International Journal of Plant & Soil Science

Volume 35, Issue 17, Page 220-230, 2023; Article no.IJPSS.102817
ISSN: 2320-7035

Uncovering the Impact of Erosion Conservation Techiques on Soil Attributes in Shivaliks of Lower Himalayas of Jammu, India

Vivak M. Arya [a*], Meena Yadav [a], Vikas Sharma [a], Rajeev Bharat [b], M. Iqbal Jeelani Bhat [c], Altaf Hussain [a] and Haziq Shabir [a]

[a] Division of Soil Science and Agriculture Chemistry, Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu, J&K, India.
[b] Division of Plant Breeding and Genetics, Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu, J&K, India.
[c] Division of Agricultural Statistics, Sher-e-Kashmir University of Agricultural Sciences and Technology, Kashmir, J&K, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2023/v35i173202

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/102817

Original Research Article

Received: 03/05/2023
Accepted: 05/07/2023
Published: 05/07/2023

ABSTRACT

The present study uncovering the impact of erosion conservation techniques on soil attributes in Shivaliks of lower Himalayas of Jammu. Soil erosion is considered as the main cause of land degradation in hilly areas espially in outer Himalayas. Although the problem persisted on the earth for a longer period, it has become severe in recent times due to increased man-environment interactions. The study was conducted in 2021 at the Merth village of Jammu and Kashmir, India,

**Corresponding author: E-mail: dr.arya999@gmail.com;*

which is situated in the Kathua district. The catchment area investigated had a clay loam texture and a slope gradient of 3-6%, with a total area of 24.8 acres. The result shows that mean value of bulk density under various erosion control techniques was highest in overgrazing prevention (1.40g cm^{-3}) followed by perimeter runoff control, terrace farming and contour plowing and was lowest in cover crop (1.33g cm^{-3}). The carbon content also increased with the and was highest under cover crop. Carbon act as bridge between nutrient, water and soil. The study strongly recommends adoption of resource conservation techniques for reducing soil erosion & water conservation in submontane *Shivaliks*.

Keywords: Erosion conservation modules; bulk density; infiltration rate; water holding capacity.

1. INTRODUCTION

"Land degradation and its potential causes on a worldwide basis are challenging the economic and social well being of the present and future generation by declining the productivity of croplands and rangelands" [1,2]. "Most people in the developing countries are dependent completely on agriculture for their livelihood, so it has been identified as a major threat to sustainability of agriculture and economy of nations" [3]. "The continous maintenance of fertile soil is essential in order to meet basic human needs. In India land degradation is a common problem in the Shivaliks of Lower Himalayas of Jammu, extending from district Kathua in the southeast to Rajouri in the northwest. It is a dry semi-hilly belt, locally known as kandi. Increased human and cattle population pressure along with decrease in the size of land holdings in the study area have resulted in the indiscriminate felling of trees, removal of bushes for household consumption. It has led to unabated soil loss and land degradation. Soil erosion by water is the root cause of ecological degradation in these areas. The estimated annual soil loss from the Shivaliks or sub-montane region of Jammu is more than 80 tonnes ha^{-1}. The physiographic characteristic of the area is itself a major factor contributing to the continuous degradation of these catchments. The weak lithology of the Shivaliks of Lower Himalayas consisting of rocks like sandstone, conglomerate, shale, silt stone and limestone are relatively easily weatherable and therefore prone to quick erosion. The topography of the region ranging from gently sloping to moderately-steep sloping retards the vertical development of soils. These highly erodible soils are poor in nutrients and low in organic carbon contributing to poor physical attributes and poor productivity" [4]. "Therefore, different adoption of resource conservation techniques are very necessary in the hilly areas to control the soil loss to a tolerable limit. The different resource conservation techniques are designed to intercept sediments, reduce runoff velocity, facilitate infiltration of runoff water, transmit runoff at non erosive power and reduces sedimentation of waterways, streams, and rivers" [5].

2. MATERIALS AND METHODS

Study Area: The study was conducted in the Merth village of Jammu and Kashmir, India, which is situated in the Kathua district. The catchment area investigated had a clay loam texture and a slope gradient of 3-6%, with a total area of 24.8 acres. The geographic location of the study area is between 32^{o} 17' to 32^{o} 55' North latitude and 75^{o} 70' to 76^{0} 16' East longitude.

Erosion Control Techniques: The erosion control techniques employed in maize-wheat cropping system of the study area included:

- Terrace farming
- Perimeter runoff control
- Cover crop (Black gram, *var.* Uttara)
- Agrostological measures (Bhabar, Khus-khus, Bermuda grass, Agati, Elephant grass
- Overgrazing prevention

Method of implementation of resource conservation techniques:

- Contour lines were identified. It was done by using a topographical map and in some cases by visually observing the slope.
- Terrace farming structures parallel to the contour lines were constructed. The terraces were leveled and have a slight slope to allow for water drainage.

