Journal of Applied and Natural Science 8 (3): 1479 - 1484 (2016)

JANS

Impact of cropping systems on soil properties, nutrient availability and their carbon sequestration potential in Shiwalik hills of Himachal Pradesh

Nancy Loria*, S. K. Bhardwaj and Charles K. Ndungu

Department of Environmental Science, Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan – 173230 (Himachal Pradesh), INDIA
*Corresponding author. E-mail: lorianancy@gmail.com

Received: January 28, 2016; Revised received: May 29, 2016; Accepted: August 06, 2016

Abstract: The impact of cropping systems on soil properties, nutrient availability and their carbon sequestration potential was studied during the years 2014 and 2015 in Shiwalik hills of Himachal Pradesh. The four commonly occurring cropping systems namely vegetable, fruit, cereal crop and agroforestry were selected. Uncultivated land in the region was considered as control. In total, there were five treatments which were replicated six times under randomized block design. The study indicated that the cropping systems in the Shiwalik hills varied significantly (P=0.05) with respect to their impact on soil properties, nutrient availability and carbon sequestration potential. The pH and EC was in the range of 6.04 to 6.90 and 0.094 to 0.138 dSm^{-1}, respectively and were normal in range. Organic carbon and bulk density in surface soils ranged from 8.06 to 9.70 g kg^{-1} and 1.19 to 1.34 Mg m^{-3}, respectively. The available NPK was highest (267.21, 19.99, 172.42 kg ha^{-1}) under vegetable based cropping system as compared to other systems. Carbon density in surface soil ranged from 11.33 to 15.39 Mg C ha^{-1} and total carbon sequestered upto 30cm soil depth ranged from 601.96 to 12646.29 Gg. The study indicated that in Shiwalik hills of Himachal Pradesh, the commonly occurring cropping systems did not influence the soil properties and nutrient availability adversely. Agroforestry based cropping system is having highest potential of sequestering soil carbon in Shiwalik hills. Therefore to adapt to changing climatic situation and to mitigate its effect in the region, agroforestry based cropping system need to be encouraged.

Keywords: Agroforestry, Carbon density, Cereal, Fruit, Vegetable

INTRODUCTION

Agriculture plays a valuable role in our everyday lives by not only providing us with food, but also by maintaining a strong economy. On a worldwide basis, more people are in some way involved in agriculture than in all other occupations combined. Agriculture sector in our country contributes to 13.7% of the GDP and source of employment for 22% of total population (FAO, 2013) and thus plays a crucial role in the country's development and shall continue to occupy an important place in the national economy. About 52 per cent of the India's population is still dependant on agriculture for their livelihood and employment (Joshi *et al.*, 2011). The demands placed on infinite natural resources are increasing exponentially due to growing population and increasing economic activity. In order to meet the food requirement of growing population the yield of the cropland is being enhanced with the use of irrigation, fertilizer, pesticide and high-yielding varieties. Consequently, one of the most important challenges facing humanity today is to conserve/sustain natural resources like soil and water for increasing food production, while protecting the environment. The sustainability of country's agriculture is being threatened by sharp declining factor productivity due to deteriorating soil quality, imbalanced use of fertilizers, mismatch between nutrient additions and removal and escalating cost of production. Increase in food production must keep pace with the country's increasing population at a rate of 1.97 per cent demanding not only the food security but also nutritional security. In 2014-15, India's estimated food grain production stands at 257 million tonnes. India's foodgrains requirement has been estimated to cross 300 million tonnes by 2020, which will have to come from nearly 142 Mha cultivated area (Vasuki, 2010). Indian soils are generally poor in inherent fertility and have been depleted due to continuous cultivation therefore; expected food grains have to be attained by enhancing the productivity per unit area. To manage our soil for maximum productivity and sustainability, soil characterisation is the first and foremost step. Cropping systems are designed and managed to achieve human goals so they are purposeful systems. Globally, climate negotiations have highlighted the importance of these systems in mitigating the climate change through carbon sequestration using innovative soil and crop management practices (IPCC, 2013).

