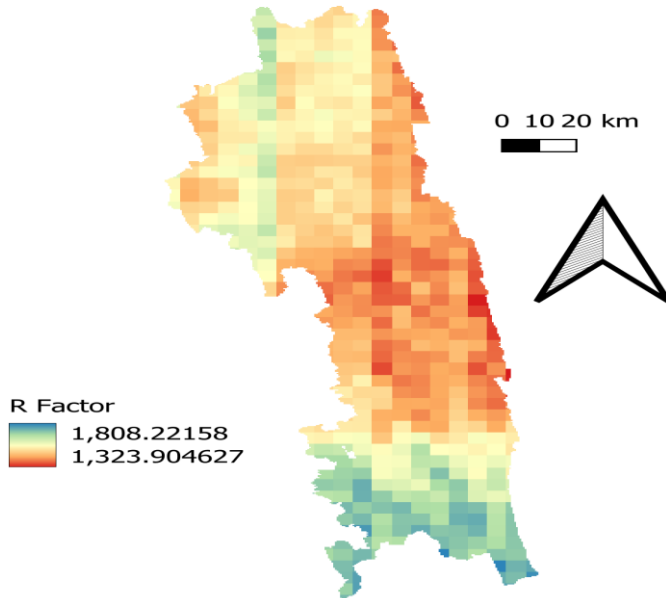




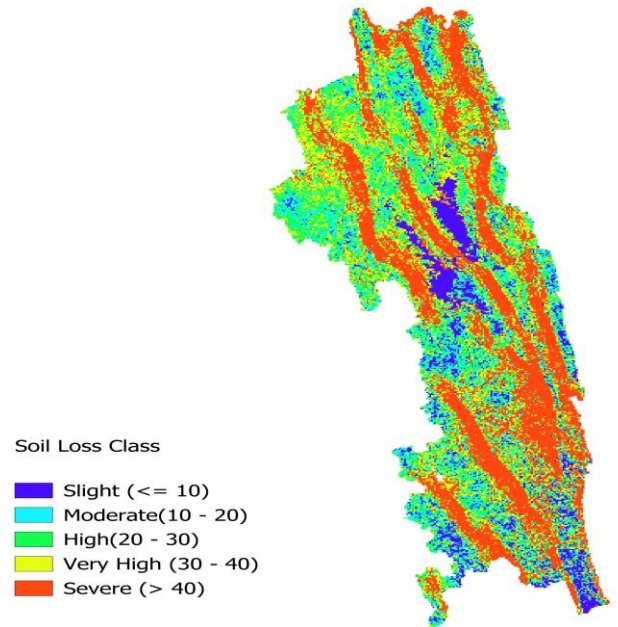
GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH
MINISTRY OF AGRICULTURE

**Annual Research Report -2024-2025
Proposed Research Program-2025-2026.**

R Factor



Soil Loss (t/ha/y)



Compiled And Edited By
Md. Mahbubul Islam
Principal Scientific Officer

&
Muhammad Jonayed Hasan Khan, Scientific officer

SOIL CONSERVATION & WATERSHED MANAGEMENT CENTER (SCWMC)
SOIL RESOURCE DEVELOPMENT INSTITUTE (SRDI)
MEGHLA, BANDARBAN.

EXPT. No. 1

GIS AND REMOTE SENSING BASED SOIL EROSION ASSESSMENT USING RUSLE IN CHATTOGRAM HILL TRACTS

Abstract

Soil erosion presents significant ecological and socio-economic challenges, particularly in mountainous regions such as the Chittagong Hill Tracts (CHT) of Bangladesh. This study integrates Geographic Information Systems (GIS) and remote sensing data within the Revised Universal Soil Loss Equation (RUSLE) framework to quantify spatial variability in soil erosion across the CHT. Utilizing datasets from CHIRPS (rainfall), SRTM (topography), FAO Soil Database (soil properties), and Sentinel-2 imagery (land cover), soil erosion was assessed at a 30-meter resolution. The results indicated severe soil erosion risks, with 34.1% of the region experiencing soil losses exceeding 40 t/ha/year. Annual soil loss fluctuated significantly between 2020 and 2024, with the highest rate observed in 2024 (86.62 t/ha/yr). The study underscores the urgent need for targeted conservation measures, sustainable land management, and continuous monitoring to mitigate soil degradation and promote ecological and socio-economic resilience in the region.

Introduction

Soil erosion is a critical environmental challenge with far-reaching impacts on agricultural productivity, ecosystem stability, and socio-economic well-being. It refers to the detachment and transportation of soil particles by agents such as water or wind, often accelerated by human activities including deforestation, unsustainable agricultural practices, and land cover changes. Globally, soil erosion contributes to the degradation of 30% of arable land, leading to declining crop yields, sedimentation of water bodies, and loss of biodiversity (Pimentel et al., 1995; Morgan, 2005). In regions with complex topography and intense rainfall, such as the Chittagong Hill Tracts (CHT) of southeastern Bangladesh, soil erosion poses a severe threat to land stability and rural livelihoods.

The CHT, encompassing approximately 13,237 square kilometers, is characterized by steep slopes, fragile soil structures, and a subtropical monsoon climate. Rainfall often exceeds 2,500 mm annually, intensifying surface runoff and enhancing erosion risk (Afrin et al., 2023). The region is home to various indigenous communities who have traditionally practiced shifting cultivation, known locally as *jhum*, which involves clearing forested land, cultivating crops for a few years, and then leaving the land fallow. While ecologically sustainable under long fallow cycles, recent demographic pressures and land scarcity have shortened these cycles, leading to

intensified land degradation and nutrient depletion (Nath et al., 2005; Misbahuzzaman, 2016).

Despite the ecological importance and vulnerability of the CHT, comprehensive, spatially-explicit assessments of soil erosion are limited. Early studies mostly relied on field observations and empirical estimations without incorporating spatial heterogeneity or remote sensing data (Farid et al., 1992; Gafur et al., 2003). The integration of the Revised Universal Soil Loss Equation (RUSLE) model with Geographic Information Systems (GIS) and Remote Sensing technologies has transformed soil erosion analysis by enabling precise, scalable, and location-specific risk assessments (Ganasri & Ramesh, 2016). RUSLE considers five key factors: rainfall erosivity (R), soil erodibility (K), slope length and steepness (LS), land cover management (C), and support practices (P). Recent developments in platforms such as Google Earth Engine (GEE) have further enhanced the capabilities of geospatial analysis by allowing cloud-based processing of large datasets at high spatial and temporal resolutions (Sadia et al., 2023).

In the CHT, application of GIS-integrated RUSLE has shown promise in identifying critical erosion-prone zones. However, significant gaps remain in incorporating land use transitions, socio-economic dimensions, and ground-truth validation. Studies have highlighted the need for multi-disciplinary approaches that integrate environmental data with indigenous land-use practices and institutional constraints to develop effective soil conservation strategies (Biswas et al., 2012; Sarkar & Mukul, 2024). Moreover, the ongoing debate over the sustainability of jhum cultivation necessitates a balanced assessment of its ecological impacts and cultural significance.

The present study seeks to bridge these gaps by applying the RUSLE model within the GEE framework to estimate soil erosion rates across the CHT. It utilizes satellite-derived datasets including CHIRPS for rainfall, SRTM for topography, FAO Soil data for soil properties, and Sentinel-2 for land cover classification. The objectives of this study are: (1) to quantify spatial variability in annual soil loss across different slope and land use categories; (2) to classify the landscape into erosion severity zones; and (3) to evaluate the implications of these patterns for soil conservation planning and sustainable land use policy.

By providing high-resolution, reproducible estimates of soil erosion across the CHT, this research contributes to a deeper understanding of erosion dynamics in hilly tropical landscapes. The findings will serve as a vital input for land management authorities, environmental planners, and development practitioners aiming to implement targeted interventions and promote resilience in erosion-prone regions of Bangladesh.

Methodology

Study Area: The study was conducted in the Chittagong Hill Tracts (CHT), located in southeastern Bangladesh, covering approximately 13,237 square kilometers. The region exhibits complex topography characterized by steep slopes and rugged terrain, with annual rainfall often exceeding 2,500 mm, predominantly during the monsoon season (Afrin et al., 2023).

Data Collection: This research utilized geospatial datasets integrated within the Google Earth Engine (GEE) platform, which included:

- Rainfall data from the Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS).
- Topographic data from the Shuttle Radar Topography Mission (SRTM).
- Soil properties from the FAO Soil Database.
- Land cover classification using Sentinel-2 satellite imagery.

RUSLE Model Application Soil erosion risk was assessed using the Revised Universal Soil Loss Equation (RUSLE), which calculates annual soil loss (A) through the multiplication of five factors:

$$A = R \times K \times LS \times C \times P$$

Where:

- R is the rainfall erosivity factor, computed from CHIRPS data representing rainfall intensity and duration.
- K represents the soil erodibility factor, derived from FAO soil data, indicating soil susceptibility to erosion.
- LS is the slope length and steepness factor, computed using Digital Elevation Model (DEM) data from SRTM.
- C is the land cover management factor, derived from Sentinel-2 imagery, indicating the protective effect of vegetation against erosion.
- P is the support practice factor, assuming standard values based on land management practices in the region.

