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RESEARCH ARTICLE

Soil conservation measures improve vegetation development and ecological processes in the Himalayan slopes

J. M. S. Tomar[1] · Raj Kumar[2] · Rajesh Kaushal[1] · S. K. Kar[1] · H. Mehta[1] · O. P. Chaturvedi[1]

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Abstract
High soil erosion in the Himalayan region adversely affects the growth and development of vegetation, which ultimately increases the slope instability and makes the area prone to landslides. Restoration of native vegetation through adopting soil and water conservation measures (SWCM) is extremely important to prevent soil erosion and improve sustainability of Himalayan landscapes. SWCM are mainly practiced for controlling soil erosion, but their effectiveness in restoration of native vegetation is lesser known, particularly in the Himalayas. Therefore, we assessed the impact of coir geotextiles, wattling and trenching based soil conservation measures on richness, diversity, density, and biomass of plant species in a eroded steep slope of North-West Indian Himalaya. Our findings showed that both the number of species and Shannon diversity index was observed maximum in coir geotextiles (20 and 4.6, respectively), followed by wattling (11 and 3.0, respectively), trenching (10 and 2.4, respectively), and minimum in control (7 and 1.8, respectively) treatment. Likewise, density of plant species was observed higher in coir geotextiles (77.0 nos. m^{-2}) followed by wattling (53.0 nos. m^{-2}), trenching (36.0 nos. m^{-2}), and lower in control (30.0 nos. m^{-2}). Results further showed that the designing coir geotextiles, wattling and trenches enhanced the species total biomass (dry) productions by 117 g m^{-2}, 65.0 g m^{-2} and 48 g m^{-2}, respectively, over the control. The soil moisture was recorded greater in coir geotextiles (4.9%) treatment compared to wattling (4.3%), trenching (2.3%) and control (1.8%). The soil organic carbon was assessed higher in coir geotextiles (0.76%) followed by trenching (0.38%), wattling (0.27%) and minimum in control (0.18%). Overall, results indicated that coir geotextiles followed by wattling and trenching were highly effective in improving the vegetation recovery, species diversity and biomass in the Himalayan slopes. Therefore, the present study demonstrated some important aspects of vegetation recovery processes following soil conservation measures, and it can be useful in planning rehabilitation measures on the eroded and steep Himalayan slopes.

Keywords Erosion control · Landslide · Soil conservation · Vegetation restoration

Introduction

In mountain regions, accelerated soil erosion is a common and environmentally destructive consequence of development (Harden 2001). Himalaya is one such peculiar landform and is always vulnerable to soil erosion as a consequence of steep slopes, high runoff, intensive agriculture, improper road construction, and other unplanned development activities which ultimately leads to the frequent occurrence of erosion induced landslides (Negi 2002). Soil erosion in long-term affects the soil formation processes and their functions, which subsequently alter the vegetation succession and diversity; and hence influences the various growth and development processes of plant species (Kumar et al. 2020). Thus, erosion affects the functions and productivity of Himalayan ecosystems, causing the negative effects on regional ecology and existence of human civilization (Dobhal et al. 2020). However, soil and water conservation measures (SWCM) demonstrate a strong potential to improve and sustain biological productivity of such lands through stabilization of the erosion-prone steep slopes.

To protect and stabilize the Himalayan steep slopes, various soil and water conservation measures, for example, tree

✉ J. M. S. Tomar
jmstomar@gmail.com

✉ Raj Kumar
rajcswcrti@gmail.com

[1] ICAR-Indian Institute of Soil and Water Conservation, Dehradun 248195, Uttarakhand, India

[2] ICAR-Central Soil Salinity Research Institute, Karnal 132001, Haryana, India

plantation, check dams, contour farming, trenching, retaining walls, crib structure, geotextiles, and gabion structure etc. have been found highly effective in controlling the soil erosion (Sharma et al. 2001; Mehta et al. 2018). These conservation measures positively influence and regulate vegetation growth and development at the eroded slopes. Although improvements in the plant growth, biomass and species diversity under various conservation measures have been extensively documented across the different regions (Ale metal 2020; Ovalle et al. 2020; Kumar et al. 2021), except in the Himalaya. However, the different soil conservation measures create contrasting soil conditions (Dagnachew et al. 2020; Alemayehu et al. 2020); resulting in notable difference in the plant species development and ecological processes (Adhikary et al. 2017), but their relative effectiveness and comparison are little known. Types and number of plant species and their relative dominance at a particular site depend on the environmental conditions developed as a result of the implemented conservation measure (Rodrigues et al. 2018). Soil properties and productivity are the most important factors influenced by the different management practices (Ebabu et al. 2020), and the soil functions are reported to drastically change under the influence of soil conservation measures (Dagnachew et al. 2020). Moreover, in some regions, soil conservation measures have been observed to create better soil environment that positively contribute to improvement in plant growth and development and restoration of regional ecology.

