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## Research Article

# Assessment of Regulating Ecosystem Services of Buner watershed

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## ABSTRACT

A watershed is a land area that drains into a river, lake, or ocean. Forests play a crucial role in maintaining watershed health by acting as natural filters, trapping contaminants, stabilizing soil, reducing sedimentation and erosion, and controlling water quality. A research site is the Buner Watershed located in Khyber Pakhtunkhwa, Pakistan, known to have complex, variable, and potentially problematic mountain terrain for water management, sediment deposition, and soil erosion issues. The study aimed to highlight on how soil stabilization, water flow regulation and improved water quality can all be achieved through forest conservation and management. comparable areas with hydrological and environmental issues. Comparatively, comparable areas are those that host similar hydrological and environmental circumstances. This comprehensible assessment has stressed upon the major role that forests have with respect to the sustenance of this Buner Watershed health and functionality. Water quality and erosion control were taken into consideration in the Research study. Two sites, i.e. Vegetative and non-vegetative were selected for sample collection. Physical parameters like temperature, turbidity and TSS were taken for statistical analysis. Data collected were comparatively analyzed using statical tests which shows that the vegetated site generally shows better water quality parameters, which is consistent with the expectations of reduced turbidity, temperature, and sediment in vegetated environments. The non-vegetated site shows higher turbidity, temperature, and TSS, which might indicate issues such as erosion or lack of vegetation management. Both the sites were comparatively analyzed and from the results we would recommend that it is crucial to prioritize the conservation of existing forests to protect against soil erosion by implementing policies that prevent deforestation and degradation, ensuring that forested areas remain intact.

**Keywords:** Watershed Management, Regulating Ecosystem Services, Water Quality, Soil Erosion, Forest Ecosystem Services, Total Suspended Solids (TSS), Sedimentation.

## INTRODUCTION

Watersheds are a hydrological unit of interest for managing water and soil resources through scientifically based technical management alternatives because they are catchment areas from which all water flows into a common point. In order to fully realize the promise of agroecology on a sustainable basis, biodiversity can also be properly maintained at the watershed scale, in addition to water and soil (Wani and Garg, 2009; Costello, 2024). Despite the landscape, every location on Earth is part of a watershed, even deserts. Watersheds can range in size and are often nested within larger ones, ultimately leading to a maximum size when draining into an ocean or sea (Edwards et al., 2015). Land, water and vegetation are essential



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natural resources that provide food, feed, fiber, and fuel necessary for human survival. However, increasing biotic pressure and overexploitation are accelerating the degradation of these resources, leading to reduced productivity. Sustainable management of these resources is crucial for the continued well-being of humanity. Water, a finite and vital resource, is becoming increasingly scarce due to overuse driven by growing population demands. Agriculture, which accounts for 75–80% of global water consumption for food production, will require an additional 2000 km<sup>3</sup> of water by 2025 to meet the needs of the expanding global population if current food production practices continue (Falkenmark, 1986).

Watersheds support various economic activities, including agriculture, forestry, and fisheries. They also contribute to property values by enhancing the quality of life in nearby communities (Narendra et al., 2021). Vegetation within watersheds helps stabilize soils, reducing erosion and the sedimentation of rivers and lakes. This, in turn, helps maintain water quality and aquatic habitat. Some watersheds are used for hydropower generation, providing a source of renewable energy. It's important to note that the health and functionality of watersheds are closely linked to land use and human activities within the watershed. Sustainable management practices are essential to ensure the continued provision of these ecosystem services. Watersheds are degraded through activities such as deforestation, urbanization pollution, the services they provide can be compromised, leading to negative impacts on the ecosystem. Conservation efforts and watershed management plans aim to protect and restore these vital services (Montgomery, 2007).

Numerous ecosystem services are provided by healthy watersheds, including the production of soil, wildlife movement corridors, retention of carbon, enhanced biodiversity, cycling of nutrients, water storage and filtration, flood control, and the provision of food, timber, and recreational opportunities. They also help reduce vulnerability to invasive species, climate change effects, and natural disasters. These benefits are crucial for our social, environmental, and economic well-being (US-EPA, 2024).