Effect of cropping systems on soil properties provides an opportunity to evaluate sustainability of agro ecosystem and thus the basic processes of soil degradation

ISSN : 0974-9411 (Print), 2231-5209 (Online) www.jans.ansfoundation.org

in relation to agricultural use. However, the systematic information with respect to inherent soil properties, their fertility status and carbon sequestration potential, particularly under different cropping systems is lacking. Keeping in view the importance of these cropping systems in Shiwalik hills of of Himachal Pradesh, the present investigation was taken up to know the impact of cropping systems on soil properties, nutrient availability and their carbon sequestration potential.

MATERIALS AND METHODS

Study area: The study area consisted of the Shiwalik foothill (upto 800m amsl) regions falling in two districts namely Hamirpur and Kangra of Himachal Pradesh (Figure 1). This region occupies about 35 percent of the total geographical area and 40 percent of the cultivated area of the state. The soils of Shiwalik hills are shallow and light textured. The major crops of the region are rice, wheat, citrus, mango, litchi, guava, vegetables and barley. The average annual rainfall of this zone is about 130 cm.

Cropping systems and experimental details: The four cropping systems namely cereal, vegetable, fruit and agroforestry were selected in Shiwalik hills of Hamirpur and Kangra districts of Himachal Pradesh. Uncultivated land in the region was considered as control. In total, there were five treatments which were replicated six times under randomized block design.

In Shiwalik hill region of Hamirpur and Kangra district of Himachal Pradesh, the fruit farming system was composed of mango, litchi or citrus. The vegetable farming system was composed of pea, cauliflower, brinjal, ladyfinger, potato crops etc. Cereal based farming system was composed of maize, paddy and wheat while agroforestry system was consisted of agri-silviculture or agri-horticulture. Uncultivated land constituted the barren and unculturable land with no vegetation cover. In Shiwalik hills of Himachal Pradesh, the total area under cereal, vegetable, fruit and uncultivated land was 253631 ha, 29221.5 ha, 34961.85 ha and 623891.8 ha, respectively (Anonymous, 2012). The approximate areas under selected cropping sytems in Shiwalik hills of Himachal Pradesh were calculated by taking 35 percent of their total area under state. Agroforestry area in the state was 230000 ha (FSI, 2013) and for Shiwalik hills it comes out to be 80500 ha. Amongst the four dominant cropping systems in Shiwalik hills of Himachal Pradesh, the cereal based and agroforestry were the oldest systems and are being followed by the people for the last about 50 years. On the other hand fruit and vegetable based cropping system are being practised for the last about 30 and 15 years, respectively.

Soil sampling and analysis: Composite soil samples from surface (0-15 cm) and sub-surface (15-30 cm) layers were taken from each cropping system during year 2014 and 2015 and transported to the laboratory for processing and analysis. Soil samples were air dried, ground and sieved (2mm) before laboratory examination. The soil bulk density was estimated by standard core method (Singh, 1980). Soil organic carbon was determined by rapid titration method (Walkley and Black, 1934). The available nitrogen was estimated by alkaline potassium permanganate method (Subbiah and Asijia, 1956) and available phosphorus by using Olsen's method (Olsen *et al*., 1954). The available potassium was estimated by ammonium acetate method (Merwin and Peech, 1951). Soil electrical conductivity and pH was determined by 1:2.5 soil: water suspension method (Jackson, 1973). The critical limits followed for categorizing available nutrient status of soils are presented in Table 1. The soil organic carbon density (Mg C ha^{-1}) of Shiwalik foothill region was calculated using the following equation as per the IPCC Good Practice Guidance for LULUCF (IPCC, 2003).

