Evaluation of Spatial and Temporal Changes of Soil Quality near Sorang Hydroelectric Power Project in District Kinnaur, Himachal Pradesh, India

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Abstract: Soil is a natural body of mineral and organic material differentiated into horizons, which differ among themselves as well as from underlying materials in their morphology, physical make-up, chemical composition and biological characteristics. Soil quality is one of the most important factors in sustaining the global biosphere and developing sustainable agricultural practices. It has been defined in several different ways in recent years from view points of bioproductivity, sustainability, environmental protection, and human and animal health. The present study was carried out to determine the potential of soil in the study area and to identify the impacts of urbanization and construction of Sorang Hydroelectric power project on the soil quality of the study area. Soil samples collected from 20 locations were analyzed for physico- chemical characteristics. After analyzing soil samples it was found that the pH of soil at various sites lies within the normal range which is optimum for most of the crops. Soil samples of the study area were slightly enriched with Na2O, with average content of 3.20%. Sodium concentration in the soil of the study area was little higher than normal value of 1.5%, but, do not indicate any potential for soil salinization or adverse impacts on soil productivity.

Keywords: Mineral, Organic Material, Horizons, Chemical Composition, Sustainability, Environmental Protection and Salinization.

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1. INTRODUCTION

Soil is an unconsolidated material of the earth's crust in which terrestrial plants grow if water and temperature are adequate with minimum available nutrients. According to Joffe (1949) the soil is a natural body of mineral and organic material differentiated into horizons, which differ among themselves as well as from underlying materials in their morphology, physical make-up, chemical composition and biological characteristics (Solanki and Chavda, 2012). Soil can develop from weathered rocks, volcanic ash deposits or accumulated plant residues. Soil thus forms a substrate for plant growth which performs many functions essential to life and in general, most plants grow by absorbing nutrients from the soil whose ability to do this depends on the nature of the soil. Soil formation is a constructive as well as destructive process (Pujar, *et al*., 2012) the predominant destructive processes are physical and chemical breaking down of materials, plants and animal structures which result in the partial loss of more soluble and volatile products. Soil types are a major factor in determining what types of plants will grow in a certain area as plants use inorganic elements from the soil such as nitrogen, potassium and phosphorus. However micro organisms like fungi, bacteria and other microscopic life forms available within the soil are also vital and hence soil is a dynamic medium made up of minerals, organic matter, water, air and micro organisms (Wagh, *et al*., 2013). The nature of soil primarily depend upon its continued change under the effect of physical factors like the parent material, time, the climate, the organic activity in it etc. (Solanki and Chavda, 2012).

Declining soil quality (SQ) is emerging as an environmental and economic issue of increasing global concern as degraded soils are becoming more prevalent due to intensive use and poor management, often the result of over-population (Eswaran, *et al.,* 2005). Pressing problems such as erosion, compaction, acidification, organic matter losses, nutrient losses and desertification reduce agricultural production capacity. SQ decline severely impacts the environment and agricultural viability, and thus eco-systems and the population's health, food security, and livelihoods.

Physico-chemical properties of soils depend on both natural and anthropogenic factors, together acting over different spatial and temporal scales. Natural pedological processes (rock weathering and organic matter decomposition) are related to parent material, geomorphology of the area, presence of vegetation, the climatic conditions and other interactions with the environment. The effects of these processes are strictly time-dependent and exposed in a quite complex structure of soils. In contrast, soil management practices significantly affect pedological properties by changing soil structure mechanically due to agricultural and urban activities, and by changing chemical composition through pollution load. The presence of any element in a fatal concentration in the soil could be due to both natural and anthropogenic factors; therefore it is often quite difficult to discriminate among the different causes. The parent material largely influences heavy metal content in many soil types, with concentration sometimes exceeding the critical values (Palumbo, *et al*., 2000; Salonen and Korkka-Niemi, 2007).

2. DESCRIPTION OF THE STUDY AREA

Kinnaur, located on the Indo-Tibetan border, is very scenic; and is surrounded by the Tibet on the east, Garhwal

Himalaya on south, Spiti Valley on the north and Kullu on the west. It lies between North latitude 31°35’40” to 31°34’42” and East longitude 77°52’38” to 78°51’28”. Kinnaur is about 235 kilometers from Shimla.

The Sorang Hydroelectric Power Project (SHEP) is located on Sorang Khad a tributary of river Satluj near the village Nigulsari, which is about 170 kilometers from Shimla, the State Capital of Himachal Pradesh. Sorang Khad is on right bank of river Satluj, opposite village Nigulsari that falls along NH-22 and it originates at an altitude of 5625 meters in the high reaches of Kokshane Mountain in the Himalayas. The powerhouse will be fitted with a ventilation tunnel. From the powerhouse, the water will be discharged back into Satluj River, via a tail race tunnel. It will enter the Satluj River immediately downstream of the power house site (Lata, *et al.*, 2013). The switchyard will be located above ground. The electricity will be exported to the grid via an 18km double circuit transmission line from SHEP to HPSEB’s Kotla Sub-station.

3. SOIL QUALITY OF THE STUDY AREA

Soil in the research area is skeletal, mountain meadow and sub-montane type. It is thin on most hillsides; however, the soil profile is well developed in dense forest and at higher altitude. Soil over most of the area is developed insitu and varies from loam to clayey-loam. Soil erosion at steeper slopes, however, has resulted into no soil development. Generally, on ridges, spurs, precipitous slopes and southern slopes, the soil is shallow. On the other hand, it is moderately deep on the cooler aspects and on gentle slopes. Rocks are generally covered by glacial deposits, rock debris, alluvial terraces and fans. The soils of Satluj valley are relatively poor sandy loam with exposed bedrock, rocks and gravel abound. In the valley bottom, there is virtually no soil, but between elevation 1200 and 3500 m, the soils support some forest cover and are cultivable to a certain extent. The soil map of the study area is depicted at Figure 1.

