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Assessment of Soil Fertility and nutrients status of Simrawal and part of Asrawal watershed, Tons sub-Basin, Ganga Basin

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Abstract

In earth, soil is the basic requirement of all life. Soil nutrients are the major source of soil fertility that helps for the plant growth. The Soil data download from Department of Agriculture Govt. of India web portal. 105 Samples were collected from portal. The study area comes under Vindhyan hill range covering Rewa and Bhander Group and located in North-East part of Madhya Pradesh. It stretches between 80^0 38' 41.143" and 81^0 12' 55.097" E and 24^0 37' 47.994" and 24^0 55' 36.438" N. The pH values of soils in the study area varied from slight alkaline to strongly alkaline (5.32 to 8.59). Results shows that the deficiency of Nitrogen (N), Boron (B) and Zinc (Zn).

Keywords: *Watershed boundary, Soil samples, Parker's nutrients method, GIS Technique.*

1. Introduction

India is facing sever soil fertility deficiency (Indian institute of soil science report, 2014) the assessment revealed that about 59 per cent, 49 per cent and 9 per cent are low in available Nitrogen, Phosphorous and Potassium respectively. Simrawal watershed and Asrawal Watershed (part) comes under Tons sub-basin, Lower Ganga Basin. It covers total geographical area of Simrawal watershed is 87951.26 Ha and part of Asrawal Watershed is 29333.54 Ha. It stretches between 80^0 38' 41.143" and 81^0 12' 55.097" E and 24^0 37' 47.994" and 24^0 55' 36.438" N. Climate of the area is dry and moist and hot in summer. The study area received Lower rainfall (850.50 mm) during kharif period of 2004 as compared to rainfall of 2013 (1465.9 mm) (Source: http://www.mpwrd.gov.in/). The rainfalls from 2001 to 2017 are showing fluctuation trends. Paddy (Dhan), Wheat, Linseed, Bengal grams (Gram), Mustard, Soyabean, Arhar (Tur), Black grams (urd bean), Sesamum (Sesame, Gingelly, Til), Garlic, Onion, Vegetables are the main crops of study area. Simrawal river is the main river in the study area with Hathiya Nala, Jhirwah nala, Lagna nala, Chauhar nala and Gorsari nala as its major sub-tributaries in Simrawal watershed while in Asrawal watershed; Mau nala, Sitwa nala and Jokaha nala are major sub-tributary. The drainage pattern is mainly dendritic. The present investigation was carried out

for assessment of soil spatial variability and temporal variability of soil fertility and evaluating the nutrient status of soils using nutrient index approach of Simrawal and part of Asrawal watershed, Lower Ganga basin.

The Study area comes under Vindhyan hill range covering Rewa and Bhander Group and located in North-East part of Madhya Pradesh. The Bhander Group constitutes the youngest group of the Vindhyan Basin. The original classification proposed by Auden (1933) and Krishnan (1968) was modified by Sastry & Moitra (1984), Banerjee et al. (2006). With detailed study of literature, published maps, papers and ground survey; we have updated the Litho-stratigraphic sequence of study area showing in Table-1.

Table-1: Litho-stratigraphic sequence of the study area.

Super-group	Group	Subgroup Formation	
		Simrawal Watershed	**Asrawal Watershed**
	Alluvium		
Upper Vindhyan	Bhander	Nagod Limestone	
		Simrawal Shale	Simrawal Shale
	Rewa	Govindgarh Sandstone (Upper Rewa Sandstone)	Govindgarh Sandstone (Upper Rewa Sandstone)

