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Research Article

ASSESSMENT OF SOILS FERTILITY STATUS IN KUMAON HIMALAYAS USING GIS TECHNIQUE

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Abstract- Nutrient deficiencies have become one of the major constraints in sustaining crop production in the Himalayan ecosystem, particularly in Kumaon Himalayas which are highly prone for severe erosion and land degradation. Hence, study was conducted to assess the soil fertility status of Kumaon Himalayan region in grid-based analysis of surface soil samples collected by using systematic sampling methodology using GPS points. The soils of this region were predominantly gravely loamy sand to sandy loam in texture with medium to slightly acidic in reaction (61 %) and high in organic carbon content. Soil fertility assessment showed the soils of Kumaon hills region, majority of soils are low in available P (52%), medium in available K (79%), low in available sulphur (64%) content. The DTPA extractable micronutrients such as Fe, Zn, Mn, Cu content were varied from medium to high, relatively high in available zinc (52%), copper (88 %) and adequate in of available iron and magnesium content. So, soils will respond to application of fertilizers containing phosphorus, sulphur, zinc and manures. The maps of various nutrient elements clearly indicated the specific locales, where deficiency of nutrients constrained crop production Soil fertility maps generated in GIS will serve as a base line for predicting the deficiencies. Delineation of site-specific soil nutrient status, multi-nutrient (NPK) analysis suggested that balance fertilization based on soil tests need to be followed for higher productivity and would be of high significance to manage soil health, to help the farmers to make more informed decisions to increase the productivity and to improve their livelihood security.

Keywords- *Soil fertility status, Macro and micronutrients, Multi-nutrient deficiencies, GIS, Kumaon Himalayas*
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Introduction

Soil is the basic natural resource for crop production and it supplies essential nutrients for plant growth. Plants require 19 essential nutrients for its growth, metabolic functions and reproduction and depend on soil fertility status. Soil fertility refers to the status of soils with respect to the amount and availability of nutrients necessary for plant growth. Of all the nutrients N, P, and K are most likely to be in short supply on cultivated lands. Among the essential nutrients, micronutrients are those required by plants in smaller quantities and their occurrence in soil is often critical for crop production. Macro and micronutrients deficiencies have become one of the major constraints in sustaining crop production in the present hilly agriculture. Limited area under the fertile soils in the mountain landscapes is assuming extra significance because of the decreasing land availability for agriculture caused by the demand for alternate uses. Under these conditions, the high cropping intensity and unscrupulous use of chemical fertilizers adopted by the farmers to reach the higher productivity levels have ultimately rendered the soils in this region with depleted nutritional status [1]. Analysis of soil samples from 141 districts of irrigated ecosystem clarly indicates that majority of soils are low in P fertility, low in N except hilly regions [2,3]. However, increasing evidences of macro and micro-nutrient deficiencies were reported due to multiple cropping, inappropriate use of fertilizers and other management practices has become a constraint in sustainable agricultural production. These deficiencies appeared much faster in the mountainous states, which may be attributed primarily to the limited adoption of site-specific nutrient management, adoption of new agricultural technology, limited area under cultivated lands and confine under rainfed agriculture and increased use of high analysis fertilizers [4]. Soil properties exercise considerable influences on the availability of nutrients and the extent of macro and micro-nutrient deficiency varies not only in Kumaon hills but also in Himalayan region depending upon soil characteristics and other management conditions. Nutrient deficiencies have been reported to be one of the main causes for low yield plateau or crop yield decline in irrigated system [5] and rain fed cropping system in agriculture [6]. Deficiencies of micronutrients have been on the rise one by one in the country for the last four decades [7]. Recently published data [8] on analyses of soil samples from different states of India indicated a decline in deficiency of Zn (39.9%) and increase in Fe deficiency (14.4%). Long- term sustainability of hill agriculture system must rely, as much as possible on balanced use of fertilizers and effective management of resource inputs. The crop lands in the mountain province of Himachal Pradesh in the western Himalayas have witnessed depleting N from the soil system at an alarming rate. On the basis of computation of exhaustion period of micronutrient reserve under different cropping system soil zinc is the most limiting micronutrients followed by copper. Among the hill ecosystem cereals-pulses-vegetable based system appeared to be more exhaustive [9]. Since, soil fertility status information in the Kumaon Himalayas of Himachal Pradesh is very scanty and inconclusive. Hence, assessment of site-specific soil fertility status and study of their availability need great significance to manage soil health through soil test based balanced nutrition to bring in sustained crop production and crop diversification. Therefore, the present study was envisaged to understand the current soil fertility status of Kumaon hills region was carried out by taking a case study in Khulgad watershed, Almora District, Uttarakhand to help the farmers to make more informed decisions to increase the productivity of their lands.

