				Available contents (mg kg^{-1})			
			Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu
1. *Tatahail*	Ap	0-17	8763	963	209	20.4	39	2.9	1.4	0.2
	Bw1	17-40	8698	947	187	19.8	41	3.9	0.7	0.2
	Bw2	40-75	8841	979	142	17.6	45	3.2	0.7	0.2
	R	75+	-	-	-	-	-	-	-	-
2 *Nouri Jhikli*	Ap	0-15	9487	1042	254	22.6	31	2.4	0.8	0.3
	AB	15-35	9356	1019	241	20.2	33	2.8	0.6	0.2
	Bw1	35-51	9874	1064	196	18.2	37	2.8	0.5	0.2
	Bw2	51-81	9756	1049	132	16.5	34	2.4	0.3	0.2
	R	81+	-	-	-	-	-	-	-	-
3 *Sungal*	Ap	0-16	9654	1074	307	22.9	37	3.5	1.5	0.3
	AB	16-37	9387	1051	278	20.7	42	4.1	1.4	0.4
	Bt1	37-65	11312	1327	285	19.1	59	4.7	1.4	0.3
	Bt2	65-112	10967	1259	273	17.6	52	5.1	0.7	0.2
	Bt3	112-155	10715	1223	236	16.9	52	3.4	0.7	0.3
4 *Chandropa*	Ap	0-16	9472	1012	248	21.5	52	13.1	1.2	0.6
	AB	16-38	9216	987	213	18.4	42	8.6	0.7	0.3
	Bt1	38-69	10581	1167	236	17.2	72	20.3	0.4	0.1
	Bt2	69-105	10213	1099	89	10.1	65	17.4	0.2	0.1
	R	105+	-	-	-	-	-	-	-	-
5 *Biara*	Ap	0-16	11132	1557	437	26.8	71	21.1	1.6	0.4
	AB	16-34	10973	1523	417	23.6	72	23.6	1.4	0.3
	Bt1	34-60	12517	1442	397	19.7	92	32.4	1.2	0.3
	Bt2	60-92	12631	1497	402	17.5	95	33.4	1.1	0.2
	Bt3	92-155	12658	1486	384	17.2	81	31.9	1.1	0.2
6 *Kalu-di-Hatti*	A	0-14	7907	897	139	18.5	38	7.9	0.6	0.3
	AC	14-30	7324	835	96	17.4	29	5.4	0.4	0.1
	Cr	30+	-	-	-	-	-	-	-	-
7 *Holta Bharmat*	A	0-19	10875	1165	365	24.8	55	10.1	1.8	0.3
	Bt1	19-43	10313	1027	327	22.8	39	8.6	1.1	0.2
	Bt2	43-75	10709	1047	347	20.1	64	11.3	0.4	0.1
	Bt3	75-113	10483	996	296	18.6	60	11.3	0.3	0.1
	Bt4	113-152	10407	854	154	18.1	72	12.1	0.1	0.1
8 *Badehar*	A	0-18	7542	817	114	18.7	12	0.8	0.8	0.2
	AC	18-35	7036	791	89	17.1	9.8	0.3	0.1	0.1

Table 4.20 Distribution of total and available contents of primary nutrients in representative soil profiles of low-hill soil zone

Profile	Horizon	Depth (cm)	Total contents (%)			Available contents (kg ha^{-1})		
			N	P	K	N	P	K
1. Simbal	Ap	0-18	0.056	0.089	2.40	283	11.9	162
	AB	18-45	0.046	0.091	2.41	252	7.4	181
	Bw1	45-65	0.024	0.095	2.46	148	6.8	212
	Bw2	65-83	0.016	0.092	2.24	92	1.2	174
	Bw3	83-112	0.013	0.091	2.24	88	1.2	168
	Cr	112+	-	-	-	-	-	-
2. Bhirdi	Ap	0-26	0.057	0.092	2.43	427	12.1	212
	CA1	26-51	0.049	0.087	2.37	283	7.2	197
	CA2	51-89	0.019	0.088	2.39	105	2.1	171
	Cr	89+	-	-	-	-	-	-
3. Bhuana	A	0-19	0.057	0.086	2.34	395	10.0	176
	AC	19-45	0.028	0.078	2.23	167	6.4	132
	Cr	45+	-	-	-	-	-	-
4. Bhulana	A	0-20	0.059	0.087	2.35	299	11.2	172
	AC1	20-40	0.029	0.082	2.29	138	6.7	97
	AC2	40-64	0.009	0.079	2.23	64	1.2	131
	Cr	64+	-	-	-	-	-	-
5. Darug	A	0-21	0.037	0.087	2.36	137	5.1	102
	CA1	21-48	0.024	0.083	2.31	72	2.4	78
	CA2	48+	-	-	-	-	-	-
6. Check	A	0-21	0.039	0.091	2.41	235	6.2	96
	CA1	21-46	0.019	0.088	2.37	104	4.7	69
	CA2	46-80	0.014	0.085	2.33	68	1.6	52
	Cr	80+	-	-	-	-	-	-

Table 4.21 Distribution of total and available contents of secondary nutrients in representative soil profiles of low- hill soil zone

Profile	Horizon	Depth (cm)	Total contents			Available contents		
			Ca (%)	Mg (%)	S (%)	Ca {cmol (p+) kg^{-1}}	Mg {cmol (p+) kg^{-1}}	S (mg kg^{-1})
1. Simbal	Ap	0-18	1.26	0.37	179	3.3	1.3	11.1
	AB	18-45	1.27	0.38	141	3.1	1.5	10.3
	Bw1	45-65	1.30	0.40	81	3.8	1.6	8.9
	Bw2	65-83	1.28	0.39	53	3.6	1.3	8.0
	Bw3	83-112	1.28	0.39	41	3.6	1.3	6.7
	Cr	112+	-	-	-	-	-	-
2. Bhirdi	Ap	0-26	1.29	0.39	183	3.3	1.4	13.2
	CA1	26-51	1.23	0.38	153	2.4	1.0	9.0
	CA2	51-89	1.24	0.38	58	2.2	0.9	7.1
	Cr	89+	-	-	-	-	-	-
3. Bhuana	A	0-19	1.21	0.37	181	2.9	1. 1	14.9
	AC	19-45	1.11	0.36	79	1.3	0.6	9.4
	Cr	45+	-	-	-	-	-	-
4. Bhulana	A	0-20	1.21	0.37	175	3.1	1.3	8.5
	AC1	20-40	1.81	0.37	86	2.4	0.9	3.8
	AC2	40-64	1.12	0.36	26	1.3	0.4	0.8
	Cr	64+	-	-	-	-	-	-
5. Darug	A	0-21	1.23	0.38	119	3.2	1.5	4.9
	CA1	21-48	1.18	0.37	69	2.4	0.9	2.7
	CA2	48+	-	-	-	-	-	-
6. Check	A	0-21	1.27	0.38	128	3.6	1.9	5.2
	CA1	21-46	1.22	0.38	59	2.7	1.1	2.7
	CA2	46-80	1.20	0.37	43	2.7	1.1	1.1
	Cr	80+	-	-	-	-	-	-