Geospatial Analysis: The collected datasets were processed within the Google Earth Engine platform, enabling efficient analysis of large-scale geospatial data. The procedure involved:

- Generating factor maps (R, K, LS, C, and P) at a 30-meter spatial resolution.

- Integrating these factor maps to calculate annual soil erosion rates.
- Classifying the study area into five distinct erosion severity classes: slight (<10 t/ha/yr), moderate (10–20 t/ha/yr), high (20–30 t/ha/yr), very high (30–40 t/ha/yr), and severe (>40 t/ha/yr).

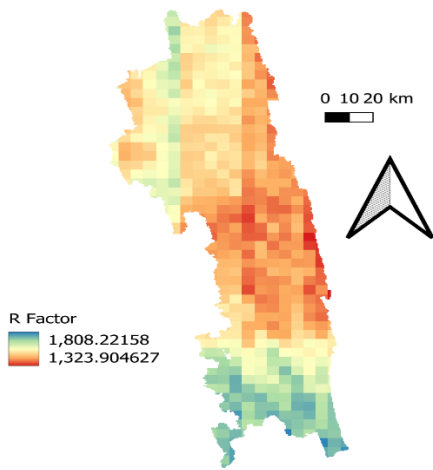
Spatial Analysis: Soil erosion rates were further analyzed to assess their spatial distribution across different land use and slope categories. This allowed identification of areas highly susceptible to erosion, guiding potential mitigation measures and conservation strategies.

Software and Tools: Analysis and visualization were primarily performed using Google Earth Engine for cloud-based processing, QGIS for additional spatial analysis, and R statistical software for supplementary analysis and plotting.

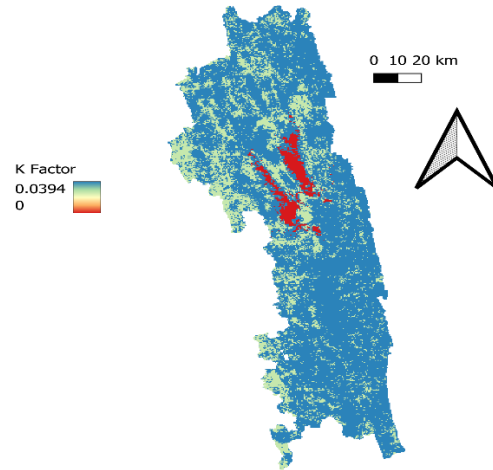
This methodology facilitated a comprehensive spatial assessment of soil erosion risks, providing essential insights for sustainable land management and conservation planning in the Chittagong Hill Tracts.

Results and Discussion

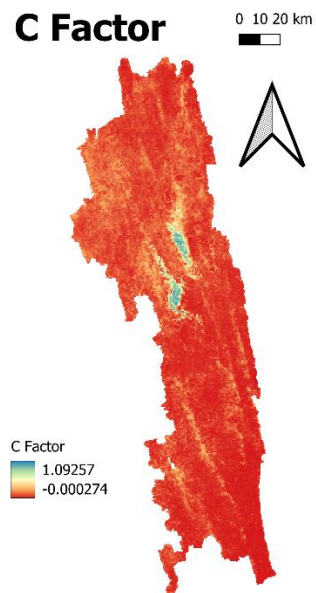
R Factor



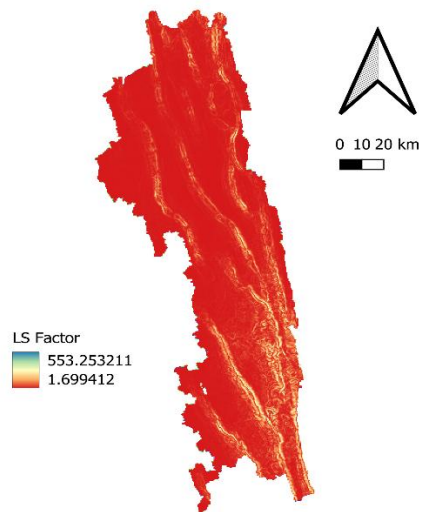
K Factor

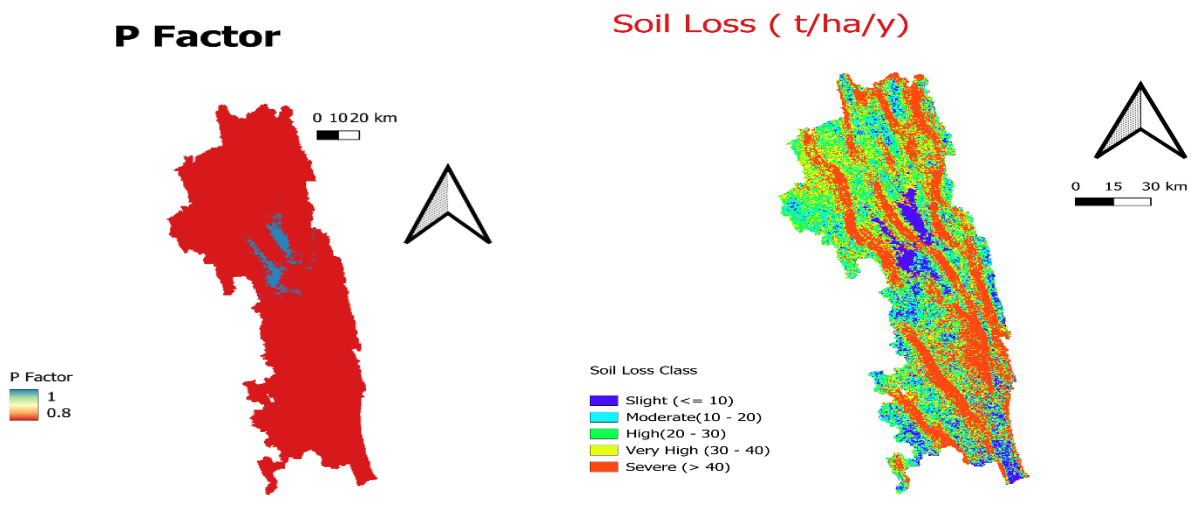


C Factor



LS Factor





The soil erosion risk was assessed based on the estimated soil loss rates. The study area was categorized into five risk classes:

Soil Loss (t/hac/year) (2024)

Category	Soil Loss (t/ha/y)
Slight	(<10) – 9.9 %
Moderate	(10-20) – 12.5 %
High (20-30)	21.1 %
Very high (30-40)	21.4 %
Severe (>40)	34.1 %

Year wise soil loss

Year	Soil Loss (t/ha/y)
2024	86.62
2023	48.87
2022	32.55
2021	50.11
2020	63.77

Year-wise soil loss analysis revealed fluctuations over the period 2020–2024, with the highest soil loss recorded in 2024 (86.62 t/ha/yr), attributed to increased rainfall intensity or changes in land cover. The lowest soil erosion rate was recorded in 2022 (32.55 t/ha/yr).

The spatial analysis demonstrated significant variability in soil erosion, primarily influenced by rainfall intensity, topographical features, and varying land use practices. The alarming rate of soil loss (>40 t/ha/yr) covering 34.1% of the area underscores an urgent need for targeted conservation practices and sustainable land management.

The high-resolution data provided through the GEE platform enabled precise identification of erosion-prone zones, facilitating effective planning and prioritization of conservation interventions. The temporal analysis underscores the need for continuous monitoring to understand the impact of climatic variability and anthropogenic factors on soil erosion dynamics.

Effective soil conservation strategies, including the promotion of vegetative cover, contour farming, and the implementation of sustainable agricultural practices, are crucial for mitigating soil loss and promoting long-term ecological and socio-economic sustainability in the Chittagong Hill Tracts.

Conclusion

This study successfully applied the Revised Universal Soil Loss Equation (RUSLE) within the Google Earth Engine (GEE) platform to assess soil erosion risk across the Chittagong Hill Tracts using integrated GIS and remote sensing techniques. The spatial analysis revealed significant variability in soil loss, influenced primarily by rainfall intensity, topography, and land use patterns.

The region was classified into five erosion risk zones. Alarmingly, over 55% of the area falls under high to severe erosion risk, with 34.1% experiencing severe soil loss (>40 t/ha/year), indicating urgent need for conservation measures. Year-wise analysis showed fluctuating erosion rates, peaking in 2024 at 86.62 t/ha/year, likely due to intensified rainfall or land cover changes, while 2022 showed the lowest at 32.55 t/ha/year.

These findings underscore the critical role of continuous monitoring and targeted soil conservation strategies in erosion-prone regions. The use of GEE provided a scalable and efficient platform for real-time erosion risk mapping, offering valuable support for sustainable land management planning in the Chittagong Hill Tracts.