A wide variety of benefits and services are provided by the forest ecosystem. These services ranges from supplying local people with timber and non-timber items to water management, carbon sequestration, nutrient cycling, and microclimate adjustment. There was no study on the assessment of values of forest ecosystem services in the study area. Watersheds are directly or indirectly used as sources of timber, fuel wood, recreation, soil protection and enhancing the air quality. The main objectives of this paper is to assess the role of forest in protection of watershed health and water quality and to find out the role of forest in protecting soil erosion within watershed.

### Study Area

The current study was conducted in the Buner Watershed division which is part of the Malakand forest region of Khyber Pakhtunkhwa. Buner is located between latitudes 34°-9' and 34°-43' north and longitudes 72°-10' and 72°- 47' east. On the north, it is bordered by the Swat district and Shangla, on the west, the districts of Malakand and Mardan, and on the east, the district of the Hazara Division. Six Tehsils, namely Daggar, Gagra, Khudu Khel, Mandanr, Chagharzai, and Gadezai/Salarzai, make up the Buner District at the moment. The map of the study area is depicted in figure 1.

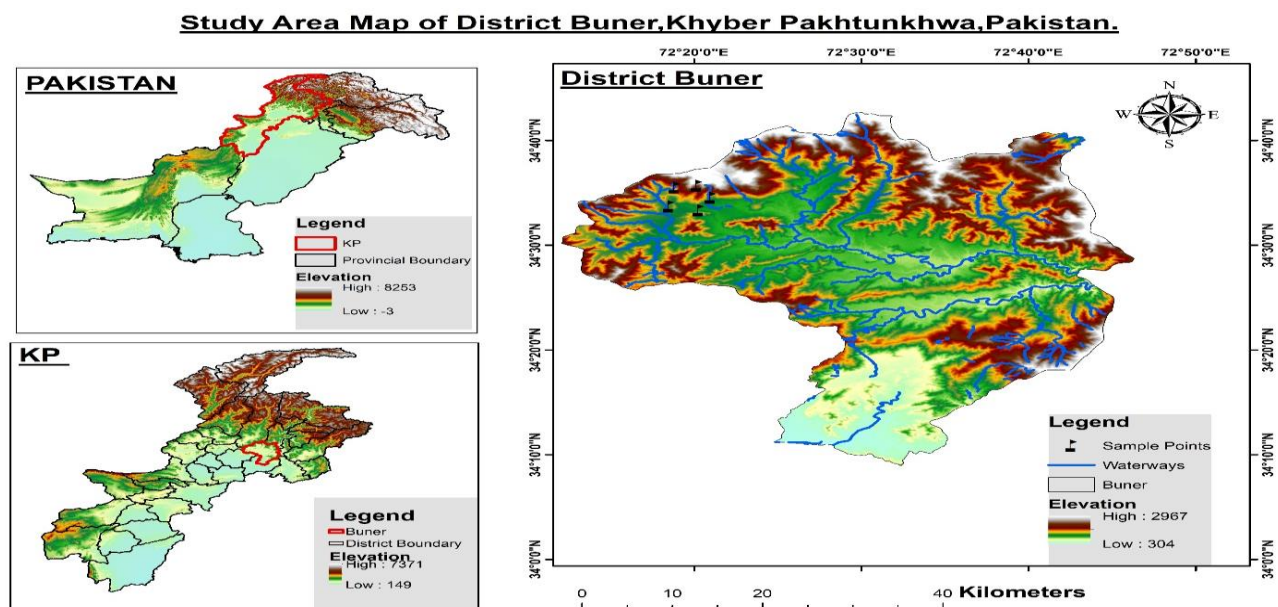


Figure 1. Map of Study Area.