Huge meta-data analyses are available on the mechanisms and benefits of soil conservation measures in terms of enhancing plant growth, controlling soil erosion and improving soil properties at the degraded sites (Mehta et al. 2018; Singh et al. 2020; Kaushal et al. 2021; Tomar et al. 2016, 2021), but in contrast, their effectiveness on natural vegetation development, biomass productions and species diversity are completely lacking in the Himalayan region. Although the effects of soil conservation on the productivity of agronomic crops have been well-documented (Saha et al. 2005), but their effect on natural vegetation development and ecological recovery processes is unknown in the Himalayas and elsewhere. Specifically, the comparative study on the efficiency of various soil and water conservation practices-geotextile compared to wattling and trenches- are completely lacking in the Himalayan region. Therefore, identifying the type of conservation measures that significantly contributes to achieving the greater environmental and ecological benefits in the eroded Himalayan slopes needs to be prioritized. Quantification of plant growth and ecological parameters under different conditions is required to plan and design the site specific soil conservation measures. The resolution of these questions will provide important information about the vegetation recovery processes under different conditions that will be helpful in the ecological restoration planning for large-scale implementation.

Soil and water conservation measures have demonstrated strong potential to rehabilitate the degraded and erosion-prone sites. Therefore, we investigated the impact of geotextile compared to wattling and trench on the development and recovery process of native vegetation at the highly eroded sites. We hypothesized that soil conservation measures reduce soil erosion and improve soil properties that would improve the growth, biomass, and diversity of plant species. The objectives of the present study were to assess the impact of soil conservation measures on (i) species density, richness, diversity, and biomass; and (ii) change in soil properties under different conservation measures.

Material and methods

Study area

The study was initiated during 2014–2015 at Udpalta village located in the mid-Himalayan region (30° 62′ N; and 77° 89′ E; 1571 m amsl) of the Uttarakhand state, India (Fig. 1). The study site is characterized by a mountainous terrain having an undulating topography and steep slopes (> 50%). The site considered for study was severely degraded because of continuous landslides caused by heavy rains and cloud bursts during the monsoon season. The selected site was considered as the representative of most Himalayan landscapes in terms of the slope, altitude and aspect. The climate of the region varies from sub-tropical to sub-temperate with 1600 mm annual average rainfall, most of which is received during the monsoon period (June–Sept) and occasional snowfall during winter (Dec-Jan). The vegetation mostly consists of scattered shrubs and annuals. The soil type belongs to the alluvial, entisol and inceptisols taxonomic group and gravelly sandy loam to silty clay loam texture class. Soils are slightly acidic in nature with low available nitrogen and medium to high in phosphorus and potassium.

Experimental design and treatment description

The present study was conducted to assess the potential of soil conservation measures (SWCM) on the restoration of erosion-prone slopes. The SWCM were executed during 2014–2015, and the data on vegetation and soil were recorded during August–September, 2019 and April–May, 2020. The three SWCM—coir geotextile, wattling and staggered contour trenches (SCT)—were implemented on erosion-prone sites consisting of slope varying from 30 to 50% with the aim to observe their effectiveness in restoring the Himalayan slopes. One control was also designed to observe the impact of SWCM on natural vegetation development and