Materials and Methods

Study area

The study was carried out at Khulgad watershed (29°34' 31" to 29°41' N latitude and 79°32' 15" to 79°37' E longitude), Almora district, Uttarakhand India [Fig-1] represents highly folded and faulted chain of Kumaon hills of Kumaon Himalayas. It covers an area of about 3278 ha area and comprised of 34 villages. The topography is extremely hilly and rolling. The landscape covers an elevation range of 900-2200 m above mean sea level (amsl). Geologically, the area is composed of pre-Cambrian metamorphic rocks such as gneiss, schist, quartzite, slate and phyllites. Climatically, the area represents humid, sub-temperate and monsoonal type. Annual mean temperature of 19.8°C and annual average rainfall is about 950 mm. About 65% of total rainfall is received during rainy season. Agriculture is mainly confining to upland terraces, mid terraces and valley terraces. The cultivated area constitutes 43 percent of the study area, mainly under wheat, coarse millets (mandua), mustard, beans, lentil, barley, vegetables *etc.*,

Fig-1 Location Map of Study Area

Collection and analysis of soil samples

To delineate the soil fertility status, a systematic survey has been conducted in the grid points in the whole Khulgad watershed. Total, 200 composite surface soil samples from 0-15 cm depth were collected. The soil samples collected from surface soils (15 cm) were processed (< 2 mm sieve) and analyzed for various soil physico-chemical properties by following standard procedures [10]. Organic carbon was estimated by Walkley and Black's [11] rapid titration method as described by Jackson (1973). Available N was determined by alkaline $KMnO_4$ method [12], available P was determined using colorimetric method, while K by flame photometric method and S by $CaCl_2$ extraction 2 method as out lined by Tabatabai (1996) [13]. The available Fe, Cu, Mn and Zn in soil samples were extracted with DTPA (0.005 M DTPA + 0.01 M $CaCl_2$ + 0.1 M triethanolamine, pH 2 7.3) as per method described by Lindsay and Norvell (1978) [14] and determined by Atomic Absorption Spectrophotometer. The critical level used to delineate the deficiency and sufficiency level for different for micronutrients were 3.7 ppm for iron, 2 ppm for manganese, 1.2 ppm for zinc and copper.

Geo-referencing and map generation

Information collected for 200 surface soil samples covering different physiographic settings and land use were geo-referenced by recording Latitude ºN and Longitude ºE values from each sampling sites/grid point by using Global Positioning System (GPS). These data were transferred on base map on 1:50,000 scales prepared from State Revenue Maps and digitized using Arc-info GIS 9. The soil nutrient data was transferred into GIS environment (ARC/INFO) for spatial analysis for fertility assessment [15,16] and generated soil nutrient status maps.

Results and Discussion

Soil properties

The texture of soils is mostly sandy loam with varying proportions of various size and shapes of coarse fragments in the surface. The pH of the soil varies from less than 5.0 to more than 7.8. [Table-1] Majority of soils fall in the range of slightly to medium acidic (5.6-6.5) covering about 69 percent area. Slightly alkaline to neutral soils occupy about 1 percent area of the watershed; this is the optimum pH range where most of the nutrients are available in adequate amounts. Strongly to very strongly acidic soils occupy about 31 percent area of the watershed. So, this wide range of pH is apparently due to variations in organic matter content, intensity of cultivation or fertilizer application and degree of profile development classes. Higher rainfall and lower temperatures associated with increasing altitude results in lower pH [17]. These soils may require liming, if acidity sensitive crops like legumes are grown. The spatial distribution of soil pH classes is depicted [Fig-2].