A total of 895,460 people lived in the district as of the 2017 census, including 445,872 men and 449,555 women. The literacy rate was 65.10% for men and 29.40% for women. The majority of the inhabitants, 97.56%, speak Pashto as their native tongue (Wahab et al., 2022). The flora of the district is mainly dominated by *Dodonea viscosa* (Sanatha), *Accacia modesta* (Phulai), *Pinus roxburghii* (chirr) *Justicia adhatoda* (Baker), *Mallotis philpensis* (Kambela), and *Olea ferruginea* (Kau). Local elders have the opinion that the Buner word is of Sanskrit language which means forest (Jungle). It seems to be true to some extent because Buner is rich in forestry (Ali et al., 2015).

## MATERIALS AND METHODS

In order to assess the regulating ecosystem services of watershed methodology of sampling was adopted. Sampling was required in the field because a detailed inventory was impossible to complete. The field data was collected through random sampling techniques. The sampling method was used for the field survey because it is less expensive, easier to implement, and requires less time and effort. (Gorde and Jadhav, 2013). A total of 06 samples were collected within watershed. Factors to be considered were size, flow patterns, land use, and potential pollution sources. Permanent shapes for collection of water samples were made. It was easier to collect water samples having sedimentation at its base. (Bhateria et al., 2016) Water samples from selected locations were collected from two sites to capture variations. Collection of 03 water samples from those areas where there exists vegetation, and also 03 water samples from those areas where there was no vegetation comparative analysis of samples from selected points. Figure 1 shows the sampling sites within study area. It was made easier to fulfill my first objective, Role of forest in protection of watershed health and water quality. Samples from both sites were then compared with standard water quality index and was comparatively analyzed.

## RESULTS

### Physical parameters

The Following parameters were studied and analyzed after collection of water samples from field. Turbidity, Temperature, pH, and TSS etc.

#### Turbidity

Turbidity measures the cloudiness or haziness of a liquid caused by large numbers of individual particles that are generally invisible to the naked eye. It is commonly used to assess water quality, as higher turbidity often indicates the presence of suspended sediments, pollutants, or microorganisms.

#### Temperature

It was made possible through the instrument (Thermometer) at an appropriate depth and away from direct sunlight or heat sources for precise readings.

#### pH

A pH meter was used to gauge the pH level of water. I ensured proper calibration of the pH meter for precise results.

#### Total Suspended Solids

Total Suspended Solids (TSS) quantifies the amount of particulate matter suspended in a liquid, such as water. High TSS levels can indicate pollution and impact water quality, affecting aquatic life and clarity. TSS is often used in environmental monitoring and water treatment processes.

The below mentioned calculations show the statistical analysis of the provided data, including the computation of the mean and standard deviation, and the comparison of these results with the quality standards for pure drinking water. three vegetated sites and three non-vegetated sites, whereas table 4.3 highlights the WHO recommended values for turbidity, temperature, pH and TSS. Tables 1 and 2 present the measured values for water parameters from vegetated and non-vegetated sites, respectively. Table 3 lists the WHO recommended values.

Table 1. Water Quality Parameters at Vegetated Sites.

Parameter	Sample 1	Sample 2	Sample 3	Mean $\pm$ SD
Turbidity (NTU)	8	10	11	9.67 $\pm$ 1.53
Temperature ( $^{\circ}$ C)	20	21	19	20 $\pm$ 1
pH	6.3	6	6.4	6.23 $\pm$ 0.21
TSS (mg/L)	10	12	11	11 $\pm$ 1

Table 2. Water Quality Parameters at Non-Vegetated Sites.

Parameter	Sample 1	Sample 2	Sample 3	Mean $\pm$ SD
Turbidity (NTU)	16	17	19	17.33 $\pm$ 1.53
Temperature ( $^{\circ}$ C)	22	23	24	23 $\pm$ 1
pH	5.9	5.7	5.58	5.73 $\pm$ 0.16
TSS (mg/L)	30	35	40	35 $\pm$ 5

Table 3. WHO Limits of Water Quality Parameters.