SOC = [SOC] X Bulk Density X Depth X Coarse Fragments X 10

where:

SOC = soil organic carbon stock , Mg C ha^{-1}

[SOC] = concentration of soil organic carbon in a given soil mass, g C (kg $soil)^{-1}$,

Bulk Density = soil mass per sample volume, Mg m^{-3}

Depth = sampling depth or thickness or soil layer, m

Coarse Fragments = 1 – (% volume of coarse fragments / 100), dimensionless

The final multiplier of 10 is introduced to convert units to Mg C ha^{-1}.

Statistical analysis: Analysis of variance (ANOVA) was used to evaluate the influence of cropping systems on soil physico-chemical properties, nutrient contents and carbon density and stocks in Shiwalik hills of Himachal Pradesh. The means were separated and compared through critical difference at 5% level of significance under the RBD (Randomised Block Design). For the sake of brevity, data of both the years with respect to the various parameters was pooled to assess the long term impact of cropping systems.

RESULTS AND DISCUSSION

Soil pH: In Shiwalik hills of Himachal Pradesh the soils under dominant cropping systems were having mean pH values ranging from 6.04 to 6.90 and 6.0 to 6.93 in surface and sub surface soils, respectively (Table 2). In surface soils the cropping system wise order of soil pH was; control (6.90) > agroforestry (6.73) > fruit (6.63) > vegetable (6.06) > cereal (6.04). The sub-surface soils followed the same trend with respect to pH under the selected cropping systems. It is evident from the data in Table 2 that soils under selected cropping systems were slightly acidic to normal in reaction. Since the Shiwalik hills of this region are characterized by hyperthermic soil temperature regime and normal rainfall and the soils of the area are developed from the soft sandstones and flood plains from alluvium of the adjoining hills, therefore, the soil reaction from slightly acidic to normal range seems obvious (Sehgal *et al*. 1987 ; Chaudhri, 2000). Sharma and Kumar (2011) have also reported slightly acidic to normal reaction of Shiwalik hill soils of Himachal Pradesh. The slightly acidic soil pH in cereal based system may be attributed to long term use of acid forming fertilizers like urea in the region. The results are in agreement with the findings of Lungu and Dynoodt (2008) and Babbu *et al.* (2015) who have also reported soil acidification due to long-term annual applications of urea. However, the soil pH did not follow any consistent trend with depth. The results are in conformity with the findings of Walia and Rao (1996), Mahajan (2001) and Shekhar (2009) who have also noticed such trends for soil pH with increasing depth in low-hills soils.

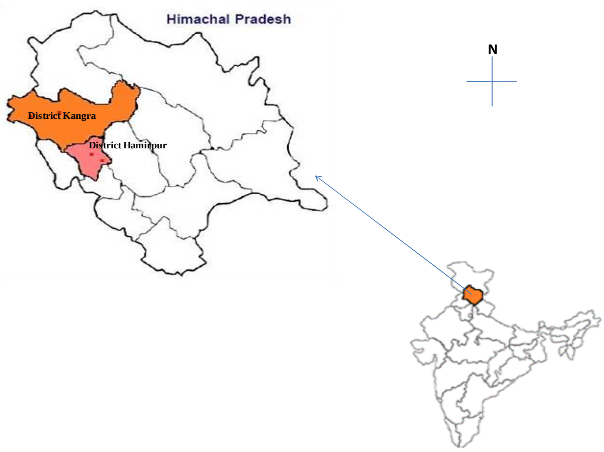

Fig. 1. *Study districts in Shiwalik hills of Himachal Pradesh.*

Soil electrical conductivity: The electrical conductivity in surface soil ranged from 0.094 to 0.138 dSm^{-1} (Table 2). Under the different cropping systems, EC followed the order; agroforestry (0.138 dSm^{-1}) > vegetable (0.137 dSm^{-1}) > cereal (0.118 dSm^{-1}) > fruit (0.114 dSm^{-1}) > control (0.094 dSm^{-1}). EC under different cropping systems did not reflect any consistent trend with increasing soil depth. However, it was normal under all the systems indicating that the common cropping systems of the region have not influenced salt concentration of the soils. Little accumulation of soluble salts may be attributed to excessive leaching of soluble salts in lower soil profiles. EC in the normal range (0.05 - 0.7 dS/m) have also been reported by

Table 1. Critical limits of Available NPK contents in soils of Himachal Pradesh.