Table 4.22 Distribution of total and available contents of micro-nutrients in representative soil profiles of low-hill soil zone

Profile	Horizon	Depth (cm)	Total contents (mg kg^{-1})				Available contents (mg kg^{-1})			
			Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu
1. Simbal	Ap	0-18	5912	519	137	17.4	11	1.7	0.5	0.2
	AB	18-45	5876	497	121	17.1	17	2.3	0.4	0.2
	Bw1	45-65	6679	559	128	16.6	19	3.7	0.4	0.1
	Bw2	65-83	6167	529	109	15.2	17	3.9	0.3	0.1
	Bw3	83-112	6062	518	96	14.1	14	3.1	0.3	0.1
	Cr	112+	-	-	-	-	-	-	-	-
2. Bhirdi	Ap	0-26	6271	537	168	17.9	22	2.3	0.6	0.3
	CA1	26-51	5786	502	135	16.9	14	1.5	0.4	0.3
	CA2	51-89	5851	509	117	15.5	7	0.4	0.3	0.2
	Cr	89+	-	-	-	-	-	-	-	-
3. Bhuana	A	0-19	5298	456	112	16.1	16	6.1	0.9	0.3
	AC	19-45	4921	389	59	15.3	11	3.9	0.4	0.2
	Cr	45	-	-	-	-	-	-	-	-
4. Bhulana	A	0-20	5673	491	125	16.6	18	7.8	0.9	0.2
	AC1	20-40	5008	445	101	15.4	10	5.3	0.5	0.1
	AC2	40-64	4974	397	68	14.8	8	4.2	0.2	0.1
	Cr	64+	-	-	-	-	-	-	-	-
5. Darug	A	0-21	5654	493	127	16.4	8	0.9	0.3	0.1
	CA1	21-48	5179	451	104	15.5	5	0.5	0.2	0.1
	CA2	48+	-	-	-	-	-	-	-	-
6. Check	A	0-21	6479	531	154	17.9	8	2.1	0.5	0.2
	CA1	21-46	5891	494	119	16.5	6	0.9	0.3	0.1
	CA2	46-80	5276	457	109	14.9	5	0.2	0.2	0.1
	Cr	80+	-	-	-	-	-	-	-	-

Table 4.23 Distribution of pH, EC, organic carbon (OC), mechanical separates, CEC and base saturation (BS) in representative soil profiles of mid-hill soil zone

Profile	Horizon	Depth (cm)	pH (1:2.5)	EC (dSm^{-1})	OC ($g\ kg^{-1}$)	MS (%) Clay	Silt	Sand	Coarse fragments	CEC {cmol (p+) kg ha^{-1}}	BS (%)
. *Tatahail*				Coarse loamy, mixed, thermic, moderately-deep, slightly-acid, family of *Typic Dystrudepts*							
	Ap	0-17	6.0	0.27	5.9	14.0	29.2	56.8	-	7.6	58
	Bw1	17-40	6.0	0.31	4.3	15.5	27.0	57.5	-	8.1	58
	Bw2	40-75	6.1	0.31	1.2	15.1	26.9	58.0	-	7.5	59
	R	75+				Sand stone					
				Fine loamy, mixed, thermic, moderately-deep, slightly-acid, family of *Typic Dystrudepts*							
	Ap	0-15	6.0	0.26	8.1	18.6	21.0	60.4	-	8.1	58
	Bw1	15-35	6.1	0.26	6.0	19.2	21.0	59.8	-	8.3	59
2. *Nouri Jhikli*	Bw2	35-51	6.1	0.30	4.8	19.9	20.1	60.0	-	8.4	59
	Bw3	51-81	6.1	0.30	2.4	19.2	19.5	61.3	-	7.6	59
	R	81+				Sand stone					
				Fine loamy, mixed, thermic, very-deep, medium-acid, family of *Typic Hapludalfs*							
	Ap	0-16	5.8	0.30	8.8	19.6	37.8	42.6	-	10.6	55
	AB	16-37	5.9	0.32	6.7	19.2	37.0	43.8	-	9.9	57
3. *Sungal*	Bt1	37-65	6.0	0.38	5.2	30.6	33.5	35.9	-	15.4	58
	Bt2	65-112	6.0	0.36	2.8	28.1	32.8	39.1	-	13.7	58
	Bt3	112-155	6.0	0.36	2.2	27.0	33.7	39.3	-	13.1	58
				Fine loamy, mixed, thermic, deep, medium-acid, family of *Typic Hapludalfs*							
	Ap	0-16	5.4	0.26	11.9	16.5.	39.3	44.2	-	9.7	48
4. *Chandropa*	BA	16-38	5.5	0.26	9.7	17.2	40.0	42.8	-	9.3	50
	Bt1	38-69	5.6	0.29	5.1	24.0	36.5	39.5	-	11.9	51
	Bt2	69-105	5.6	0.27	3.2	20.7	37.4	48.7	-	9.9	51
	R	105+				Sand stone					
				Fine silty, mixed, thermic, very deep, strongly-acid, family of *Typic Paleudalfs*							
	Ap	0-16	5.3	0.38	9.4	27.8	45.8	25.0	-	15.7	46
	AB	16-34	5.4	0.34	5.2	26.9	46.4	26.7	-	14.4	48
5. *Biara*	Bt1	34-60	5.5	0.44	3.4	34.8	47.3	17.3	-	17.2	50
	Bt2	60-92	5.6	0.43	3.4	35.4	45.8	18.8	-	17.5	51
	Bt3	92-155	5.6	0.43	2.1	35.4	47.3	17.3	-	16.8	51
				Coarse loamy, mixed, thermic, shallow, medium-acid, family of *Lithic Udorthents*							
	A	0-14	5.9	0.25	8.9	10.9	10.3	78.5	10	6.2	57
6. *Kalu-di-hatti*	AC	14-30	6.0	0.26	6.7	8.4	10.7	80.9	30	5.9	58
	Cr	30+				Weathered sandstone					
				Fine silty, mixed, thermic, very deep, strongly-acid, family of *Typic Paleudalfs*							
	A	0-19	5.4	0.24	11.8	23.7	43.0	33.3	-	13.7	48
	Bt1	19-43	5.5	0.28	7.2	30.4	47.1	22.5	-	16.1	50
7. *Holta Bharmat*	Bt2	43-75	5.5	0.39	5.9	36.9	47.8	15.3	-	19.2	50
	Bt3	75-113	5.6	0.37	3.9	35.7	46.8	17.5	-	18.2	51
	Bt4	113-152	5.6	0.37	3.9	35.2	46.8	18.0	-	18.0	51
				Coarse loamy, mixed, thermic, shallow, slightly-acid, family of *Lithic Udorthents*							
	A	0-19	6.0	0.23	5.3	10.0	10.9	79.1	12	5.4	58
8. *Badehar*	AC	19-35	6.1	0.26	3.3	8.2	11.4	80.4	21	4.2	59
	R	35+				Sand stone					