Parameter	WHO Standard Value
Turbidity (NTU)	5
Temperature ( $^{\circ}$ C)	20
pH	6.5-7.5
TSS (mg/L)	5-10

## Statistical Analysis

### Turbidity

Significant differences were found between the turbidity levels at vegetated and non-vegetated areas. In both groups, the standard deviation was 1.53, and the mean turbidity was 9.67 NTU for vegetated sites and 17.33 NTU for non-vegetated sites. After doing a t-test calculation, the t-value of -6.19 was obtained. This value is considerably less than the crucial t-value of  $\pm 2.776$  ( $\alpha = 0.05$ ,  $df = 4$ ). This suggests that the two sites' turbidities differ significantly from one another. This was not the expected result, as vegetation stabilizes the soil and filters runoff to reduce turbidity. Instead, the non-vegetated location showed higher turbidity. This surprising conclusion implies that more research is necessary to determine the source(s) of possible contamination or problems with erosion at the site that is not in vegetation.

### Temperature

Comparisons of the temperatures at the vegetated and non-vegetated areas revealed a noteworthy variation. T-Values derived from the t-test at -3.66; is less than the critical t-values of  $\pm 2.776$ ; indicate there was significant difference between mean temperature at the two sites. Those temperature values were again tests against acceptable drinking water standards. This enormous gap raised chances that site-specific aspects could affect the variability in temperature which in turn could affect the health of the ecosystem and quality of water.

### pH

There was a difference in pH that stood out between the two sites. As shown through the t-test and t-value of 3.85, there was a significant difference in pH between vegetated and non-vegetated sites, wherein t-value surpassed the critical value of  $\pm 2.776$ . pH in no vegetated locations was higher than the vegetated site; therefore, it was more acidic. This difference might be due to higher concentrations of organic acid or any other acidic compounds at the non-vegetated site. The importance of vegetation in stabilizing pH in water bodies is an important finding for the wellbeing of aquatic ecosystems.

### Total Suspended Solids (TSS)

A significant difference was established between TSS values at the two locations. The t-test provided a t-value of -8.35, which was well below the critical t-value of  $\pm 2.776$  and was found to be significant. This means that higher TSS concentrations are found in the areas not covered with vegetation, indicating possible problems of erosion or increased sedimentation. Vegetation generally aids in the reduction of TSS by stabilizing the soil and preventing sediment runoff. This result reflects the importance of vegetation in the control of soil erosion and water quality maintenance.

Table 4. Statistical Analysis of Water Quality Parameters.

Parameter	Site	Mean	Standard Deviation	t-Value	Critical t-Value	Significance
Turbidity	Vegetated	9.67	$\pm 1.53$	-6.19	$\pm 2.776$	Significant (non-vegetated site has higher turbidity)
	Non-Vegetated	17.33	$\pm 1.53$			

Temperature (°C)	Vegetated	20	± 1	-3.66	±2.776	Significant (temperature differs between sites)
	Non- Vegetated	23	± 1			
pH	Vegetated	6.23	± 0.21	3.85	±2.776	Significant (non-vegetated site is more acidic)
	Non- Vegetated	5.73	± 0.16			
TSS (mg/L)	Vegetated	11	± 1	-8.35	±2.776	Significant (non-vegetated site has higher TSS)
	Non- Vegetated	35	± 5			

**Sediment Traps Construction**

Sediment traps were installed downslope from the study area to collect sediment transported by runoff. Sediment was weighed and analyzed the collected sediment to determine the rate of erosion and also show variation between both forested and non-forested sites. Table 4.5 presents the sediment quantity recorded at various sites before the rainfall, serving as a baseline for sediment conditions. Table 5 details the sediment amount measured at the same locations after the rainfall. By comparing these tables, changes in amount of sediments collected can be observed, indicating the impact of rainfall on sediment transport, erosion, and deposition within the study area. This comparison helps to assess the effects of rainfall on sediment dynamics and inform management strategies for soil and water conservation.

Table 5. Sediment Collected Before Rainfall.

Site	Sample 1 (g)	Sample 2 (g)	Sample 3 (g)	Mean (g)
Forested Area 1	119	131	113	121
Forested Area 2	141	139	129	136.33
Non-Forested Area 1	239	269	253	253.7
Non-Forested Area 2	260	228	247	245

Table 6. Sediment Collected After Rainfall.