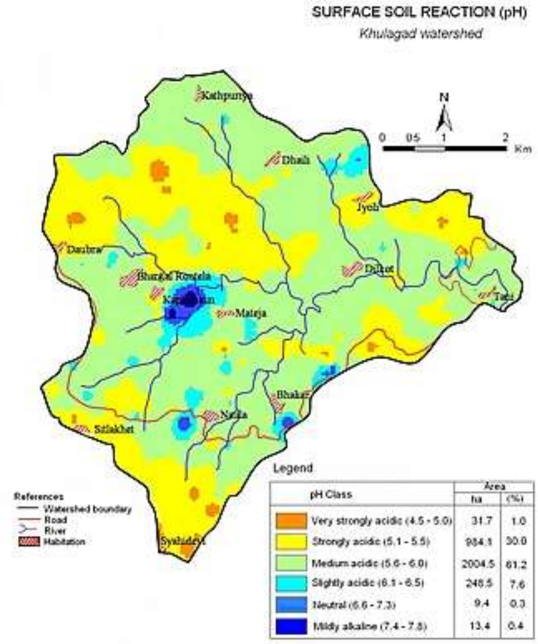

Fig-2 Soil Reaction map

Available Nutrients Status

The organic matter acts as a reservoir of plant nutrients that are essential for plant growth. It also helps in the improvement of soil physical conditions and therefore, considered as vital and essential for maintaining soil productivity and health. The soils of the study area are predominantly high in organic carbon (OC) which ranges from 0.15 to 1.68 percent [Table-2]. It is observed from the data [Table-2] that most of the surface soils fall in high level of organic carbon covering about 96 percent of the TGA of the watershed due to dense vegetation cover and slow decomposition. Soils of the 4 percent of the TGA are low to medium in organic carbon which includes mostly very severely eroded soils, other barren lands and intensively cultivated land. The status of organic matter in the soil depends upon the quantity that is periodically added, the soil temperature and the rate of its decomposition. Decomposition of organic matter is affected by climate, moisture, soil pH, soil texture and drainage. Most of the N and to some extent P and S are present in their organic forms which are released in mineral form during mineralization of organic matter. The organic carbon status of the soils is depicted in [Fig-3].

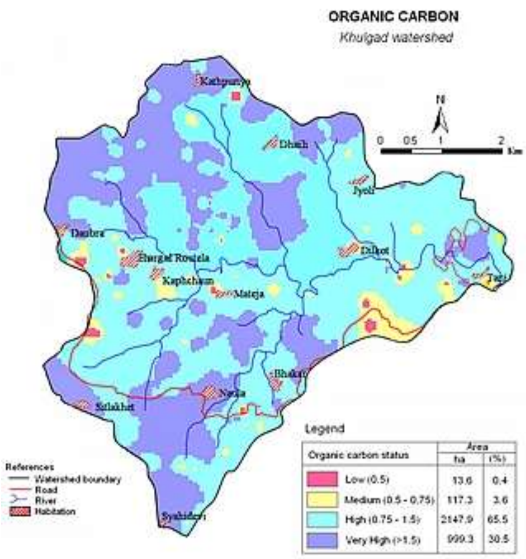

Fig-3 Soil Organic Carbon map

The prevailing low temperature results in suppression of microbial and enzymatic activities, which results least soil organic matter decomposition and its accumulation in surface soils [18]. Parallel to the present findings, Khera *et al.* (2001) [19] 4also reported the higher levels of OC ranged between 0.80-2.30 percent in the Central Himalayan region [20].

Available Soil Phosphorus (P), the data indicated that [Table-2] nearly 52 percent of the total area falls under low category which is distributed all over the watershed indicating fixation by soluble Fe, Al and Mn due to low pH [Fig-4].