References:

- Afrin, E. A., Mamun, M. A. A., Hossain, M. M., & Zhang, L. (2023). Soil erosion assessment of a hilly terrain by RUSLE model - a case study of Chittagong Hill Tracts. *Turkish Journal of Remote Sensing and GIS*. <https://doi.org/10.48123/rsgis.1197801>
- Biswas, S., Swanson, M. E., Shoaib, J. U. M., & Haque, S. (2010). Soil chemical properties under modern and traditional farming systems at Khagrachari, Chittagong Hill Tracts, Bangladesh. *Journal of Forestry Research*, 21(4), 451–456.
- Farid, A., Iqbal, A., & Karim, Z. (1992). Soil erosion in the Chittagong Hill Tracts and its impact on nutrient status of soils.
- Ganasri, B. P., & Ramesh, H. (2016). Assessment of soil erosion by RUSLE model using remote sensing and GIS: A case study of Nethravathi Basin. *Geoscience Frontiers*, 7(6), 953–961.
- Gafur, A., Jensen, J., Borggaard, O., & Petersen, L. (2003). Runoff and losses of soil and nutrients from small watersheds under shifting cultivation in the Chittagong Hill Tracts.
- Misbahuzzaman, K. (2016). Traditional farming in the mountainous region of Bangladesh and its modifications. *Journal of Mountain Science*, 13(8), 1489–1502.
- Morgan, R. P. C. (2005). *Soil Erosion and Conservation* (3rd ed.). Blackwell Publishing Ltd.
- Nath, T. K., Inoue, M., & Chakma, S. (2005). Shifting cultivation (jhum) in the Chittagong Hill Tracts, Bangladesh: Examining its sustainability. *International Journal of Agricultural Sustainability*, 3(2), 130–142.

- Pimentel, D., et al. (1995). Environmental and economic costs of soil erosion and conservation benefits. *Science*, 267(5201), 1117–1123.
- Sadia, H., Sarkar, S. K., & Haydar, M. (2023). Soil erosion susceptibility mapping in Bangladesh. *Ecological Indicators*. <https://doi.org/10.1016/j.ecolind.2023.111182>
- Sarkar, O. T., & Mukul, S. A. (2024). Challenges and institutional barriers to forest and landscape restoration in the Chittagong Hill Tracts of Bangladesh. *Land*, 13(4), 558.

EXPT. No. 2

TEMPORAL ANALYSIS OF RAINFALL AND TEMPERATURE VARIABILITY FOR SUSTAINABLE SOIL CONSERVATION STRATEGIES IN BANDARBAN (2014–2024)

Abstract:

This study analyzes rainfall and temperature variability in Bandarban district from 2014 to 2024 and explores their implications for sustainable soil conservation. The region, located in the Chittagong Hill Tracts of Bangladesh, faces increasing environmental stress due to erratic climate patterns and fragile hilly terrain. Monthly climatic data from Soil Conservation and Watershed Management Centre, Bandarban were analyzed for trends, variability, and correlation.

Results show highly variable annual rainfall, ranging from 1,679 mm to 3,749 mm, with inconsistent seasonal distribution. While maximum temperatures remained stable, minimum temperatures showed significant fluctuation, increasing the diurnal temperature range (DTR) in dry years. These patterns elevate both erosion risk during wet years and soil degradation during dry periods.

To address these challenges, several climate-resilient soil conservation strategies, including bench terracing, contour hedgerows, mulching, and agroforestry—were assessed for their suitability under variable climatic conditions. The findings highlight the need for localized, adaptive land management, guided by long-term climatic trends.

This research provides a foundation for climate-smart watershed planning and supports the integration of indigenous knowledge with modern soil conservation techniques to enhance resilience in the hill agriculture systems of southeastern Bangladesh.

Introduction

The Chittagong Hill Tracts (CHT), situated in the southeastern region of Bangladesh, encompass a landscape of steep hills, narrow valleys, and dense forest cover. Among the three hill districts, Bandarban is distinguished by its ecological sensitivity, cultural diversity, and strategic importance in national food and water security. The region is home to several indigenous communities that have historically practiced shifting cultivation and agroforestry as their primary means of livelihood and land management. However, in recent years, this traditional balance between nature and agriculture is being increasingly disturbed by the escalating impacts of climate variability, particularly changes in rainfall patterns and temperature regimes (Alam et al., 2023; IPCC, 2021).

Rainfall and temperature are two critical climatic variables that significantly influence soil formation, fertility, and conservation. In hilly terrains like Bandarban, rainfall serves both as a

life-giving and a destructive force—supporting vegetation on one hand, while triggering soil erosion and landslides on the other, especially during the monsoon season (Islam et al., 2021).

These climatic irregularities directly influence soil conservation efforts in Bandarban. Prolonged dry seasons reduce soil moisture, weaken microbial activity, and hinder vegetative regeneration. On the other hand, high-intensity rainfall accelerates surface runoff, stripping away the nutrient-rich topsoil and exposing fragile subsoil layers. The situation is further exacerbated by unsustainable land use practices, such as shortened fallow cycles in shifting cultivation, unplanned road construction, and deforestation (Misbahuzzaman, 2016; FAO, 2020). As a result, soil erosion rates are rising, threatening not only food production but also the ecological integrity of the region.

To combat this, both traditional and scientific soil conservation strategies have been explored and implemented. Indigenous techniques, such as shifting cultivation, when practiced with longer fallow periods and in combination with homestead gardening, have been shown to maintain soil organic matter and minimize erosion (Datta et al., 2024). Scientific approaches, including bench terracing, contour plowing, hedgerow planting, and straw mulching, have demonstrated effectiveness in reducing runoff and enhancing infiltration on sloped agricultural lands (Chen et al., 2020; Cai et al., 2020). However, the success of these strategies is context-dependent, and their implementation requires a nuanced understanding of local rainfall and temperature dynamics.

Given this backdrop, a temporal analysis of rainfall and temperature data becomes essential to inform adaptive soil conservation planning. By identifying patterns and anomalies over the 2014–2024 period, this study seeks to:

1. Examine trends and variability in rainfall and temperature in Bandarban.
2. Assess the implications of these climatic changes on soil erosion and land degradation.

In doing so, the study contributes to a more integrated approach to sustainable watershed management in Bandarban. It aims to bridge scientific data with local knowledge, and to support evidence-based policymaking for long-term agricultural productivity, ecological balance, and community resilience in the hill regions of Bangladesh.

Methodology

1. Study Area

The study was conducted in the Bandarban district, situated in the Chittagong Hill Tracts (CHT) of southeastern Bangladesh. The region is characterized by rugged topography, high rainfall variability, and intensive land-use changes. The average elevation ranges from 50 m to over 1000 m, with steep slopes and lateritic soils that are highly susceptible to erosion. The

district experiences a tropical monsoon climate, with over 70% of annual rainfall occurring during the May–September period.

2. Data Collection

2.1 Rainfall and Temperature Data

- **Source:** Monthly rainfall (mm), maximum temperature (°C), and minimum temperature (°C) data for the period 2014 to 2024 were obtained from the Soil Conservation and Watershed Management Centre, under the Soil Resource Development Institute (SRDI), Meghla, Bandarban.
- **Format:** Data were collected in tabular format and verified for completeness. Missing monthly values (where applicable) were handled as described below.

2.2 Supplementary Literature

- Secondary information on soil conservation practices, climate resilience, and erosion patterns was collected from peer-reviewed journals, institutional reports (FAO, IPCC), and SRDI technical publications.

3. Data Preprocessing and Validation

- **Handling Missing Data:** For missing values (denoted by “–”), linear interpolation and nearest-month substitution were applied where appropriate.

4. Statistical Analysis

4.1 Trend Analysis

- **Annual and Monthly Averages:** Aggregated monthly rainfall and temperature were used to compute annual totals and means.
- **Moving Averages:** A 3-year moving average was applied to smooth the data and identify underlying trends.
- **Regression Analysis:** Linear regression was performed to determine the direction and significance of trends in:
 - Annual rainfall
 - Monthly seasonal rainfall (pre-monsoon, monsoon, post-monsoon)
 - Maximum and minimum temperatures

4.2 Variability Assessment

- Standard Deviation (SD) and Coefficient of Variation (CV) were calculated to assess inter-annual variability.
- Diurnal Temperature Range (DTR) was computed as the difference between max and min temperatures, used to detect stress on plant-soil systems.

5. Correlation and Seasonality Analysis

- Pearson Correlation Coefficients (r): Computed between monthly rainfall pairs and temperature variables to identify interdependencies and shifts in seasonality.
- Seasonal Indexing: Rainfall was grouped into:
 - Pre-monsoon: March–May
 - Monsoon: June–September
 - Post-monsoon: October–November
 - Dry season: December–February