Table 4.24 Distribution of pH, EC, organic carbon (OC), mechanical separates, CEC and base saturation (BS) in representative soil profiles of low- hill soil zone

Profile	Horizon	Depth (cm)	pH (1:2.5)	EC (dS m^{-1})	OC (g kg^{-1})	MS (%)				CEC {cmol (p+) kg ha^{-1}}	BS (%)
						Clay	Silt	Sand	Coarse fragments		
			Slightly gravelly, coarse loamy, mixed, thermic, deep,neutral, *Typic Eutrudepts*								
1. Simbal	Ap	0-18	6.7	0.29	6.8	11.3	18.4	70.3	10	5.8	70
	AB	18-45	6.8	0.31	5.7	11.7	18.0	70.3	15	5.9	70
	Bw1	45-65	6.8	0.34	3.2	13.4	16.7	69.9	20	6.0	71
	Bw2	65-83	6.9	0.37	2.0	12.1	16.3	71.6	20	5.0	73
	Bw3	83-112	7.0	0.37	1.5	12.0	16.3	71.6	30	5.0	75
	Cr	112+	Gravelly stratum								
			Loamy skeletal, mixed, thermic, moderately deep, neutral, *Typic Udorthents*								
2. Bhirdi	Ap	0-26	6.6	0.33	7.2	12.3	21.2	66.5	18	7.5	68
	CA1	26-51	6.7	0.34	5.9	10.6	22.3	67.1	45	5.3	70
	CA2	51-89	6.8	0.34	2.3	10.9	21.2	67.9	56	4.6	71
	Cr	89+	Conglomeratic stratum								
			Loamy skeletal, mixed, thermic, shallow, neutral, *Typic Udorthents*								
3. Bhuana	A	0-19	6.4	0.28	7.2	9.7	14.1	76.2	30	5.1	65
	AC	19-45	6.5	0.29	3.2	5.8	15.1	79.1	56	2.4	67
	Cr	45+									
			Loamy skeletal, mixed, thermic, moderately deep, neutral, *Typic Udorthents*								
4. Bhulana	A	0-20	6.5	0.29	7.0	10.2	13.3	76.5	35	5.3	67
	AC1	20-40	6.6	0.31	3.5	8.5	14.8	76.7	45	4.0	68
	AC2	40-64	6.6	0.31	1.1	6.0	16.1	77.9	55	2.6	70
	Cr	64+	Conglomeratic stratum								
			Loamy skeletal, mixed, thermic, shallow, neutral, *Typic Udorthents*								
5. Darug	A	0-21	6.6	0.29	4.8	10.2	44.4	45.4	20	3.8	68
	CA1	21-48	6.7	0.32	2.8	8.7	47.3	44.0	40	3.6	70
	CA2	48+									
			Loamy skeletal, mixed, thermic, moderately deep, neutral, *Typic Udorthents*								
6. Check	A	0-21	6.8	0.28	5.1	11.8	13.4	74.8	30	5.0	71
	CA1	21-46	7.0	0.28	2.4	10.2	16.3	73.5	40	3.4	74
	CA2	46-80	7.0	0.29	1.8	9.6	12.8	77.6	55	3.2	75
	Cr	80+	Conglomeritic stratum								

combinations of soil forming reactions, to be termed as soil forming processes lead to the development of different soil individuals and series. Illuviation, leaching, decalcification, podzolization, laterization, alkalization, salinization,,gleization, humification and melanisation etc. are dominant soil forming processes of hill and mountain agro-ecosystems (Sehgal 1973). Kinetics of soil development particularly directions, rate and duration as well as the conditions affecting it determine the available and total mineral reserves in a soil.

Dominant soil forming processes in the study area may be leaching, eluviation, illuviation and humification. Gupta and Tripathi (1992) and Sharma and Kumar (2003) evaluated leaching, decalcification and clay illuviation as important soil forming processes responsible for soil variability in North-Western Himalayas. The horizons where clay illuviation was too low to qualify for an argillic horizon (Bt) were identified as cambic horizons (Bw). The similar results were also obtained in the present investigation. On steeper slopes, the soil forming processes were found to be unfavourable for the formation of the B horizon.

A considerable increase in the amount of clay in subsurface horizons may be due to clay-illuviation process. Consequently, that process affects the vertical distribution of silt and sand contents. The mechanism of clay illuviation was explained nicely by Buol *et al.* (1973). According to them, this mechanism could be brought about by depletion of percolating water through soaking peds, swelling shut of voids and consequent slowing of percolating water, sieve action of clogging fine pores, and flocculation of negatively charged clay by positively charged iron oxides in the Bt horizon. Gupta and Tripathi (1992) found clay illuviation as an important soil forming process for the development of argillic horizons in valley soils of Himalayas. Verma *et al.* (1976) reported a substantial increase in clay content (about 14 %), Fe and Mn contents with depth in soils of wet temperate zone of Himachal Pradesh.

Higher soil organic matter and lower soil pH values in surface as compared to subsurface horizons may be attributed to the continuous process of leaf fall/decay, pedogenic factors (vegetation and parent material low in bases, high rainfall, low temperature and variation in topography) and nutrient management practices followed in an area. Dhale and Prasad (2009) reported similar results on organic carbon and pH in wet temperate soils of orange orchards of Maharashtra.

High rainfall, silica rich in parent material and poor vegetation in bases are considered as primary factor for causing soil acidity in Himalayan Regions. Mandal (1984) reviewed that majority of the *Alfisols* and *Inceptisols* in Himalayas were acidic in reaction.

Due to heavy rainfall in the area, leaching assumed a dominant role for lowering per cent base saturation in all the soils and to the formation of an argillic horizon in some soils. Higher values of base saturation were noticed in subsurface soils. The probable reason for this was higher pH values in soils in subsurface as compared to surface soils. The difference in CEC and BS in between the soils and within the soils may be ascribed largely to the varied type and content of soil colloids and soil pH values. Sharma *et al.* (2004) explained the effect of soil pH and soil colloids on these characteristic nicely. Fluvio-glacial deposits in Kangra valley are low in bases. Whatever bases are released by weathering, these are lost over and through the soils by percolating water. Clay particles within a soil profile acts as binding agents for bases. On the other hand, continuous release of bases from the weathering of sedimentary rocks e.g. conglomerates in this valley maintains a regular supply of Ca and Mg to plants. Under acidic conditions, the polysaccharide production declines markedly due to limited microbial activity. At the same time, polymerisation of the soluble organic products of decay does not take place properly and they remain in soluble form. The organic acids thus form react with sesquioxides and form organic-sesquioxides complexes and move with the percolating water to the lower horizons. Therefore, lower horizons of well developed soils of wet temperate zone of Himachal Pradesh are rich in Fe and Mn reserves.