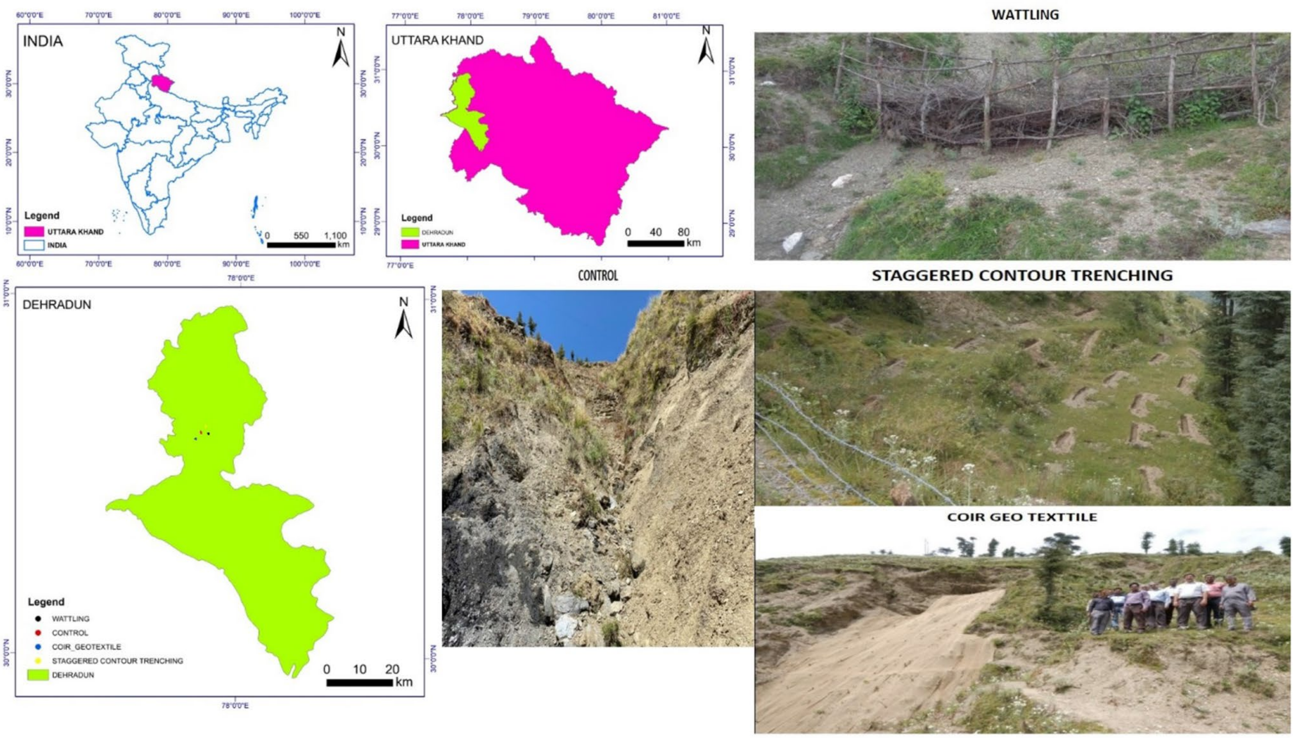

Fig. 1 Location map of the experimental site

rehabilitation of landslide sites. Each treatment was executed on a plot size of about 0.25 ha. The different soil conservation measures were designed to observe their impact on species richness, diversity, density biomass, and soil properties. Therefore, for the present study, three-soil conservation measures—Coir geotextile, wattling, staggered contour trenches, and control—were considered.

Coir geotextile

Geo-jute was considered for conservation purposes because it increases water absorption, improves water holding and water storage capacity of soils (Shao et al. 2014). Moreover, it controls the detachment of soil particles, intercepts splashed particles, improves soil contact, and reduces the leaching of soil nutrients (Mayer and Wischmeier 1969; Rickson 1988). Based on these considerations, a 400 m^2 coir geotextile with 700 GSM (grams per square meter) density was laid down to hold the runoff and to prevent the soil erosion at the site. A diversion drain was constructed at top of the site to drain excess runoff, as in the fragile hilly slopes runoff is the major cause of soil erosion.

Wattling

Wattling or filter strips are effective bioengineering measures to reduce the velocity of flowing water by breaking the long and steep slope into short segments to dissipate its energy. The stakes were placed on the contour at 0.5 m apart and at 1.2 m intervals between the rows. A trench of 20 cm (wide) × 25 cm (deep) was excavated above the contour stakes. Bundles (13 cm in diameter and 3 m long) of locally available live vegetative materials (*Salix* spp., *Vitex* spp., etc.) were prepared and placed in an overlapping manner inside the trench and some portion was covered with soil while the rest portion was retained above the ground.

