RESEARCH ARTICLE

CHANGES IN THE PHYSICO-CHEMICAL PROPERTIES OF SOIL IN DIFFERENT DEODARFORESTS OF GARHWAL HIMALAYA

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Abstracts: The present study was undertaken in different deodar temperate forest of Uttrakhand in Garhwal Himalaya, India. The aim of the study was to evaluate the changes in the physico-chemical properties of soils in different deodar forest of Garhwal Himalaya after 15 years as previous study was carried out in 2000 in the same studied sites by Bhatt et al. The changes in physico-chemical properties of soil were assessed by laying out five 0.1 ha sample plots by recognizing GPS location of the earlier study on each location. The composite soil samples were collected from each sample plot at three different soil depths (0-10 cm, 11-20 cm and 21-30 cm). The standard method was used to analyze the soil sample. To study the Physico-chemical properties of soil various parameter viz. Soil organic carbon %, available phosphorus, available potassium, pH and moisture content % was analyzed. The outcome of the study revealed that the values of soil organic carbon %, available phosphorus, available potassium, pH and moisture content % ranged between 0.24% to 0.68 %, 7.76 to 64.21 kg/ha, 63.5 kg/ha to 406.6 kg/ha, 5.07 to 5.87, 14.72 % to 41.99 % respectively. In the present re-visitation study, the huge changes was seen in the physico-chemical properties of soil mainly in Organic Carbon %, soil pH and moisture content % as they all decreases due steep topographic condition, slow decomposition rate whereas there was increase in the available Phosphorus. These changes are more likely attributable to the combined effect of growth and use of soil nutrients by the trees in respective sites.

Keywords: Decomposition, Deodar, Garhwal Himalaya, Nutrient changes, Physico-chemical properties

INTRODUCTION

Soil is a complex system wherein living soil organisms belonging to different taxonomic groups interact at different levels within the community and plays a significant role in the maintenance of soil properties (Garbeva *et al.*, 2004, *Van et al*., 2002). Soil microorganisms constitute a source and sink for nutrients and are involved in decomposition of wood, litter, organic matter, generating organic C, N and energy from these organic substrates (Ganjegunte *et al.*, 2004, Lindahl *et al.*, 2007).

Soils in the Himalayan region are very well suited for high productivity and sustainability. But due to increased anthropogenic activities like rapid urbanization and infrastructure development in the naturally delicate ecosystem with unstable geology, steep slopes and heavy rains had hastened the degradation process of fertile soil in the Himalayan region. Many studies confined to agricultural soils have been performed to determine the ecological and environmental factors regulating microbial community structure (Baek and Kim, 2009, Grayston *et al*., 2001, Hogberg *et al*., 2007). Besides, the soil and vegetation have a complex interrelation because they develop together over a long period. Soil analysis shows the forest types and plant density of any area because the different species of plants need different types of soils. The selective absorption of nutrient elements by different plant species and their capacity to return them to the soil brings about changes in soil properties (Singh *et al.*, 1986).The properties of the soil are an important factor for the growth of the plants. Some of these properties including the percentage of nitrogen, phosphorus, potassium, soil acidity, soil salinity, and pH affect vegetation cover in an ecosystem (Zarinkafsh, 1987). Bhatt in 2000 studied five different forests of deodar at five sites namely Ghimtoli, Dhanolti, Dewarkhal, Devidhar and Jhandidhar of Garhwal Himalaya to study the physico-chemical properties of soil. The present study was also conducted on the same sites mentioned above by recognizing the GPS location of the earlier study as the re-visitation study, which was aimed to understand the changes in the various physico-chemical characteristics of soil of *Cedrus deodara* forests of Garhwal Himalayas over 15 years.

MATERIALS AND METHODS

Five forest stands of *Cedrusdeodara* in different parts of Garhwal Himalayas (Lat.29^0 26' to 31^0 28' N and Longi.77^0 49' to 80^0 06' E) were recognized with the help of GPS coordinates for identifying the changes in the physico-chemical properties of soil in a re-visitation study over 15 years (Fig.1). The earlier study was made by Bhatt *et al*. (2000) at these studied sites. The same sites in the present study were located with the help of geographic information as presented in Table 1.

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Table 1. The geographic information of different studied sites

S.No	Locality /District	Alt (m)	Longitude	Latitude
1	Ghimtoli / Rudraprayag	2300	78^0 15’	30^0 ‘23
2	Dhanolti / TehriGarhwal	2200	78^0 52’	30^0 23’
3	Dewarkhal / Uttarkashi	2300	78^0 26’	39^0 44’
4	Devidhar / Rudraprayag	1900	78^0 15	29^0 25’
5	Jhandidhar / Pauri	2000	78^0 46’	30^0 8’

METHODOLOGY

To investigate the changes in the physico-chemical properties of soil in *Cedrus deodara* forests, five sample plots of 0.1 ha were laid out on each location. Thus a total of 25 sample plots were laid out in all the five locations.