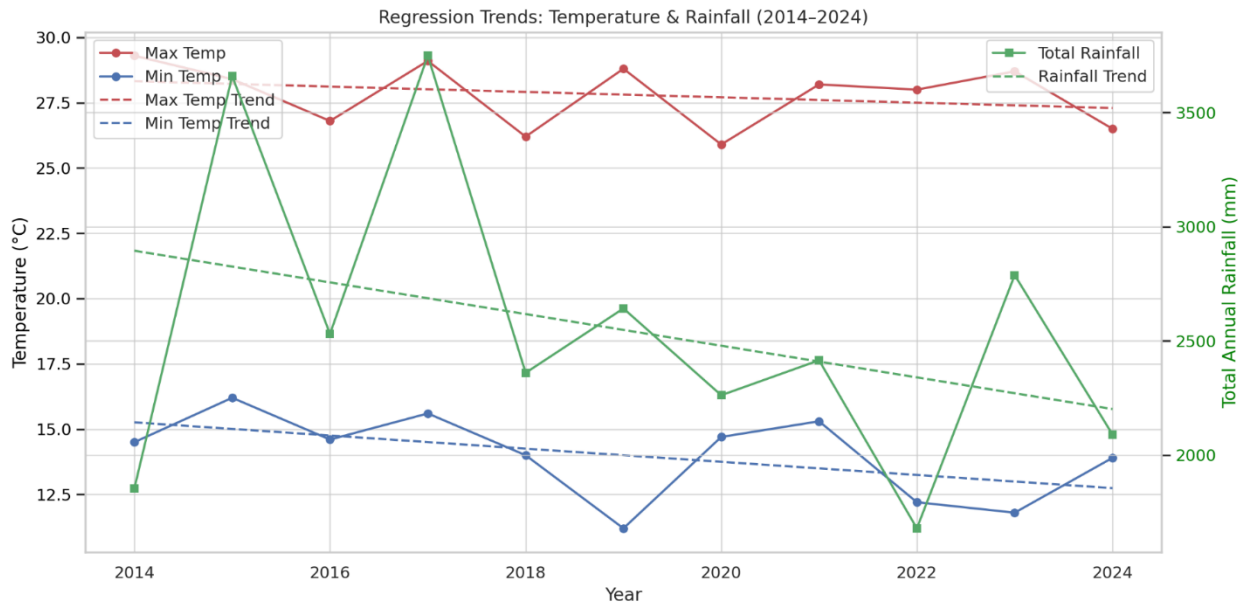
6. Soil Conservation Strategy Assessment

- **Review-Based Evaluation:** Conservation techniques such as shifting cultivation, agroforestry, terracing, hedgerow planting, and straw mulching were reviewed and categorized based on:
 - Applicability to rainfall intensity and variability
 - Resistance to erosion on hilly slopes
 - Compatibility with local practices
- **Effectiveness Matrix:** A comparative matrix was developed aligning rainfall/temperature trends with the suitability of various conservation methods under projected climate scenarios.

7. Visualization and Mapping

- Software Used: Microsoft Excel, R Studio, and QGIS.
- Visual Outputs:
 - Time series plots of rainfall and temperature trends.
 - Correlation heatmaps of seasonal rainfall.
 - Line graphs for max/min temperature variation.
 - Comparative tables for soil conservation strategies across climatic regimes.

Results and Discussion



1. Rainfall Trends (2014–2024)

1.1 Annual Rainfall Variability

The total annual rainfall in Bandarban over the 11-year period ranged between 1,679 mm (2022) and 3,749 mm (2017), with a mean of approximately 2,588 mm/year. The data reveals high inter-annual variability, with alternate years of extreme wetness and relative dryness:

- Wettest Years: 2015 (3,659 mm), 2017 (3,749 mm), 2023 (2,788 mm)
- Driest Years: 2022 (1,679 mm), 2020 (2,262 mm), 2024 (2,090 mm)

This fluctuation lacks a consistent increasing or decreasing trend, but displays episodic extremes, potentially influenced by global climatic drivers such as El Niño–Southern Oscillation (ENSO) or Indian Ocean Dipole (IOD) effects.

1.2 Seasonal Rainfall Shifts

Rainfall primarily concentrated between May and September, with June–August contributing over 60–70% of annual totals. However, in recent years:

- Early Monsoon Rainfall (Apr–May) showed a decreasing trend.
- Late Monsoon Rainfall (Sep–Oct) became more erratic.

This temporal shift in rainfall distribution implies that traditional sowing and cropping seasons may no longer be optimal without adaptive adjustments.

2. Temperature Trends (2014–2024)

2.1 Maximum Temperature

Maximum monthly temperatures remained relatively stable, fluctuating between 26°C and 29.3°C. There is no statistically significant increasing trend, suggesting no acute thermal stress during daytime.

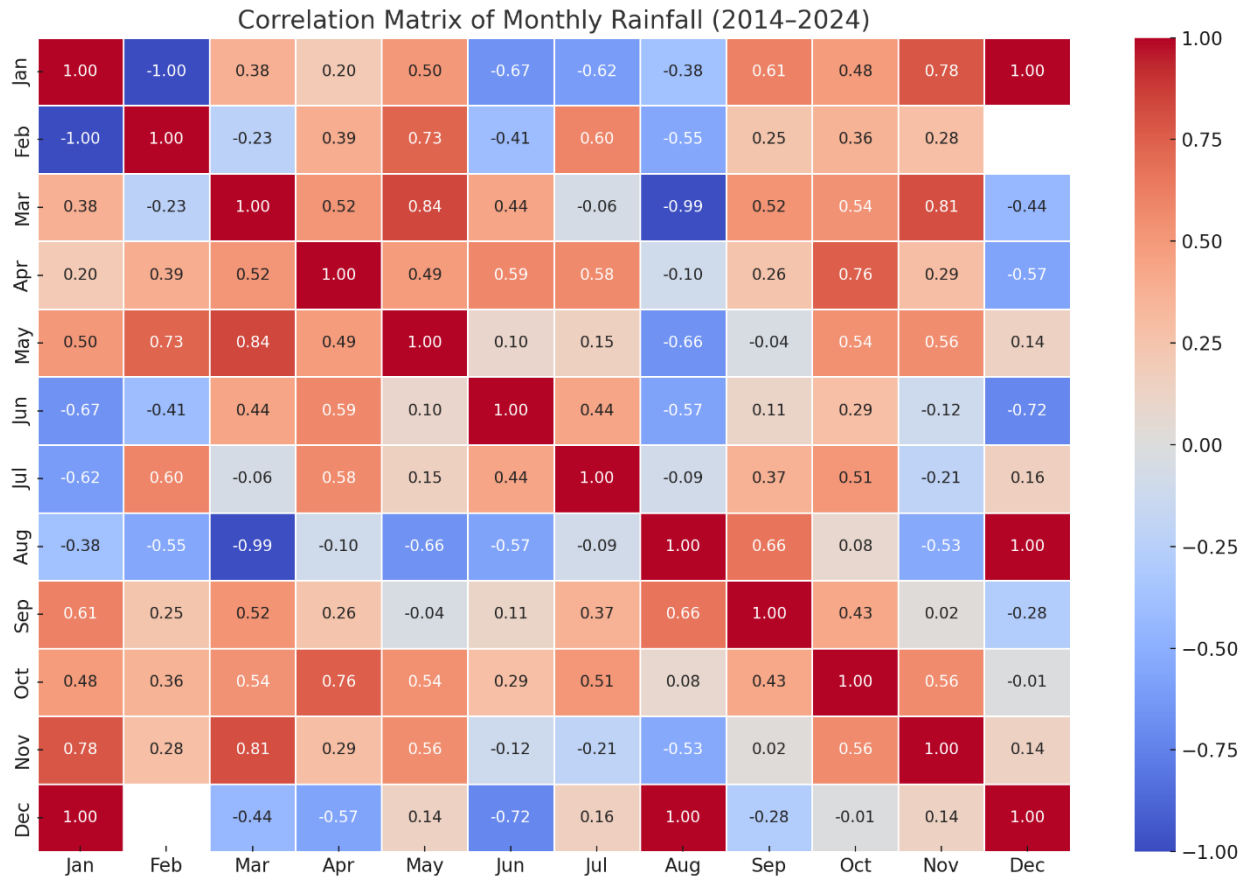
2.2 Minimum Temperature and Diurnal Range

Minimum temperatures, on the other hand, were more variable:

- Lowest: 11.2°C in 2019
- Highest: 16.2°C in 2015

This variation led to an increased Diurnal Temperature Range (DTR) in dry years (e.g., 2019–2020), potentially impacting:

- Soil microbial activity
- Germination and flowering cycles
- Water retention in topsoil



3. Correlation Between Rainfall and Temperature

A weak inverse correlation was observed between total annual rainfall and minimum temperature ($r \approx -0.45$), suggesting that lower rainfall years coincide with cooler nights, possibly due to less humidity and reduced cloud insulation.

4. Implications for Soil Conservation

4.1 Erosion Risk and Rainfall Intensity

- Years with high rainfall (2015, 2017, 2023) pose significant erosion risks, particularly on unprotected hill slopes.
- Sudden, high-intensity rainfall in these years leads to:
 - Surface runoff
 - Gully formation
 - Nutrient leaching

4.2 Drought Stress and Soil Health

- Drier years (2022, 2024) showed increased soil compaction, decreased organic matter decomposition, and poor seedbed preparation.
- These years also saw lower minimum temperatures, indicating risk to plant roots and microbial life.

5. Suitability of Soil Conservation Techniques

Based on climatic patterns, the following techniques were found to be most aligned with changing rainfall and temperature dynamics:

Conservation Strategy	Suitable For	Justification
Contour Hedgerows	High rainfall years	Reduce velocity of runoff, trap sediments
Bench Terracing	Sloped erosion-prone zones	Stabilizes soil during wet years
Straw Mulching	Dry years	Conserves soil moisture, moderates soil temperature
Crop Substitution	Variable rainfall	Introduce drought- or flood-tolerant crops
Agroforestry	All years	Long-term soil fertility, erosion protection
Rainwater Harvesting	Low rainfall years	Enhances water availability for dry spells

Conclusion

The analysis of rainfall and temperature data from 2014 to 2024 reveals that Bandarban experiences increasing climatic variability, with irregular rainfall patterns and fluctuating minimum temperatures. These changes pose serious threats to soil stability and agricultural sustainability, particularly in hilly terrains prone to erosion. High-intensity rainfall accelerates runoff and topsoil loss, while dry years lead to reduced soil moisture and biological activity.