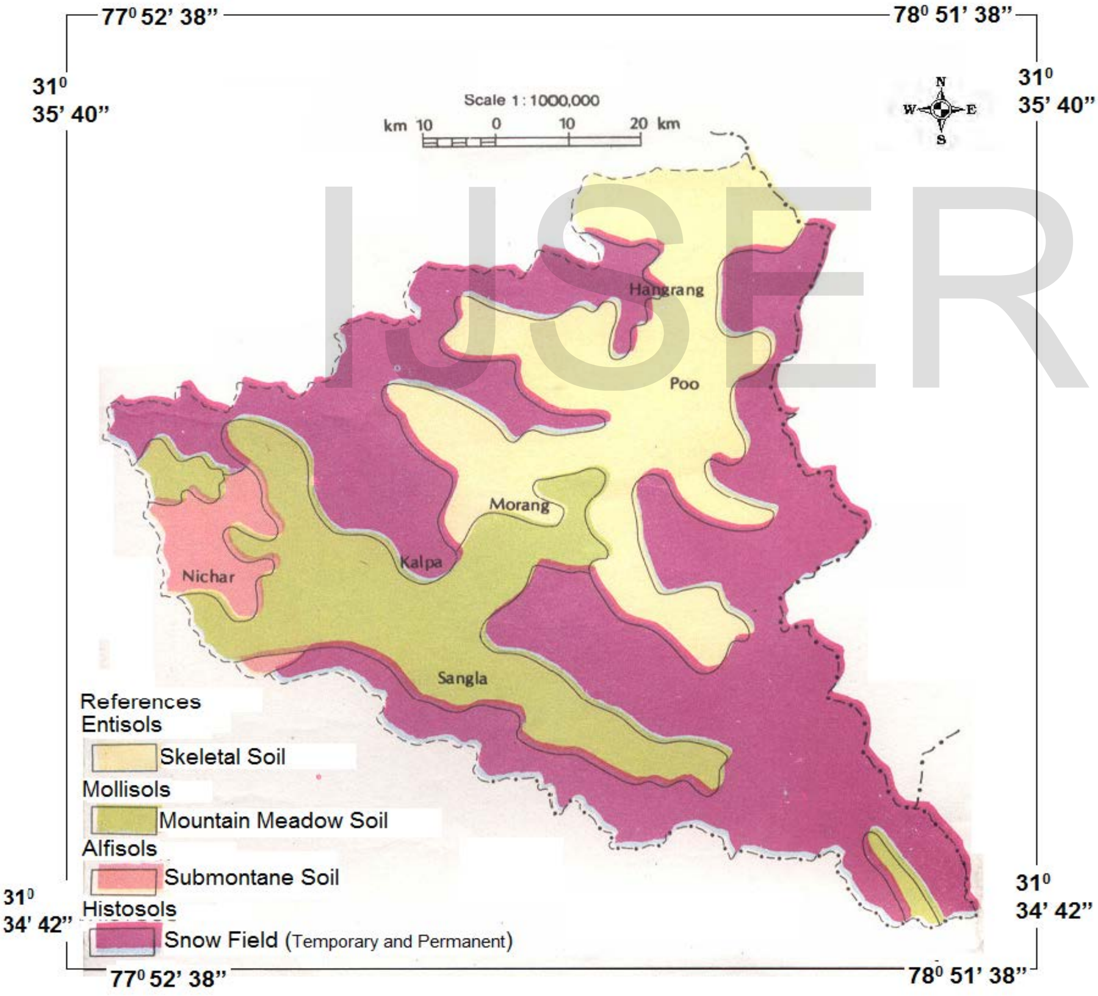

Fig. 1. Soil Map of District Kinnaur

(Source: After, Directorate of Agricultural Census, H.P., 2003)

Soil quality is the ability of a soil to perform the functions necessary for its intended use. It may be defined as the capacity of a reference soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation (Karlen, *et al.*, 2001). The quality of soil is rather dynamic and can affect the sustainability and productivity of land use. Soil quality indicators are significant, however, will vary according to the location, and the level of sophistication at which measurements are likely to be made (Riley, 2001). In much of the literature, it is postulated that basic soil quality indicators should reflect criteria which are relevant to existing soil data bases (Doran and Parkin, 1994). Based on these prepositions a list of basic soil properties that may be indicative of soil quality were established and are given in Table 1. and Table 2.

Table 1. Minimum Data Set (MDS) of Chemical and Physical Indicators for Soil Quality

Function and Rationale for Measurement (a). Relationship to soil condition and function (b). Rationale for measurement	
Property	**Remarks**
Physical	
Soil texture	(a) Indicates how well water and chemicals are retained and transported (b) Provides an estimate of soil erosion and variability
Chemical	
Soil organic matter	(a, b) Defines soil fertility and stability
pH	(a, b) Defines biological and chemical activity thresholds
Electrical Conductivity	(a, b) Defines plant and microbial activity thresholds
Extractable P and K	(a) Describes plant-available nutrients and potential for N loss (b) Indicates productivity and environmental quality

(Source: Doran, et al., (1996), Larson and Pierce (1994))

Table 2. Summary of Soil Health Indicators Used to Asses Soil Function

S.No.	Indicator	Soil function
1	Soil organic matter (SOM)	Soil structure, stability, nutrient retention; soil erosion (Carter, 2002)
2	**Chemical:** pH, extractable soil nutrients, P-K and base cations Ca, Mg and K	Soil biological and chemical activity thresholds; plant available nutrients and potential for P as well as loss of Ca, Mg and K (Doran and Jones, 1996)
	Electrical conductivity	Plant growth, microbial activity, and salt tolerance
	pH	Biological and nutrient availability
	Extractable phosphorus (P) and potassium (K)	Plant available nutrients and potential for K and P loss