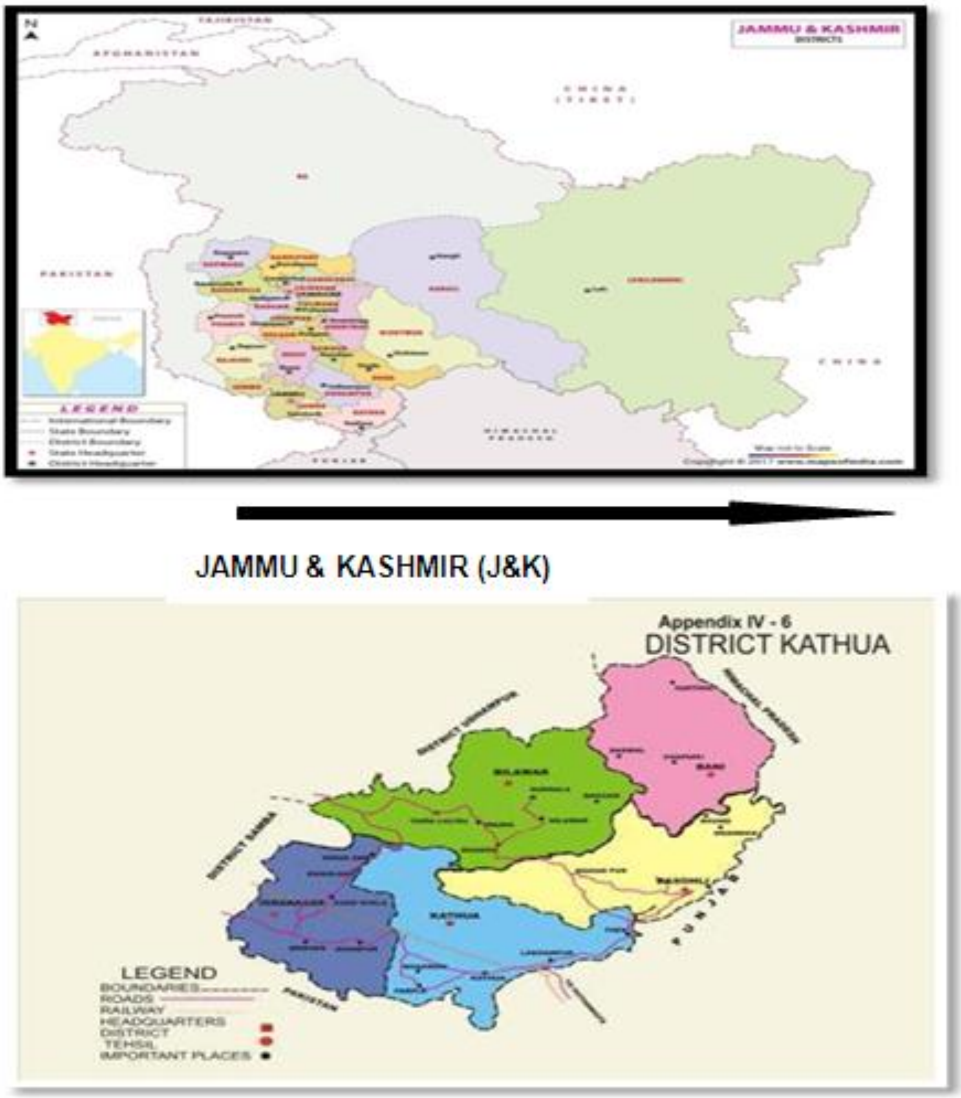

Fig. 1. Location of study area District kathua, J&K

- Perimeter runoff control structures such as bunds, trenches, and ditches along the contour lines to control the flow of water and reduce soil erosion were constructed
- The cover crops was planted in rows and spaced at regular intervals. Agrostological measures such as grasses, shrubs, and trees parallel to the contour lines. were spaced at regular intervals to provide maximum coverage.
- Overgrazing prevention measures such as limiting the number of livestock that graze on the land were by constructing fences and by providing alternative grazing areas.

The composite surface soil samples were collected randomly from the watershed areas by using GPS. Collection of soil samples were based on the different types of erosion control modules used. The collected soil samples were then air-dried, mixed well and passed through a 2 mm sieve for the analysis of selected soil physical attributes.

The composite surface soil samples were collected randomly from the watershed areas by using GPS. Collection of soil samples were based on the different types of erosion control modules used. The collected soil samples were then air-dried, mixed well and passed through a 2 mm sieve for the analysis of selected soil physical attributes.