Trenches

The staggered contour trenches are small depressions of varying sizes commonly created for conserving the soil and water and promoting the plant growth. These are series of small pits dug in soil on contours at a regular interval in a staggered fashion. Trenches help in the reduction of runoff and soil loss that contributes to the improvement of in-situ soil moisture regime and soil properties for facilitating the native vegetation establishment (Panigrahi et al. 2009; Ali et al. 2010; Madhu et al. 2011). In this study, trenches were excavated in the study site for in situ moisture conservation with a dimension of 1.00 × 0.30 m × 0.30 m.

Vegetation measurement and analysis

For studying the vegetation development, 12 quadrates of 1 m × 1 m per treatment were randomly selected to determine vegetation characteristics such as number of individuals of each plant species in the sample plots. Species richness was recorded to determine the increase in the number of species. The density of the species was determined using the procedure elaborated by Curtis and McIntosh (1950) and Tomar et al. (2015) and expressed as no. m^{-2}. Similarity index was expressed as the ratio of common species to all species found in the vegetation and was measured using the procedure described by Simpson (1949). Shannon's index of general diversity was computed using the following formulae (Odum 1971):

$$H = \Sigma(n_i/N)Log(n_i/N) \quad (1)$$

where, H = Shannon's index of diversity, while, n_i and N is the importance value of a species and total importance value, respectively. The fresh shoot samples of each species were cut and brought to the laboratory and oven-dried at 60 °C to determine dry biomass for computing the above-ground shoot biomass and expressed as g m^{-2}. The below-ground root biomass was determined from the above ground shoot biomass using the factor of 0.26 as per IPCC (2003).

Soil properties

The soil moisture (0–15 cm depth) was determined under each treatment by the gravimetric method. Composite soil samples were collected using a soil auger for determining the soil chemical properties. The collected samples were air-dried and ground to pass through a 2-mm sieve. The Walkley and Black method (Walkey and Black 1934) was followed to determine soil organic carbon (SOC) content. Kjeldahl Method (Subbiah and Asija 1956) was followed to determine total nitrogen (TN). Available P was determined calorimetrically by the Olsen method and extracted K was determined by flame photometry method. Soil pH was measured in soil suspension (1:2.5) using the pH meter.

Statistical analysis

The Tukey's HSD (Honest Significant Difference) was performed in conjunction with one-way Analysis of Variance (ANOVA) with 12 replications in a randomized block design to detect mean differences between various SWCM, including control for the various parameters.

Table 1 Presence and absence of plant species in control and conservation treatments

Species	Control	Wattling	Trench	Coir geotextile
Ageratum conyzoides	−	+	−	+
Anaphalis busua	+	+	−	−
Anaphalis contorta	−	+	+	+
Artemisia indica	−	−	−	+
Atylosia scarabaeoides	−	−	+	+
Bidens pilosa	−	−	+	−
Bothriochloa pertusa	+	−	+	+
Bryophyllum sp	+	−	−	+
Celebrookia oppositifolia	−	−	−	+
Chenopodium album	−	+	−	−
Chrysopogon fulvus	+	−	+	−
Cirsium arvense	−	−	−	+
Compositae family	+	−	−	−
Cynodon dactylon	−	−	+	+
Dichanthium annulatum	−	−	−	+
Eupatorium sp.	+	+	+	+
Leucas mollissima	−	−	−	+
Micromeria biflora	−	−	−	+
Oxalis corniculata	−	+	−	+
Persicaria capitata	−	+	−	+
Plectranthus rugosus	−	−	−	+
Rumex hastatus	+	+	+	+
Saccharum sp.	−	+	+	+
Sida cordifolia	−	+	+	+
Tagetes minuta	−	−	−	+
Vicia sp.	−	+	−	−

+: Present; −: Absent

Results

Species richness

Species presence and their distribution were observed non-uniform in different treatments as well as in control sites. In soil and water conservation measures (SWCM), the number of species were ranged from ten to twenty, while only seven species were recorded in control (Table 1). Specifically, species richness was recorded highest in coir geotextile, followed by wattling and trench, compared to control (Fig. 2). In absolute terms, species richness in coir geotextile, wattling, and trench treatments were recorded higher by 185%, 57%, 42%, respectively, compared to control. Altogether, plant taxa in control and conservation treatments were represented with 25 species belonging to 9 families. Asteraceae and Poaceae were recorded to be the dominant families representing eight and five species, respectively (Table 2). In general, the number of species was observed