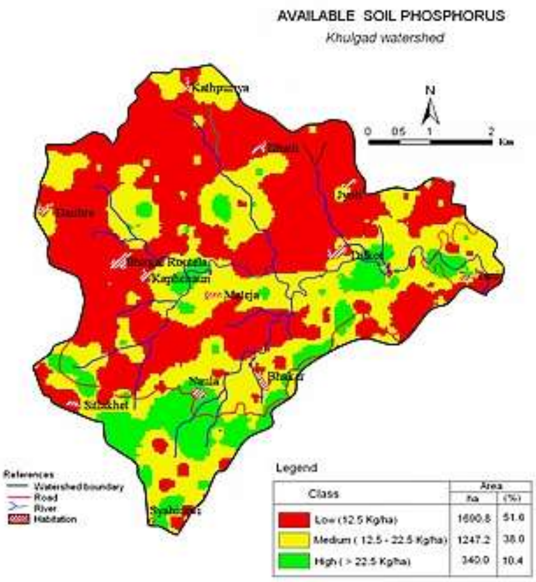

Fig-4 Available Phosphorus map

Nearly 38 percent area of the watershed is under medium class while the 10 % of the total area is under high category. The difference in P content in soils has been attributed to variations in pH, organic carbon and soil texture *etc*. The results clearly suggested that application of P in the soils is must for sustained productivity. Regarding available soil potassium (K), surface data [Table-2] and [Fig-5] revealed that about 10 percent of the total area of the watershed is low in available K randomly distributed in all the watershed, medium category found to occur in nearly 79 percent of the TGA, whereas 11 percent of the area has high K content due to dominance of mica. Khulgad soils are mostly well supplied in this nutrient due to the presence of K bearing minerals in rocks. However, in skeletal soils where weathering is in its initial stages the supply of K may be limited to plants.

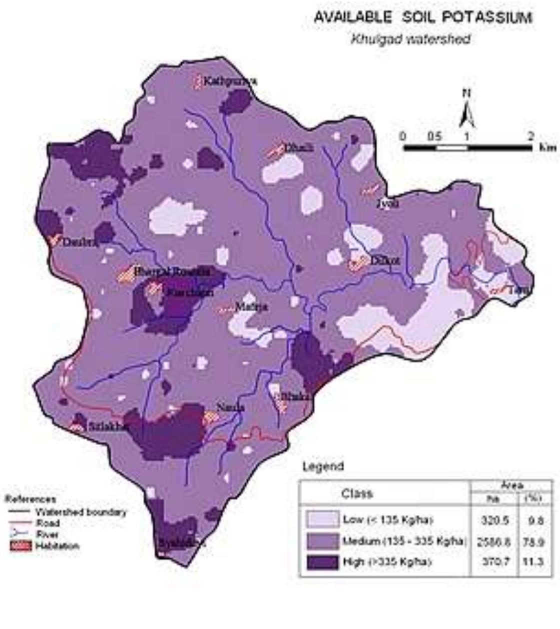

Fig-5 Available Potassium map

The variation in available K status has, thus, been controlled by soil texture, mineralogical make up, release dynamics and CEC of the soils. These results confirm the findings of Sharma *et al.,* (2001) who reported medium to high fertility status of available P and K in the soils of Lohnakhad in sub-humid mid-hill zones of Himachal Pradesh. Available 'S' content varied from 10.0-32.0 kg ha^{-1} with an average of 21.50 kg ha^{-1}. On the basis of the rating suggested for available S content by Hariram and Dwivedi (1994) [21,22], 64 percent of soils exhibit the deficiency symptoms [Fig-6], necessitating the use of S-containing fertilizers. Available S content of soils depends upon the interaction of several factors such as pH, organic matter content, soil aeration and type of N, P, K, fertilizers adopted.