Soil Analysis

Composite soil samples (four samples from four corners and one from the center of the sample plot) were taken and later on were mixed-depth-wise like 0-10 cm soil of one corner of sample plot mixed with 0-10 cm soil of other four corners of the same sample plot and like that other soil samples were mixed depth-wise). The samples were collected from three different depths viz., (i) upper (0–10 cm), (ii) middle (11–20 cm) and (iii) lower (21–30 cm) for assessing the physical and chemical properties of soil in all the five selected forest of deodar. The total number of composite soil samples from the single site was 15 and total composite soil samples among all the five sites were 75.

The samples were brought to the laboratory in tightly closed polythene bags and fresh weight of each composite sample was recorded. The samples were air-dried, grinned and passed through 2 mm sieve for pH, soil moisture content %, organic carbon content, available phosphorus, and exchangeable potassium by technique shown in Table 2. The soil analysis was done in the soil science laboratory of New Tehri, Tehri Garhwal, Uttrakhand.

Table 2. Physico-chemical properties

S. No.	Component	Method adopted	References
1	Soil pH	Standard paste technique using Ec and pH meters	Rhoades,1982
2	Organic Carbon %	Potassium dichromate reduction of organic carbon and spectrophotometric measurements	Walkey and Black, 1982
3	Available phosphorus	Olsen’s method, Colorimetry	Olsen *et al.* (1954)
4	Available potassium	Neutral normal NH_4OAc, Flame photometry	Stanford and English (1949)
5	Moisture Content %	$\frac{\text{(Fresh weight-Dry Weight)}}{\text{Dry weight}} \times 100$	Misra, 1968.

Calculation of Correlation coefficient

Correlation coefficient between Growing stock versus Organic carbon, Available phosphorus and Available potassium were calculated as per Freese (1967).

RESULTS AND DISCUSSION

Changes in Physico-chemical properties of soils under different *C. deodara* forests of Garhwal Himalaya:

Changes in Soil Organic Carbonpercentage:

The comparison of present soil organic percentage reported by Bhatt, reveals that over these 15 years, organic carbon percentage decreased in all the studied sites because of poor understory vegetation among all the sites which leads to the slow decomposition of organic matter. A decrease in organic carbon percentage may also due to slower microbial activities among all the sites. According to Bhatt, the average organic carbon % was 1.64 % (Ghimtoli), 1.47% (Dhanolti), 1.56% (Dewarkhal), 2.07 % (Devidhar) and 1.18 % (Jhandidhar), whereas after 15 years in the same studied sites it was 0.57 % (Ghimtoli),0.62% (Dhanolti), 0.24% (Dewarkhal), 0.68% (Devidhar) and 0.58% (Jhandidhar).(Table no.3 and Fig.1).Sharma *et al.*, (2012) while working on the soil chemical properties in relation to forest composition in moist temperate valley slopes of Garhwal Himalaya observed 2.29 % organic carbon in mixed *Abiespindrow* forest and 4.31 %organic carbon in *Aesculus indica* forest typessimilarly. Digvijay *et al.*, (2015) has worked on biomass and carbon stocks in different deodar forests of Garhwal Himalaya. In this study they ranged soil organic carbon percent in all the sites from 1.42 to 1.70 %, 1.29 to 1.67 % and 1.41 to 1.61 % for 0-15 cm, 16-30 cm and 31- 45 cm soil depth respectively.