The soils of Himachal Pradesh are varied and are mainly dependent on lithology, topography, altitude, climate and vegetation cover. Soil is important single factor, besides water that has determined settlement of human in this fragile region. Most of the properties related to soil morphology are inherited from the parent rock types and their mineralogical assemblage. Lithology of the area shows slate, phyllites, schist, quartzite, gneisses and granitoids. Hence the soil is silty, micaceous, clayey and also sandy (Sharma and Minhas, 1993). The higher peaks in Sorang area are mainly bare rocks and are ice covered. There is meager soil cover. The rocks are predominantly sedimentary rocks mainly argillites. The soils have little chance of staying in place. It gets accumulated on less steep slopes where land terracing has been done as in villages like Bara Khamba and Chhota Khamba. Wind, ice, snow and rain have eroded material to form drift soil. The material is heterogeneous, modified by streams, brooks, stream lets, snowmelt water and get deposited like any sediment in a basin, in a flat receptacle. To assess the soil quality characteristic of the region, a total of 20 soil samples were collected and analyzed. The sample of the soils were sieved, shade dried and stored for further use. The soil samples were analyzed for various oxides as SiO_2, Al_2O_3, Fe_2O_3, MgO, CaO, Na_2O, K_2O, TiO_2, P_2O_5, MnO and parameters like pH, EC, and TDS. The locations of soil samples are given in Figure 2. and the results of the physico-chemical analysis of soil samples are given in Table 3.

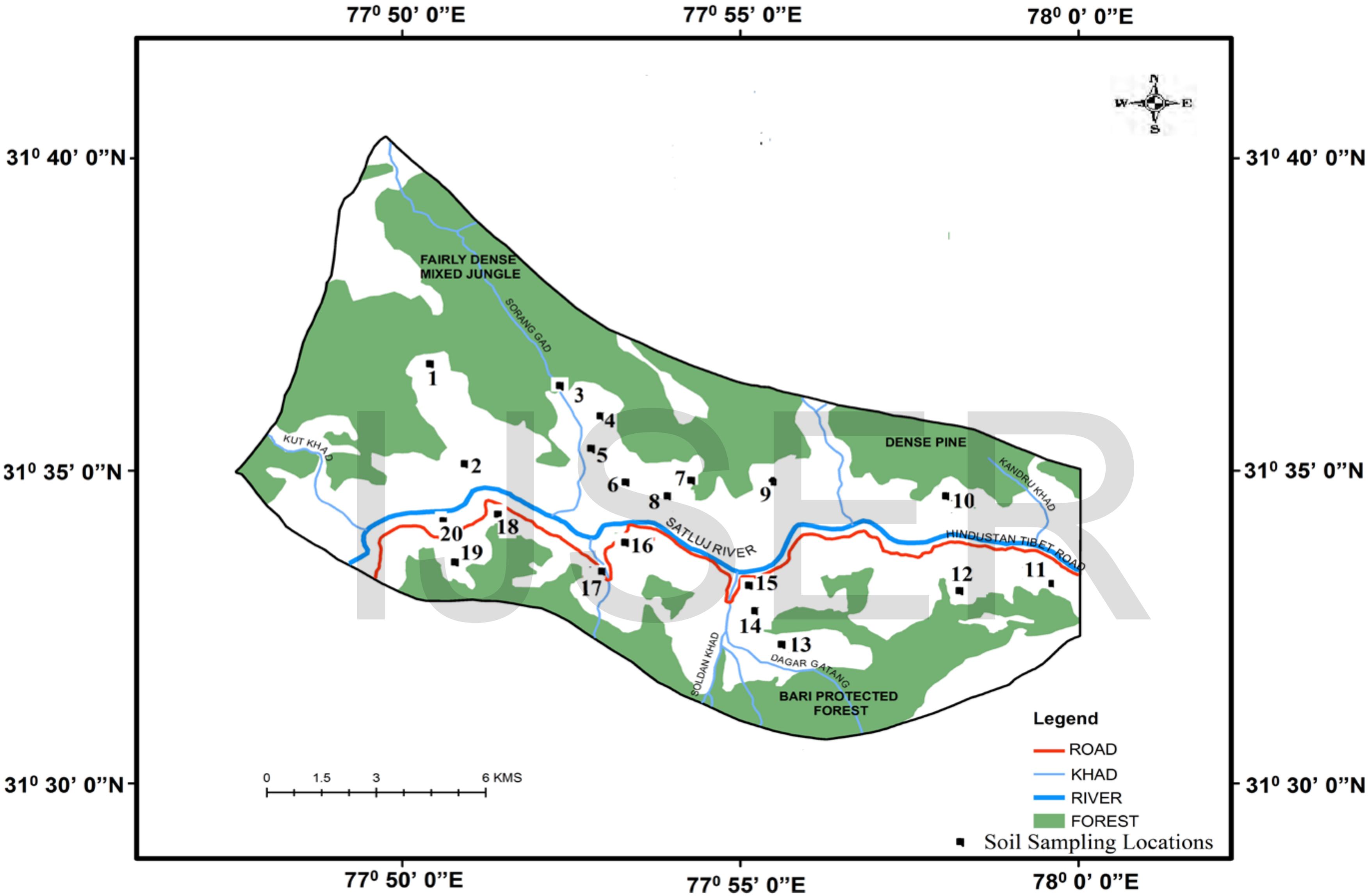

Fig. 2. Location of Soil Sampling Points in the Study Area

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Table 3. Results of Soil Sample Analysis Collected from the Study Area