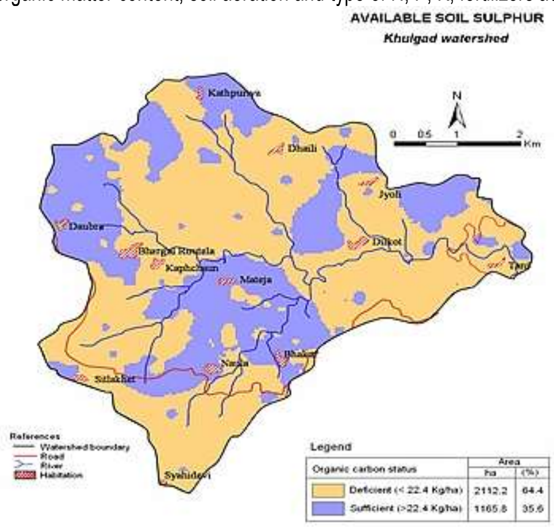

Fig-6 Available Sulphur map

Micronutrient status

The Zn content ranged between 0.25 – 5.85 m with a mean of 1.25 mg kg^{-1} in the soils of Khulgad watershed. The data revealed that about 52 percent of the total area of the watershed is high in available Zn, 39 percent is medium and nearly 9 percent of the TGA is low in available Zn, necessitating its application through Zn containing fertilizers. The spatial distribution of available Zn content classes is shown in [Fig-7].

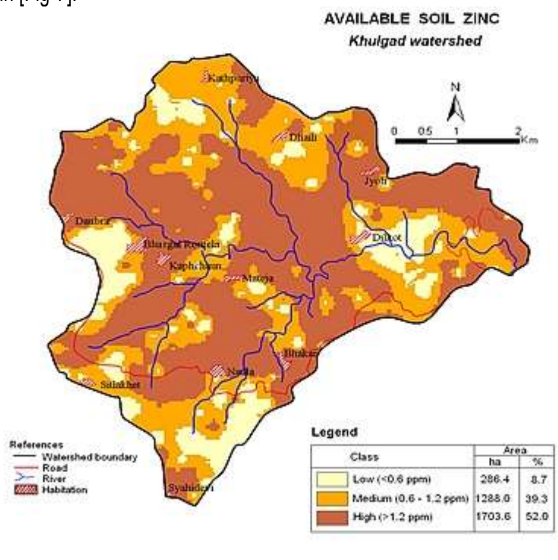

Fig-7 Available Zinc map

The deficiency of Zn reported to be wide spread in Uttarakhand particularly in coarse textured soils having low to medium organic matter content. It has now become the limiting factor in crop production in some cultivated areas. Availability of Zn to plants is sensitive to changes in pH, clay and organic matter content of the soils. This was in line with the findings reported by Walia *et al*. (2013). The data revealed in [Table-2] on available Cu availability in the soils of showed deficient to very high status 0.13 to 8.52 mg kg^{-1} with a mean value of 1.73mg kg^{-1}.

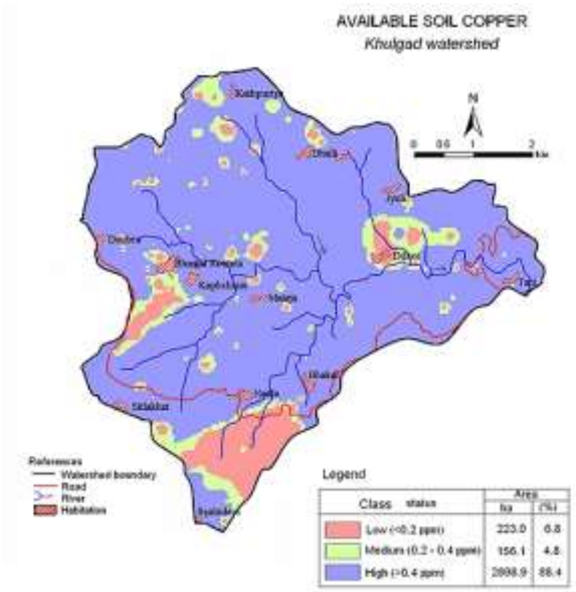

Fig-8 Available Cupper map

Table-1 *Soil Reaction Classes*

Soil Reaction Class	Soil pH range	Area (ha)	Percent of TGA
Very strongly acidic	4.5-5.0	31.7	1.0
Strongly acidic	5.1-5.5	984.1	30.0
Medium acidic	5.6-6.0	2004.5	61.2
Slightly acidic	6.1-6.5	248.5	7.6
Neutral	6.6-7.3	9.4	0.3
Mildly alkaline	7.4-7.8	13.4	0.4