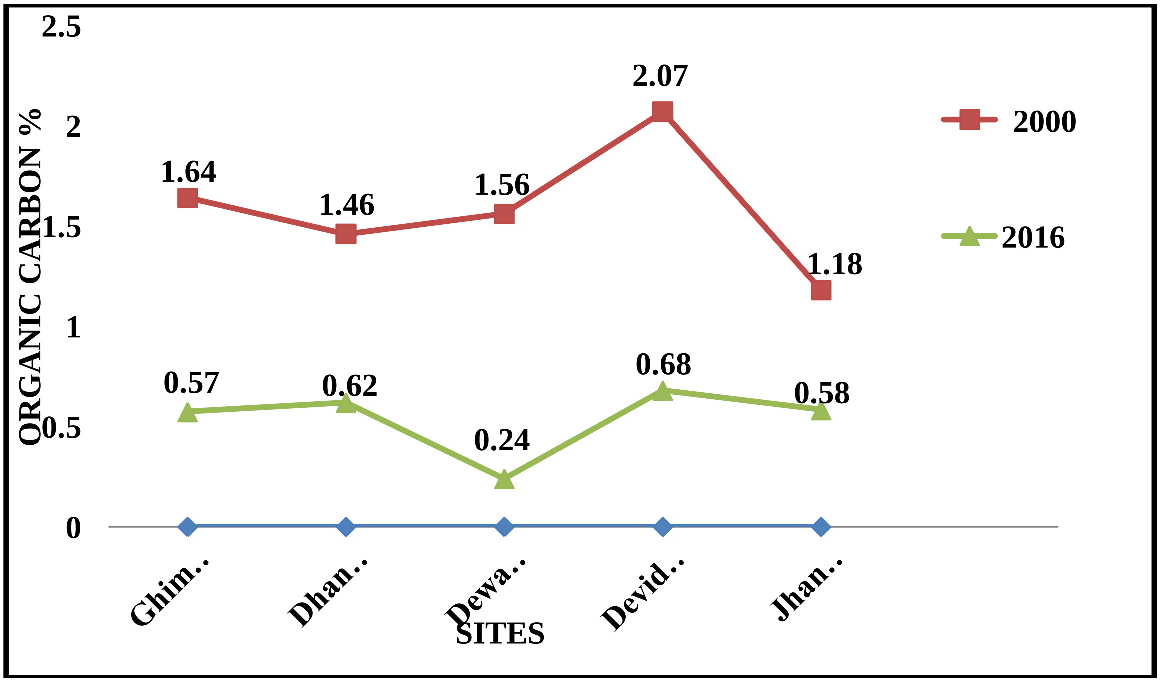

Fig. 1. Changes in soil organic carbon percentage over 15 years

The highest soil organic carbon % was obtained under Devidhar forest and lowest under Dewarkhal forest. The soil enrichment with soil organic carbon content in Devidhar could be due to the addition of litter, thick humus layer and minimum soil organic carbon % were recorded in Dewarkhal due to poor understory vegetation and heavy rainfalls recorded in Uttarkashi region as compared to Rudraprayag district. This might have a key factor contributing to decreasing soil organic carbon content, which may erode the soil surface and removed organic matter-rich fine sediments from the soil surface.

Table 3. Changes in the soil organic carbon percentage

S.NO	LOCALITY	SOIL ORGANIC CARBON % IN 2000			SOIL ORGANIC CARBON % IN 2016		
		RANGE	X*	SE*	RANGE	X*	SE*
1	GHIMTOLI A B C	1.01-2.25 0.91-1.86 1.35-2.10	1.81 1.39 1.73	0.21 0.61 1.73	0.03-1.40 0.03-1.17 0.02-1.31	0.66 0.35 0.71	0.29 0.31 0.28
Average			**1.64**	**0.13**		**0.57**	**0.26**
2	DHANOLTI A B C	0.62-2.27 0.49-2.21 0.41-2.69	1.35 1.32 1.81	0.31 0.31 0.48	0.27-1.05 0.33-0.90 0.30-1.05	0.21 0.26 0.25	0.06 0.01 0.07
Average			**1.47**	**0.18**		**0.62**	**0.12**

3	**DEWARKHAL**						
	A	1.07-2.02	1.61	0.22	0.12-0.44	0.21	0.06
	B	0.61-2.02	1.35	0.25	0.21-0.32	0.26	0.01
	C	1.07-2.21	1.73	0.22	0.05-0.45	0.25	0.07
Average			**1.56**	**0.18**		**0.24**	**0.04**
4	**DEVIDHAR**						
	A	0.76-6.70	3.42	1.35	0.02-1.44	0.83	0.32
	B	0.33-6.21	0.66	0.20	0.08-1.32	0.43	0.23
	C	0.25-1.28	0.76	0.18	0.02-1.35	0.78	0.30
Average			**2.07**	**0.90**		**0.68**	**0.28**
5.	**JHANDIDHAR**						
	A	0.49-2.05	1.16	0.25	0.03-1.35	0.58	0.20
	B	0.58-1.61	1.09	0.19	0.06-1.35	0.80	0.29
	C	0.61-1.54	0.85	0.18	0.20-1.35	0.37	0.25
Average			**1.18**	**0.22**		**0.58**	**0.24**

***X=MEAN,SE= STANDARD ERROR**

Changes in Soil pH

The present study results showed in Fig.2 , according to Bhatt, the average soil pH of the same studied sites was 6.37 (Ghimtoli), 6.43 (Dhanolti), 6.45 (Dewarkhal), 6.16 (Devidhar), and 6.12 (Jhandidhar). However, after 15 years the soil pH decreased and in the present study, it was 5.82 (Ghimtoli), 5.07 (Dhanolti), 5.87 (Dewarkhal), 5.64 (Devidhar) and 5.55 (Jhandidhar). The decrease in soil pH over a period of 15 years clearly depicting that the nature of conifer forests became acidic in due course of time as a result of podzolozation. (Table no. 4). Gairola *et al.*, (2012) studied the Conifer mixed broadleaf forest and *Abiespindrow* forest in Mandal – chopta, Chamoli Garhwal region and Khera *et al.* (2001) for *Quercusleucotrichophora and Q. floribunda* forest in Uttarkashi Garhwal region have also reported acidic pH values *i.e.* 5.47 and 5.20. This may be due to higher organic matter content and protected nature of forest. Tiwari *et al.*, (2013) studied the Physico-chemical properties of soils in cool-temperate forests of the "Nanda Devi Biosphere Reserve" in Uttarakhand (India). Their study revealed that the parent material of the study area represents crystalline rocks and comprises of garnetiferous mica, schists, garnet mica and mica quartzite. The soil was found acidic in nature, which ranged from 5.09 ± 0.06 to 6.46 ± 0.05 for 0 to 45 cm depth.