S. No.	Location	pH	EC dS/m	TDS mg/l	SiO_2%	Al_2O_3%	$Fe_2 0_3$%	Na_2O%	K_2O%	CaO%	MgO%	P_2O_5%	TiO_2%
1	Rupi	7.2	27.4	17.81	65.63	16.94	2.48	5.45	5.60	0.82	0.21	0.56	0.59
2	Linge Dogri	8.4	41.5	26.98	32.50	16.80	2.58	6.10	8.40	1.95	1.91	0.46	0.58
3	Sorang(Intake Site)	8.6	25.2	16.38	85.03	31.80	2.91	5.40	4.20	0.41	0.12	0.71	0.72
4	Sorang Village	7.4	36.1	23.47	56.75	24.02	3.37	0.89	0.57	0.32	0.16	0.81	0.67
5	Power House Site	6.8	50.3	32.69	68.93	19.91	3.55	2.50	0.98	2.40	0.81	0.79	0.68
6	Bada Khamba	6.9	29.5	19.18	57.78	14.98	3.01	1.23	0.78	0.05	0.20	0.73	0.96
7	Chhota Khamba	7.0	34.4	22.36	69.14	19.28	3.15	2.06	1.60	0.39	0.71	2.01	0.35
8	Chikwa Village	7.7	24.6	15.99	69.14	27.25	2.83	3.10	3.20	0.65	0.48	0.59	0.60
9	Garshu Village	6.5	32.6	21.19	61.29	20.17	3.12	3.80	0.64	0.51	0.17	0.37	0.66
10	Nathpa	7.5	38.7	25.16	67.28	17.89	2.18	3.50	4.30	1.01	0.92	0.76	0.74
11	Bhabanagar	7.1	20.7	13.46	68.11	14.41	1.62	4.70	0.96	0.91	0.74	0.43	0.85
12	Nichar	7.9	24.8	16.12	61.29	19.72	3.10	2.92	6.70	1.71	0.42	0.48	0.50
13	Bari Village	8.1	33.8	21.97	34.05	10.11	2.66	2.70	5.10	1.12	0.83	0.75	0.73
14	Paunda	6.7	25.8	16.77	62.32	18.96	3.06	3.65	5.40	1.23	1.41	0.66	0.59
15	Pilingi	7.3	21.9	14.23	71.20	20.29	1.21	1.90	4.60	2.00	1.90	0.55	0.68
16	Tranda Village	7.8	30.2	19.63	65.42	25.03	2.97	2.30	7.80	1.05	0.30	0.49	0.95
17	Nigulsari	6.4	30.5	19.83	59.64	18.02	2.79	5.91	5.90	0.98	0.17	1.31	0.81
18	Chaura	7.6	29.5	19.18	60.88	23.90	3.50	1.11	4.40	0.08	0.10	0.46	0.55
19	Sailan Dogri	6.3	29.8	19.37	65.02	18.71	0.97	3.04	2.90	0.37	0.32	1.34	0.74
20	Kapurang Village	6.5	22.9	14.89	40.03	10.31	1.52	1.80	0.54	0.75	0.25	0.79	0.76
Minimum		6.3	20.7	13.46	32.50	10.11	0.97	0.89	0.54	0.05	0.10	0.37	0.35
Maximum		8.6	50.3	32.69	85.03	31.80	3.55	6.10	8.40	2.40	1.91	2.01	0.96
Average		7.3	30.5	19.83	61.07	19.45	2.63	3.20	3.73	0.94	0.61	0.75	0.68
Standard Deviation		0.7	7.3	4.71	12.64	5.24	0.75	2.12	1.60	0.65	0.56	0.39	0.15

4. PHYSICO-CHEMICAL ROPERTIES OF THE SOIL OF THE STUDY AREA

4.1 Soil Water

Major part of soil water is runoff or percolating water. Water in soil is in the form of soil moisture which contains various solutes and dissolved gases. Amount of water in the form of soil moisture is estimated to range from 0.001 to 0.0005% of the total water content of the earth (Bohn, *et al*., 2001). The concentration of these solutes and gases differs according to their solubility, conditions of formation of soil, water content, organics and gases (Wild, 1996).

4.2 Soil Air

Air in the soil is not of uniform nature but a mixture of nitrogen, oxygen and carbon dioxide. Concentration of nitrogen remains constant (79%) while oxygen and nitrogen dioxide fluctuate (Hausenbuiller, 1972). CO_2 is higher than oxygen in soils which are rich in flora and fauna, due to respiration of plants and soil organisms and the reduced diffusion of gases.

4.3 pH

The acid/alkali balance is very important in maintaining optimum availability of applied nutrients. At very low pH values, soluble aluminium becomes toxic, phosphate is unavailable and calcium levels can be low. At high pH, iron and other trace elements are rendered unavailable because they are locked up as hydroxides and carbonates. Figure 3. shows distribution of pH in the soils of the study area. Average soil pH of the samples was 7.29 with a range of 6.3 to 8.6 (Table 4.). Highest pH 8.6 was recorded at Sorang Intake Site. This pH range is normal and is optimum for the majority of crops.