Site	Sample 1 (g)	Sample 2 (g)	Sample 3 (g)	Mean (g)
Forested Area 1	589	563	540	564
Forested Area 2	681	599	629	636.3
Non-Forested Area 1	1279	1409	1503	1397
Non-Forested Area 2	1353	1423	1449	1408

**Descriptive Statistics**

**Mean Sediment Collected Before Rainfall:**

$$\text{Forested Areas: } \frac{121+136.33}{2} = 128.665 \text{ g}$$

**Mean Sediment Collected After Rainfall:**

$$\text{Forested Areas: } \frac{564+636.33}{2} = 600.15 \text{ g}$$

**Paired Sample t-Test (Pre- vs. Post-Rainfall)**

Table 7. Frosted areas.

Site	Mean Sediment Before Rainfall (g)	Mean Sediment After Rainfall (g)	Mean Difference (g)	Standard Deviation	t- Value
Forested Area 1	121	564	471.485	24.99	18.95
Forested Area 2	136.33	636.3	471.485	43.46	18.95

Table 8. Non-Forested Areas.

Site	Mean Sediment Before Rainfall (g)	Mean Sediment After Rainfall (g)	Mean Difference (g)	Standard Deviation	t- Value
Non-Forested Area 1	249.35	1397	1153.15	94.45	21.85
Non-Forested Area 2	245	1408	1153.15	38.46	21.85

**Independent Sample t-Test (Forested vs. Non-Forested)**

Table 9. Before Rainfall.

Comparison	Mean Difference (g)	Pooled Standard Deviation (g)	t-Value
Forested vs. Non-Forested	120.685	53.33	3.90

Table 10. After Rainfall.

Comparison	Mean Difference (g)	Pooled Standard Deviation (g)	t-Value
Forested vs. Non-Forested	802.35	54.19	26.49

Table 11. Analysis of Variance (ANOVA).

Source of Variation	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	F-Statistic	P-value
Between Groups	1,287,422.8	3	429,140.9	130.8	< 0.001
Within Groups	19,685.3	8	2,460.7		
Total	1,307,108.1	11			

Table 11 presents the results of the Analysis of Variance (ANOVA) for the study. The table includes the Source of Variation, Sum of Squares (SS), Degrees of Freedom (df), Mean Squares (MS), F-statistic, and P-value. The 'Between Groups' variation accounts for 1,287,422.8 with 3 degrees of freedom, resulting in a Mean Square of 429,140.9 and an F-statistic of 130.8, with a P-value of less than 0.001, indicating a statistically significant difference among group means. The 'Within Groups' variation totals 19,685.3 with 8 degrees of freedom and a Mean Square of 2,460.7. The total variation considered is 1,307,108.1 with 11 degrees of freedom. The analysis reveals significant sediment differences among four sites, indicating that forested areas have lower soil erosion rates, emphasizing their importance in protecting watersheds.