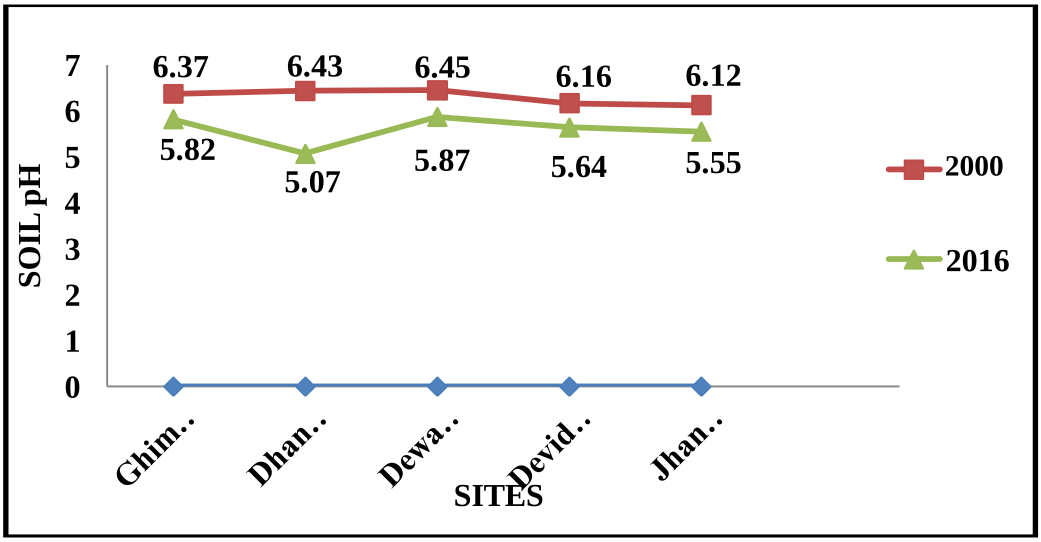

Fig. 2. Changes in soil ph over 15 years

Table 4. Changes in the soil ph

S.NO	LOCALITY	SOIL pH IN 2000			SOIL pH IN 2016		
		RANGE	X*	SE*	RANGE	X*	SE*
1	**GHIMTOLI**						
	A	6.2-6.6	6.38	0.07	5.30-6.50	5.88	0.19
	B	6.3-6.5	6.38	0.04	5.30-6.80	6.14	0.31
	C	6.2-6.6	6.36	0.07	5.10-5.80	5.44	0.15
Average			**6.37**	**0.01**		**5.82**	**0.21**
2	**DHANOLTI**						
	A	6.4-6.5	6.42	0.02	4.60-5.30	4.96	0.13
	B	6.3-6.5	6.42	0.02	4.70-5.50	5.14	0.16
	C	6.4-6.6	6.46	0.04	4.60-5.50	5.12	0.18
Average			**6.43**	**0.01**		**5.07**	**0.15**
3	**DEWARKHAL**						
	A	6.4-6.5	6.44	0.02	5.90-6.62	6.04	0.05
	B	6.3-6.5	6.44	0.04	5.50-6.62	5.80	0.15
	C	6.4-6.6	6.48	0.05	4.90-6.30	5.78	0.24
Average			**6.45**	**0.01**		**5.87**	**0.14**
4	**DEVIDHAR**						
	A	5.9-6.2	6.12	0.06	4.80-7.30	5.68	0.42
	B	6.0-6.3	6.12	0.06	5.30-6.10	5.50	0.15
	C	6.1-6.4	6.24	0.05	5.50-6.00	5.74	0.09
Average			**6.16**	**0.04**		**5.64**	**0.22**
5.	**JHANDIDHAR**						
	A	6.0-6.2	6.12	0.04	5.30-6.80	5.92	0.27
	B	5.9-6.1	6.02	0.04	4.90-5.80	5.28	0.15
	C	6.0-6.5	6.22	0.09	5.20-5.80	5.24	0.06
Average			**6.12**	**0.06**		**5.55**	**0.16**

*** X= MEAN, SE= STANDARD ERROR**

Table 5. Changes in the soil available phosphorus

S.NO	LOCALITY	AVAILABLE PHOSPHORUS (kg/ha) IN 2000			AVAILABLE PHOSPHORUS (kg/ha) IN 2016		
		RANGE	X*	SE*	RANGE	X*	SE*
1	**GHIMTOLI**						
	A	3.95-14.78	6.59	2.07	8.96-22.4	15.23	2.28
	B	3.25-7.88	6.34	0.90	8.96-26.88	15.23	3.35
	C	3.45-11.23	7.17	2.24	8.93-17.92	15.23	1.79
Average			**6.70**	**0.25**		**15.23**	**4.49**
2	**DHANOLTI**						
	A	13.34-22.65	17.84	1.52	31.36-62.72	51.07	6.43
	B	13.74-22.65	19.08	1.78	31.36-67.2	51.96	5.94
	C	16.75-31.52	22.43	3.18	40.32-76.12	49.27	6.78
Average			**19.75**	**1.34**		**50.77**	**6.38**
3	**DEWARKHAL**						
	A	10.44-13.99	12.33	0.63	44.8-85.12	71.68	7.88
	B	9.46-13.99	10.95	0.79	67.2-76.12	68.18	2.60
	C	4.21-13.99	9.86	1.59	49.28-53.12	52.86	0.89
Average			**11.05**	**0.71**		**64.21**	**3.79**