Table-2 *Available Nutrient status for Macronutrients and its spatial distribution*

Class	Range	Area (ha)	Percent of TGA
Organic carbon status (%)			
Low	>0.5 (%)	13.6	0.4
Medium	0.5-0.75	117.3	3.6
High	0.75-1.00	2147.9	65.5
Very High	>1.00	999.3	30.5
Available P content(kg/ha)			
Low	<12.5	1690.8	51.6
Medium	12.5-22.5	1247.2	38
High	>22.5	340	10.4
Available K content (kg/ha)			
Low	<135	320.5	9.8
Medium	135-335	2586.8	78.9
High	>335	370.7	11.3
Available S content(kg/ha)			
Deficient	<22.4	2112.2	64.4
Sufficient	>22.4	1165.8	35.6
Status of Micronutrients			
Available Zn content (mg kg-1)			
Low	<0.6	286.4	8.7
Medium	0.6-1.2	1288	39.3
High	>1.2	1703.6	52
Available Cu content (mg kg-1)			
low	<0.2	223	6.8
Medium	0.2-0.4	156.1	4.8
High	>0.4	2898.9	88.4

The increased soil pH, sandy texture and lesser organic carbon content of the soils might have contributed to the greater magnitude of Cu deficiency [23,24]. Available Soil Copper (Cu), observed that the soils of the watershed are by and large high in available Cu due to favorable pH and high organic matter and nearly 12 percent of the area is low to medium in available Cu. The available Fe and and Mn content in the soils of Khulgad watershed reported sufficient content. The presence of sandy soils with lower organic carbon content in the soils of these blocks reported by Katyal and Rattan (2003), Ravikumar, *et al.*, (2007) [25] and Zekri and Obreza (2009) [26] would have affected Fe availability. The higher Mn status in the surface soils may be attributed to the lower oxidation, acidic nature of the soils and also due to the release of chelated Mn from the organic compounds. Similar findings were reported by Sharma and Chaudhary (2007) [27], Rajeswar and Arifkhan (2007) [28] and Arokiyaraj *et al.* (2011) [29]. The simple correlation was worked out to ascertain the degree of relationship between soil properties and DTPA-extractable micronutrients status of the study area. Correlation among soil parameters showed a significant and positive effect of soil pH and soil organic carbon on the availability of N, P, S and Mn contents and positive effect on other available nutrients. These results clearly suggest the need to manage optimum amounts of soil OC to regulate adequate supplies of essential plant nutrients. Strong and positive correlation exists between available N (r=0.45**) and OC. There is a definite relation of organic carbon with available N as organic matter releases most of the mineralizable N in a proportionate amount present in the soil [30,31]. The available Zn in the soil has significant and negative relationship with pH (r = -0.464**) thereby indicating that availability of Zn increases at lower pH levels.

The soils of Khulgad watershed own hills assessed for their fertility status. The soils will respond to application of lime, phosphorus, sulphur and zinc containing fertilizers. Balanced fertilization based on soiltests need to be followed for higher productivity. Integrated use of fertilizers, FYM, crop residues, farm waste may be encouraged to maintain soil heath and crop productivity.

Application of research: The soil fertility map will serve as a base line for predicting the deficiencies. The information generated is, therefore important for nutrient management and advantageous to the planners, extension workers, fertilizer dealers and individual farmers to increase the productivity, manage soil health and to improve their livelihood.

Research Category: Soil fertility mapping

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Institute: ICAR-National Bureau of Soil Survey and Land Use Planning, Regional Centre Delhi, IARI Campus, New Delhi, 110012, India
Research project name or number: Research station study

Author Contributions: All authors equally contributed

Author statement: All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Study area / Sample Collection: Khulgad, Almora district, Uttarakhand India

Cultivar / Variety / Breed name: Nil

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.

Ethical Committee Approval Number: Nil

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