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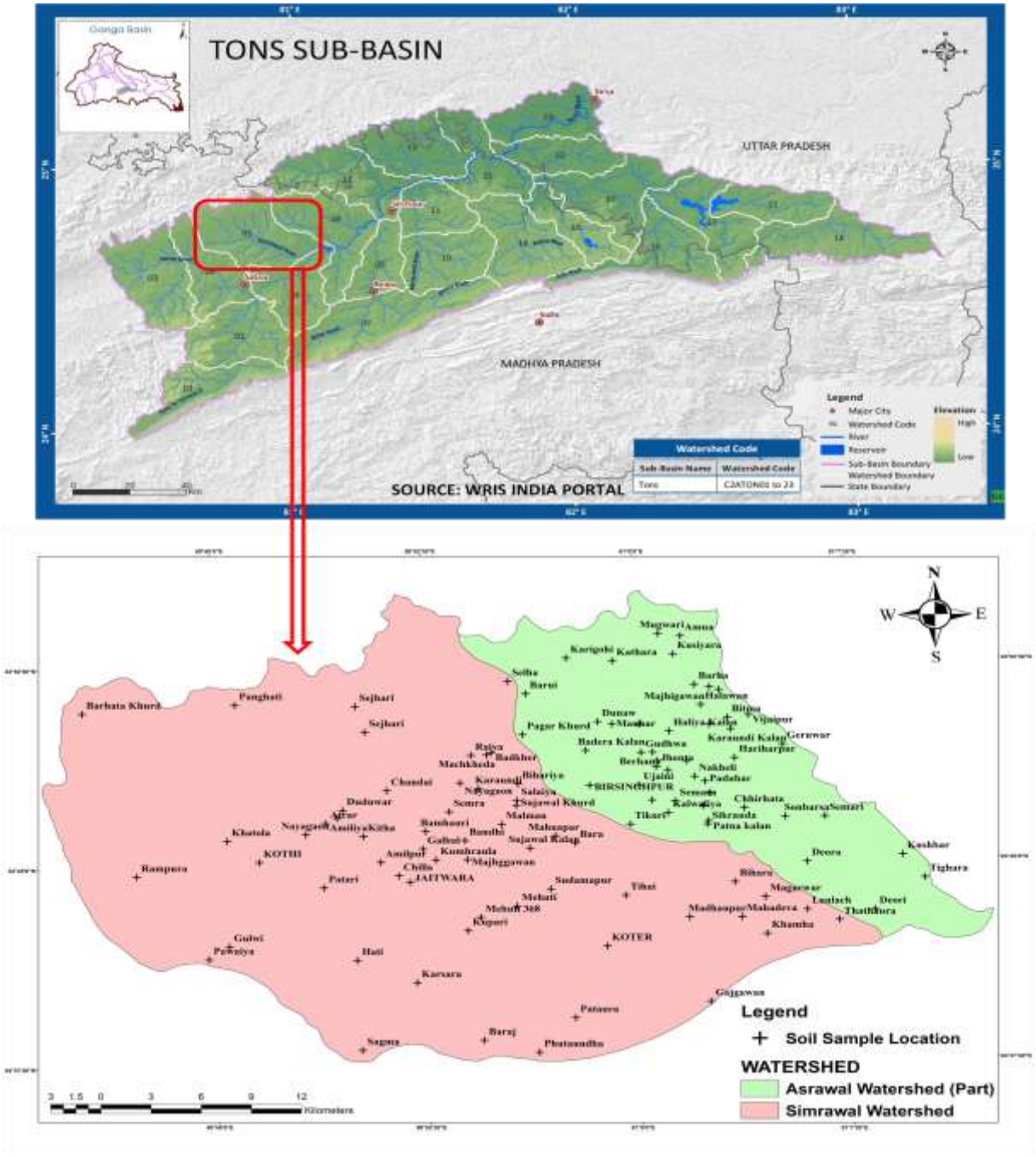
The Geomorphic landforms of study area were identified such as plateau highly dissected hills towards N and NE direction. We have identified like i.e. Cuesta, Mesa, Butte, Inselberg, residual hills present in Upper Rewa sandstone formation area while exposed Sheet rock in Nagod limestone area towards South direction. Most of these landforms covered by vegetation and carry a thinner soil cover. These zones provide a moderate to poor groundwater potential.