4	**DEVIDHAR**						
	A	4.83-10.84	7.78	1.12	4.28-22.4	14.19	2.93
	B	6.00-14.78	9.96	9.96	4.48-26.28	18.91	4.10
	C	7.09-9.26	8.36	8.36	4.48-22.04	9.85	3.29
Average			**8.70**	**0.65**		**14.28**	**3.44**
5.	**JHANDIDHAR**						
	A	6.59-9.85	8.40	0.63	4.48-17.92	9.85	2.61
	B	7.49-11.23	9.30	0.69	4.48-13.44	8.06	1.67
	C	4.83-8.07	6.54	0.61	4.48-8.96	5.37	0.89
Average			**8.08**	**0.81**		**7.76**	**1.72**

***X= MEAN, SE= STANDARD ERROR**

Table 6. Changes in the soil available potassium

S.NO	LOCALITY	AVAILABLE POTASSIUM (kg/ha) IN 2000			AVAILABLE POTASSIUM (kg/ha) IN 2016		
		RANGE	X*	SE*	RANGE	X*	SE*
1	**GHIMTOLI**						
	A	116-224	167.20	22.07	54-117	84.8	11.11
	B	128-172	164.40	10.48	5-135	78.2	26.99
	C	120-148	133.20	4.72	45.5-153	93.7	18.72
Average			**154.33**	**10.90**		**85.57**	**18.04**
2	**DHANOLTI**						
	A	200-320	251.20	23.81	315-396	360.8	13.16
	B	160-320	237.80	28.07	342-423	370.8	13.76
	C	148-324	230.40	30.58	333-405	354.6	13.52
Average			**239.80**	**6.08**		**362.4**	**13.48**
3	**DEWARKHAL**						
	A	312-452	369.60	26	356-466	430.4	20.09
	B	312-440	363.20	25.12	324-432	392.4	19.42
	C	312-440	384.00	29.26	356-423	397	11.50
Average			**372.27**	**6.15**		**406.6**	**17**
4	**DEVIDHAR**						
	A	136-288	204	29.23	41-144	73.2	18.42
	B	168-300	215.20	24.18	27-72	48.8	8.32
	C	132-352	177.80	19.87	27-90	68.5	11.53
Average			**199**	**11.08**		**63.5**	**12.85**
5.	**JHANDIDHAR**						
	A	112-342	220.40	43.21	99-153	118	8.96
	B	192-312	201.60	31.84	41-113	77	12.40
	C	124-428	276.00	64.50	41-153	92	18.60
Average			**232.67**	**22.34**		**95.67**	**13.66**

*** X= MEAN, SE= STANDARD ERROR**

Table 7. Changes in the moisture content percentage

S.NO	LOCALITY	MOISTURE % IN 2000			MOISTURE % IN 2016		
		RANGE	X*	SE*	RANGE	X*	SE*
1	**GHIMTOLI**						
	A	10.0-31.25	19.25	3.68	18.68-42.2	33.18	4.13
	B	10.0-31.25	20.59	3.87	20.62-57.92	34.08	6.15
	C	7.96-27.78	15.33	3.41	23.51-42.4	39.9	7.96
Average			**18.39**	**1.58**		**35.69**	**6.08**

2	**DHANOLTI** **A** **B** **C**	42.86- 83.33 33.33- 75.00 25.00- 66.67	62..86 62.18 43.67	7.32 16.17 8.24	12.94- 84.97 24.71- 44.52 37.47- 54.08	44.59 36.14 45.15	11.52 3.64 3.34
Average			**56.24**	**6.28**		**41.99**	**6.16**
3	**DEWARKHAL** **A** **B** **C**	15.00- 56.25 20.00- 71.42 7.14- 33.33	28.25 32.17 18.84	7.24 9.84 4.72	12.94- 21.5 9.91- 57.92 16.41- 42.16	16.83 29.40 27.29	1.54 7.87 4.50
Average			**26.42**	**3.95**		**24.48**	**4.63**
4	**DEVIDHAR** **A** **B** **C**	7.96- 40.00 9.09- 25.00 11.11- 27.27	17.86 15.68 19.18	5.91 3.03 3.24	8.95- 25.25 4.73- 23.82 5.06- 14.07	16.55 16.36 11.25	3.34 7.75 2.07
Average			**17.57**	**1.02**		**14.72**	**4.38**
5.	**JHANDIDHAR** **A** **B** **C**	10.00- 33.33 9.09- 28.83 8.33- 16.67	24.11 17.14 12.28	4.26 3.51 1.67	7.36-23.3 2.56- 51.56 6.95- 18.39	16.71 21.68 13.85	2.74 8.33 2.25
Average			**18.01**	**3.30**		**17.41**	**4.44**

***X= MEAN, SE= STANDARD ERROR**

Present study reveals that soils were slightly acidic to buffer in nature on all the 5 sites and the pH values of these soils ranged from 5.07 to 5.87. It has been reported that forest soils should be slightly acidic for nutrient supply to be balanced (Leskiw 1998).