Table 4. Soil Quality of Study Area Based on pH Values

S.No	pH	Category	No. of Samples	Recommendation
1	<6.5	Acidic	2	Requires liming for reclamation
2	6.5-8.7	Normal	18	Optimum for most crops
3	8.7-9.3	Alkaline	Nil	Requires application of organic manures
4	>9.3	Alkali (Sodic)	Nil	Requires gypsum for amelioration

(Source: After Soil Science Laboratory Manual, 1997)

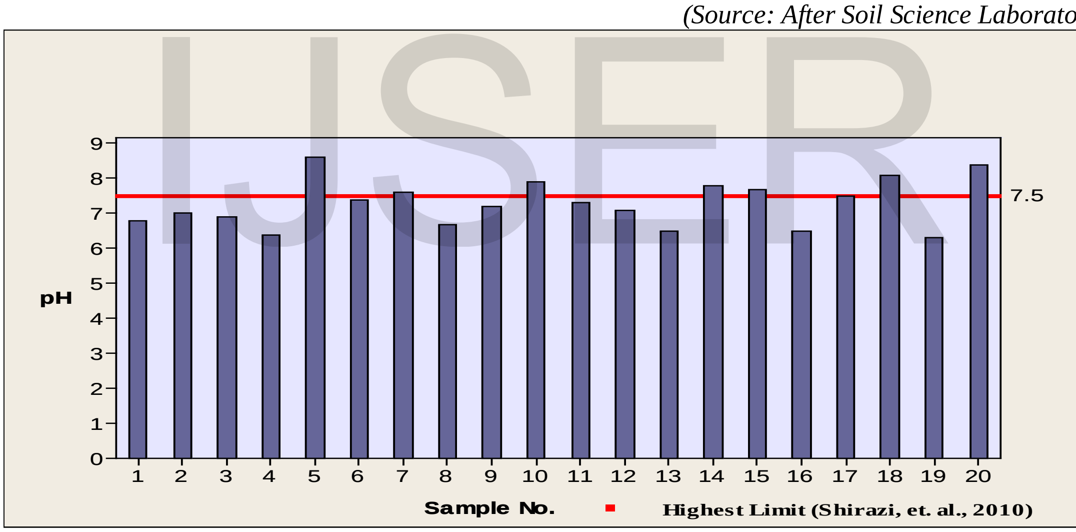

Fig. 3. Distribution of pH in the Soil

4.4 Electrical Conductivity (EC)

EC and Total dissolved Solids both are significant from agricultural point of view. High electric conductivity of the soil indicates more dissolved substances. The increase in soil salinity speeds up soil erosion and retard the plant growth (Szabolcs, 1989). Sources of soluble salts in the soil include weathering of primary minerals and native rocks, atmospheric deposition, saline irrigational water, addition of inorganic and organic fertilizers (Sparks, 2003). The EC value of soil samples of the study area varied between 20.7 dS/m at Bhabanagar and 50.3 dS/m at power house site of Sorang HEP with mean value of 30.51 dS/m (Table 3).

4.6 Silica (SiO_2%)

The silica content in the soil samples of the study area varied from 32.50% to 85.03% with average value of 61.07%. Highest concentration of silica 85.03% was observed in soil sample collected from Sorang (Intake Site) and lowest concentration 32.50% was observed at Linge Dogri. Figure 4. showing the distribution of SiO_2 (%) concentration in the soils of the study area. High silica content was shown in relatively coarse textured soils. This may be attributed to the higher content of sand in these soils because quartz is more common in this size grade.

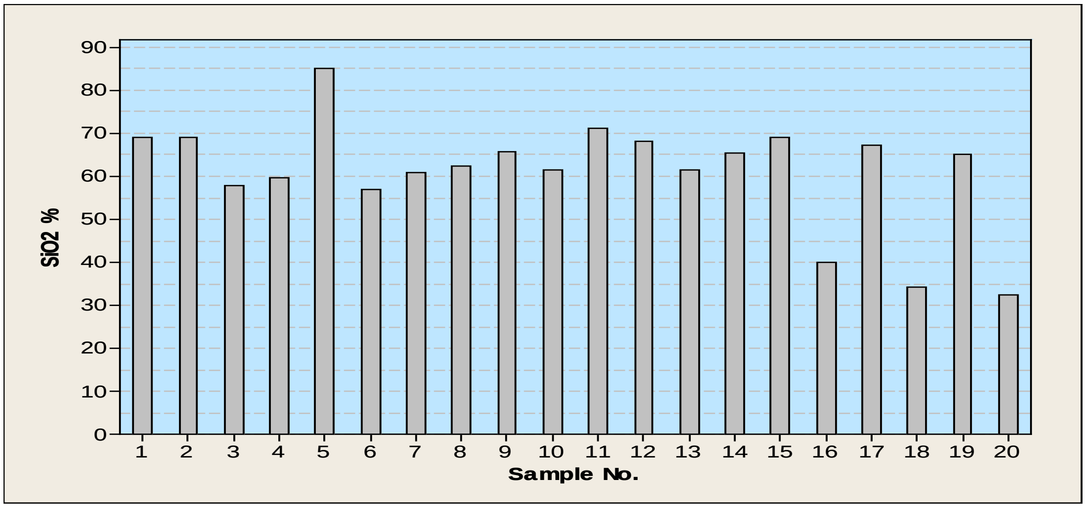

Fig.4. SiO_2 % Concentration in the Soil

4.5 Alumina (Al_2O_3%)

Among sesquioxides, alumina makes up a relatively appreciable amount of soil chemistry. Relatively fine textured soils contain higher content of alumina compared to other soils .The lower alumina content in the soil samples may be due to their lower clay content. Alumina in general shows an inverse trend from that of silica. Average Al_2O_3% of the samples was 19.43 % with a range of 10.11 % to 31.80%. Figure 5., gives the detail of Al_2O_3 concentration (%) in the soils of the study area.