Analysis of soil samples

Table 1. Methods employed for the determination of various soil physico-chemical attributes and their initial values

+	Methods	References	Initial values
Texture	Hydrometer method	Bouyoucos, 1962	Clay loam
Bulk density (g cm^{-3})	Core sampler method	Black, 1965	1.38
Particle density (g cm^{-3})	Pycnometer	Black, 1965	2.63
Infiltration rate (cm hr^{-1})	Minidisk infiltrometer	Decagon, 2005	2.01
pH	Potentiometric method	Jackson, 1973	6.4
Electrical conductivity (dSm^{-1})	Salt bridge method	Jackson, 1973	0.50
Organic carbon (g kg^{-1})	Rapid titration method	Walkley & Black, 1934	5.2
Available N (kg ha^{-1})	Kjeldahl method	Subbiah & Asija, 1956	250
Available P (kg ha^{-1})	Olsen's method	Olsen *et al.,*1954	11
Available K (kg ha^{-1})	Flame photometry method	Piper , 1966	160

Analysis was done by using analysis of variance techniques (ANOVA) and by applying DMRT test. The SPSS Software version 14.0 was used for analysis

3. RESULTS AND DISCUSSION

3.1 Impact of Resource Conservation Techniques on Physical Attributes of Soil

Table 2. Impact of resource conservation techniques on physical attributes of soil

RCT	BD (g cm^{-3}) (Mean ± S.E)	PD (g cm^{-3}) (Mean ± S.E)	Infiltration rate (cm hr^{-1}) (Mean)
CC	1.33 ± 0.02^{e}	2.62 ± 0.01^{a}	7.05
AM	1.35 ± 0.03^{d}	2.62 ± 0.01^{a}	6.10
TF	1.38 ± 0.02^{b}	2.63 ± 0.01^{a}	5.25
CP	1.38 ± 0.02^{b}	2.62 ± 0.01^{a}	5.20
PRC	1.37 ± 0.02^{c}	2.62 ± 0.01^{a}	4.75
OGP	1.40 ± 0.03^{a}	2.62 ± 0.01^{a}	2.75

Note: Means with the same letter are not significantly different
RCT (Resource conservation techniques), CC (Cover crop), AM (Agrostological measures), TF (Terrace farming), CP (Contour plowing), PRC (Perimeter runoff control), OGP (Overgrazing prevention)

3.2 Bulk Density

The result shows that mean value of bulk density under various erosion control techniques was highest in overgrazing prevention (1.40g cm^{-3}) followed by perimeter runoff control, terrace farming and contour plowing and was lowest in cover crop (1.33g cm^{-3}) (Fig. 2). Degraded lands were found to have the highest values of bulk density. The highest bulk density of the soil in overgrazing prevention may be attributed due to low clay content and organic matter. The decrease in bulk density in cover crop might be the subsequent effects of reduced soil loss and crop residue through erosion and addition of organic matter through plants. The impact of falling raindrops also decreased under the cover crop. Decrease in bulk density in cover crop, terrace farming, contour plowing, agrostological measures have also been observed by Franzluebbers and Stuedemann [6]; Autmong et al. [7]; Barreto et al. [8]; Singh et al. [9]. The results also confirm the findings of Sharma et al. [10] and Wallia et al. [11]. The reduction in bulk density is related to increase of organic carbon in cover crop which results in more pore space and good soil aggregation, Selvi et al. [12]; Khursheed et al. [13]; Yaduvanshi et al. [14].

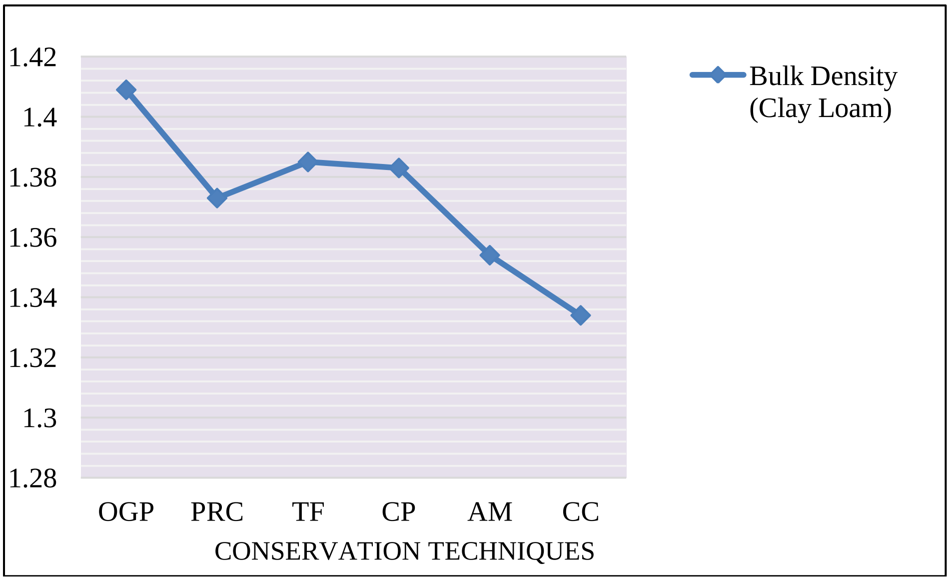

Fig. 2. Impact of erosion conservation modules on bulk density in clay loam soil

3.3 Particle Density (PD)

The statistical result indicated that PD did not get significantly affected by resource conservation techniques (Table 2). Particle density is an exclusive density of soil particles and excludes pore spaces. Particle density theoretically can be changed but in practical terms it needs enormous amount of organic carbon/ biomass addition along with the addition of heavy minerals. As resource conservation techniques are effective in modifying pore space by adding organic matter and increasing microbial activity in the rhizosphere, Chhina et al. [15] but particle density is totally independent of pore space, thus their impact on particle density was insignificant. Similar values and reasons had also been observed by Baisden et al. [16]; Sollins et al. [17]; Rasool et al. [18]; Rasool and Kukal [19]; Chhina et al. [15].