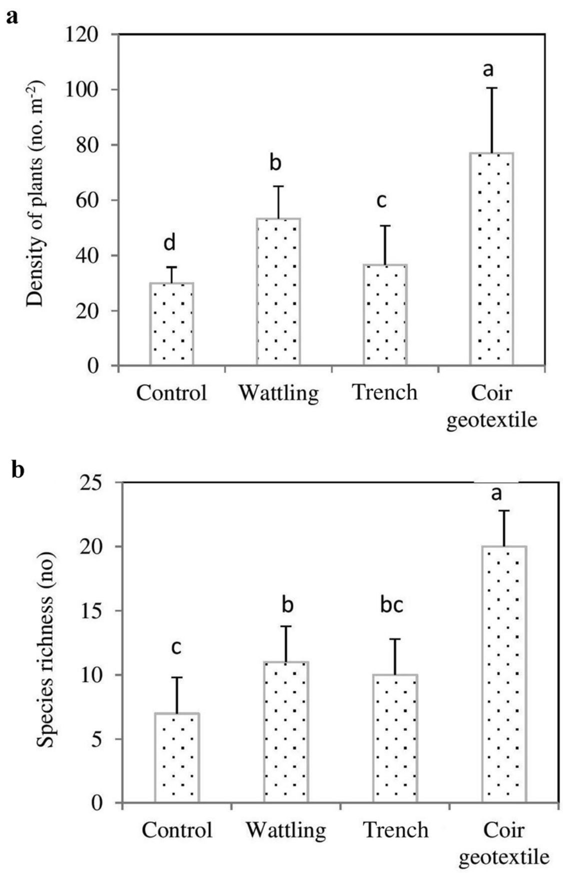

Fig. 2 Effect of Soil conservation measures on density of plants (**a**) and species richness (**b**)

maximum ($P < 0.05$) in coir geotextiles (20), followed by wattling (11), trench (10), and minimum in control (7) treatment. Results further showed that the maximum species similarity was recorded between coir geotextiles and trenches followed by between wattling and trenches, while minimum species similarity was observed between wattling and control (Table 3). The influence of SWC measures was also observed on the diversity of plant species at the experimental site (Fig. 2). Shannon Weaver's Index was observed higher at coir geotextile (4.64) site followed by wattling (2.95), trench (2.35) and its minimum value was observed at control (1.84) site. Therefore, the results demonstrated that the soil conservation measures improved the species richness and diversity in the highly eroded Himalayan slopes.

Vegetation density and biomass

The different plant species were compared for their density under conservation measures and in control, and it was found that *Saccharum* sp. and *Eupatorium sp.* were dominant species in terms of plant density, compared to rest of the species (Table 4). Overall, our results explained that the different conservation measures significantly ($P < 0.05$) affected density of different plant species. The density of plant species was observed higher in coir geotextiles (77.0 no. m^{-2}) followed by wattling (53.0 no. m^{-2}), trench (36.0 no. m^{-2}), and control (30.0 no. m^{-2}), in the decreasing order (Fig. 3). Likewise, the different SWCM significantly ($P < 0.05$) affected species biomass which was observed in the order of coir geotextile > wattling > trench > control (Fig. 3). Both fresh and dry total biomass was observed maximum in coir geotextiles (670 g m^{-2} and 219 g m^{-2}, respectively) and minimum in control (274 g m^{-2} and 102 g m^{-2}, respectively). The present results explained that the application of different soil conservation measures enhanced the species density and biomass at the erosion prone landslide site.