Changes in Available Phosphorus

Bhatt revealed that the maximum average phosphorus (19.75±1.34 kg/ha) was recorded in the soils of site-2 (Dhanolti), followed by Dewarkhal (11.05 kg/ha), Devidhar (8.70 kg/ha), Jhandidhar (8.08 kg/ha) and minimum average (6.70 kg/h) was recorded in site-1 (Ghimtoli). After 15 years in a re-visitation study results showed in figure. 3, the available average phosphorus was increased in four similar sites as 15.23 kg/ha in Ghimtoli, followed by 50.77 kg/ha in Dhanolti, 64.21 kg/ha in Dewarkhal, 14.28 kg/ha in Devidhar. However, in the Jhandidhar site, it declined (7.76 kg/ha) as compared to that of the previous study of Bhatt in 2000. (Table no. 5). Bhatt *et al.* (2014) have studied the physico-chemical properties of the soil in Central Himalaya and observed that the available phosphorus is varied between 16.12 kg/ha in the Oak-mixed conifer forest and 35.15 Kg/ ha in Pine-Oak forest.

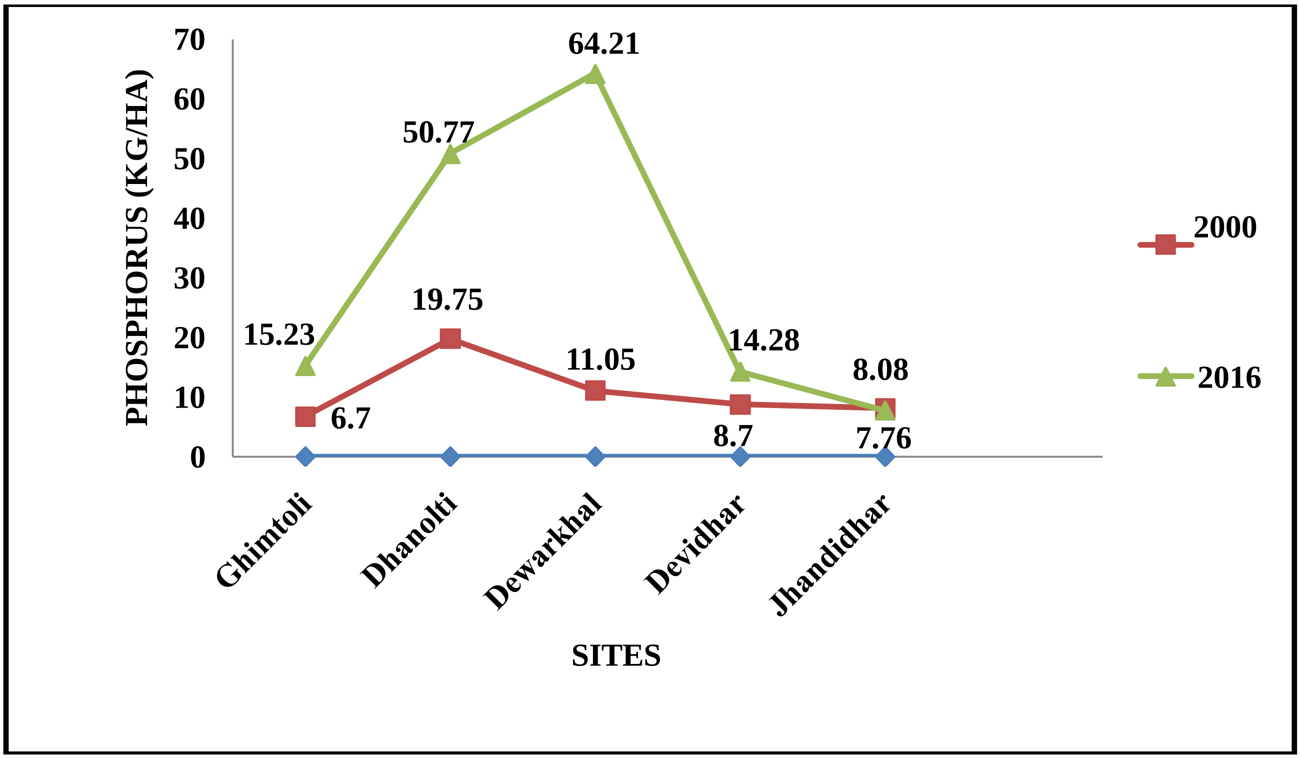

Fig. 3. Changes in phosphorus (kg/ha.) over 15 years

Shrestha (1979) has reported the available Phosphorus range from 1.03 to 71.15 kg/ha in the specified part of the Godavari hill forest area, Kathmandu. However, Baral (1983) have reported the available Phosphorus range 44.66 to 90.66 kg/ha from the same sites.