3.4 Infiltration Rate

Soil erosion conservation techniques significantly decreased the infiltration rate. The mean value of infiltration rate was highest in cover crop and lowest in overgrazing prevention. The infiltration rate as a function of elapsed time followed the trend in different erosion conservation techniques as: cover crop > Agrostological measures > Terrace farming > contour plowing > perimeter runoff control > overgrazing prevention (Table 2). "The highest infiltration rate under cover crop and other resource conservation techniques was due to the addition of organic matter, which in turn increased the total pore space of the soil. It might also be due to the loosening of the surface soil due to the lateral spread of the roots. In addition to this, infiltration rate is also affected to a great extent by the texture of the soil. Coarser texture resulted in higher infiltration rate", Hadda et al. [20]; Hadda et al. [21]; Chandel and Hadda [22]. Cover crops neutralizes the destructing power of rain drops and suppress surface compaction, hence resulted into lesser runoff and more infiltration. Similar values were observed by McCormack et al. [23]; Singh and Khera [24]; Mandal and Sharda [25].

3.5 Impact of Resource Conservation Techniques on Chemical Attributes of Soil

3.5.1 Soil pH

The soil pH in clay loam soil varies between 6.64 and 7.73, depending on the resource conservation techniques employed. Interestingly, the pH values were found to be at their lowest in areas where overgrazing was prevented, while cover crops yielded the highest pH values (Table 3). No significant difference in soil pH was noted between terrace farming and contour plowing methods. It's worth noting that the lower average pH in overgrazing prevention could be attributed to the high level of soil erosion, leading to the loss of important basic nutrients, lower base saturation percentage, and reduced soil organic matter content. Several studies by reputable researchers have confirmed that organic carbon has a positive and significant correlation with soil pH, including Habtamu et al. [26], Million [27], Haweni [28], Worku [29], and Solomon et al. [30].

Table 3. Resource conservation techniques impact on soil chemical properties in clay loam soil

RCT	pH (Mean ± S.E)	EC(dSm^{-1}) (Mean ± S.E)	OC ($g\ kg^{-1}$) (Mean ± S.E)	Available N ($Kg\ ha^{-1}$) (Mean ± S.E)	Available P ($Kg\ ha^{-1}$) (Mean ± S.E)	Available K ($Kg\ ha^{-1}$) (Mean ± S.E)
CC	7.73 ± 0.12[a]	0.44 ± 0.21[bc]	8.25 ± 0.66[a]	440.10 ± 74.42[a]	30.29 ± 4.79[a]	309.70 ± 46.60[a]
AM	7.44 ± 0.07[b]	0.52 ± 0.19[b]	7.02 ± 0.41[b]	271.25 ± 31.47[c]	26.94 ± 3.75[b]	273.08 ± 33.20[b]
TF	7.18 ± 0.12[c]	0.35 ± 0.17[cd]	6.03 ± 0.43[c]	310.87 ± 46.01[b]	16.12 ± 1.95[c]	225.50 ± 39.46[c]
CP	7.18 ± 0.11[c]	0.41 ± 0.19[cd]	3.70 ± 0.97[d]	235.66 ± 26.44[d]	13.43 ± 1.97[d]	160.35 ± 18.79[d]
PRC	6.84 ± 0.98[d]	0.33 ± 0.13[d]	3.78 ± 0.76[d]	223.63 ± 17.20[d]	14.26 ± 1.82[d]	148.85 ± 20.59[d]
OGP	6.64 ± 0.19[e]	1.33 ± 0.27[a]	2.37 ± 0.55[e]	163.67 ± 32.54[e]	11.41 ± 1.76[e]	126.33 ± 15.49[e]

Note: Means with the same letter are not significantly different

RCT (Resource conservation techniques), CC (Cover crop), AM (Agrostological measures), TF (Terrace farming), CP (Contour plowing), PRC (Perimeter runoff control), OGP (Overgrazing prevention

3.5.1 Soil EC

As the statistical result indicated, EC of the soils (clay loam) did not significantly decreased by resource conservation techniques. Relatively high (1.33 dSm^{-1}) and low mean value of EC (0.33 dSm^{-1}) was recorded in overgrazing prevention and perimeter runoff control respectively. The high electrical conductivity value in overgrazing prevention compared to other resource conservation techniques could be due to the upward movement of the soluble salts to the surface, through capillary rise of water under prevailing hyperthermic temperature regime in submontane Shivaliks soil, Sondhi [31] and Nazir [32]. The results are in conformity with the findings of various workers viz. Burle and Mielniczuk [33]; Verhulst et al. [34]; Verhulst et al. [35]; Singh (2010); Baishya and Sharma [36].