Nutrient elements	Soil fertility classes			References
	Low	Medium	High	
Organic carbon (g/kg)	< 5	5-10	>10	Bhandari and Tripathi (1979)
N(kg ha^{-1})	< 280	280-560	>560	FAI (1977)
P(kg ha^{-1})	< 10	10-24.6	>24.6	FAI (1977)
K(kg ha^{-1})	< 98.6	98.6-280	>280	FAI (1977)

Table 2. Effect of different cropping systems on soil pH, EC , OC and Bulk Density in Shiwalik hills of Himachal Pradesh.

Cropping systems	pH		EC ($dS\ m^{-1}$)		OC ($g\ kg^{-1}$)		Bulk density ($Mg\ m^{-3}$)	
	Mean*							
	Surface	Sub-surface	Surface	Sub-surface	Surface	Sub-surface	Surface	Sub-surface
Cereal	6.04	6.00	0.118	0.123	8.75	6.93	1.22	1.27
Vegetable	6.06	6.03	0.137	0.134	7.34	5.41	1.19	1.25
Fruit	6.63	6.54	0.114	0.121	9.70	7.27	1.32	1.35
Agroforestry	6.73	6.57	0.138	0.133	9.42	7.41	1.28	1.31
Uncultivated	6.90	6.93	0.094	0.091	8.06	6.17	1.34	1.37
CD (P=0.05)	0.22	0.22	0.013	0.017	1.68	1.46	0.06	0.05

* Mean of six replications

Table 3. Effect of different cropping systems on the nutrient availability in Shiwalik hills of Himachal Pradesh.

Cropping systems	Available N (kg ha^{-1})		Available P (kg ha^{-1})		Available K (kg ha^{-1})	
	Mean*					
	Surface	Sub-surface	Surface	Sub-surface	Surface	Sub-surface
Cereal	223.22	145.64	17.55	11.10	168.07	137.41
Vegetable	267.21	202.15	19.99	14.10	172.42	150.62
Fruit	185.11	144.09	15.03	9.83	146.57	128.85
Agroforestry	227.74	173.04	18.93	13.92	168.87	146.20
Uncultivated	157.36	113.55	9.84	7.04	119.46	100.88
CD (P=0.05)	35.96	22.06	4.60	4.28	36.03	27.56

* Mean of six replications

Table 4. Status of carbon density and total carbon stocks under different cropping systems in Shiwalik hills of Himachal Pradesh.

Cropping systems	Soil depth wise Carbon density ($Mg\ C\ ha^{-1}$)		Carbon density ($Mg\ C\ ha^{-1}$)	Area in hectares	Total Carbon stock
	(0-15 cm)	(15-30 cm)	(0-30cm)		(Gg C)
Cereal	12.57	10.38	22.95	253631.00	5820.83
Vegetable	11.65	8.95	20.6	29221.50	601.96
Fruit	14.38	11.12	25.5	34961.85	891.53
Agroforestry	15.39	12.28	27.67	80500.00	2227.43
Uncultivated	11.33	8.94	20.27	623891.80	12646.29
CD (P=0.05)	2.57	2.35	-	-	-

Loria *et al.* (2015) in agriculture soils of Shiwalik hills.