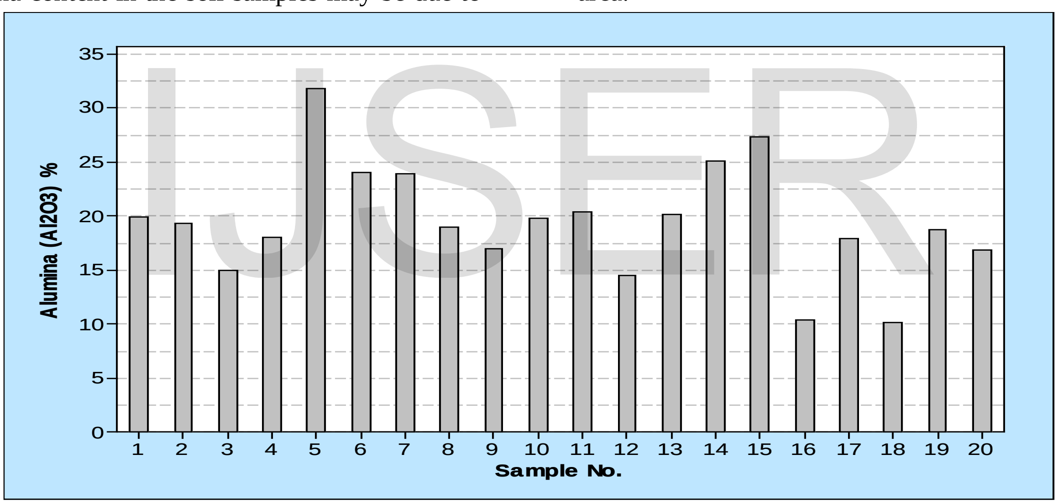

Fig. 5. Al_2O_3% Concentration in the Soil

4.7 Calcium Oxide (CaO %)

Amount of Ca present in soil varies greatly from 0.05% to 25% of the whole soil weight (Hausenbuiller, 1972). Limestone derived soils are not very productive because of excessive leaching of Ca (Bohn, *et al.*, 2001).

Crops grow rapidly when Ca is adequate in the soil. Calcium maintains the soil pH neutral for plants and micro-organisms survival (Bohn, *et al.*, 2001). Ca deficiency results in chlorosis, root damage and malformation of younger leaves (Jain, 2006). According to Bohn, *et al.* (2001) the safe limit for CaO in normal agricultural soils is 2.5 %. Average CaO (%) of the samples was 0.94 % with a range of 0.05 % to 2.40%. Higher value of CaO content was observed in the soil sample collected from Power House Site (2.40%). The distribution of CaO concentration is shown in Figure 6. All the soil samples of the study area are fit for agricultural purposes.

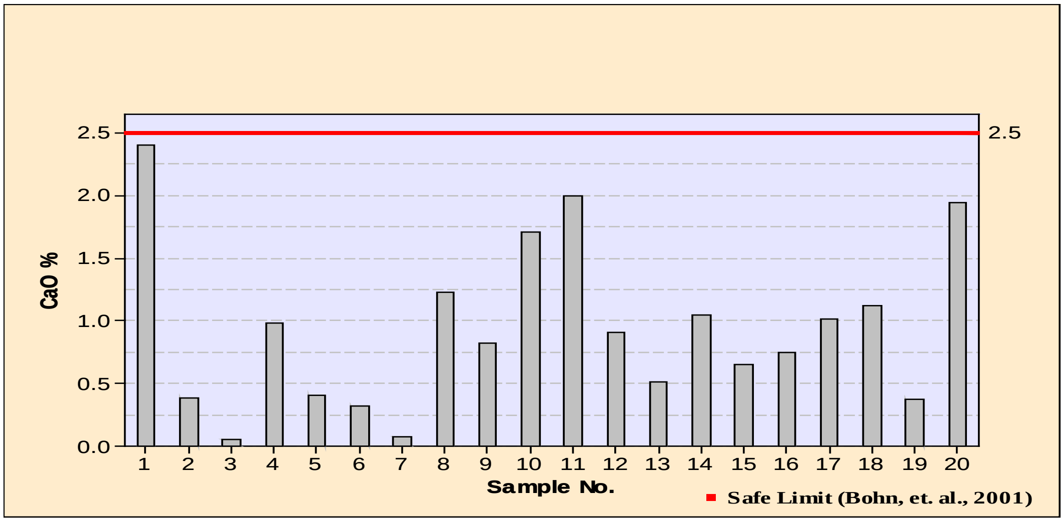

Fig. 6. CaO % Concentration in the Soil

4.8 Magnesium Oxide (MgO %)

Magnesium is a part of chlorophyll and helps in the translocation of starch within plant tissues. It is also significant in the formation of plant oils and fats and for the growth of new cells (Bohn, *et al.*, 2001). Magnesium deficiency appears in the form of leaf chlorosis and necrotic patches on leaves (Jain, 2006). Soils with high Mg content experience some problems like high pH. The magnesium concentration in the study area varied from 0.10% to 1.91% with the average value of 0.61%. Figure 7. shows MgO concentration (%) in the soil of the study area and all soil samples are well within the safe limit of 1.5% (Bohn, *et al.*, 2001) except for the two samples. Thus it is fit for the agricultural use.