3.7 Soil Organic Carbon

According to Table 3, the mean value of soil organic carbon (OC) varied significantly among different resource conservation techniques, ranging from 8.25 g kg-1 to 2.37 g kg-1. The highest mean value was observed in the cover crop technique, while the lowest was recorded in overgrazing prevention. The presence of root biomass and leaf litter in cover crop might have contributed to the high soil organic carbon content, particularly in the subsurface layer. On the other hand, the poor growth, high runoff, and soil erosion in overgrazing prevention could have led to the lowest soil organic carbon content, as suggested by Hassink [37] and Sollins et al. [38]. The results showed that cover crop had the highest soil organic carbon content compared to other resource conservation techniques, which is consistent with the findings of Nagaraja et al. [39] and Kumar et al. [40]. This could be attributed to the higher amount of litter production and return under this technique. Several other studies have also reported similar results, including Bhat et al. [41], Feyissa et al. [42], Du et al. [43], and Araujo et al. [44].

Despite the lower value of soil organic carbon at the initial stage, its content was observed higher in cover crop as compared to other resource conservation techniques which is in agreement with other studies, Alvarez et al. [45]; Halvorson et al. [46]; Alvarez and Steinbach [47]. The introduction of cover crops in rotation generally significantly increases soil organic matter as reported by Smith et al. [48]; Drinkwater et al. [49]; Lal [50]. The results in our studies confirm the importance of introducing cover crops in crop rotation for maintaining or increasing soil organic carbon in loamy texture even under submontane condition. The study is in confirmative with the work of Drinkwater et al. [49] and So et al. [51], that legume cover crop in a crop rotation may easily conserve or increase soil organic matter which in turn increases the soil organic carbon.

3.8 Available Nitrogen

Statistically, significant difference was observed in available nitrogen under different resource conservation techniques except contour plowing and perimeter runoff control. The mean value of available nitrogen was highest in cover crop (i.e. 440.10 kg ha^{-1}) and lowest in overgrazing prevention (i.e. 163.67 kg ha^{-1}).

This increase can be attributed due to the addition of root and leaf biomass in varying degree under resource conservation techniques but comparatively more addition was observed in cover crop which indirectly through the process of mineralization increases the availability of available nitrogen, Drinkwater et al. [49]; Sainju et al. [52]; Alvarez and Steinbach [47]. Our results and studies by several other researchers shows that soil organic carbon content and available nitrogen are positively correlated with each other. Beside this cover crops (Black gram etc.) also has role in biological nitrogen fixation, thus increases the pool of easily mineralized organic N as revealed by Murrell [53] through its roots and root exudates.

3.9 Available Phosphorous

Available P among different resource conservation techniques in clay loam was highly variable. It varied from 11.41 to 30.29 kg ha^{-1} (Table 3). The mean value of available phosphorous was found highest in cover crop and lowest in overgrazing prevention. From the studies it was Recorded that availability of phosphorous has been significantly affected by resource conservation techniques, it might be due to changes in soil pH, restoration of soil organic carbon and maintenance of externally added P by reducing soil erosion and runoff.

Accumulation of organic matter through cover crop enhances the availability of phosphorous as 30 – 35% of phosphorous comes from the organic pool of the soil, this has been documented by Arya [54]; Cao et al. [55]; Arya et al. [56]. Furthermore**,** addition of organic matter through incorporation of cover crop in crop rotation or recycling of crop residues in soil, influence the reaction of phosphate and its availability to plants. With the addition of organic matter the process of mineralization of phosphorous is enhanced and value of bonding energy (K) L Kg^{-1} decreased, Arya [54]. By adding organic matter through various means, such as cover crops, root biomass, or composite varieties, the soil solution's inorganic phosphorous increases significantly through mineralization of organic phosphorous and solubilization of native phosphorous compounds. This phenomenon has been observed by Vig and Chand [57], Hiradate and Uchidia [58], and Guppy et al. [59].

3.10 Available Potassium

Resource conservation techniques can have a significant impact on the concentration of available potassium in clay loam soil. According to research, cover crops resulted in the highest concentration of available potassium, reaching an impressive 309.70 kg ha^{-1}. On the other hand, overgrazing prevention yielded the lowest concentration of available potassium, with only 126.33 kg ha^{-1}. The reason behind this discrepancy may be attributed to the minimal erosion impact of cover crops, as stated in a study by Kyaruzi [60] which effectively control runoff and improve potassium content. Additionally, cover crops possess higher root biomass and litter fall, which indirectly enhance the availability of potassium through mineralization. Experts in the field such as Drinkwater et al. [49], Sainju et al. [52], and Alvarez and Steinbach [47] have conducted studies that support these findings. So, adopting resource conservation techniques like cover crops could help improve soil fertility [61-68].