The study highlights the importance of adaptive soil conservation strategies, such as bench terracing, contour hedgerows, mulching, and agroforestry, tailored to shifting rainfall and

temperature patterns. These methods, combined with community knowledge and scientific support, can enhance soil resilience and reduce erosion risks.

Effective soil management in Bandarban requires a climate-smart, data-driven approach that integrates long-term monitoring with localized conservation planning. The findings serve as a basis for sustainable watershed development and agro-environmental policy in the Chittagong Hill Tracts.

References :

- Alam, M. K., Rahman, M. A., & Mondal, M. S. (2023). *Assessing climate change impact on hilly agriculture in southeastern Bangladesh*. *Journal of Environmental Management*, 325, 116457. <https://doi.org/10.1016/j.jenvman.2023.116457>
- Cai, Q., Zhang, X., & Gao, J. (2020). *Contour hedgerow technology for sustainable slope agriculture in the Loess Plateau*. *Agriculture, Ecosystems & Environment*, 295, 106918.
- Chen, S., Wang, Y., & Zhao, W. (2020). *Erosion control using straw mulching in semi-arid hilly areas*. *Soil & Tillage Research*, 199, 104566.
- Datta, R., Ghosh, S., & Paul, S. (2024). *Climate resilience through indigenous practices: A study in the Chittagong Hill Tracts*. *Environmental Research Communications*, 6(2), 025007.
- FAO. (2020). *Soil erosion: The greatest challenge to sustainable soil management*. Food and Agriculture Organization of the United Nations.
- IPCC. (2021). *Climate Change 2021: The Physical Science Basis*. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.
- Islam, M. S., Hossain, M. B., & Sultana, N. (2021). *Soil erosion risks in the hill regions of Bangladesh under changing climatic conditions*. *Sustainability*, 13(4), 2089. <https://doi.org/10.3390/su13042089>
- Misbahuzzaman, K. (2016). *Forest-dependent livelihoods and land use in the CHT region: Policy perspectives*. *South Asian Forestry Journal*, 10(2), 87–96.

EXPT. No. 3

TITLE: ANALYZING THE PERFORMANCE OF *PIPER CHABA* (CHUI JHAL) AS AN AGROFORESTRY PRACTICE IN THE CONTEXT OF CHATTOGRAM HILL TRACTS

Abstract

Piper chaba (Chui Jhal) is an economically valuable spice crop with medicinal properties and growing market demand in Bangladesh. This study examined its growth performance under different agroforestry systems in the Chattogram Hill Tracts. A field trial was conducted at the Soil Conservation and Watershed Management Centre, Bandarban, using a completely randomized design with 15 replications and four treatments: Mango, Jackfruit, Gamari as supporting plants, and a control without support. Growth parameters were recorded at six and 18 months, followed by statistical analysis (ANOVA, DMRT, LSD). After 18 months, vines supported by Mango showed the greatest growth with mean plant height of 974.93 cm, 482.07 leaves/plant, and stem diameter of 11.36 mm, significantly outperforming Jackfruit (795.6 cm, 365.27 leaves, 8.44 mm), Gamari (570.47 cm, 303.93 leaves, 7.72 mm), and the control (266.2 cm, 244.87 leaves, 8.57 mm) ($p < 0.001$). Early growth differences were minor, but long-term monitoring revealed pronounced treatment effects. Findings confirm that Mango is the most suitable companion species for *Piper chaba*, enhancing growth and yield performance. These results highlight the potential of *Piper chaba*-based agroforestry to improve farmer income, conserve soil, and promote sustainable land use in the hill regions of Bangladesh.

Introduction

Chui Jhal (*Piper chaba* H.) is a pungent vegetable belonging to the Piperaceae family, commonly utilized in the southern region of Bangladesh, West Bengal, and Tripura in India. It is also recognized as Java long pepper or Choi Jhal, and it thrives in warmer regions of Asia, including Sri Lanka, Malaysia, Indonesia, and Singapore (1) (2) Chui Jhal is widely utilized as a spice in popular dishes, including meat, fish, and mutton curry, owing to its pungent and flavorful taste. This creeper type flowering vine from the Piperaceae family spreads on the ground and may also grow around large trees, making it a year-round additive spice for various culinary delights. In Bangladesh, Chui Jhal is considered a relatively costly spice, with its roots being more expensive than the stems due to their more potent aroma. (25)

Chui Jhal plant possesses numerous medicinal properties and can be beneficial in treating various ailments such as bronchitis, asthma, colic pain, piles, colic, gastralgia and dyspepsia. (3) (4)

Each part of the Chui Jhal plant, including the leaves, stems and fruits, contains active medicinal compound (16)

The aerial parts of this plant have shown various beneficial properties, including antibacterial, anti-diarrheal, carminative, anti-hypertensive, diuretic, stimulant, analgesic, expectorant, and smooth muscle relaxant effects. (5) (6) (7) (8)

The primary phytochemical constituents of *Piper chaba* Hunter are isoflavanons and alkaloids, which contribute to its main pharmacological activities such as antioxidant, antimicrobial, anti-inflammatory, cytotoxic, and hypolipidemic effect (9)

Piper chaba contains a significant alkaloid that exhibits antimycobacterial activity (10) along with various pharmacological effects like antihyperlipidemic (11), antiandrogenic (12), immunoregulatory (13), and antidepressant (14) properties. Additionally, the fruits of *Piper chaba* are used for their gastro-protective, anti-flatulent, appetizing, expectorant, anti-fungal, and anti-tussive properties. They are also known for their cholesterol-lowering effects (15).

The ethanolic fruit juice of *Piper chaba* has demonstrated erythropoietic effects (18) as well as central nervous system depressant and anxiolytic effects. (19). The stem of *Piper chaba* is utilized to alleviate post-delivery pain in mothers and is also beneficial for treating rheumatic pains and diarrhea. (20)

Natural resource degradation in modern agriculture, especially soil and water, threatens sustainability due to reduced productivity, profits, ecological imbalances, and environmental security. Agroforestry offers a viable solution for maintaining sustainable agriculture. (17)

Agroforestry's potential is often studied through its biophysiological aspects, cost-benefit analysis, and impact on poverty reduction. Research in CHT revealed that agroforestry interventions boosted farmers' income by creating jobs, selling farm products, and improving ecological conditions through reduced soil erosion, increased tree coverage, and enhanced soil fertility. (24)

Another study in the Chinai union of Rajarhat Upazila, Kurigram district, Bangladesh, surveyed 105 *Piper chaba* farmers to evaluate the effects of an agroforestry system on their livelihoods. By providing a consistent supply of food, fruit, timber, fodder, and fuelwood, this agroforestry approach significantly enhanced the sustainability of their livelihoods. It is believed that this practice strengthens farmers' livelihood assets, with the most improvement seen in natural capital and the least improvement in social capitals. (26)

Agroforestry systems are widely acknowledged as an integrated approach to sustainable land use, offering benefits not only in climate change mitigation and adaptation but also in various other aspects. (27)

Combining agroforestry with Climate-Smart Agriculture (CSA) holds the potential to address multiple concerns, including soil health, resource allocation, carbon sequestration, biodiversity, water management, and food security, leading to significant progress in these areas. (28)

Spice crop-based agroforestry systems, like the Choi Jhal (*Piper chaba*)-based system, are commonly integrated into home gardens. These agroforestry practices serve as valuable sources of fuelwood and charcoal. Moreover, agroforestry practitioners reduce their expenses, dependency, and time spent gathering fuelwood. For vulnerable food producers, agroforestry can enhance farm income and crop resilience (29)

By adopting this approach, one can enhance resilience to climate change while simultaneously improving access to food, livelihood opportunities, health, and environmental stability (30)

Farmers in the Kurigram district have observed that *Piper chaba* is a highly lucrative and cost-effective crop, primarily because of its high market value and low production cost (31)

Rasul and Thapa evaluated the financial and economic benefits of agroforestry in the Chittagong Hill Tracts, showing that economic returns from agroforestry were better than from shifting cultivation (jhum) (32)

Adoption of sustainable agricultural technologies is very significant due to the global climate crisis. Due to soil erosion and wrong agricultural practices in the hills, on the one hand the living standards of the people living in the hills are decreasing and on the other hand we are losing the precious soil of the hills. Sustainable agriculture in the hills is possible through the practice of agroforestry. Chui Jhal is recognized as an economically viable spice in southwestern and northern regions of Bangladesh. Chui Jhal-based agroforestry has great potential in the hills.