Soil properties

Soil properties of different SWCM and control treatments were analyzed after four years of treatment execution. The different SWCM significantly ($P < 0.05$) affected moisture content in the soils. Higher ($P < 0.05$) soil moisture content was measured under coir geotextile (4.9%) followed by wattling (4.3%) and trench (2.3%), while minimum soil moisture content was recorded under control (1.8%) (Fig. 4). The result further showed that the maximum ($P < 0.05$) organic carbon content was recorded in coir geotextile (0.76%) followed by trench (0.38%), wattling (0.27%), and it was minimum in control (0.18%) (Table 4). Available nitrogen was observed maximum ($P < 0.05$) in coir geotextile (0.0012%) followed by trench SCT (0.006%), wattling (0.004%) and minimum in control (0.003%). Available P was found maximum ($P < 0.05$) in case of Coir geotextile (11.96 kg/ha) followed by wattling (10.7 kg/ha), trench (10.4 kg/ha) and was minimum in control (9.46 kg/ha). Available potassium was found highest ($P < 0.05$) in coir geotextile (24.0 kg/ha), followed by trench (19.9 kg/ha), wattling (19.5 kg/ha) and was minimum in control (19.4 kg/ha). Soil pH is slightly acidic and was ranged from 6.15 in control to 6.41 in coir geotextile. The results demonstrated that SWC measures improved soil properties at the erosion-prone slope.

Discussion

Himalayan regions are subjected to the influence of severe soil erosion, high anthropogenic disturbances, and unplanned construction that affects the vegetation structure and function, and slope stability, leading to the frequent occurrence of landslides**.** Present findings demonstrated the strong potential of soil conservation measures (SWCM) in improving vegetation growth, ecological processes, and soil properties at the study sites. Therefore, we discussed the

Table 2 Effect of soil conservation measures on the species density (no. m^{-2}) (mean ± SD, n = 12)

Species	Control	Wattling	Trenching	Coir geotextile
Ageratum conyzoides	–	1.66 ± 0.3	–	6.75 ± 2.5
Anaphalis busua	2.90 ± 0.6	5.08 ± 2.2	–	–
Anaphalis contorta	–	4.25 ± 1.6	3.42 ± 1.3	5.16 ± 2.2
Artemisia indica	–	–	–	2.00 ± 0.3
Atylosias carabaeoides	–	–	1.75 ± 0.4	1.50 ± 0.5
Bidens pilosa	–	–	3.92 ± 1.5	–
Bothriochloa pertusa	3.00 ± 0.8	–	0.92 ± 0.07	3.17 ± 0.6
Bryophyllum sp.	2.10 ± 0.4	–	–	0.75 ± 0.2
Celebrookia oppositifolia	–	–	–	2.33 ± 0.8
Chenopodium album	–	3.00 ± 0.6	–	–
Chrysopogon fulvus	8.10 ± 0.5	–	2.33 ± 0.6	–
Cirsium arvense	–	–	–	4.25 ± 1.8
Compositae family	2.75 ± 0.6	–	–	–
Cynodon dactylon	–	–	2.58 ± 0.4	2.33 ± 0.6
Dichanthium annulatum	–	–	–	1.17 ± 0.2
Eupatorium sp.	6.20 ± 1.8	4.41 ± 1.5	6.58 ± 2.5	10.83 ± 3.6
Leucas mollissima	–	–	–	5.08 ± 1.8
Micromeria biflora	–	–	–	4.08 ± 1.2
Oxalis corniculata	–	1.50 ± 0.4	–	1.16 ± 0.4
Persicaria capitata	–	4.92 ± 1.6	–	2.25 ± 0.8
Plectranthus rugosus	–	–	–	2.33 ± 0.7
Rumex hastatus	4.75 ± 1.5	11.70 ± 3.2	8.33 ± 3.2	2.75 ± 0.3
Saccharum sp.	–	6.70 ± 2.8	4.83 ± 1.8	12.00 ± 4.5
Sida cordifolia	–	8.50 ± 2.5	1.92 ± 0.5	3.16 ± 0.12
Tagetes minuta	–	–	–	0.92 ± 0.03
Vicia sp.	–	2.50 ± 0.6	–	–

Value followed by mean is the standard deviation of mean

Table 3 Similarity index for plant species between the different soil conservation measures including control

	Control	Wattling	Coir geotextile	Trench
Control	100.00	-	–	–
Wattling	24.00	100.00	–	–
Coir geotextile	29.63	32.26	100.00	–
Trench	47.06	47.62	53.33	100.00

cause and effect relationships, comparison with similar studies and future consequences of the present outcome**.**