In the present study, the minimum average phosphorus (7.76 kg/ha) was recorded in the soils of site-5 (Jhandidhar) whereas the maximum average phosphorus (64.21 kg/ha) was recorded in the soils of site-3 (Dewarkhal). The values of available Phosphorus in the present study are much higher than those recorded by some other investigators in similar and other parts of the Garhwal region of Central Himalaya (Bhatt *et al.*, 2000, Digvijay *et al.*, 2015). It may be because in low pH, the Phosphorus reacts with Iron, Aluminium, Calcium and other minerals to form Iron phosphate, Aluminium phosphate and Calcium phosphate, which is unavailable to the plants in higher amount. The Phosphorus was also found higher in the lower horizons of all the forest types, which may be due to the leaching properties of the soils.

Changes in Available Potassium

According to Bhatt, the mean maximum (372.27 kg/ha) potassium was recorded in the soils of site-3 (Dewarkhal) followed by (239.80 kg/ha) Dhanolti, (232.67 kg/ha) Jhandidhar, (199.00 kg/ha) Devidhar and (154.93 kg/ha) in Ghimtoli. After 15 years in a re-visitation studyindicated by figure. 4, it is evident that average potassium increased in Dhanolti (362.4 kg/ha) and Dewarkhal site (406.6 kg/ha), whereas it decreases in Ghimtoli (85.57 kg/ha), Devidhar (63.5 kg/ha) and Jhandidhar site (95.67 kg/ha).These changes are more likely attributable to the combined effect of growth and the use of soil nutrients by the trees in respective sites. (Table no. 6). Digvijay *et al.*,(2015) has worked on biomass and carbon stocks in different deodar forests of Garhwal Himalaya. In this study, they ranged soil potassium in all the sites from 84.56 kg/ha to 243.4/ha.

Kaushal *et al.*, (1997) have observed the available K status of the dry temperate zone of *Cedrus deodara* in surface soil from 188.4 - 860.0 kg ha^{-1} and sub-surface soils from 67.2 - 710.0 kg ha^{-1} respectively.

In the present study, the mean maximum (406 kg/ha) potassium was recorded at site-3 (Dewarkhal) and mean minimum (63.5 kg/ha) was recorded at site-4 (Devidhar).The reduction in availability of potassium is due to leaching and drainage, which results in the destruction of vegetation (Basumatary and Bordoloi, 1992).

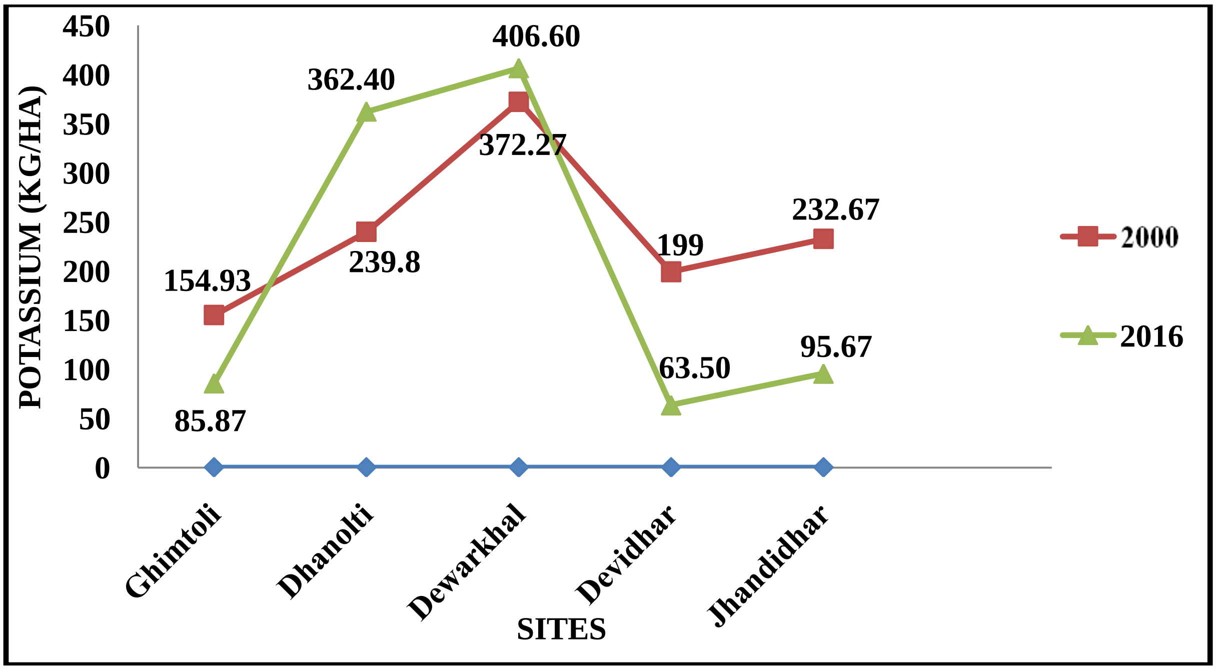

Fig. 4. Changes in available potassium (kg/ha) over 15 year

Changes in Moisture content

Bhatt has also recorded the average moisture content percentage on same sites i.e. Ghimtoli (18.39±1.58 %), Dhanolti (56.24±6.28), Dewarkhal (26.42±3.95 %), Devidhar (17.57±1.02 %) and Jhandidhar (18.01±3.30 %) which was within the moderate range of its availability.