Figure-1: Location map of Study area.



Stripped Plain with shallow basement area identified in between and along the river channel of study area. Moderate and shallow pediplain areas were identified in Simrawal shale area and Nagod limestone area. Lineaments are natural, linear surface elements, interpreted directly from satellite imagery and geophysical map. Major lineaments (>3km) and Minor lineaments (<3km) were identified towards NNW-SSE, NW-SE, NNE-SSW, ENE-SSW and NE-SW direction.

The Soil of Study area comes under ITMA series

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with soil association Typic Ustorthents. Table-2 is showing detailed soil properties of study area-

Table 2: Soil properties of study area.

Soil properties	Simrawal Watershed		Asrawal watershed (Part)	
	Soil Class	**Area (%)**	**Soil Class**	**Area (%)**
Soil Texture	Coarse Texture	8	Coarse Texture	0
	Medium Texture	42	Medium Texture	55
	Fine Texture	50	Fine Texture	45
Soil Erosion	Moderate	78.56	Moderate	67
	Severe	19.58	Severe	33.05
	Very Severe	1.86	Very Severe	0.14
Soil Depth	>50 (cm)	78.52	>50 (cm)	67
	25 – 50 (cm)	19.61	25 – 50 (cm)	33
	10 – 25 (cm)	1.87	10 – 25 (cm)	0.15
			<10 (cm)	0.34
Soil Slope	Moderately sloping (8-15%)	10.02	Moderately (8-15%)	0.70
	Gently sloping (3-8%)	89.98	Moderately steep (15-30%) to Steep (>30%)	0.30
			Nearly level (0-1%) to Very gently sloping (1-3%)	99
Soil Productivity	Highly productive	18	Highly productive	44.30
	Moderately productive	32	Moderately productive	3
	Moderately low productive	20.73	Moderately low productive	19
	Low productive	27.69	Low productive	32.79
	Non productive	1.86	Non productive	0.47

2. Methodology

We have taken ResourceSAT-2 LISS-IV (2012) satellite image procured from NDC-NRSC Hyderabad and SOI Toposheet, Datum-WGS84 (Part Sheet) G44U09, G44U10, G44U13, G44U14, G44V01 and G44V02 (download from SOINAKSHE portal) for updating Simrawal and part of Asrawal watershed. The Soil data collected from Department of Agriculture, cooperation & farmers welfare, Govt. of India web-portal (https://soilhealth.dac.gov.in). Total 105 soil samples were collected from web-portal. The collected data are sorted, tabulated and classified into three categories, i.e. Low, Medium and High using ArcGIS 10.4 Software. Spatial interpolation technique is often used in analyzing soil physicochemical parameters distribution of villages where there are data missing (Three villages are Birsinghpur, Kothi, Barthata khurd).

Assessment of the spatial and temporal variability of soil quality and evaluating the fertility status of soils using nutrient index approach, calculated with help of Parker's nutrient index

3. Results and Discussion

In the present study, 105 soil samples were collected (https://soilhealth.dac.gov.in) from Agriculture portal of different location of Simrawal watershed and part of Asrawal watershed. To evaluate the fertility status of soils in the study area, different soil physicochemical properties that affect nutrient availability including pH, electrical conductivity, available macro-nutrients N, P, K and S and available micro-nutrients (Zn, B, Mn, Fe and Cu) were calculated based on the specific rating chart modified from Brajendra *et al.*, (2014) and Department of former welfare and agriculture development Govt. of M.P. (Table-3).

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Table 3: Rating Chart for Soil Test Values and their Nutrient Indices.