Objectives:

1. To assess the growth and productivity of *Piper chaba* in agroforestry systems in Chattogram Hill Tracts
2. To analyze the economic viability and profitability of incorporating *Piper chaba* in agroforestry practices

Materials and Methods

The study is being conducted at the research field of the Soil Conservation and Watershed Management Centre in Bandarban to evaluate the performance and economic viability of Chaba germplasm (*Piper chaba*) in the agroforestry system of Chattogram Hill Tracts. The experimental site represents the agroecological zone (AEZ)-29, which is recognized as the Northern and Eastern Hill region. Germplasm of Chui Jhal was collected from Khulna. Saplings were collected and transplanted near different tree species such as *Gmelina arborea*, *Mangifera indica*, and *Artocarpus heterophyllus* to provide support for the creeping growth habit of Chui Jhal. Chui Jhal is being cultivated as a vine crop on these supporting trees. Fertilizers and manures are being applied according to the recommendations in the fertilizer guide. Light irrigation is being provided just after transplantation to ensure optimum soil moisture for normal growth and development. The crop is being managed using the recommended package of intercultural practices.

To ensure the proper growth of all supporting trees, necessary management activities such as pruning, watering, cleaning, weeding, and fertilizing are being performed in a timely manner. The growth and yield performance of the supporting trees are being recorded. The Chui Jhal saplings have been then planted beside the supporting plants in pits filled with manures and fertilizers. Pits were prepared one week before plantation. Waterlogging Condition will be avoided for all of them.

Completely randomized design with thirty replications is being used for all crops in association with the supporting trees. Four treatments will be employed, including Mango as supporting plants (Treatment 1), Gamari as supporting plants (Treatment 2), Jackfruit as supporting plants (Treatment 3), and no supporting plants (Treatment 4).

Data collection is being carried out for the growth parameters and yield parameters of Chui Jhal both inside and outside the agroforestry system. Observations on different morphological and yield attributing characters such plant height, number of leaves per plant, leaf length, leaf breadth, branch number, will be recorded for Chui Jhal. The average total yield value of a supporting tree will be estimated. Statistical analysis will be performed on all recorded data using the CRD design to determine the statistical significance of the experimental results. The means for all recorded data of the studied multistoried agroforestry system were calculated and analyzed statistically by using R Programming software package to find out the statistical significance of the experimental results for all growth and yield parameters were performed. The mean differences were evaluated by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984) at 1% level of significance and also by Least Significance Difference (LSD) test.

Result & Discussion

Table 1: Data of first six months

Treatment	Plant Height(cm)	Leaves/Plant	Stem Diameter(mm)
No Bearing Plant	111.66 a	55.40 a	6.74 a
Gamari	134.20 a	27.13 b	4.58 b
Jack fruit	99.93 a	17.40 c	4.86 b
Mango	97.60 a	27.80 b	6.75 a
Mean	110.85	31.93	5.739
CV	48.26637	39.42	25.24288
F value	1.4683	25.2925	9.8204
P	0.2369	1.656e-09 ***	4.955e-05 ***
Level of significance		***	***

Significance codes: ****' 0.001, **' 0.01, *' 0.05.
Means in column followed by the different letters are significantly different by DMRT at P< 0.001

Table 2: ChuiJhal Growth Parameters after 18 Months (with DMRT Group Letters)

Treatment	Plant Height (cm)	Leaves/Plant	Stem Diameter (mm)
Mango	974.93 ± 162.51 a	482.07 ± 61.95 a	11.36 ± 1.48 a
Jack fruit	795.6 ± 105.79 b	365.27 ± 25.45 b	8.44 ± 1.42 c
Gamari	570.47 ± 75.14 c	303.93 ± 47.11 c	7.72 ± 1.49 d
Without bearing plant	266.2 ± 70.94 d	244.87 ± 41.28 d	8.57 ± 1.67 b
Mean	651.8	349.03	9.02
CV (%)	44.13	28.42	22.58
F value	116.1523	73.3629	16.7893
P value	5.099e-24	2.16e-19	6.701e-08
Significance levels	***	***	***

Significance codes: ****' 0.001, **' 0.01, *' 0.05.
Means in column followed by the different letters are significantly different by DMRT at P< 0.001

The 18-month evaluation of *Piper chaba* growth under different companion plant treatments revealed statistically significant variation across all measured parameters, indicating the substantial influence of support species on vine development within an agroforestry system.

Plant Height

Significant differences (ANOVA, $F = 116.15$; $p < 0.001$) were observed in vine height across the four treatments. The tallest vines were consistently associated with one particular companion species, which significantly outperformed all other treatments as confirmed by post hoc analysis (DMRT, group 'a'). This suggests that the structural and microclimatic advantages provided by this species—possibly related to optimal light penetration, humidity moderation, or physical support—substantially promote vertical growth in *P. chaba*. The shortest vines were recorded in the control treatment (without a bearing plant), highlighting the critical role of a suitable host in supporting upward growth.

Leaf Production

Leaf number per plant also varied significantly among treatments ($F = 73.36$; $p < 0.001$), following a similar trend to plant height. The highest leaf counts were observed in association with the same species that promoted the greatest height, suggesting a synergistic effect of the host on both vertical and foliar development. Treatments with moderate or no support showed reduced leaf production, likely due to suboptimal growing conditions and reduced light exposure, which can limit photosynthetic capacity and vegetative expansion.

Stem Diameter

Differences in stem diameter were also statistically significant ($F = 16.79$; $p < 0.001$), though the ranking of treatments varied slightly from those observed in height and leaf number. The companion species that led in height and leaf production also resulted in the thickest stems, which may reflect enhanced structural support and nutrient allocation. Interestingly, one non-dominant treatment exhibited relatively moderate stem development despite lower values for other growth parameters, suggesting that certain tree-vine interactions may selectively influence specific aspects of morphology.

Biological Variability

The coefficient of variation (CV) for plant height (44.13%), leaf number (28.42%), and stem diameter (22.58%) indicated moderate to high variability among individual plants within treatments. This is characteristic of field-based agroforestry trials, where interactions between biotic and abiotic factors contribute to heterogeneous plant responses.

Temporal Dynamics and Long-Term Insights

Comparison with the initial six-month data reveals an important temporal trend: early observations showed minimal or no statistically significant differences across treatments, while the extended 18-month monitoring period captured pronounced and consistent growth differentials. This progression underscores the necessity of long-term assessment in agroforestry research. Short-term studies may fail to detect the cumulative effects of interspecific interactions

and environmental feedbacks, which are essential for accurate evaluation of companion plant suitability.

Implications for Agroforestry Practice

The findings clearly demonstrate that companion species selection plays a pivotal role in the growth and productivity of *Piper chaba* vines. Trees that provide a supportive physical structure, favorable microclimatic conditions, and possibly complementary root zone interactions offer the greatest potential for enhancing vine performance. Conversely, the absence of a bearing plant or selection of suboptimal hosts can significantly limit growth. These insights are critical for the design and management of integrated agroforestry systems aiming to optimize both crop yield and ecological sustainability.

Conclusion

The 18-month study of *Piper chaba* cultivated under different companion plant treatments clearly demonstrates that the choice of support species significantly affects vine growth and development. Among the evaluated treatments, the use of Mango as a companion plant consistently promoted superior performance across all key parameters—plant height, leaf production, and stem diameter—indicating its strong potential as an optimal host in agroforestry systems. Jackfruit showed moderate compatibility, while Gamari and the control (no bearing plant) provided limited benefits.

These results emphasize the importance of species-specific interactions in designing effective agroforestry models. The significant divergence in growth performance over time also highlights the necessity of long-term evaluations to capture the full impact of companion planting on perennial vine crops like *P. chaba*. Integrating well-suited support species not only enhances crop productivity but also contributes to the ecological and structural integrity of mixed cropping systems.

Future research should explore the underlying physiological and ecological mechanisms driving these interactions, as well as assess the economic and environmental outcomes of different tree–vine combinations under varied agroclimatic conditions.

References

1. Bhandari SPS, Babu UV, Garg (Late)H. S. A lignan from *Piper chaba* stems. *Phytochemistry*. 1998 Apr 1;47(7):1435–6.
2. Basu B.D KKR. *Indian Medicinal Plants*. 3rd ed. International Book Distributors; 1987. 2130–2131 p.
3. N CR, Chopra IC. *Indigenous Drugs Of India*. Academic Publishers; 1994. 868 p.