Higher values of N, P, S, Zn and Cu in surface soils may be attributed to prevailing plant nutrient recycling processes and nutrient additions through manures and fertilizers. Soil organic matter is of importance in soil fertility primarily as a reservoir of N, phosphorus and sulphur. Source of other nutrients is basically the inorganic or parent material. Generally, parent material contains Fe and Mn in larger amounts material as compared to Zn and Cu. The favourable environment for leaching and clay illuviation may be responsible for more amounts of available K, Ca, Mg, Fe and Mn in most subsurface horizons. These observations can clearly be noticed in well-developed soils. Further similar results were reported by Kanwar (1979) and Sharma and Anil Kumar (2003).

4.4.3 Interrelationship between available nutrients and soil properties

The results pertaining to simple correlation coefficients (r) between the available nutrient contents and soil properties affecting soil fertility followed the similar trend of results in each soil zone of a block and in block as a whole (Tables 25 and 26).

Total amounts of all nutrients except P correlated positively and significantly with their available amounts. It is obvious because total amount of any nutrient includes the amount present in clay and non-clay fractions. Non-significant correlation with P may be due to the limited variation in amounts of available P. Similar results were observed by Kaistha *et al.* (1990), Bhogal *et al.* (1996), Ghosh and Mukhopadhyay (1996) and Khan et al. (1997).

Soil pH and EC had a positive and significant correlation only with available Ca and Mg contents. Available N, P, K, S, Fe, Mn, Zn and Cu were negatively and non-significantly correlated with it. Similar results were obtained with EC. Katyal and Agarwal (1982), Rajkumar *et al.* (1990) and Sharma and Kanwar (2011) have earlier reported similar type of results.

OC correlated positively and significantly with available N, P, K, S, Fe, Mn, Zn and Cu and a non-significantly with available Ca and Mg. It may be attributed to larger contribution of inorganic soil fraction to supply Ca and Mg to plants. Similar observations were taken Ruhal and Paliwal (1980), Kanthalia and Bhatt (1991) and Singh et al. (2006).

Clay content had a positive and significant relationship with available K, Ca, Mg, Fe, Mn, Zn and Cu and a non-significant correlation with N, P and S. It may due to the fact that soil organic matter is the main source of N, P and S. Silt exhibited a positive and significant relation with all nutrients except available K, Ca and Mg. Sand didn't had a positive and significant relation with any of the available nutrients. These results may be supported with the findings of Katyal and Vlek (1985), Basumatary and Bordoloi (1992) and Chahal and Saini (1995).

CEC correlated positively and significantly with K, Ca, Mg, Fe, Mn, Zn and Cu but non-significantly with available N, P and S. Though CEC depends upon organic as well as inorganic colloids, there may be the dominance of inorganic colloids in that context in the study area. Base saturation had a positive and significant relation with available Ca and Mg contents, but non-significant with N,

Table 4.25 Correlation coefficients (r) between available nutrients and soil properties in mid- and low-hill soil zone

Soil properties	Total content	pH	EC	OC	Clay	Silt	Sand	CEC	BS
				Mid-hill soil zone					
N	0.889*	-0.302	-0.257	0.913*	-0.193	0.089	0.012	-0.055	-0.305
P	-0.289	-0.137	-0.241	0.831*	-0.277	-0.039	0.127	-0.173	-0.276
K	0.712*	-0.247	0.282	0.139*	0.495*	0.398*	-0.769*	0.568*	-0.301
Ca	0.386*	0.325*	0.321*	-0.269	0.382*	0.267*	-0.173	0.323*	0.378*
Mg	0.423*	0.346*	0.454*	-0.197	0.302*	0.226*	-0.352*	0.412*	0.317*
S	0.819*	-0.311	0.189	0.813*	-0.100	0.232	-0.118	0.029	-0.232
Fe	0.833*	-0.202	-0.243	0.318*	0.387*	0.206	-0.426*	0.817*	-0.301
Mn	0.667*	-0.227	-0.232	0.394*	0.323*	0.217	-0.412*	0.646*	-0.238
Zn	0.339*	-0.266	-0.241	0.315*	0.312*	0.219	-0.393*	0.352*	-0.275
Cu	0.423*	-0.219	-0.129	0.732*	0.371*	0.194	-0.371*	0.316*	-0.299
				Low-hill soil zone					
N	0.933*	-0.353	-0.303	0.942*	0.281	-0.194	0.135	0.206	-0.325
P	0.198	-0.378	-0.371	0.925*	0.213	-0.166	0.122	0.207	-0.356
K	0.422*	-0.050	0.218	0.559*	0.645*	0.456*	-0.417*	0.552*	-0.092
Ca	0.419*	0.422*	0.468*	-0.315	0.908*	0.435*	0.153	0.411*	0.451*
Mg	0.674*	0.411*	0.418*	-0.219	0.839*	0.405*	-0.468*	0.457*	0.438*
S	0.744*	-0.329	0.049	0.732*	0.393	-0.202	0.119	0.196	-0.152
Fe	0.446*	-0.205	-0.232	0.462*	0.445*	-0.294	-0.407*	0.705*	-0.317
Mn	0.446*	-0.267	-0.221	0.419*	0.426*	-0.361	-0.495*	0.408*	-0.219
Zn	0.406*	-0.228	-0.222	0.798*	0.417*	-0.347	-0.414*	0.488*	-0.277
Cu	0.417*	-0.222	-0.089	0.733*	0.416*	-0.135	-0.418*	0.504*	-0.265

** Significant at 5 per cent level of significance*

Table 4.26 Correlation coefficients (r) between available nutrients and soil properties in Panchrukhi block

Soil properties	Total content	pH	EC	OC	Clay	Silt	Sand	CEC	BS
N	0.895*	-0.187	-0.208	0.922*	0.115	0.189	-0.176	0.232	-0.215
P	-0.156	-0.189	-0.125	0.836*	-0.089	-0.029	0.048	-0.021	-0.181
K	0.413*	-0.203	-0.131	0.248*	0.853*	0.338*	-0.766*	0.571*	-0.206
Ca	0.427*	0.368*	0.345*	-0.220	0.259*	0.327*	0.037	0.431*	0.447*
Mg	0.418*	0.308*	0.253*	-0.061	0.625*	0.314*	-0.450*	0.490*	0.415*
S	0.814*	-0.133	-0.127	0.808*	0.130	0.240	-0.217	0.218	-0.226
Fe	0.903*	-0.134	-0.217	0.257*	0.879*	0.203	-0.846*	0.504*	-0.237
Mn	0.636*	-0.149	-0.203	0.263*	0.683*	0.193	-0.680*	0.496*	-0.167
Zn	0.536*	-0.141	-0.211	0.403*	0.458*	0.149	-0.489*	0.314*	-0.195
Cu	0.526*	-0.192	-0.131	0.743*	0.283*	0.167	-0.386*	0.375*	-0.109

Significant at 5 per cent level of significance

P, K, S, Fe, Mn, Zn and Cu. Kaistha *et al.* (1990), Hasan (1991), Khan *et al.* (1997), Bhanwaria *et al.* (2011) reported similar type of results.