Soil Property	Unit	Range		
Soil pH		< 6.0 (Acidic)	6.0 – 8.0 (Neutral)	> 8.0 (Alkaline)
EC	dS/m	< 1.0 (Normal)	1.0 – 2.0 (Critical)	> 2.0 (Injurious)
OC	%	< 0.5 (Low)	0.5 – 0.75 (Medium)	> 0.75 (High)
Macro-Nutrients				
N	Kg/ha	<280 (Low)	280 – 560 (Medium)	>560 (High)
P	Kg/ha	<10 (Low)	10 – 25 (Medium)	>25 (High)
K	Kg/ha	<108 (Low)	108–280 Medium)	>280 (High)
S	ppm	<10 (Deficient)	10 – 30 (Sufficient)	>30 (Exceed)
Micro-Nutrients				
B	ppm	<0.5 (Deficient)	0.5 – 1.0 (Sufficient)	>1.0 (Exceed)
Mn	ppm	<2.0 (Deficient)	2 – 4 (Sufficient)	>4.0 (Exceed)
Zn	ppm	<0.6 (Deficient)	0.6 – 1.0 (Sufficient)	>1.0 (Exceed)
Fe	ppm	<4.5 (Deficient)	4.5 – 9.0 (Sufficient)	>9.0 (Exceed)
Cu	PPM	<0.2 (Deficient)	0.2 – 5.5 (Sufficient)	>5.5 (Exceed)

The data (table) indicated that pH of all the soil samples of Simrawal watershed was Neutral (Normal) to moderately alkaline in nature (6.4 to 8.6) whereas pH of the soil samples of Asrawal watershed are ranges from moderately acidic to moderately alkaline (5.32 -8.3). Table-4 shows that EC values indicating that 100 percent (58 samples) of the soil in the Simrawal watershed and 100 percent (47 samples) of the soil in the Asrawal watershed area are normal which is suitable for good growth of plants. Organic matter has a vital role in agricultural soils. It supplies plant nutrients, improves oil structure, water infiltration and retention, feeds soil micro flora and fauna and enhances the retention and cycling of applied fertilizer (Johnston, 2007). The organic content of the soils in the Simrawal watershed varied from 0.02 to 0.9% whereas in the Asrawal watershed varied from 0.11 to 0.98%. The result shows that 37.93% and 36.17% of soil samples in Simrawal and Asrawal watershed, respectively fall in the low category (<0.5). Nitrogen is the basic nutrient helps in seed formation and increases the food and feed value of crops. The appropriate growth of the plant, it needs appropriate proportion of nitrogen in the soil and it is consider as most essential, but there is universal deficiency of naturally available nitrogen in India. The available nitrogen content was low in major portion of Simrawal watershed and asrawal watershed (part) as 51.72 and 59.57% respectively of soil samples analyzed showed nitrogen content below 280 kg/ha. In soil of Simrawal and Asrawal watershed, 48% and 40% of samples respectively analyzed recorded nitrogen content that was in the medium category (280-560 kg/ha). Nitrogen and phosphorous are the most significant nutrients for the crop yield. Decrease in the phosphorous in the soil will directly affect the production of crop; this nutrient is also called as 'Master key to agriculture'.

Phosphorous is used by the plant for the development of different stages of its growth. In general out of 58 samples in Simrawal watershed, 68.96% samples comes under very high, 31.04% samples were sufficient while In Asrawal watershed, 61.70% samples were very high, 36.17% samples comes under sufficient status and 2.13% samples were deficient in K status. The available S content of the soils of Simrawal watershed and Asrawal watershed ranged from 1.15 – 35 kg/ha and 0.15 – 35 kg/ha respectively. Considering the soil test rating for available S (<10 kg/ha as low, 10-30 kg/ha as medium and >30 kg/ha as high in the status of S) the soils of Simrawal watershed fall under low (37.9%), medium (56.90%) and high (5.17%) whereas Asrawal watershed (part) fall under low (29.79%) medium (68.08%) and high (2.13%) status in available S content. The available Zn content of the soils of simrawal watershed ranged from 0.15 -3.36 ppm, mean value 0.59 and SD 0.47 whereas Asrawal watershed ranged from 0.12-2.77, mean value 0.62 and SD 0.45. Considering the soil test rating for available Zn (<0.6 ppm as deficient, 0.6 – 1.0 ppm as sufficient and >1.0 ppm as high in the status of Zn). According to Singh et al., (2016), zinc uptake by plants decreases with increased soil pH. Uptake of zinc also is adversely affected by high levels of available phosphorus in soils (Pulakeshi et al., 2012). The entire study area was under sufficient iron status as all samples analyzed showed that the iron content was in the sufficient category 4.5 – 9.0ppm). Boron also a micro-nutrient is required for cell wall structure and may also have a role in maintaining cell membrane integrity. In general out of 58 samples in simrawal watershed, 10.34% samples comes under