4. CONCLUSION

From the study therefore, it can be concluded that resource conservation techniques should be adopted in submontane *Shivaliks*. As these practices not only decreased the rate of runoff and sediment yield load but are also effective in maintaining the nutrient status and various physical and chemical properties of soil. Among the various resource conservation techniques at the adopted site (*viz.* cover crop, agrostological measures, terrace farming, contour plowing, perimeter runoff control and over grazing prevention), As soil erosion in major challenge in submontane *Shivaliks* the resource conservation modules offerd a good scope for conserving the soil. Resource Conservation technologies also reduced sediment yield there by reducing the nutrient loss from soil. Amomg all the RCTs cover crop was most efficient in trapping detached sediments and reducing velocity and volume of overland flow. The carbon content also increased with the use of resource conservation techniques which is very good indicator as carbon act as bridge between nutrient, water and soil. Resource conservation techniques exerts the least of soil disturbance and adds root biomass along with litter fall contributes to more soil aggregation, accumulation of nutrients and soil organic carbon, better physical condition of the soil along with good soil quality. The soils of submontane *Shivaliks* are under tremendous stress because of high soil erosivity and poor soil management practices. The study strongly recommends adoption of resource conservation techniques for reducing soil erosion & water conservation in submontane *Shivaliks*.

ACKNOWLEDGEMENT

Authors are thankful to DST-GOI for externally funding the research work.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Keno K, Suryabhagavan KV. Multi-temporal remote sensing of landscape dynamics and pattern change in Dire district, Southern Ethiopia. J Earth Sci Clim Change. 2014;5(9):226.
2. Rasool SN, Gaikwad SW, Saptarshi PG. Soil erosion assessment in Sallar Wullarhama watershed in the Lidder catchment of Jammu and Kashmir using, USLE, GIS and remote sensing. Int J Adv Eng Res Stud. 2014;3(2):46–l54.
3. Gemechu A. Estimation of soil loss using revised universal soil loss equation and determinants of soil loss in Tiro Afeta and Dedo districts of Jimma zone, Oromiya National Regional State, Ethiopia. Trends Agric Econ. 2016;9(1):1-12.
4. Sharma V, Mir SH, Arora S. Assessment of fertility status of erosion prone soils of Jammu Shiwaliks. J Soil Water Conserv. 2009;8(1):37-41.

5. Blanco R, Lal R. Principles of soil conservation and management. New York: Springer; 2008.
6. Franzluebbers AJ, Stuedemann JA. Soil carbon and nitrogen pools in response to tall fescue endophyte infection, fertilization, and cultivar. Soil Sci Soc Am J. 2005;69(2):396-403. doi: 10.2136/sssaj2005.0396a.
7. Aumtong S, Magid J, Bruun S, de Neergaard A. Relating soil carbon fractions to landuse in sloping uplands in northern Thailand. Agric Ecosyst Environ. 2009;131(3-4):229-39.
8. Barreto PAB, Gama-Rodrigues EF, Gama-Rodrigues AC, Fontes AG, Polidoro JC, Moco MKS, et al. Distribution of oxidizable organic C fractions in soils under cacao agroforestry system in Southern Báhia, Brazil. Agrofor Syst. 2010;81(3):213-20.
9. Singh H, Pathak P, Kumar M, Raghubanshi SA. Carbon sequestration potential of Indo-Gangetic agroecosystem soils. Trop Ecol. 2011;52(2):223-8.
10. Sharma AK, Thakur NP, Kour M, Sharma P. Effect of integrated nutrient management on productivity, energy use efficiency and economics of rice- wheat system. J Farming Syst Res Dev. 2007;13(2):209-13.
11. Walia MK, Walia SS, Dhaliwal SS. Long term effect of Integrated Nutrient Management of properties of Typic Ustochrept after 23 cycles of an irrigated rice- wheat system. J Sustain Agric. 2010;34(7):724-43.
12. Selvi D, Santhy P, Dhakshinamoorthy M. Effect of inorganics alone and in combination with farm yard manure on physical properties and productivity of Vertic Haplustepts under long term fertilization. J Indian Soc Soil Sci. 2005;53(3):302-7.
13. Khursheed S, Arora S, Ali T. Effect of different organic sources on biochemical properties in Typical inceptisols of Jammu. Prog Agric. 2012;12(2):348-53.
14. Yaduvanshi NPS, Sharma DR, Swarup A. Impact of integrated nutrient management on soil properties and yield of rice and wheat in a long term experiment on a reclaimed sodic soil. J Indian Soc Soil Sci. 2013;61(3):188-94.
15. Chhina LK, Gupta RK, Kukal SS. Soil structural attributes in relation to land use in Shiwaliks region of northwest India. J Soil Water Conserv. 2019;18(1):22-6.
16. Baisden WT, Amundson R, Cook AC, Brenner DL. Turnover and storage of C and N in five density fractions from California annual grassland surface soils. Global Biogeochem Cycles. 2002;16(4):64-1.
17. Sollins P, Swanston C, Kleber M, Filley T, Kramer M, Crow S, et al. Organic C and N stabilization in a forest soil: evidence from sequential density fractionation. Soil Biol Biochem. 2006;38(11):3313-24.
18. Rasool R, Kukal SS, Hira GS. Soil organic carbon and physical properties as affected by long term application of FYM and inorganic fertilizers in maize- wheat system. Soil Till Res. 2008;101(1-2):31-6.
19. Rasool R, Kukal SS, Hira GS. Root growth and soil water dynamics in relation to inorganic and organic fertilization in maize – wheat. Commun Soil Sci Plant Anal. 2010;41(20):2478-90.
20. Hadda MS, Sandhu BS, Singh T. A runoff model for micro- watershed in north-western tract of India. J Punjab Acad Sci. 2002;1:1-8.
21. Hadda MS, Chandel S, Singh S. Assessment of soil loss tolerance through statistical and fuzzy techniques in submontane Punjab. J Soil Water Conserv. 2017;16(2):133-41.
22. Chandel S, Hadda MS. Soil loss tolerance assessment under different land uses in submontane Punjab. J Soil Water Conserv. 2018;17(4):303-10.
23. McCormack DE, Yang KK, Kimberlin LW. Determinants of soil loss tolerance. Agronomy Society of America, Special Publication No. 45. WI: Madison Book Company; 1982.
24. Singh MJ, Khera KL. Soil erodibility indices under different land uses in lower Shiwaliks. J Trop Ecol. 2008;49:113-9.
25. Mandal D, Sharda VN. Assessment of permissible soil loss in India employing a quantitative bio- physical model. Curr Sci. 2011;100:383-90.
26. Habtamu K, Husien O, Haimanote B, Tegeun E. The effect of land use on plant nutrient availability and carbon sequestration. In: Proceedings of the of the 10th conference on ”Natural Resource Management” March 25-27. Addis Ababa: Ethiopian Society of Soil Science. 2009;208-19.
27. Million A. Characterization of indigenous stone bunding (Kab) and its effect on crop yield and soil productivity at Mesobit-