Soil organic carbon: Soil organic carbon ranged from 7.34 to 9.70 g kg^{-1} and 5.41 to 7.41 g kg^{-1} in surface and sub surface soils, respectively (Table 2). The cropping system wise trend of soil organic carbon in surface soil was; fruit (9.70 g kg^{-1}) > agroforestry (9.42 g kg^{-1}) > cereal (8.75 g kg^{-1}) > uncultivated (8.06 g kg^{-1}) > vegetable (7.34 g kg^{-1}). A definite decreasing trend in SOC distribution was observed with the increase in soil depth under all cropping systems. However, the corresponding SOC values of surface soils were relatively higher than the subsurface soils. Relatively higher SOC contents of surface soils as compared to subsurface ones may be attributed to accumulation of root and plant biomass. The relatively higher SOC under agroforestry system as compared to cereal, vegetable and control can be attributed to high litter fall contribution under such systems. Compared to fruit based cropping system, the vegetable registered relatively low soil organic carbon in spite of higher farm yard manure application. This trend may be attributed to intensive cultivation under vegetable based cropping system which might have increased decomposition of soil organic matter into CO_2. Similar results of higher amount of organic carbon observed in fruit cropping systems compared to croplands were reported by Jing *et al*. (2012) and Cheng *et al*. (2011), respectively. Relatively higher SOC contents of surface soils as compared to subsurface ones may be attributed to accumulation of root and plant biomass. Similar vertical distribution pattern of organic carbon have also been reported by Bhandari and Randhawa (1985), Minhas *et al.* (1997) and Krishnan *et al.* (2004) in soils of Shiwalik hill region of Himachal Pradesh.

Bulk density: Soil bulk density varied significantly (P=0.05) among different cropping systems (Table 2). In surface soil, it ranged from 1.19 Mg m^{-3} to 1.34 Mg m^{-3}. Under the different cropping systems, the soil bulk density followed the descending order; control (1.34 Mg m^{-3}) > fruit (1.32 Mg m^{-3}) > agroforestry (1.28 Mg m^{-3}) > cereal (1.22 Mg m^{-3}) > vegetable (1.19 Mg m^{-3}). The bulk density of soil in the sub surface layer was higher than that of surface layer. However it followed the same trend. The lower bulk density values under the vegetable cropping system may be attributed to high rate FYM application as compared to other systems. These results are in agreement with the findings of Cheng *et al.* (2011) who have also observed lower bulk density in vegetable based cropping system than the cereal based cropping system and increasing trend with the increasing soil depth in agricultural soils of Beijing, China. Bulk density increase with soil depth can be ascribed to overburdened soil pressure, which might have reduced root penetration thus reduced organic matter and aggregation, compared to surface layers.

Available NPK : The data presented in table 3 shows that the cropping systems of Shiwalik hills of Himachal Pradesh have significantly influenced the nutrient availability in the soil. In surface soils mean values of available N, P and K ranged from 157.36 to 267.21 kg ha^{-1}, 9.84 to 19.99 kg ha^{-1} and 119.46 to 172.42 kg ha^{-1}, respectively (Table 3). The order of available nitrogen as affected by cropping systems in soil surface was vegetable (267.21 kg ha^{-1}) > agroforestry (227.74 kg ha^{-1}) > cereal (223.22 kg ha^{-1}) > fruit (185.11 kg ha^{-1}) > control (157.36 kg ha^{-1}). Available phosphorus followed the order; vegetable (19.99 kg ha^{-1}) > agroforestry (18.93 kg ha^{-1}) > cereal (17.55 kg ha^{-1}) > fruit (15.03 kg ha^{-1}) > control (9.84 kg ha^{-1}). The order of available potassium in surface soils was; vegetable (172.42 kg ha^{-1}) > agroforestry (168.87 kg ha^{-1}) > cereal (168.07 kg ha^{-1}) > fruit (146.57 kg ha^{-1}) > control (119.46 kg ha^{-1}). In sub-surface soil, the available nutrients were lower as compared to surface soil under the different cropping systems, but followed the same order. Comparatively higher available nutrient contents in vegetable soils may be attributed to regular additions of NPK containing fertilizers and organic manures. Degryze *et al*. (2004) also reported much stronger nutrient enrichment in vegetable field than in the orchard and cropland due to continues fertilization. Several other workers have reported higher amount of available nutrients in cropping systems characterised by high application of inorganic fertilizers (Jing *et al*., 2012; Nisar and Lone, 2013; Gicheru and Kimigo, 2012). Higher available NPK in surface than sub surface soils in all cropping systems could be due to more organic contents in surface than in subsurface soils. These results are in agreement with those of Somasundaram *et al*. (2009), Rajeshwar *et al*. (2009) and Sigdel *et al*. (2015) who have also reported higher available NPK contents at the surface and a decreasing trend with depth.