Species richness and diversity

In the Himalayas, a land with a slopy topographical feature promotes continuous soil erosion that adversely affects the land morphology, vegetation development, and the socio-economic conditions of the regional population. Under such conditions, SWCM offers significant potential to protect degraded slopes and generate ample ecological and economic benefits. The present study showed that SWCM had a positive influence on the vegetation growth and development on an extremely fragile Himalayan slope. In particular, an increase in plant species under coir geotextile, wattling, and trench after five years of implementation indicates the better nutrient and moisture conservation and their greater availability to plants. Previous findings have also advocated the role of SWCM in vegetation growth and development in the similar conditions (Mehta et al. 2018; Kumar et al. 2021). The superiority of coir geotextile over other measures for species richness and diversity might have resulted from the creation of better environmental conditions that promoted the greater emergence and growth of species. Indeed, coir geotextile enhances water absorption and storage capacity of the soil (Lou et al. 2013; Lekha 2004) that consequently contribute in improving the species richness and diversity under such conditions. Mehta et al. (2018) also highlighted the improved ecological conditions in terms of

Table 4 Soil properties under different soil conservation including control after four years

Treatment	Organic carbon (%)	Available N (%)	Available P (kg ha^{-1})	Available K (kg ha^{-1})	pH
Control	$0.18^a \pm 0.05$	$0.003^a \pm 0.0001$	$9.49^a \pm 0.8$	$19.4^a \pm 3.3$	$6.15^a \pm 0.4$
Wattling	$0.27^b \pm 0.03$	$0.004^a \pm 0.0015$	$10.7^b \pm 1.1$	$19.5^a \pm 2.2$	$6.25^a \pm 0.3$
Trench	$0.38^c \pm 0.06$	$0.006^b \pm 0.0018$	$10.4^b \pm 1.0$	$19.9^a \pm 7.8$	$6.40^a \pm 0.4$
Coir geotextile	$0.76^d \pm 0.16$	$0.012^c \pm 0.0029$	$11.96^c \pm 1.2$	$24.0^b \pm 4.2$	$6.41^a \pm 0.4$

Letter in the same column indicates significant differences at 5% level of significance ($P < 0.05$). Value followed by mean is the standard error of mean

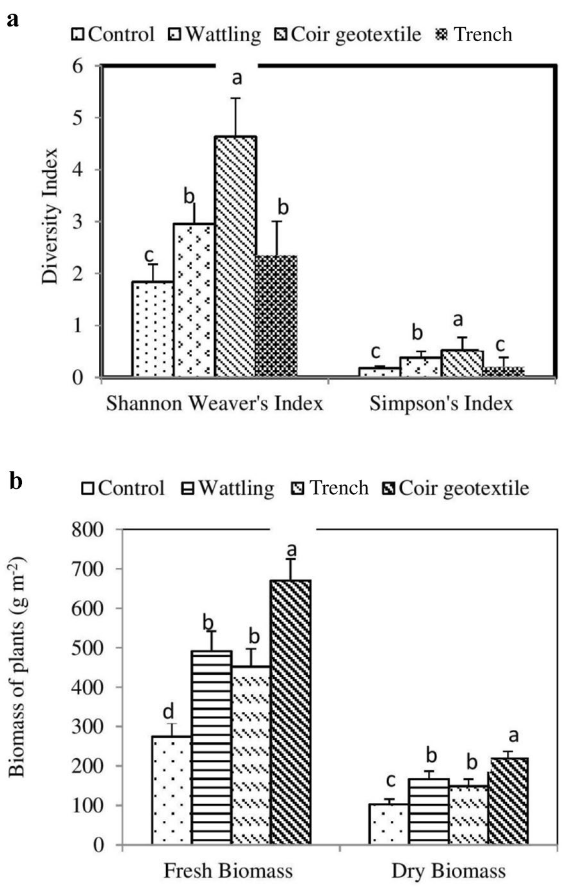

Fig. 3 Effect of soil conservation measures on species diversity (**a**) and biomass production in plants (**b**)