After 15 years, the average moisture content percentage showed in figure 5. at Ghimtoli (35.69±6.08) increased, whereas it decreased in other sites like Dhanolti (41.99±6.16), Dewarkhal (24.48±4.63), Devidhar (14.72±4.48) and Jhandidhar (17.41±4.44) which may be due to less utilization of water by plants or may be due to less transpiration rate. The highest average moisture content (41.99 %) was recorded on site-2 (Dhanolti) because of more atmospheric precipitation on this site (Table-no.10).

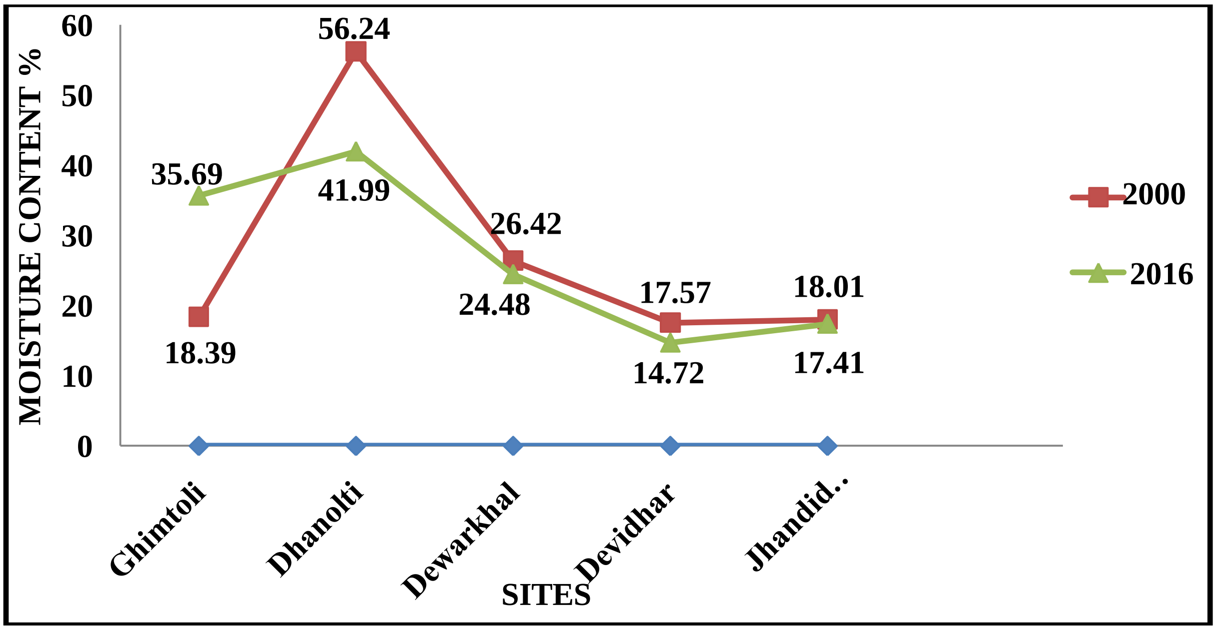

Fig. 5. Changes in moisture content of soil (%) over 15 years

Bhatt *et al.*, (2014) studied the Analysis of the physico-chemical properties of the soil and climatic attribute on vegetation in Central Himalaya in which forest types were Pine- Oak forest, mixed oak-conifer forest, mixed broadleaved conifer forest, conifer forest. According to him the average moisture content in these forests were 18.8% in pine-oak forest, 24.66 % in mixed oak-conifer forest, 26.33 % in mixed broadleaved conifer forest and 20.5 % in a conifer forest.

The average moisture contents on three study sites i.e., Dewarkhal (24.48 %), Devidhar (14.72 %) and Jhandidhar (17.41 %) although found within the moderate range of its availability which was significantly higher (average 35.59 % and 41.99 %) on site-1 (Ghimtoli) and site-2 (Dhanolti). An increase in the retention of soil moisture through the incorporation of humus has been reported by Biswas and Ali (1969).

CONCLUSION

The present study revealed important results over a long period in changesof physicochemical properties. It will help all the scientific community, researches and forester to understand the changes in soil over a long period. The present study will be a key factor to manage and maintain for the deteriorating plant growing media to improving its fertility and productivity per hectare.

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