Gedba, North Showa Zone of Amhara Region [Master of Science thesis]. Ethiopia: Alemaya University. 2003;45-54.

28. Haweni H. Effect of soil and water conservation on selected soil characteristics in Dimma Watershed, Central Ethiopia [M.Sc. thesis]. Ethiopia: Addis Ababa University. 2015;99.
29. Worku H. Impact of physical soil and water conservation structure on selected soil physicochemical properties in Gondar Zuriya Woreda. Resour Environ. 2017;7(2):40-8.
30. Hishe S, Lyimo J, Bewket W. Soil and water conservation effect on soil properties in the Middle Silluh Valley, northern Ethiopia. Int Soil Water Conserv Res. 2017;5(3):231-40.
31. Sondhi AK. Soil resources inventory of Nara Dada Manshi watershed area of Hoshiarpur district [M.Sc. thesis]. Ludhiana, Punjab: Punjab agricultural University; 1992.
32. Nazir GR. Characterization and management of salt affected soils of Jammu district [M.Sc. thesis]. Jammu, India: Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu; 1993.
33. Burle ML, Mielniczuk J, Focchi S. Effect of cropping systems on soil chemical characteristics, with emphasis on soil acidification. Plant Soil. 1997;190(2): 309-16.
34. Verhulst N, Govaerts B, Verachtert E, Mezzalama M, Wall PC, Chocobar A, et al. Conservation agriculture, improving soil quality for sustainable production systems. In: Lal R, Stewart BA, editors. Boca Raton, FL. 2010a;137-208.
35. Verhulst N, Kienle F, Sayre KD, Deckers J, Raes D, Limon-Ortega A et al. Soil quality as affected by tillage residue management in a wheat- maize irrigated bed planting system. Plant Soil. 2010b;340:453-66.
36. Baishya J, Sharma S. Analysis of physico-chemical properties of soil under different land use system with special reference to agro ecosystem in Dimoria Development Block of Assam, India. International Journal of Scientific. research education. 2017;5(6):6526-32.
37. Hassink J. Density fraction of soil macroorganic matter and microbial biomass as prediction of C and N mineralization. Soil Biol Biochem. 1995;27(8):1099-108.
38. Sollins P, Homann P, Caldwell BA. Stabilization and destabilization of soil organic matter: mechanisms and controls. Geoderma. 1996;74(1-2):65-105.
39. Nagaraja MS, Bhardwaj AK, Reddy GVP, Parama VRR, Kaphaliya B. Soil carbon stocks in natural and man made agri-horti-silvipastural land use systems in dry zones of Southern India. J Soil Water Conserv. 2016;15(3):258-64.
40. Kumar V, Sharma KR, Arya VM, Sharma V. Land use effects on structural stability and soil organic carbon in the submontane areas of north- western Himalayas, India. J Soil Water Conserv. 2018;17(2):117-22.
41. Bhat JA, Kumar M, Negi AK, Pala NA, Todaria NP. Soil organic carbon stock and sink potential in high mountain temperate Himalayan forests of India. Int J Curr Res. 2012;4(12):206-9.
42. Feyissa A, Soromessa T, Argaw M. Forest carbon stocks and variations along altitudinal gradients in Egdu forest: implications of managing forests for climate change mitigation. Sci Technol Arts Res J. 2013;2(4):40-6.
43. Du B, Kang H, Pumpanen J, Zhu P, Yin S, Zou Q, et al. Soil organic carbon stock and chemical composition along an altitude gradient in the Lushan Mountain, subtropical China. Ecol Res. 2014;29(3): 433-9.
44. Araujo MA, Zinn YL, Lal R. Soil parent material, texture and oxide contents have little effects on soil organic carbon retention in tropical highlands. Geoderma. 2017;300:1-10.
45. Alvarez R, Diaz RA, Barbero N, Santanatoglia OJ, Blotta L. Soil organic carbon microbial biomass and CO_2-C production from three tillage systems. Soil Till Res. 1995;33(1):17-28.
46. Halvorson AD, Wienhold BJ, Black AL. Tillage, nitrogen, cropping system effects on soil carbon sequestration. Soil Sci Soc Am J. 2002;66(3):906-12.
47. Alvarez R, Steinbach HS. A Review of the effects of tillage systems on some soil physical properties, water content, nitrate availability and crops yield in the Argentine Pampas. Soil Till Res. 2009;104(1):1-15.
48. Smith P, Powlson DS, Glendining MJ, Smith JU. Potential for carbon sequestration in European soils: preliminary estimates for five scenarios using results from long term experiments. Glob Change Biol. 1997;3(1):67-79.