Carbon density and total carbon stock : The cropping systems in Shiwalik hills of Himachal Pradesh have been found to significantly influence the soil carbon sequestration potential in the region (Table 4). Carbon density ranged from 11.33 to 15.39 and 8.94 to 12.28 Mg C ha^{-1} in surface and sub-surface soils, respectively. Carbon density of surface soils was highest in agroforestry based cropping system (15.39 Mg C ha^{-1}) followed by fruit (14 .38 Mg C ha^{-1}), cereal (12.57 Mg C ha^{-1}), vegetable (11.65 Mg C ha^{-1}) and lowest (11.33 Mg C ha^{-1}) in uncultivated soils. In subsurface soil, the carbon densities under the different cropping systems were lower as compared to surface soil but system wise the trend was the same. Highest carbon density in agroforestry based cropping system can be ascribed to higher organic carbon and bulk density and lower volume of coarse fragments than other cropping systems (Table 2). Further agroforestry system improved soil aggregation and enhanced SOC pool. The results are in line with the findings of Gupta *et al.* (2009) who have also reported highest carbon density in poplar based agroforestry system in North Western India. Continuous cropping and integrated use of organic and inorganic fertilizers increased soil C sequestration and crop yields (Babbu *et al.*, 2015). Next to agroforestry, higher carbon density in fruit based cropping system can be ascribed to less cultivation, which might have resulted in slow decomposition of organic matter as compared to cereal and vegetable based systems. Lowest carbon density in uncultivated land may be attributed to their barren nature with no vegetation cover which makes them prone to erosion. Total carbon sequestered in the soil profile (30cm) ranged from 601.96 to 12646.29 Gg (Table 4). The order for total carbon stock as influenced by the different cropping systems was uncultivated soils (12646.29 Gg) > cereal crop (5820.83 Gg) > agroforestry (2227.43 Gg) > fruit (891.53 Gg) > vegetable (601.96 Gg). The highest total carbon stock of uncultivated soils may be attributed to their relatively higher area in Shiwalik hills of Himachal Pradesh as compared to other systems. The rest of the trend may also be ascribed to the area under such regions (Table4).

Conclusion

The study indicated that in Shiwalik hills of Himachal Pradesh, the soil nutrients contents, carbon stock and physical chemical parameters were significantly influenced by cropping systems and seasons. The level of influence of cropping system on the soil characteristics was determined by the intensity of cultivation of the cropping system in question. Cropping systems characterised by high inputs of farm yard manure and artificial fertilizers scored high in NPK nutrients and carbon. However, the cropping systems of this region are having low and medium levels of nitrogen (157.36 - 267.21 kg/ha), phosphorus (9.84 - 19.99 kg/ha) and potassium (119.46 - 172.42 kg/ha), respectively. The agroforestry based cropping system of the low-hills has the highest potential of sequestering soil carbon in the region. Therefore, in order to minimise the adverse impacts of cropping systems conservation tillage and manure application that matches the nutrients use efficiency of a particular cropping system be adopted in the region as well as integrated agroforestry based cropping systems having high level of diversity need to be encouraged.

ACKNOWLEDGEMENTS

The paper is based on the first author's Ph.D study at Department of Environmental Science, Dr. YS Parmar University of Horticulture and Forestry, Nauni (Solan) HP, India. The author is thankful to Department of Science and Technology, Ministry of Science and Technology, India for providing financial assistance in Ph.D. Studies in the form of INSPIRE Fellowship. Last but not the least, the author is grateful to the Faculty and staff of Environmental Science for providing all necessary facilities and support during the course of this investigation.