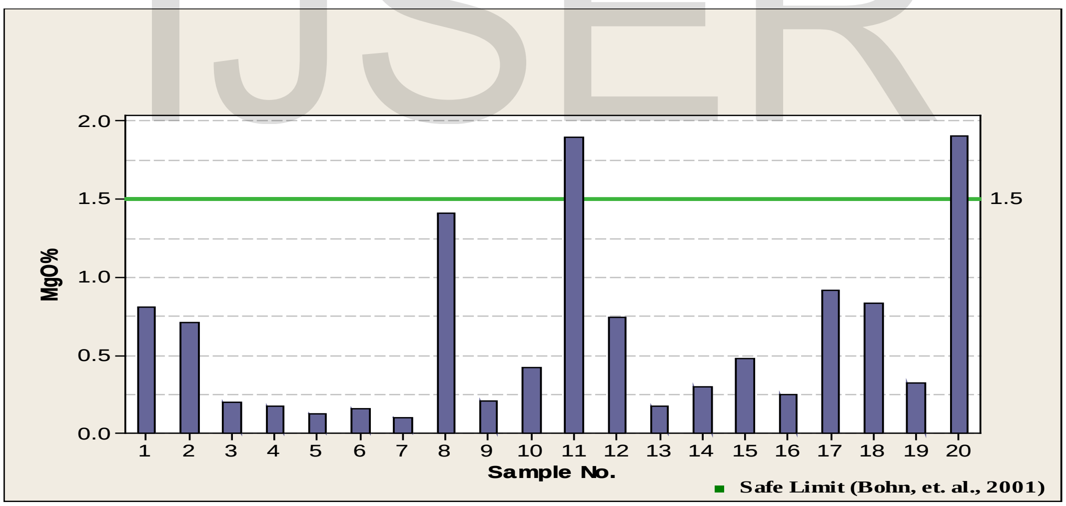

Fig.7. MgO % Concentration in the Soil

4.9 Sodium Oxide (Na_2O %)

Sodium oxide content of the soil varied from 0.89 % to 6.10% with an average of 3.20%. Sodium is not required by plants and inhibits the absorption of K. It is estimated that 5%-15 % of exchangeable Na has inhibitory effect on water movement (Bohn, *et al.*, 2001). Elevated concentrations of Na results in soil swell (Pendias and Pendias, 1992). High Na reduces photosynthesis and disrupts the balance of Reactive Oxygen Species (ROS) (Marschner, 1995). The recommended value of Na_2O% for agricultural soil is 1.5% (Bohn, *et al.*, 2001). In this respect, majority of the samples of the study area were having elevated level of Na_2O. Higher percentage of sodium oxide was shown by the soils which are relatively coarser in texture and those that are salt affected. This is possibly due to the association of Na_2O primarily in the minerals common in sand size fraction. Figure 8. depicts Na_2O concentration (%) in the soils of the study area.

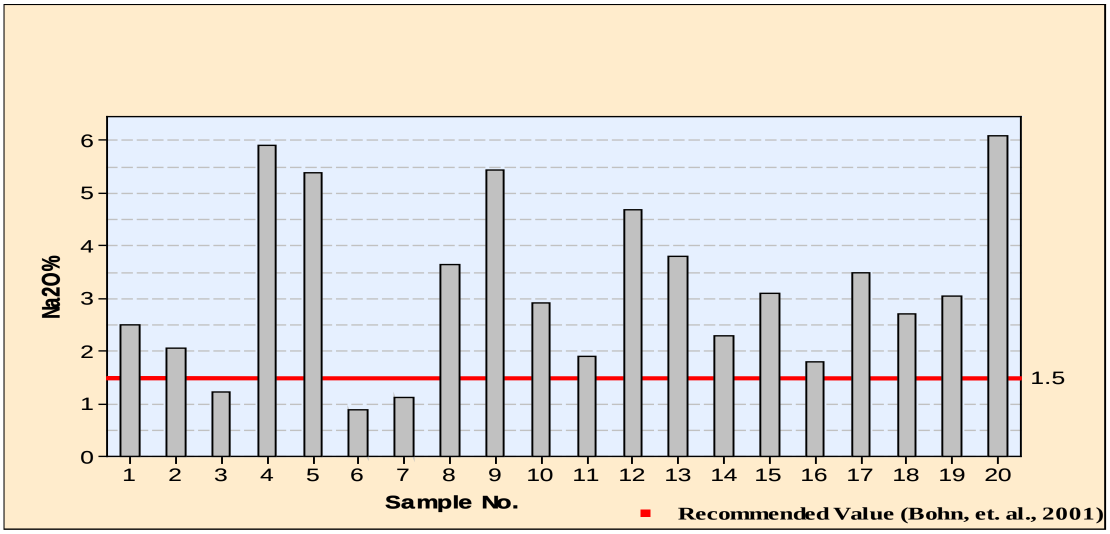

Fig. 8. Na_2O % Concentration in the Soil

4.10 Potassium Oxide (K_2O %)

Potassium is the 3rd most used element in fertilizers after nitrogen and phosphorus (Bohn, *et al*., 2001). In soil the minerals having K in abundance are mica, feldspar and illite (Hausenbuiller, 1972). In plants K remains in ionic form having different functions e.g., synthesis of protein, chlorophyll and carbohydrate, transformation of nitrogen from nitrates, helps in the root absorption, translocation and storage of carbohydrates (Hausenbuiller, 1972). Symptoms of K deficiency are chlorosis and necrosis of leaves and stunted plant growth (Jain, 2006). Average K_2O % of the samples was 3.73% with a range of 0.54% to 8.40%.

The safe limit of K_2O content in normal agricultural soil is 1.5% (Bohn, *et al*., 2001). Only six samples were below the safe limit, rest 70% of the samples were above the safe limit. The higher content of K_2O may be due to overuse of K based fertilizers. Figure 9. shows K_2O concentration (%) in the soil of the study area.