49. Drinkwater LE, Wagoner P, Sarrantonio M. Legume based cropping systems have reduced carbon and nitrogen losses. Nature. 1998;396(6708):262-5.
50. Lal R. Soil carbon sequestration to mitigate climate change. Geoderma. 2004;123(1-2):1-22.
51. So HB, Dalal RC, Chan KY, Menzies NM, Freebairn DM. Potential of conservation tillage to reduce carbon dioxide emission in Australian soils. In: Mohtar DE, Steinhardt GC, editors. Sustaining the global farm. Selected papers from the 10th International Soil Conservation Organization Meeting. 2001;821-6.
52. Sainju UM, Senwo ZN, Nyakatawa EZ, Tazisong IA, Reddy KC. Soil carbon and nitrogen sequestration as effected by long term tillage, cropping systems, and nitrogen fertilizer sources. Agric Ecosyst Environ. 2008;127(3-4):234-40.
53. Murrell TS. The science behind the nitrogen credit for soybeans, International Plant Nutrition Institute. GA: Peachtree Corners; 2011. Available:http://www.ipni.net
54. Arya VM. Effect of added phosphorous, organic matter and moisture regimes on phosphorous adsorption in soils of various agroclimatic zones of Jammu region [Ph.D. thesis]. Sher- e- Kashmir University of Agricultural Science and technology. Jammu. 2007;1-16.
55. Cao C, Jiang S, Ying Z, Zhang F, Han X. Spatial variability of soil nutrients and microbiological properties after the establishment of leguminous shrub Caragana microphylla Lam. plantation on sand dune in the horqin sandy land of northeast China. Ecol Eng. 2011;37(10):1467-75.
56. Arya VM, Sharma V, Vaid A, Sharma A, Bharat R, Sharma R, et al. Phosphorous adsorption and desorption in agroclimatically disparate soils representing foothills of northwest Himalayas. Indian J Ecol. 2016;1:58-64.
57. Vig AC, Chand M. Transformation of labile P in two alkaline soils amended with Sesbania at two moisture levels. Trop Agric. 1993;70:1-4.
58. Hiradate S, Uchida N. Effect of soil organic matter on pH dependent phosphate sorption by soils. Plant Nutr. 2004;50(5):665-75.
59. Guppy CN, Menziez NW, Moody PW, Blamey FPC. Competition sorption reactions between phosphorous and organic matter in soil. Aust J Soil Res. 2005;43:189-202.
60. Kyaruzi L. Relationship between soil and landform derived land qualities and conservation agriculture practices in West Usambara Mountains, Tanzania [M.Sc. thesis]. Tanzania: Sokoine University of Agriculture. 2013;140.
61. Black CA. Methods of soil analysis. Part 1, Physical and mineralogical properties. Madison, WI: American Society of Agronomy; 1965.
62. Bouyoucos GJ. Hydrometer method improved for making particle size analysis of soils. Agron J. 1962;54(5):464-5.
63. Decagon. Minidisk Infiltometer User's manual. Pullman: Decagon Devices, Inc; 2005.
64. Jackson ML. Soil chemical analysis, prentice hall of india private limited. New Delhi; 1973. p. 38-56.
65. Olsen SR, Cole CV, Watanabe FS, Dean LA. Estimation of available phosphorous by extraction with sodium bicarbonate. United States Department of Agriculture. 1954;939.
66. Piper CS. Soil and Plant analysis. Bombay: Hans Publisher; 1966.
67. Subbiah BV, Asija GL. A rapid procedure for the estimation of available nitrogen in soil. Curr Sci. 1956;25:259-60.
68. Walkley A, Black IA. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Sci. 1934;37(1):29-38.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/102817