very high, 51.73% samples were sufficient and 37.93% samples were deficient while In Asrawal watershed, 4.26% samples were very high, 55.32% samples comes under sufficient status, 40.42% samples were low in B status. The available Fe content of the soils of Simrawal watershed ranged from 3.1 – 18.71 ppm with an average value of 7.69 ppm while Asrawal watershed ranged from 0.56 – 37.5 ppm. In general out of 58 samples in Simrawal watershed, 22.42% samples fall under very high, 67.24% samples were sufficient in Fe status and 10.34% samples were low in Fe status. In Asrawal watershed, 14.89% samples were very high in Fe status, 80.85% samples fall under sufficient status, 4.25% samples were low in Fe stats. Manganese is an essential element and appears to have a role in the formation or synthesis of chlorophyll. Due to deficiency of manganese the carbohydrate synthesis is disturbed, resulting in retarded growth, decrease in the content of ash and failure to reproduce.

The manganese content of soils varied from 2.30 – 11.56 ppm of Simrawal watershed and 1.58-25.30 ppm of Asrawal watershed (part). It was significantly Medium (12.07%) to high (87.93%) in soil of Simrawal watershed and Asrawal watershed fall under Low (2.13%), Medium (2.13) to High (95.74%) in Mn status. The sufficiency levels indicative of these soils might be due to the neutral to low pH and nature of the parent material as reported by Prasad and Sahi (1989). In the chloroplasts of leaves there is an enzyme which is concerned with the oxidation-reduction processes. The presence of copper is essential for this enzyme to function. Thus, Copper plays an important role in the process of photosynthesis. The copper content of the soils varied from low to high (0.05–2.10ppm) in Simrawal watershed and Low to high (0.12-2.02) in Asrawal watershed.

Table 4: Descriptive Statistics of Measured Soil Properties in Simrawal and Asrawal (part) watershed.

pH

Location	Percent of Samples falling within range			Range	Mean ± SD
	<6.0	**6.0– 8.0**	**>8.0**		
Simrawal Watershed	5.17	75.86	18.96	6.4 – 8.6	7.41 ±0.57
Asrawal Watershed	4.25	89.36	6.38	5.32 – 8.3	7.20±0.58

Electrical Conductivity (EC)

Location	Percent of Samples falling within range			Range	Mean ± SD
	<1.0	**1.0 – 2.0**	**>2.0**		
Simrawal Watershed	100	0	0	0.02 – 0.9	0.3 ± 0.24
Asrawal Watershed	100	0	0	0.11 – 0.98	0.42 ± 0.22

Organic Carbon (OC)

Location	Percent of Samples falling within range			Range	Mean ± SD
	<0.5	**0.5 – 0.75**	**>0.75**		
Simrawal Watershed	37.93	8.62	53.45	0.02 – 0.9	1.52 ± 6.04
Asrawal Watershed	36.17	27.66	36.17	0.11 – 0.98	0.70 ± 0.39

Nitrogen (N)

Location	Percent of Samples falling within range			Range	Mean ± SD
	<280	**280 – 560**	**>560**		
Simrawal Watershed	51.72	48.28	0	2.7 - 413	233.16±113.22
Asrawal Watershed	59.57	40.42	0	43 - 385	247.98±83.91

Phosphorous (P)