REFERENCES

Anonymous (2012). Statistical Handbook of Himachal Pradesh, Directorate of Economics and Statistics, Government of Himachal Pradesh, Shimla.199 p.

Babbu, S., Jagdeep, S., Gurbir, S. and Gurpreet, K. (2015). Effects of long term application of inorganic and organic fertilizers on soil organic carbon and physical properties in maize- wheat rotation. *Agronomy.* 5: 220-238.

Bhandari, A. K. and Tripathi, B. R. (1979). Soil testing in fertilizer recommendations. Department of Soil Science and Chemistry. Technical Bulletin No. 10. Department of Agriculture, Himachal Pradesh, Shimla.

Bhandari, A. R. and Randhawa, N. S. (1985). Distribution of available micronutrients in soils of apple orchards in Himachal Pradesh. *Journal of the Indian Society of Soil Sciences.* 33 : 171-175.

Chaudhri, R. S. (2000). Geology of the Shiwalik group of western and central Himalaya. In: Mittal, S.P.; Aggarwal, R.K. and Samra, J. S. (eds.) Fifty Years of Research on Sustainable Resource Management in Shivaliks. Central Soil and Water Conservation Research and Training Institute, Chandigarh, India. pp 3-18.

Cheng, L., Qi, X., Zhang, X., Li, Q. and Zhang, Y. (2011). Effect of agricultural land use changes on soil nutrients use efficiency in an agricultural area, Beijing, China. *Chinese Geographical Science.* 21(4): 392-402.

Degryze, S., Six. J., Paustian, K., Morris, S.J., Paul, E.A. and Merckx, R. (2004). Soil organic carbon pool changes following land-use conversions. *Global Change Biology.* 10 (7): 1120–1132.

FAI (1977). Handbook of Fertilizer Usage. Fertilizer Association of India, New Delhi, India.

FAO (2013). FAO Statistical Yearbook 2012–2013. Food and Agricultural Organization. Rome.

FSI (2013). India State of Forest Report. Forest Survey of India, Ministry of Environment and Forests, Government of India, Dehradun. 252 p.

Gicheru, P.K. and Kimigo, J. (2012). Impact on soil quality of land use change and continuous cultivation in Sasumua catchment, Kenya. *Pedologist.* 4: 326-331.

Gupta, N., Kukal, S. S., Bawa, S. S. and Dhaliwal, G. S. (2009). Soil organic carbon and aggregation under poplar based agroforestry system in relation to tree age and soil type. Agroforestry Systems. 76 : 27-35.

IPCC. (2003). Good Practice Guidance for Land Use, Land Use Change and Forestry. Intergovernmental Panel on Climate Change, Institute for Global Environmental Strategies (IGES), Japan for the IPCC.

IPCC (2013). Climate Change 2013 : The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of Intergovernmental Panel on Climate Change [Stocker, T. F., Qin, D., Plattner, G.K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V. and Midgley, P.M. (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, 1535p. doi:10.1017/CBO9781107415324.

Jackson, M. L. (1973). Soil chemical analysis. Prentice Hall of India Private Limited. New Delhi. 498 p.

Jing, T., Mingshang, F., Jingheng, G., Petra, M., Xiaolin, L. and Yakov, K. (2012). Effects of land use intensity on dissolved organic carbon properties and microbial structure. *European Journal of Soil Biology.* 52 : 67-72.

Joshi, P., Trivedi, T., Sharma, R., Verma, S., Bharti, V. and Gyota, K. (2011). ICAR's Vision 2030. Indian Council of Agricultural Research, New Delhi.

Krishnan, P., Nair, K. M., Naidu, L. G. K., Srinivas, S., Koyal, A., Nasre, R.A., Ramesh, M. and Gajbhiye, K. S. (2004). Land, soils and land use of Lakshdeep coral islands. *Journal of the Indian Society of Soil Sciences.* 52 : 226-231.