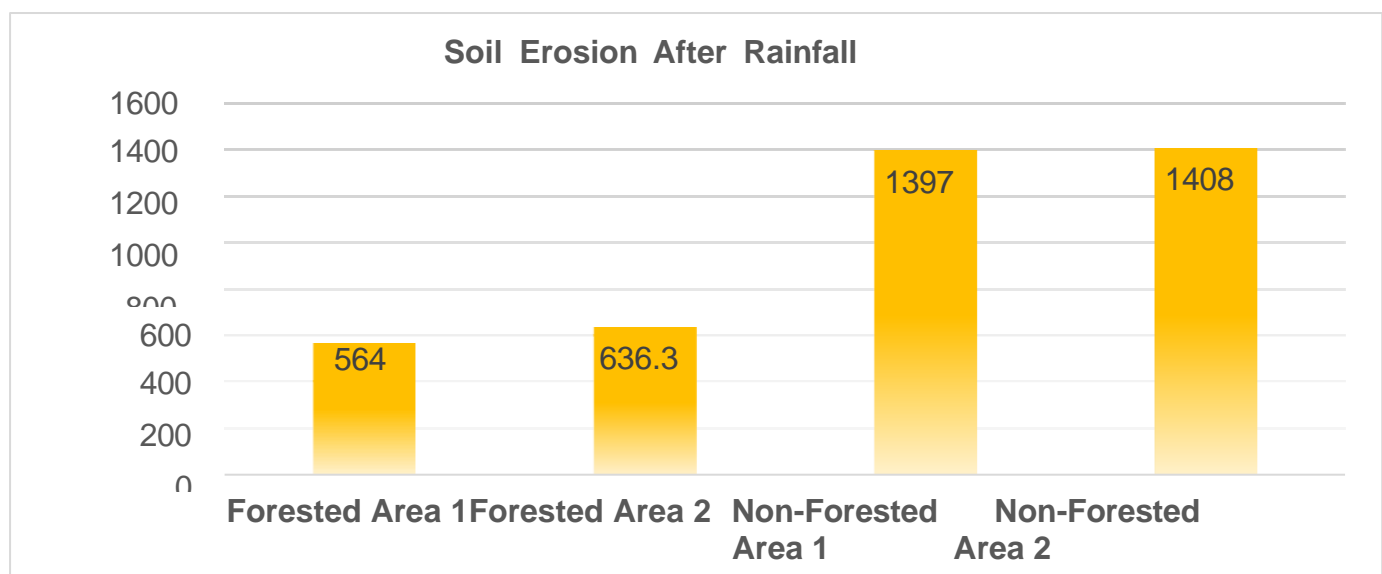


Figure 2. Comparison of average soil erosion (g) between forested and non-forested areas following rainfall

Figure 2 illustrating the mean soil erosion rates after rainfall for both forested and non-forested areas. Mean soil erosion weight for forested area 1 is 564 g while for forested Area 2 mean soil erosion weigh is 636.3 g. Similarly mean soil erosion weight for non-forested area 1 is 1397 g and for non-forested area 2 mean soil erosion weight is 1408 g that clearly demonstrates the higher soil erosion rates in non-forested areas compared to forested areas after rainfall. The significant difference highlights the role of forests in protecting soil and reducing erosion, reinforcing the importance of maintaining and enhancing forest cover within watersheds.

## DISCUSSION

The results show that forested areas have significantly lower soil erosion rates compared to non-forested areas. Before rainfall, the mean sediment collected from forested areas (128.67 g) is substantially lower than that from non-forested areas (249.35 g). After rainfall, the difference becomes even more pronounced, with forested areas averaging 600.15 g of sediment and non-forested areas averaging 1402.5 g. Rainfall increases soil erosion in both forested and non-forested areas, but the increase is much higher in non-forested areas. The mean difference in sediment collected after rainfall is 471.49 g for forested areas and 1153.15 g for non-forested areas. This demonstrates that forests significantly mitigate the impact of rainfall on soil erosion. This study correlates with the results that afforestation had direct impacts in degrading soils, whereby reducing water erosion of soils and risk of flooding, increasing infiltration by eight and topsoil organic matter (SOM) (Smith et al, 2013; Bonnesoeur et al, 2019). The conventional paired sample t-test showed statistically significant increases in sediment deposition after rainfall in forested and nonforested sites, with the t-values for nonforested areas being overwhelmingly larger. This serves as a proof of the role of forest covers in reducing rainfall-induced soil erosion (Lgwe et al., 2017; Tufail et al., 2020). Independent sample t-tests show that sediment collected before and after rainfall differs significantly between the forested and nonforested areas. This supports the theory that forests prevent erosion, thus preserving entire regions in high-quality soils (Masi et al., 2021). Evidence from ANOVA has indicated that the sediment collection between the four sites presented significant differences, further endorsing such a view in that forested locations were associated with lower levels of soil erosion.