Location	Percent of Samples falling within range			Range	Mean ± SD
	<10	**10 – 25**	**>25**		
Simrawal Watershed	1.72	43.11	55.17	10 - 49	26.011 ± 8.63
Asrawal Watershed	2.13	65.96	31.91	10 - 58	23.76±11.26

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Potassium (K)

Location	Percent of Samples falling within range			Range	Mean ± SD
	<108	**108 - 280**	**>280**		
Simrawal Watershed	0	31.04	68.96	112 - 543	324.80±91.91
Asrawal Watershed	2.13	36.17	61.70	38.80 - 515	290.15±110.85

Sulfur (S)

Location	Percent of Samples falling within range			Range	Mean ± SD
	<10	**10 - 30**	**>30**		
Simrawal Watershed	37.93	56.90	5.17	1.15 - 35	14.09 ±7.50
Asrawal Watershed	29.79	68.08	2.13	0.15 - 35	13.97±6.76

Zinc (Zn)

Location	Percent of Samples falling within range			Range	Mean ± SD
	<0.6	**0.6 – 1.0**	**>1.0**		
Simrawal Watershed	68.96	24.14	6.90	0.15 – 3.36	0.59±0.47
Asrawal Watershed	70.21	23.40	6.38	0.12 – 2.77	0.62±0.45

Boron (B)

Location	Percent of Samples falling within range			Range	Mean ± SD
	<0.5	**0.5 – 1.0**	**>1.0**		
Simrawal Watershed	37.93	51.73	10.34	0.2-16.8	1.19±2.60
Asrawal Watershed	40.42	55.32	4.26	0.03 – 2.48	0.60±0.37

Iron (Fe)

Location	Percent of Samples falling within range			Range	Mean ± SD
	<4.5	**4.5 – 9.0**	**>9.0**		
Simrawal Watershed	10.34	67.24	22.42	3.5 – 18.71	7.69±3.30
Asrawal Watershed	4.25	80.85	14.89	0.56 – 37.5	8.06±5.47

Manganese (Mn)

Location	Percent of Samples falling within range			Range	Mean ± SD
	<2.0	**2.0 – 4.0**	**>4.0**		
Simrawal Watershed	0	12.07	87.93	2.30 – 11.56	6.48 ± 1.97
Asrawal Watershed	2.13	2.13	95.74	1.58 – 25.30	7.12±3.32

Copper (Cu)

Location	Percent of Samples falling within range			Range	Mean ± SD
	<0.2	**0.2 – 0.4**	**>0.4**		
Simrawal Watershed	36.20	15.52	48.28	0.05 – 2.10	0.43±0.33
Asrawal Watershed	14.90	25.53	59.57	0.12 – 2.02	0.50±0.33

Parker's Nutrient Index

In order to compare the levels of soil fertility of one area with those of another it is necessary to obtain a single value for each nutrient. Here the nutrient index introduced by Parker et al., (1951) was employed.

Parker's nutrient index is a three tier system used to evaluate the fertility status of soils based on the percentage of samples in each of the three classes, i.e., low, medium and high and multiplied by 1, 2 and 3 respectively. The sum of the figures thus Obtained is divided by 100 to give the index or weighted average as given in the equation below-

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$$\text{Nutrient Index} = \frac{(NLX1) + (NMX2) + (NHX3)}{NT}$$

Where,
NL – Number of samples falling in Low,
NM – Number of samples falling in Medium,
NH – Number of samples falling in High,
NT – Total number of samples

Nutrient index value (NIV) is the measure of nutrient supplying capacity of soil to plants (Singh et al., 2016). The soil nutrient index of the study area (Tables-5 & 6) was calculated from low nutrients, optimum nutrients and high nutrients ratings of soil nutrients.