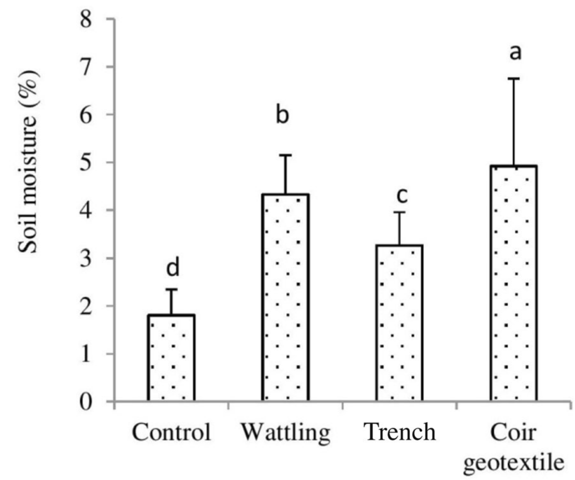

Fig. 4 Effect of soil conservation measures on soil moisture content (%) in the soils

increase in species diversity post implementation of soil and water conservation at a landslide site. In general SWCM increase the species richness and diversity that eventually contributes to biodiversity conservation, ecosystem stabilization and vegetation succession regulation in the Himalaya landscape (Dobhal et al. 2020).

Species density and biomass production

The density and biomass production of plant species is influenced by soil properties and environmental conditions created under the different SWCM. Present findings showed an increase in species density and their biomass productions-because of higher availability of soil moisture and nutrient—under different soil conservation measures. The enhancement of species density and their biomass productions contribute to the improvement in environmental conditions in general and ecological processes in particular. For example, Kumar et al. (2020) also highlighted that controlling soil erosion plays a pivot role in enhancing plants growth and biomass productions; resulting in a positive effect on the regional ecology processes. Among the different SWCMs, the greater effectiveness of coir-geotextiles resulted in the favorable soil moisture conditions and better nutrient availability that promoted the better growth and development of native vegetation. This is also evident from higher values of organic carbon, total N, available P and K under coir-geotextiles, as compared to control and other SWCM (Table 4). Likewise, Mehta et al. (2018) also observed that the improved soil properties in coir geotextiles treatments produces greater plant biomass and carbon stock, compared to control. Moreover, previous researchers have also suggested the role of SWCM in enhancing the plant growth and biomass productions under similar topographic regions (Madhu et al. 2011; Adhikary et al. 2017; Alem et al. 2020). Therefore, the implementation of any measure that can result in a slight favourable effect in terms of soil and nutrient conservation may greatly contribute towards sustaining and restoring the erosion prone Himalayan landscapes.

Soil properties

The significant improvement in soil moisture under conservation measures was perhaps due to the greater water conservation. SWCM obstruct the overland flow, enhance water retention and storage over the surface and thereby contribute to water infiltration in the deeper layers (Adhikary et al. 2017). For example, tree hedges and trench rows are reported to retain and store more water, which plays a significant role in making water available to the adjacent plants during water stress conditions in dry areas (Walter et al. 2003; Alem et al. 2020). Moreover, higher soil moisture under coir geotextiles compared to wattling and trench was resulted from the greater interception, absorption, and storage of water by coir geotextiles that contributed to the increased soil moisture (Lou et al. 2013). Reduction in overland rainwater flow and surface water losses, and increased water infiltration also improve water in the soils (Islam 2013). The improved soil moisture condition creates favourable conditions for the growth of diverse plant species that promotes the natural ecological succession in such sites.

The significant improvement in soil organic matter in wattling, trench, and coir geotextiles based conservation measures may be due to better plant growth and vegetation development; resulting in greater biomass production and subsequently its decomposition over time in the soils. The increase in soil organic carbon (OC) and available soil nutrients (N, P, and K) in conservation measures was probably because of the reduced loss of nutrients and organic carbon during the erosion process. Similarly, previous SWCMs have also observed the increased OC and nutrients in the soils (Abay et al. 2016; Mesfin et al. 2018). Coir geotextiles textiles showed great potential over wattling and trench in terms of nutrient conservation that may significantly contribute in sustaining soil fertility and productivity to restore the native vegetation and regional ecology of Himalaya.

Conclusions

Presently, the Himalayan ecosystem is worst affected by the continuous soil erosion, which negatively affects the regional ecological and land functions in terms of vegetation, soil, topography and local populations settlement**.** The current study demonstrated that soil conservation measures successfully improved species density, which promoted the greater biomass production on the eroded Himalayan slopes. These measures also improved the soil moisture regime and soil properties; resulting in the improved vegetation growth, species richness, and plant diversity in such sites. Therefore, coir geotextiles followed by wattling and trenches can be recommended for restoring ecology, recovering natural vegetation, improving soil properties and controlling soil erosion in the Himalayan slopes.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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