## CONCLUSIONS

The present study, through its endeavors, highlighted the vital role that the forest ecosystems played in the moderation of such watershed functions as water quality and soil erosion control. The Buner Watershed indicated that vegetated sites, in comparison to nonvegetated sites, showed significantly lower turbidity, steadier temperatures, higher pH, and lower TSS. Vegetation detoxifies some pollutants, normalizes temperatures, and reduces the soil runoff of sediments. Data collected from sediment traps indicated stark contrast in the erosion rates between forested and nonforested areas. Areas lacking vegetation have collected much more sediment than those with vegetation before and after rain, as vegetation-wise, there indicates that soil erosion and sedimentation can be limited. This study puts great emphasis on the need of conserving existing forests to attain watershed health, improve water quality and control soil erosion. Good forest management strategies and conservation policies are extremely important for countering deforestation and degradation. By putting emphasis on the conservation of forests, it assures a synergistic nutritious vitality for watershed conservation, Water quality, and preventing soil erosion for the Buner Watershed and ecosystems alike.

## ACKNOWLEDGEMENTS

Not applicable.

## AUTHOR CONTRIBUTIONS

All the authors contributed equally to this research.

## COMPETING OF INTEREST

No conflicts of interest have been disclosed by the authors.

## REFERENCES

- Ali, A., Perveen, A., Qaiser, M., et al 2015. Flora of Buner District, Khyber Pakhtunkhwa, Pakistan. *Pak. J. Bot.* 47(5): 1487-1494.
- Bhateria, R., Kaur, S., Bhardwaj, A., et al 2016. Assessment of sedimentation in water reservoirs and its impact on water quality. *J. Environ. Manage.* 184: 27-36.

- Bonnesoeur, V., Locatelli, B., Guariguata, M.R., et al 2019. Impacts of forests and forestation on hydrological services in the Andes: A systematic review. *For. Ecol. Manag.*, 433, pp.569-584.
- Costello, C., 2024. Finding synergies between agroecology and industrial ecology toward sustainable agricultural systems. *JAFSCD*, 13(3), pp.1-4.
- Edwards, F.R., Gentry, A., Smith, L., et al 2015. Watershed management and its implications for the water cycle. *Hydrol. Process.* 29(11): 2475-2491.
- Falkenmark, M. 1986. The massive water scarcity now threatening Africa: Why isn't it being addressed? *Ambio*. 15(3): 120-125.
- Gorde, A.D., Jadhav, A.R., et al 2013. Sampling techniques in environmental studies. *Int. J. Adv. Res. Eng. Technol.* 4(5): 12-22.
- Igwe, P.U., Ezeukwu, J.C., Edoke, N.E., et al 2017. A review of vegetation cover as a natural factor to soil erosion. *Int. J. Rural Dev. Environ. Health Res*, 1, pp.21-28.
- Masi, E.B., Segoni, S., Tofani, V., 2021. Root reinforcement in slope stability models: a review. *Geosciences*, 11(5), p.212.
- Montgomery, D.R. 2007. Soil erosion and the evolution of landscape relief. *Geomorphology*. 85(3-4): 141-159.
- Narendra, B.H., Siregar, C.A., Dharmawan, I.W.S., et al 2021. A review on sustainability of watershed management in Indonesia. *Sustainability*, 13(19), p.11125.
- Smith, P., Ashmore, M.R., Black, H.I., et al 2013. The role of ecosystems and their management in regulating climate, and soil, water and air quality. *J. Appl. Ecol*, 50(4), pp.812-829.
- Tufail, M., Ahmed, A.M., Ali, J., 2020, September. Assessment of Economic Values of Goods and Services Provided by Conifer Forest Ecosystems in the Khyber Pakhtunkhwa Province of Pakistan. In *RSEP CONFERENCES* (p. 95).
- US-EPA. 2024. Watershed ecosystem services. *Environ. Prot. Agency*.
- Wahab, N., Ahmed, S., Hussain, S., et al 2022. Demographic and educational profile of Buner District. *Pak. J. Soc. Sci.* 42(2): 203-210.
- Wani, S.P., Garg, K.K., et al 2009. Agroecological management of watersheds: An overview. *Agric. Syst.* 102(1-3): 83-95.