4. M.K.S. Krishnan. The useful plants of India. CSIR, New Delhi, India,: Publication and Information Directorate; 1986.
5. Ghani A. Medicinal Plants of Bangladesh. 2nd ed. Dhaka: Medicinal Plants of Bangladesh; 2003. 267–268 p.
6. Yusuf M., Chowdhury J.U., Begum D.J. Medicinal Plants of Bangladesh. Bangladesh Council of Scientific and Industrial Research; 1994. 192 p.
7. Rahman MdA, Amin A, Shekher H. Alkamide and Lignan from the Stem Bark of Piper chaba (Piperaceae). Dhaka University Journal of Pharmaceutical Sciences. 2007 Jun 14;3.
8. Sarfaraz S., Najam R., Hassan F. Evaluation of Erythropoietic effects of ethanolic extract of fruit of Piper chaba in albino rabbits. International Journal of Pharmaceutical Research and Bioscience. 2014;3:759–62.
9. Haque E, Roy AC, Rani M. Review on Phytochemical and Pharmacological Investigation of Piper chaba Hunter. 2018;9(3).
10. Jin J, Zhang J, Guo N, Feng H, Li L, Liang J, et al. The plant alkaloid piperine as a potential inhibitor of ethidium bromide efflux in Mycobacterium smegmatis. J Med Microbiol. 2011 Feb;60(Pt 2):223–9.
11. Jin Z, Borjihan G, Zhao R, Sun Z, Hammond GB, Uryu T. Antihyperlipidemic compounds from the fruit of Piper longum L. Phytother Res. 2009 Aug;23(8):1194–6.
12. Hirata N, Tokunaga M, Naruto S, Iinuma M, Matsuda H. Testosterone 5 α -reductase inhibitory active constituents of Piper nigrum leaf. Biol Pharm Bull. 2007 Dec;30(12):2402–5.
13. Pradeep CR, Kuttan G. Piperine is a potent inhibitor of nuclear factor-kappaB (NF-kappaB), c-Fos, CREB, ATF-2 and proinflammatory cytokine gene expression in B16F-10 melanoma cells. Int Immunopharmacol. 2004 Dec 20;4(14):1795–803.
14. Lee SA, Hwang JS, Han XH, Lee C, Lee MH, Choe SG, et al. Methylpiperate derivatives from Piper longum and their inhibition of monoamine oxidase. Arch Pharm Res. 2008 Jun;31(6):679–83.
15. Chojnowska I, Kucharczyk K, Myszkowski L, Radzikowski A, Szymańska K. Blood serum proteins in experimental chronic liver injury in rabbit. Patol Pol. 1979;30(1):71–88.
16. Islam S, Roy AC, Haque M, Hossain S, Abu M. PHYTOCHEMICAL STUDIES ON PIPER CHABA HUNTER. International Journal of Pharmaceutical Sciences and Research. 6.

17. Sireeratawong S, Itharat A, Lerdvuthisopon N, Piyabhan P, Khonsung P, Boonraeng S, et al. Anti-Inflammatory, Analgesic, and Antipyretic Activities of the Ethanol Extract of *Piper interruptum* Opiz. and *Piper chaba* Linn. *ISRN Pharmacol.* 2012 Mar 18;2012:480265.
18. Lumb PJ, Slavin BM. Determination of serum cholesterol concentration in the presence of ascorbate. *J Clin Pathol.* 1993 Mar;46(3):283–4.
19. M. Yusuf, J.U. Chowdhury, M.A. Wahab, J. Begum. Medicinal plants of Bangladesh, BCSIR, Dhaka, Bangladesh. 1994;193.
20. Daware MB, Mujumdar AM, Ghaskadbi S. Reproductive toxicity of piperine in Swiss albino mice. *Planta Med.* 2000 Apr;66(3):231–6.
21. Piyachaturawat P, Glinsukon T, Toskulkao C. Acute and subacute toxicity of piperine in mice, rats and hamsters. *Toxicol Lett.* 1983 May;16(3–4):351–9.
22. Dogra RKS, Khanna S, Shanker R. Immunotoxicological effects of piperine in mice. *Toxicology.* 2004 Mar 15;196(3):229–36.
23. Kumar A, Hasanain M, Singh R, Verma G, Meena D, Mishra R, et al. Role of Agroforestry Measures for Soil and Water Conservation. 2020 Mar 1;
24. Nath TK, Inoue M, Myant H. Small-scale agroforestry for upland community development: a case study from Chittagong Hill Tracts, Bangladesh. *Journal of Forest Research.* 2005 Dec 1;10(6):443–52.
25. Islam MdR, Mehedi MdNH, Ara R, Obaidullah AJM, Moniruzzaman Md, Aktar N. Evaluation of Different Chaba (*Piper chaba*) Germplasm for Growth and Yield Performances. *APRJ.* 2021 Feb 24;23–9.
26. Hemel SAK, Hasan MK, Wadud MdA, Akter R, Roshni NA, Islam MdT, et al. Improvement of Farmers' Livelihood through Choi Jhal (*Piper chaba*)-Based Agroforestry System: Instance from the Northern Region of Bangladesh. *Sustainability.* 2022 Dec 1;14(23):16078.
27. Cubbage F, Balmelli G, Bussoni A, Noellemeyer E, Pachas AN, Fassola H, et al. Comparing silvopastoral systems and prospects in eight regions of the world. *Agroforest Syst.* 2012 Nov 1;86(3):303–14.
28. Newaj R, Chavan S, Prasad R. Climate-smart agriculture with special reference to agroforestry. *Indian Journal of Agroforestry.* 2015 Jun 1;17:96–108.
29. Waldron A, Garrity D, Malhi Y, Girardin C, Miller D, Seddon N. Agroforestry Can Enhance Food Security While Meeting Other Sustainable Development Goals. *Tropical Conservation Science.* 2017 Aug 1;10:194008291772066.

30. Duffy C, Toth GG, Hagan RPO, McKeown PC, Rahman SA, Widyaningsih Y, et al. Agroforestry contributions to smallholder farmer food security in Indonesia. *Agroforest Syst.* 2021 Aug 1;95(6):1109–24.
31. Piper chaba vines lucrative for Kurigram farmers | The Daily Star [Internet]. [cited 2023 Aug 6]. Available from: <https://www.thedailystar.net/country/piper-chaba-vines-lucrative-kurigram-farmers-1443340>
32. Rasul G, Thapa GB. Financial and economic suitability of agroforestry as an alternative to shifting cultivation: The case of the Chittagong Hill Tracts, Bangladesh. *Agricultural Systems.* 2006 Nov 1;91(1):29–50.

EXPT. No. 4

TITLE: PERFORMANCE ASSESSMENT OF KHASIA BETEL LEAF AS AN AGROFORESTRY PRACTICE IN CHATTOGRAM HILL TRACTS.

Abstract

The cultivation of Khasia betel leaf (*Piper betle L.*) represents a unique tree-based agroforestry practice that supports both livelihoods and ecological sustainability in the hilly regions of Bangladesh. This study was conducted at the Soil Conservation and Watershed Management Centre, Bandarban, within Agroecological Zone-29, to evaluate the growth performance and productivity of Khasia betel leaf under different supporting tree species. Using a completely randomized design with fifteen replications, four treatments were tested: mango (*Mangifera indica*), litchi (*Litchi chinensis*), jackfruit (*Artocarpus heterophyllus*), and control (without supporting trees). Growth and yield parameters including plant height, stem diameter, and number of leaves per plant were recorded over an 18-month period. Results revealed highly significant treatment effects, with mango trees emerging as the most compatible and productive host, supporting superior vine growth (plant height 945.33 cm, stem diameter 12.6 mm, and 1071 leaves/plant). Litchi provided moderate benefits, particularly for leaf production, while jackfruit and control treatments performed comparatively lower. These findings underline the importance of host tree selection in optimizing vine performance, with mango offering the most favorable canopy structure and microclimatic conditions. The results confirm that Khasia betel leaf cultivation in agroforestry systems is not only agronomically viable but also economically promising for sustainable hill farming in the Chattogram Hill Tracts. Long-term monitoring and economic analysis are recommended to further refine management practices and enhance farmer profitability while conserving hill ecosystems.

Introduction

Piper betle L. is a widely familiar perennial creeping plant that belongs to the Piperaceae family. It has its origins in central and eastern Peninsular Malaysia but can also be found in East Africa and various tropical Asian countries (1)

It serves as a profitable cash crop primarily grown in countries such as India, Bangladesh, Sri Lanka, Thailand, Taiwan, Malaysia, and a handful of other nations in Southeast Asia (2) (3)

The term "green gold of India" is attributed to the betel vine due to its role as a livelihood source for nearly 20 million individuals. These people rely on the plant for their earnings, which come from various stages like cultivating, transporting, managing, processing, and arranging betel leaves (4) (5)

The betel vine, often asexually propagated, features multiple cultivars with male and female plants. Worldwide, there are about a hundred betel plant varieties, with 40 exclusives to India. Of these, 30 are identified in West Bengal and Bangladesh. (6)

P. betel is recognized by diverse names across the globe in various countries, yet 'Paan' is predominantly employed in India, Pakistan, Nepal, and Bangladesh. (7)

Betel quid consumption is a widespread tradition in multiple nations, valued for its natural revitalizing properties that help combat oral malodor. The International Agency for Research on Cancer conducted a survey, approximating a global user count ranging between 200 to 600 million individuals. (8) (9)

In Bangladesh, approximately 30% of adults partake in betel quid chewing, while on a global scale, this practice is observed at around 10-20% (10) (11)

In addition to its socio-cultural and ceremonial significance, betel quid possesses antacid, carminative, and calming properties. These attributes aid in digestion, eliminate oral malodor, enhance taste and appetite, and fortify dental health. (12)

P. betle finds roles in traditional medicine systems including Ayurveda, Chinese medicine, and West Indies/Latin American remedies. Ayurveda employs it in formulations like Lokantha Rasa, Puspadhava Rasa, and others to treat diverse conditions. Betle leaf juice is a common Ayurvedic enhancer in herbal combinations. (13)

In the realm of tradition, the plant is employed to heal various maladies like colds, bronchial asthma, cough, stomach pain, and rheumatism. It also serves as a remedy for conditions like boils, halitosis, constipation, conjunctivitis, gum inflammation, abscesses, and cuts, whether contagious or non-contagious in nature. (14)

The intense, sharp scent emitted by betel leaves originates from the presence of abundant terpenes and phenols within its essential oil. (15,16)