A perusal of the data on simple correlation coefficients (r) reveals that total nutrient content, soil organic carbon, clay and base saturation are the better soil fertility indicators in the study area.

Maintaining the fertility of soils is of paramount importance not only for the present agriculture but for future also. Keeping in view the findings of present investigation, it is recommended that

- Soil-test based fertilizer recommendations should be advocated to sustain the productivity of different soils. Soil testing is only a management tool to determine optimum fertilizer dose for any land use type. General fertilizer dose may be reduced or enhanced by 25 per cent in soils rating high or low in available nutrient status, respectively.
- Since each land use contributes to improve the quality of life, nutrient status of soils under different land uses at a panchayat level is crucial for effective agricultural planning.
- It is advisable to apply fertilizers on soil test basis in grasslands meant for dry fodder production. Besides fertilizer application, adequate soil and water conservation measures should be taken to restore natural soil fertility cycle in non-agricultural lands.

- While working out/ recommending fertilizer doses for any crop/ tree, it is essential to consider vertical distribution patterns of available nutrients in major soil taxa of an area.

SUMMARY AND CONCLUSIONS

5. SUMMARY AND CONCLUSIONS

5.1 Summary

Soil is the most precious resource. Maintaining soils in the state of high productivity on sustainable basis is important for meeting out the basic needs of the people and livestock. Soil fertility management is an important step in creating a sustainable agriculture. This offers a big challenge to the land users and planners. Nutrients are being continually removed from and added to the soil with time. The conditions that are present now ultimately determine how much and what kind of nutrients the soil can naturally supply and hold. A lot of work has been done to assess the fertility status of cultivated soils from time to time by analyzing surface soil samples. Limited studies have been carried out on systematic fertility characterization of subsoil, probably because of lack of soil survey data and of soils under non-agricultural uses. Nowadays, sustainable land management programmes are carried out in a block level by involving local people and using panchayat as a unit. Further, each land use/cover on the earth has its role in maintaining natural eco-balance. Therefore, systematic soil fertility characterization at a panchayat level is crucial for planning and implementation of such programmes. Present investigation entitled "Fertility status of soils under different land uses in Panchrukhi block of Himachal Pradesh" was carried out to study the distribution of available nutrients and of properties affecting their contents in soils under different land uses in different panchayats of Panchrukhi block.

Panchrukhi block lies between 76°31'17" E to 76°40'35" E longitude and 32°07'15" N to 31°55'54" N latitude and represents mid- and low-hill agro-situations of Kangra district in Himachal Pradesh. It comprises of 37 panchayats, spreading in an area of 6,159 ha and two soil zones *viz.*, mid-hill soil zone (910 to 1,517 m altitude) and low-hill soil zone (< 910 m altitude). Very gently to steeply sloping fluvio-glacial terraces occur in mid-hill soil zone while moderately sloping to extremely steep side slopes of Shivalik hills are predominant in low-hill soil zone. Per cent of total area under cropland, tea garden, forest and grass/ scrub land in Panchrukhi block is 27, 3, 54 and 16, respectively. Paddy-wheat and maize-wheat are the dominant cropping sequences in the area.

Three hundred forty six surface (0-15 cm) soil samples representing different land uses were collected at a rate varying from 2 to 4 per land use and 8 to 10 per panchayat. These samples were processed and analysed for available N, P, K, Ca, Mg, S, Fe, Mn, Zn and Cu. Fertility status of each soil sample was assessed on the basis of limits adopted by the Soil Testing Laboratories of Himachal Pradesh. Macro-nutrient status at a land use/ block level was worked out by Soil Nutrient Index (SNI) as per the criterion given by Parker *et al.* (1951).

The soils of Panchrukhi block are strongly acidic to neutral in reaction, low in EC, low to high in organic carbon and moderately-coarse to moderately-fine in particle size class. Available nutrient contents exhibited a large spatial variation in the study area. Available N (kg ha^{-1}), P (kg ha^{-1}), K (kg ha^{-1}), Ca {cmol (p+) kg^{-1}}, Mg {cmol (p+) kg^{-1}}, S (mg kg^{-1}), Fe (mg kg^{-1}), Mn (mg kg^{-1}), Zn (mg kg^{-1}) and Cu (mg kg^{-1}) ranged from 121 to 746, 4.2 to 18.2, 97 to 395, 1.7 to 2.9, 0.9 to 1.6, 3.9 to 26.1, 5 to 82, 0.3 to 24.1, 0.3 to 2.6 and 0.1 to 0.6 in twenty-six panchayats of mid-hill soil zone and 105 to 618, 3.3 to 12.6, 75 to 269, 2.8 to 3.8, 1.0 to 1.8, 3.3 to 17.3, 5 to 22, 0.4 to 7.8, 0.2 to 1.3 and 0.1 to 0.5 in eleven panchayats of low-hill soil zone, respectively. Average contents of all nutrients except Ca and Mg were higher in mid-hill soil zone as compared to low-hill soil zone. Generally, agricultural lands (cropland and tea gardens) had higher contents of all nutrients except for Ca and Mg as compared to forests and grass/ scrub lands.

Soils of all panchayats of Panchrukhi block were sufficient in available Ca and Mg. Available N, P, K and S status ranged from low to high, low, medium to high and low to high in mid-hill soil zone and low, low, low to medium and low, in low-hill soil zone, respectively. Per cent panchayats rating high, medium and low in Panchrukhi block were 16, 52 and 32 in available N; nil, 52 and 48 in available P; 16, 54 and 30 in available K and 8, 57 and 35 in available S, respectively. Soils of all panchayats of Panchrukhi block were sufficient in available Fe. Per cent panchayats deficient in Mn, Zn and Cu were 30, 84 and 38, respectively.

On the basis of available soil survey reports, eight and six representative soil profiles were exposed in mid-and low-hill soil zone to study the vertical distribution of available nutrients and properties. Soils of mid-hill soil zone belong to four subgroups *viz., Typic Dystrudepts, Typic Hapludalfs, Typic Paleudalfs and*

Lithic Udorthents, whereas those of low-hill soil zone belong to *Typic Eutrudepts* and *Typic Udorthents.*

Available N (kg ha^{-1}), P (kg ha^{-1}), K (kg ha^{-1}), Ca {cmol (p+) kg^{-1}}, Mg {cmol (p+) kg^{-1}}, S (mg kg^{-1}), Fe (mg kg^{-1}), Mn (mg kg^{-1}), Zn (mg kg^{-1}) and Cu (mg kg^{-1}) contents in Panchrukhi block ranged from 137 to 650, 5.1 to 13.4, 96 to 349, 1.8 to 3.6, 1.0 to 1.9, 4.9 to 23.2, 8 to 71, 0.8 to 21.1, 0.3 to 1.6 and 0.1 to 0.6, respectively in surface soils and 72 to 273, 1.9 to 7.0, 59 to 376, 1.3 to 3.5, 0.6 to 2.2, 1.8 to 9.4, 5 to 85, 0.3 to 31.3, 0.1 to 1.2 and 0.1 to 0.3, respectively in subsurface soils.