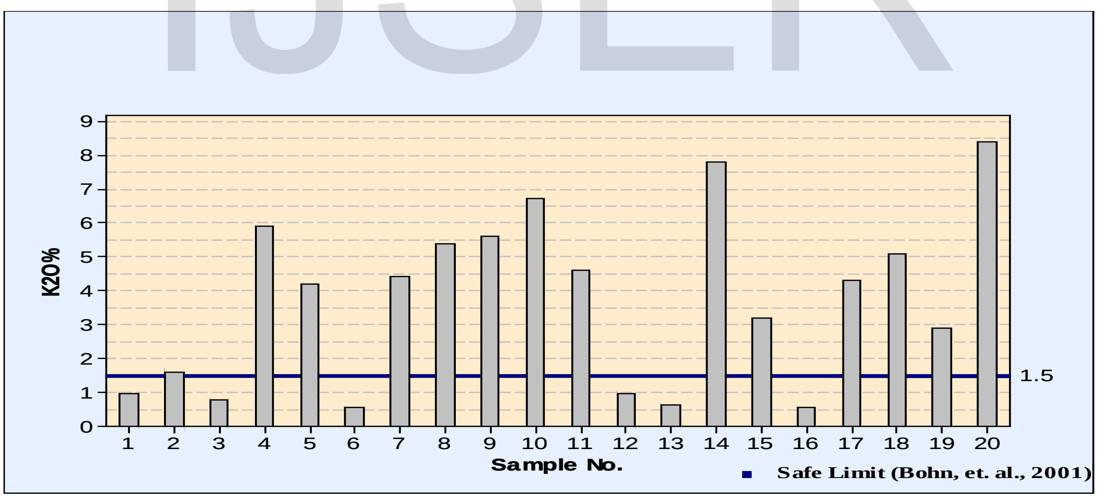

Fig.9. K_2O % Concentration in the Soil

4.11 Iron Oxide (Fe_2O_3 %)

Iron content provides base in the classification of soil types. Normal soils are supposed to contain 0.5%-5% Fe. (Pendias and Pendias, 1992). Iron is a plant micronutrient and its deficiency leads to severe impacts on growth and yield (Marschner, 1995). Iron has important part in nitrate and sulphate reduction, chlorophyll formation, metabolism and catalytic functions (Pendias and Pendias, 1992). Average Fe_2O_3 % of the samples was 2.63% with a range of 0.97% to 3.55%.

Permissible limit of Fe_2O_3 for normal agricultural soils given by Bohn, *et al*. (2001) is 5.77%. All the studied soil samples were having Fe_2O_3 concentration within normal range. Figure 10. depicts the Fe_2O_3 concentration (%) in the soils of the study area which is well within the safe limit.

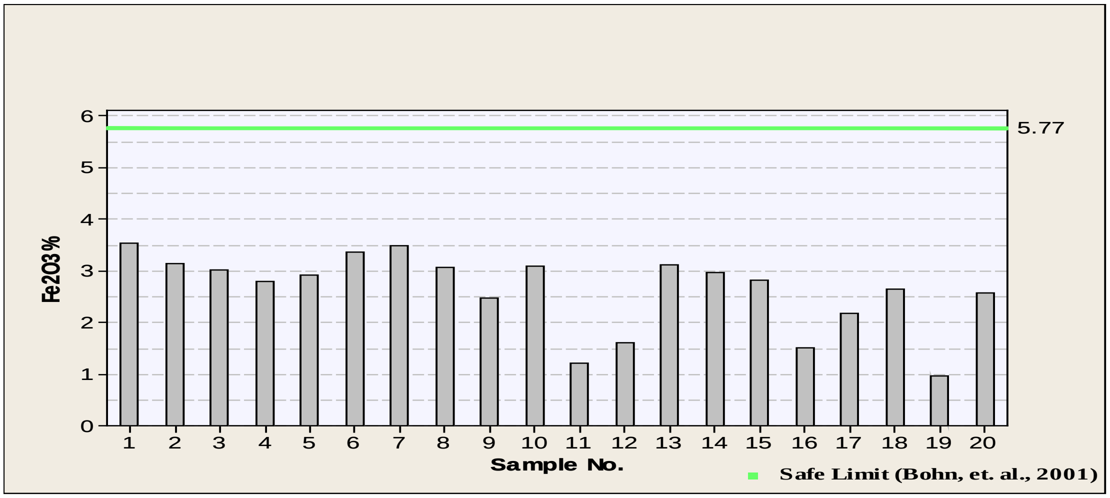

Fig. 10. Fe_2O_3 % Concentration in the Soil

5. CONCLUSION

A detailed study of soil quality in the study area revealed that the pH of soil at various sites lies within the normal range which is optimum for most of the crops. Soil samples of the study area were slightly enriched with Na_2O, with average content of 3.20%. Sodium concentration in the soil of the study area was little higher than normal value of 1.5%, but, do not indicate any potential for soil salinization or adverse impacts on soil productivity. Taking into consideration the morphological and physio-chemical characteristics of the soil and general similarity in them, the various types of soils observed in the area can be grouped into three major types. Type-I soil is coarse loamy, mixed type in nature. This type of soil is developed from granites, highly metamorphosed gneisses, schist and occurs on moderately sloping to steep lands. These soils are well drained with moderately rapid permeability. Natural vegetation exists in these soils and various crops are cultivated according to the suitability. Type-II soil is fine loamy, mixed and frigid in nature. They have developed on parent material consisting of granite-gneiss and mica schist on steep to very steep slopes at an altitude of about 3,000 meters amsl. These are grazing lands supporting alpine grasses. Type- III soil includes various series like Sangla, Spillo, Kalpa, Leo and Scree series. It is evident from the analyzed soil samples that the quality of soil in the study area is suitable for the agricultural purposes. However the soil excavated from power houses should be disposed off safely and in a scientific manner by placement on barren land or along backfill trench weir and preserve topsoil and reinstate after construction is completed. Soil erosion due to project activities will be negligible in the operation phase as the construction would be completed and landscape restoration work would also be implemented along with catchment area treatment.

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