Loria, N., Verma, K. S., Bhardwaj, S. K. and Brahmi, M. K. (2015). Impact of catchment land use on water quality of Pong wetland of Himachal Pradesh. *Indian Journal of Ecology.* 42(1): 21-26.

Lungu, O. I. M. and Dynoodt, R. F. (2008). Acidification From Long-Term Use Of Urea And Its Effect On Selected Soil Properties. *African Journal of Food, Agriculture, Nutrition and Development*. 8 (1) : 63-76Mahajan, A. (2001). Characterisation of Balh valley soils of district Mandi. MSc. Thesis, Department of Soil Science, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, India.

Merwin, H. D. and Peech, P. M. (1951). Exchangeability of soil potassium in the sand by nature of complimentary exchangeable cation. *Proceedings of the Soil Science Society of America.* 15: 125-128.

Minhas, R. S., Minhas, H. K. and Verma, S. D. (1997). Soil characterization in relation to forest vegetation in the wet temperate zone of Himachal Pradesh. *Journal of the Indian Society of Soil Sciences*. 45: 146-151.

Nisar, N. and Lone, F.A. (2013). Effect of land use / land cover change on soils of Kashmir Himalayan catchment. *Journal of Research on Earth and Environmental Sciences*. 1(1): 13-27.

Olsen, S.R., Cole, C.V., Watanabe, F. S. and Dean, L. A. (1954). Estimation of available phosphorus by extraction with sodium bicarbonate. United States Department of Agriculture. Circular No. 939, USDA, Washington DC.

Rajeshwar, M., Rao, S., Balaguraviash, D. and Khan, A. M. A. (2009). Distribution of available micronutrients in soils of Garikapadu of Krishna district of Andhra Pradesh. *Journal of the Indian Society of Soil Sciences*. 57: 210-213.

Sehgal, J. L., Saxena, R. K. and Vadivelu, S. (1987). Soil source mapping of different states in India. Technical Bulletin No. 13. National Bureau of Soil Survey and Land Use Planning, Indian Council of Agricultural Research, Nagpur, Maharashtra. 73 p.

Sigdel, S.R., Pupakheti, D., Baral, U., Tripathea, L., Aryal R., Dhital S. and Sharma, P. (2015). Physico-chemical characteristics of soil along attitudinal gradient at southern aspect of Shivapuri Nagarjun national park, central Nepal. *International Research Journal of Earth Sciences.* 3(2): 1-6.

Sharma, J. C. and Kumar, V. (2011). Hydrophysical and chemical characteristics of soils under different land use in Shivalik hills of Himachal Pradesh. *Indian Forester*. 137(4): 463-471.

Shekhar, C. (2009). Status and distribution of magnesium in acidic soils of North-western Himalaya. MSc. Thesis. Department of Soil Science, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, India.

Singh, K., Minhas, R.S., Sharma, I.P. and Razdan, P.N. (1980). Soil survey and land use report of S N Stokes Horticultural complex, Oachghat, Solan. Department of Soil Science and Water Management, H P Krishi Vishva Vidhayalaya, Solan, India.

Somasundaram, J., Singh, R.K., Parandiyal, A.K. and Prasad, S.N. (2009). Micronutrient status of soils under land use systems in Chambal ravines. *Journal of the Indian Society of Soil Sciences.* 57: 307-312.

Subbiah, B.W. and Asija, G.L. (1956). A rapid procedure for estimation of available nitrogen in soil. *Current Science.* 25: 259-260.

Vasuki, N. (2010). Micronutrient management for enhancing crop production-future strategy and requirement. *Journal of the Indian Society of Soil Sciences*. 58 : 32-36.

Walia, C.S. and Rao, Y.S. (1996). Genesis, characteristics and taxonomic classification of some red soils in Bundel Khand region of Uttar Pradesh. *Journal of the Indian Society of Soil Sciences*. 44: 476-481.

Walkley, A.J. and Black, A. (1934). Estimation of soil organic carbon by chromic acid titration method. *Soil Science.* 37: 29-38