Irrespective of the soil taxa and land use, all the nutrients decreased with increasing depth in *Entisols*. Available N, P, S, Zn and Cu in *Inceptisols and Alfisols,* decreased with increasing soil depth whereas K, Ca, Mg, Fe and Mn exhibited an irregular trend of distribution with depth. On an average, K, Ca, Mg, Fe and Mn were higher in subsoils as compared to surface soils.

Soil pH, EC (dS m^{-1}), OC (mg kg^{-1}), clay (%), silt (%), sand (%), CEC {cmol (p+) kg^{-1}} and base saturation (%) in Panchrukhi block as a whole ranged 5.3 to 6.8, 0.23 to 0.38, 4.8 to 11.9, 9.7 to 27.8, 10.3 to 45.8, 25.0 to 79.1, 3.8 to 15.7 and 46 to 71 in surface soils and from 5.6 to 7.0, 0.26 to 0.42, 2.8 to 5.5, 5.8 to 34.8, 10.7 to 47.3, 18.0 to 80.4, 2.4 to 16.7 and 50 to 75 in subsurface soils, respectively.

On an average, surface soils had higher OC and lower soil pH, EC, sand and base saturation than subsurface layers. However, clay and CEC values in surface layers were comparatively lower in *Inceptisols and Alfisols.*

Total N (%), P (%), K (%), Ca (%), Mg (%), S (mg kg^{-1}), Fe (mg kg^{-1}), Mn (mg kg^{-1}), Zn (mg kg^{-1}) and Cu (mg kg^{-1}) contents in Panchrukhi block as a whole ranged from 0.037 to 0.089, 0.067 to 0.092, 2.23 to 2.43, 0.73 to 1.29, 0.23 to 0.39, 119 to 291, 5298 to 11132, 456 to 1557, 112 to 437 and 16.1 to 26.8 in surface soils and 0.017 to 0.049, 0.070 to 0.092, 2.22 to 2.38, 0.71 to 1.28, 0.19 to 0.39, 51 to 134, 4921 to 12362, 419 to 1446, 59 to 278 and 15.1 to 19.6 in subsurface soils, respectively.

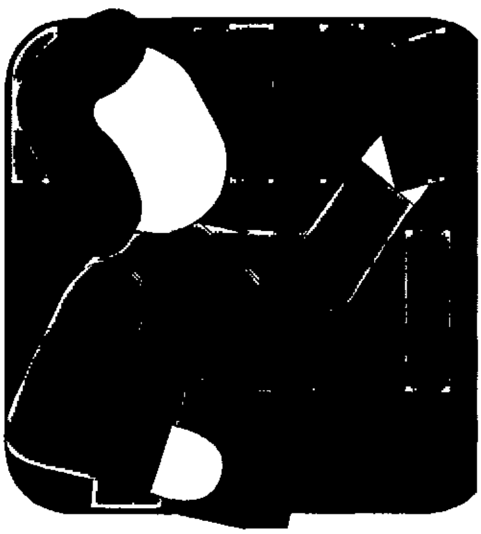
Irrespective of the soil taxa and land use, total amounts of all nutrients decreased with increasing depth in Entisols, where as an irregular trend of distribution with depth was observed with nutrients except N, S and Cu in *Inceptisols* and *Alfisols*.

Simple correlations between available nutrient contents and soil properties affecting available nutrient were worked out at a zone/ block levels. Total amounts of all nutrients except P correlated positively and significantly with their available amounts. Soil pH and EC had a positive and significant correlation only with available Ca and Mg contents. OC correlated positively and significantly with available N, P, K, S, Fe, Mn, Zn and Cu and a non-significantly with available Ca and Mg. Clay content had a positive and significant relationship with available K, Ca, Mg, Fe, Mn, Zn and Cu and a non-significant correlation with N, P and S. CEC correlated positively and significantly with K, Ca, Mg, Fe, Mn, Zn and Cu but non-significantly with available N, P and S.

5.2 Conclusions

- There is a considerable spatial variation in available nutrient contents within and between land uses and panchayats in mid- and low-hill soil zones of Panchrukhi block. Agricultural lands had higher amounts than non-agricultural lands.
- Mid-hill soil zone has better status than low-hill zone. Per cent of total panchayats rating high, medium and low in Panchrukhi block were 16, 52 and 32 in available N, nil, 52 and 48 in available P, 16, 54 and 30 in available K and 8, 57 and 35 in available S, respectively. Soils of all panchayats of Panchrukhi block were sufficient in available Fe. Per cent panchayats deficient in Mn, Zn and Cu were 30, 84 and 38, respectively.
- Surface horizons of *Entisols* had higher nutrient contents as compared to subsurface ones. Similar results were also observed with available N, P, S, Zn and Cu in *Inceptisols* and *Alfisols*. However, a reverse trend was obtained with available K, Ca, Mg, Fe and Mn.
- Irrespective of the soil taxa and land use, all the nutrients decreased with increasing depth in *Entisols*. Available N, P, S, Zn and Cu in *Inceptisols and Alfisols*, decreased with increasing soil depth whereas K, Ca, Mg, Fe and Mn exhibited an irregular trend of distribution with depth. On an average, K, Ca, Mg, Fe and Mn were higher in subsoils as compared to surface soils.

- Surface soils of *Entisols and Inceptisols* had higher OC and lower soil pH, EC, sand, and base saturation than subsurface layers. However, clay and CEC values in surface layers were comparatively lower in *Inceptisols and Alfisols.*
- Total nutrient content, soil organic carbon, clay and base saturation are the better soil fertility indicators in the study area.