Table 5: Nutrient Index with Range and Remarks

Nutrient index	Range	Remarks
I	Below 1.67	Low nutrients
II	1.67 – 2.33	Optimum nutrients
III	Above 2.33	High nutrients

If the index value was less than 1.67, the fertility status was low nutrients and the value was 1.67-2.33 than the status was optimum nutrients. The value greater than 2.33, the fertility status was high nutrients.

Figure 2: Graphical representation of nutrient index and fertility rating of study area

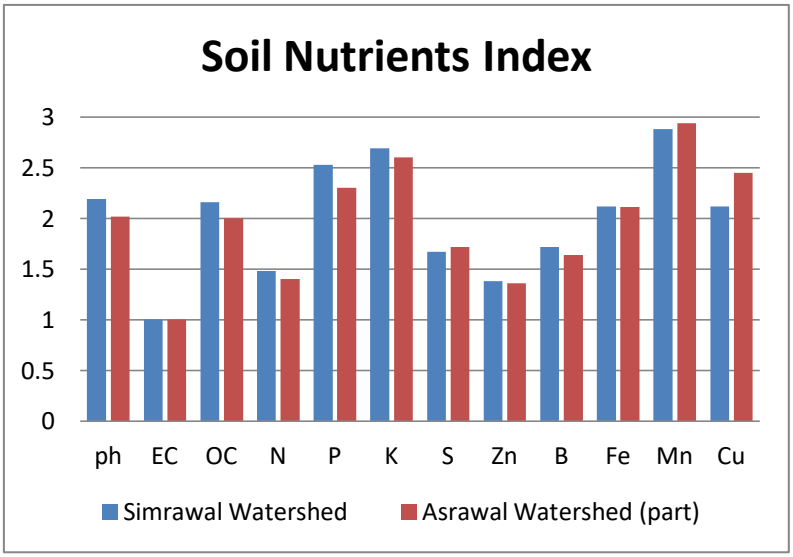

Table 6: Nutrients Index with Range and Fertility rating of study area.

	Simrawal Watershed		Asrawal Watershed	
	Nutrients Index	**Fertility Rating**	**Nutrients Index**	**Fertility Rating**
N	1.48	Low nutrients	1.40	Low nutrients
P	2.53	High nutrients	2.30	Optimum nutrients
K	2.69	High nutrients	2.60	High nutrients
S	1.67	Optimum nutrients	1.72	Optimum nutrients
Zn	1.38	Low nutrients	1.36	Low nutrients
B	1.72	Optimum nutrients	1.64	Low nutrients
Fe	2.12	Optimum nutrients	2.11	Optimum nutrients
Mn	2.88	High nutrients	2.94	High nutrients
Cu	2.12	Optimum nutrients	2.45	High nutrients

4. Conclusions

The study area lies in IIIes land capability sub class and Irrigability class 3s. The productivity potential is medium and they have medium available water holding (moderately slow permeability) and retentive capacity and medium fertility status. The physicochemical properties of soil were analyzed for 58 villages of Simrawal watershed and 47 villages of Asrawal watershed (part). Based on the nutrient indices of Parker et al., (1951), the fertility status of the Simrawal watershed showed that the Soil are low deficient (Nitrogen-1.48, zinc-1.38), optimum nutrients (Sulfur-1.67, Boron-1.72, Iron-2.12 and Copper-2.12) and high nutrients (Manganese-2.88, Phosphorous-2.53 and Potassium-2.69). In Asrawal watershed, soil were deficient in available (Nitrogen-1.48, Zinc-1.36 and Boron-1.64), optimum nutrients (Phosphorous-2.30, Sulphur-1.72, Iron-2.11) and high nutrients (Potassium-2.60, Manganese-2.94 and Copper-2.45). Majority of the farmers are following three or more crops rotation per year and are using large quantity of fertilizers, insecticides, pesticides in order to harvest maximum gross returns without taking into consideration the soil fertility status. It shows that soil have great demand of Nitrogen, zinc and Boron in study area. Soil nutrients are the prime requirement for the existence of life. This study is very important to agriculture scientist and farmers for crop growth and soil management.

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