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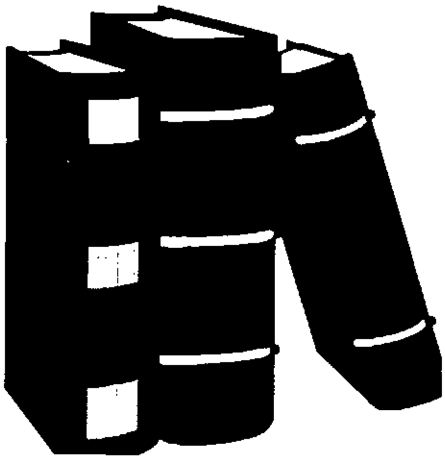

APPENDICES

APPENDIX – I

Available N and P status under different land uses in mid-hill soil zone

	Panchayat	Available N status					Available P status				
		Cropland	Tea garden	Forest	Grass/scrub land	Overall	Cropland	Tea garden	Forest	Grass/scrub land	Overall
1.	*Badehar*	L	M	L	L	L	L	L	L	L	L
2.	*Bandbihar*	M	-	M	M	M	L	-	M	L	M
3.	*Banuri Khas*	H	H	H	M	H	M	L	M	L	M
4.	*Bharwana*	M	H	M	L	M	L	L	M	L	L
5.	*Biara*	M	H	M	M	M	M	M	M	L	M
6.	*Chandropa*	M	H	H	M	H	M	L	M	L	M
7.	*Deogran*	M	M	M	L	M	M	L	L	L	L
8.	*Gadiara*	M	H	M	M	M	M	L	L	L	L
9.	*Jandpur*	M	M	M	M	M	M	L	L	L	L
10.	*Ladoh*	M	H	H	M	H	L	L	L	L	L
11.	*Mahal Banuri*	M	H	M	M	M	M	M	M	L	M
12.	*Mahal Holta*	H	H	H	M	H	M	M	M	L	M
13.	*Moulichak*	M	H	M	M	M	M	M	M	L	M
14.	*Nouri Jhikli*	M	-	M	L	M	M	-	L	L	L
15.	*Padiharkhar*	M	-	M	M	M	M	-	L	L	L
16.	*Rajpur*	M	H	M	M	M	M	M	M	L	M
17.	*Rajot*	L	-	M	L	L	M	-	L	L	L
18.	*Rakkar Bheri*	M	-	L	L	L	L	-	L	L	L
19.	*Sagoor Khas*	M	-	M	L	M	L	-	L	L	L
20.	*Saliana*	M	H	M	M	M	L	L	L	L	L
21.	*Simbal Khola*	L	H	L	L	L	L	L	L	L	L
22.	*Sungal*	M	H	M	M	M	M	M	M	L	M
23.	*Tanda*	M	-	H	M	H	M	-	L	L	L
24.	*Tikkar Khas*	L	-	L	L	L	L	-	L	L	L
25.	*Tarhail*	M	-	M	M	M	M	-	L	L	M
26.	*Tatahail*	M	-	M	M	M	M	-	L	L	M
	Mid-hill soil zone	**M**	**H**	**M**	**L**	**M**	**M**	**L**	**L**	**L**	**L**

Note: "-" indicate non-existence

APPENDIX – II

Available N and P status under different land uses in low-hill soil zone

Panchayat		Available N status					Available P status				
		Cropland	Tea garden	Forest	Grass/scrub land	Overall	Cropland	Tea garden	Forest	Grass/scrub land	Overall
1.	*Andretta*	H	-	M	M	M	M	-	L	L	L
2.	*Agojar*	H	-	H	M	H	M	-	L	L	L
3.	*Bhirdi*	M	-	M	M	M	M	-	L	L	L
4.	*Bhulana*	M	-	L	L	L	M	-	L	L	L
5.	*Bhuana*	M	-	M	L	M	L	-	L	L	L
6.	*Chadiar*	M	-	H	L	M	M		M	L	M
7.	*Check*	L	-	L	L	L	L	-	M	L	L
8.	*Darug*	L	-	L	L	L	L	-	M	L	L
9.	*Kailaspur*	L	-	L	L	L	L	-	M	L	L
10.	*Makol*	L	-	L	L	L	L	-	M	L	L
11.	*Simbal*	L	-	L	L	L	L	-	L	L	L
	Low-hill soil zone	**L**	**-**	**L**	**L**	**L**	**L**	**-**	**L**	**L**	**L**
	Panchrukhi block	**M**	**H**	**M**	**L**	**M**	**M**	**L**	**L**	**L**	**L**

Note: "-" indicate non-existence

APPENDIX – III

Available K and S status under different land uses in mid-hill soil zone

Panchayat	Available K status					Available S status				
	Cropland	Tea garden	Forest	Grass/scrub land	Overall	Cropland	Tea garden	Forest	Grass/scrub land	Overall
1. *Badehar*	M	M	M	M	M	L	M	L	L	L
2. *Bandbihar*	M	-	M	M	M	M	-	M	M	M
3. *Banuri Khas*	H	H	M	M	H	M	H	M	M	M
4. *Bharwana*	M	M	M	M	M	M	M	M	L	M
5. *Biara*	H	H	M	M	H	M	H	M	L	M
6. *Chandropa*	M	M	M	M	M	M	H	M	L	M
7. *Deogran*	M	M	M	L	M	M	M	L	L	M
8. *Gadiara*	M	M	M	M	M	M	M	M	M	M
9. *Jandpur*	M	M	M	M	M	M	H	M	M	H
10. *Ladoh*	M	M	L	L	L	M	M	M	M	M
11. *Mahal Banuri*	H	H	M	M	H	M	H	M	M	H
12. *Mahal Holta*	H	H	H	M	H	M	H	M	M	H
13. *Moulichak*	M	H	M	M	M	M	H	M	M	M
14. *Nouri Jhikli*	M	-	L	L	L	M	-	M	L	M
15. *Padiharkhar*	M	-	M	M	M	M	-	M	M	M
16. *Rajpur*	H	H	M	L	H	M	H	M	L	M
17. *Rajot*	M	-	L	L	L	L	-	L	L	L
18. *Rakkar Bheri*	M	-	M	M	M	M	-	L	L	L
19. *Sagoor Khas*	M	-	L	L	L	M	-	M	L	M
20. *Saliana*	M	M	L	L	L	M	H	M	M	M
21. *Simbal Khola*	L	-	L	L	L	L	-	L	L	L
22. *Sungal*	M	M	M	M	M	M	M	M	M	M
23. *Tanda*	H	H	H	M	H	M	H	M	M	M
24. *Tikkar Khas*	L	-	L	L	L	L	-	L	L	L
25. *Tarhail*	M	-	M	M	M	M	-	M	L	M
26. *Tatahail*	L	-	L	L	L	L	-	L	L	L
Mid-hill soil zone	**M**	**H**	**M**	**M**	**M**	**M**	**H**	**M**	**L**	**M**

Note: "-" indicate non-existence

APPENDIX – IV

Available K and S status under different land uses in low-hill soil zone

Panchayat	Available K status					Available S status				
	Cropland	Tea garden	Forest	Grass/scrub land	Overall	Cropland	Tea garden	Forest	Grass/scrub land	Overall
1. *Andretta*	M	-	M	M	M	M	-	M	M	M
2. *Agojar*	M	-	M	M	M	M	-	M	M	M
3. *Bhirdi*	M	-	M	L	M	M	-	M	M	M
4. *Bhulana*	M	-	L	M	M	M	-	L	L	L
5. *Bhuana*	L	-	M	L	M	L	-	M	L	L
6. *Chadiar*	M	-	M	L	M	M	-	M	M	M
7. *Check*	L	-	L	L	L	L	-	L	L	L
8. *Darug*	L	-	L	L	L	L	-	L	L	L
9. *Kailaspur*	M	-	M	L	M	L	-	L	L	L
10. *Makol*	L	-	L	L	L	L	-	L	L	L
11. *Simbal*	M	-	M	L	M	L	-	L	L	L
Low-hill soil zone	M	-	M	L	M	L	-	L	L	L
Panchrukhi block	M	H	M	M	M	M	H	M	L	M

Note: "-" indicate non-existence

APPENDIX – V

Percent samples deficient in available Mn, Zn and Cu under different land uses in mid-hill soil zone

Panchayat	Available Mn					Available Zn					Available Cu				
	Cropland	Tea garden	Forest	Grass/scrub land	Overall	Cropland	Tea garden	Forest	Grass/scrub land	Overall	Cropland	Tea garden	Forest	Grass/scrub land	Overall
1. Badehar	33	0	0	67	30	33	0	0	67	30	0	0	0	33	25
2.Bandbihar	0	-	0	0	0	0	-	0	50	10	33	-	0	50	22
3.Banuri Khas	0	0	0	0	0	0	0	0	0	0	0	0	0	50	10
4.Bharwana	0	0	0	0	0	0	0	0	50	10	0	0	0	0	0
5.Biara	0	0	0	0	0	0	0	0	33	10	0	0	0	50	10
6.Chandropa	0	0	0	0	0	25	0	0	50	20	0	0	0	0	0
7.Deogran	0	0	0	0	10	50	0	0	67	30	50	0	0	33	20
8.Gadiara	0	0	0	0	20	0	0	0	33	10	0	0	0	0	0
9.Jandpur	0	0	0	0	20	0	0	0	50	20	0	0	0	0	0
10.Ladoh	0	0	0	0	10	0	0	0	50	10	0	0	0	0	0
11.Mahal Banuri	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12.Mahal Holta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13.Moulichak	0	0	0	0	0	0	0	0	33	10	0	0	0	0	0
14.Nouri Jhikli	33	-	0	0	30	50	-	33	67	50	0	-	0	33	10
15.Padiharkhar	0	-	0	0	0	50	-	0	0	0	0	-	0	0	0
16.Rajpur	0	0	0	0	0	0	0	50	50	10	0	0	0	0	0
17.Rajot	33	-	0	0	0	67	-	0	50	25	0	-	0	50	13
18.Rakkar Bheri	0	0	0	0	0	50	0	50	0	50	50	0	0	33	13
19.Sagoor Khas	100	-	0	100	63	67	-	33	67	50	0	-	0	50	11
20.Saliana	0	0	0	0	0	67	0	50	50	50	0	0	0	67	25
21.Simbal Khola	0	-	0	33	10	50	-	33	67	10	0	-	0	33	10
22.Sungal	0	0	0	0	0	0	0	0	50	0	0	0	0	0	0
23.Tanda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.Tikkar Khas	33	-	0	67	33	67	-	0	50	15	33	-	0	50	25
25.Tarhail	0	-	0	67	30	0	-	33	67	30	0	-	0	33	10
26.Tatahail	67	-	0	33	33	0	-	33	33	22	50	-	0	33	33
Mid-hill soil zone	**10**	**0**	**0**	**24**	**12**	**24**	**0**	**15**	**54**	**24**	**10**	**0**	**0**	**23**	**10**

Note: "-" indicate non-existence

APPENDIX – VI

Percent samples deficient in available Mn, Zn and Cu under different land uses in low-hill soil zone

Panchayat	Available Mn					Available Zn					Available Cu				
	Cropland	Tea garden	Forest	Grass/scrub land	Overall	Cropland	Tea garden	Forest	Grass/scrub land	Overall	Cropland	Tea garden	Forest	Grass/scrub land	Overall
1.Andretta	0	-	0	0	0	0	-	0	50	13	0	-	0	0	0
2.Agojar	0	-	0	0	0	0	-	0	100	25	0	-	0	0	0
3.Bhirdi	0	-	0	0	0	0	-	0	50	11	0	-	0	0	0
4.Bhulana	50	-	0	67	33	50	-	0	100	44	50	-	0	0	11
5.Bhuana	0	-	0	0	0	33	-	0	100	40	0	-	0	0	0
6.Chadiar	0	-	0	50	11	0	-	0	100	28	0	-	0	0	0
7.Check	67	-	0	50	33	67	-	50	100	56	33	-	50	50	44
8.Darug	50	-	0	50	25	100	-	50	100	75	50	-	50	50	63
9.Kailaspur	50	-	0	50	25	50	-	25	50	38	0	-	0	50	13
10.Makol	50	-	0	50	25	50	-	50	100	63	50	-	0	50	25
11.Simbal	50	-	0	50	25	50	-	25	100	63	50	-	0	50	25
Low-hill soil zone	**27**	**-**	**0**	**33**	**16**	**35**	**-**	**18**	**88**	**40**	**19**	**-**	**9**	**21**	**15**
Panchrukhi block	**14**	**0**	**0**	**26**	**16**	**24**	**0**	**15**	**54**	**27**	**10**	**0**	**4**	**23**	**10**

Note: "-" indicate non-existence

APPENDIX – VII

Nutrient status of macro-nutrients

Nutrient	% panchayats rating			% of total samples rating		
	High	Medium	Low	High	Medium	Low
N	16	52	32	14	71	16
P	-	52	48	-	69	31
K	16	54	30	15	70	15
Ca			-----------Sufficient-----------			
Mg			-----------Sufficient-----------			
S	8	57	35	9	71	21

APPENDIX – VIII

Sufficiency/ deficiency status of micro-nutrients

Nutrient	% panchayats rating		% of total samples rating	
	Deficient	Sufficient	Deficient	Sufficient
Fe	-	100	-	100
Mn	30	70	12	88
Zn	84	16	24	76
Cu	38	62	7	93

Brief Biodata of the Student

Name	:	Poonam Gogoi
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Father's Name	:	Mr. Mahendra Nath Gogoi
Date of Birth	:	20.01.1988
Permanent Address with Contact	:	c/o M. N. Gogoi Samridhi Path, 2.No Sensua , Borbheta Jorhat, Assam
Number	:	Mobile no 9706647515

Academic Qualification: (starting with 10th class)

Qualification	Year	School/Board/University	Marks (%)	Division	Major Subject
10th	2004	CBSE	81.40	1st	Maths, Science, Hindi, English, Social Studies
10+2	2006	CBSE	71.40	1st	Maths, Physics, Chemistry, Biology, English
B.Sc. (Ag.)	2010	Assam Agriculture University, Jorhat	78.14	1st	Agriculture
M.Sc. (Ag.)	2012	CSKHPKV, Palampur	84.10	1st	Soil Science

Fellowships/ Scholarships/ Gold Medals/ Awards/ any Other Distinction	Monthly Scholarship for Department topper