Various phytochemicals found in betel plants include chavicol, chavibetol, hydroxychavicol, eugenol, estragole, methyl eugenol, hydroxycatechol, α -pinene, caryophyllene, β -pinene, 1,8-cineol, and similar compounds. (17)

Numerous research studies have demonstrated the effectiveness of the bioactive components within essential oils as antioxidants for deterring cancer, inflammation, neurodegenerative ailments, and as agents with qualities like antimutagenic, antifertility, antilipidemic, antiglycemic, and cardioprotective properties. (18) (19)

The essential oil derived from betel leaves also possesses the ability to counter bacterial, protozoan, and fungal infections, as well as repel insect assaults. (20)

Well-prepared betel quid remains a valued mouth freshener and mild energizer, commonly served during social, cultural, and religious occasions. This tradition of offering betel quid to guests signifies respect and cultural heritage, particularly in countries like Bangladesh, Burma, China, India, Indonesia, Malaysia, Nepal, Pakistan, Philippines, South Africa, Sri Lanka, and Thailand. These societies have a long history of chewing betel leaves with various natural ingredients, emphasizing its unique cultural significance (21)

Research validates the protection of tree diversity facilitated by betel leaf cultivation practiced by the Khasia community in the Sylhet district. (22)

Betel cultivation is extensive in various regions of Bangladesh including Sylhet, Moulvibazar, Jessore, Khulna, Kustia, Bagerhat, Satkhira, Narail, Bhola, Barisal, Faridpur, Rajshahi, Rangpur, Gaibanda, Pabna, Cox's Bazar, and the broader Chittagong district. (23)

In Bangladesh, betel vines are divided into plain land betel-leaf (boroj pan) and tree-betel-leaf (gach pan) based on cultivation practices. The Khasia people in the greater Sylhet district cultivate tree betel leaf, known as Khasia pan. Additionally, nearby Bengali residents also cultivate Khasia betel leaf around their homes. (24)

Over 80% of the Khasia population relies on livelihoods tied to the cultivation of tree-based betel-leaf. (25)

Cultivation of betel-leaf on trees stands as a significant agroforestry practice in Bangladesh, and it is ecologically and economically sustainable (26). In forested regions, this practice involves using forest trees as support for climbing betel vines, creating a cash-oriented production system. Although labor-intensive and localized, it holds significance for the Khasia community's agroforestry and biodiversity conservation efforts. (27)

A study in North-eastern Bangladesh's forests revealed sustainable betel leaf production within agroforestry. Positive attributes like disease control, soil fertility, profitability, and cultural acceptance thrive under traditional management. Betel leaf sales sustain livelihoods, aided by villagers conserving forest resources through collaborative efforts. (28)

The experience of economic development and forest conservation of Khasia community through cultivation of khasia betel leaf in the hilly areas of the north-eastern part of the country shows that it is possible to improve the quality of life of the tribals of Chittagong Hill Tracts and preserve the hilly soil and forest by cultivating khasia betel leaf.

Objectives:

1. To assess the growth and productivity of Khasia Betel Leaf plants in an agroforestry system
2. To evaluate the economic viability of Khasia Betel Leaf cultivation in Chattogram Hill Tract

Materials and methods:

The experiment is being held at the research area of Soil Conservation and Watershed Management Centre in Bandarban. The geographical location of this area is N 22° 10' 30'' and E 92° 11' 14''. The present study focuses on an experimental site representing agroecological zone (AEZ)-29, acknowledged as the Northern and Eastern Hill region. The germplasm of Khasia betel leaf (*Piper betle*) was collected from Moulvibajar and transplanted adjacent to diverse tree species such as *Litchi chinensis*, *Mangifera indica*, and *Artocarpus heterophyllus*, aimed at providing structural support for the creeping growth habit of Khasia betel leaf. The Khasia betel leaf is being cultivated as a vine crop utilizing these supporting trees. Fertilizers and manures are being applied as per the recommendations outlined in the fertilizer guide. After transplantation, light irrigation was administered to maintain optimal soil moisture for ensuring normal growth and development. The recommended package of intercultural practices is being implemented for managing the crop. The avoidance of waterlogging is crucial, as excessive moisture accumulation can have adverse impacts on the growth and overall health of the betel vines. To mitigate this potential issue, proper drainage measures are being implemented. The planting pits were designed and prepared in a manner that facilitates efficient water drainage, thereby minimizing the risk of waterlogging. The betel vine plantation was done in June. Prior to planting, meticulous weed and grass clearance was carried out in the base of the supporting trees. Subsequently, planting pits were carefully prepared, adhering to specific dimensions. These pits measure approximately 6 to 7 inches in depth, 1 foot in length, and 6 inches in width. During the planting process, the seedling was positioned in the pit in such a way that two nodes were buried beneath the soil surface, while one node remains exposed above the ground.

To fill the pit, loose mud was carefully added without any compacting. Two pits were created around a supporting tree. At least three years old cuttings were taken from healthy vines. After planting, the seedlings are being kept Weed-free to prevent shoot suppression. Debranching (2-3 weeks after planting) was done in supporting plants.

Completely randomized design with fifteen replications is being used for all crops in association with the supporting trees. The experiments involved four distinct treatments: Treatment 1 using mango as supporting plants, Treatment 2 utilizing litchi as supporting plants, Treatment 3 involving jackfruit as supporting plants, and Treatment 4 without any supporting plants. Appropriate and timely application of manures and fertilizers will be confirmed after testing the soil nutrients contents.

The amount of growth such as leaf size, length of plants, diameter of plant as well as compatibility with host plant will be measured over a period.

Harvesting, sampling, and data collection are being conducted to assess the growth parameters and yield parameters of the betel leaf in the agroforestry system. For betel leaf, the edible portion of individual plants will be recorded both inside and outside the agroforestry system.

Observations on different morphological and yield-related characteristics such as germination percentage, days to germination, plant height, number of leaves per plant, leaf length, stem diameter are being documented for betel leaf.

The average total yield value of a supporting tree will be estimated for various crop combinations in the multistoried agroforestry system.

Statistical analysis will be performed on all recorded data using the Completely randomized design to determine the statistical significance of the experimental results. The means for all recorded data of the studied multistoried agroforestry system were calculated and analyzed statistically by using R Programming software package to find out the statistical significance of the experimental results for all growth and yield parameters were performed. The mean differences were evaluated by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984) at 1% level of significance and also by Least Significance Difference (LSD) test.

Results & Discussion

Table 1: After six months

Treatment	Plant Height(cm)	Leaves/Plant	Stem Diameter(mm)
No Bearing Plant	247.40 a	54.00 a	5.72 a
Jack fruit	98.13 c	15.66 b	4.09 b
Litchi	185.06 b	28.13 b	4.42 b
Mango	132.60 bc	22.33 b	4.36 b
Mean	165.8	30.03333	4.6505
CV	46.04028	57.44945	17.85272
F value	10.9067	14.16	11.611
Pr	1.996e-05 ***	1.603e-06 ***	1.129e-05 ***
Level of significance	***	***	***
Significance codes: '***' 0.001, '**' 0.01, '*' 0.05.			
Means in column followed by the different letter are significantly different by DMRT at P< 0.001			

Table 2 Khasia Pan Growth Summary after 18 Months (with DMRT Group Letters)

Treatment	Stem Diameter (mm)	Leaves/Plant	Plant Height (cm)
Mango	12.6 a	1071 a	945.33 a
Without bearing plant	11.36 b	554.6 c	911.46 ab
Jack fruit	9.90 c	681.2 b	882.53 b
Litchi	8.4 d	723 b	830.53 c
Mean	10.58 d	757.45	892.4667
SD	1.79	220.9544	48.61513
CV%	16.95452	29.17083	5.447277
value	122.6	135.3	12.78
Pr	5.01E-07	3.41E-07	0.00203
Significance	***	***	**

Significance codes: ***' 0.001, **' 0.01, *' 0.05.
Means in column followed by the different letters are significantly different by DMRT at P< 0.001

The 18-month evaluation of Khasia betel leaf growth parameters under different agroforestry systems showed statistically significant differences among treatments (Table 2). The presence and type of supporting tree species had a pronounced effect on stem diameter, plant height, and number of leaves per plant.

Mango emerged as the most effective supporting plant, significantly enhancing all measured growth parameters — stem diameter (12.6 mm), number of leaves per plant (1071), and plant height (945.33 cm) — far surpassing other treatments. This result contrasts with the earlier 6-month findings, where mango was less prominent. Over time, mango's canopy structure and possibly its compatibility in terms of microclimate, shade regulation, and root interactions may have created a more favorable environment for vine growth.

Litchi also showed considerable promise, particularly in leaf development (723 leaves/plant), consistent with the previous observation. However, it lagged behind mango in height and stem diameter, possibly due to its smaller crown and lighter shade provision, which may benefit leaf growth but limit vertical extension and vine thickness.

Jackfruit and the non-bearing plant (control) systems produced moderate results. While jackfruit outperformed litchi in stem diameter (9.90 mm vs 8.4 mm), it lagged behind in leaf number. The non-bearing system still supported decent plant height (911.46 cm), indicating that in the absence of competition, vines invest in vertical growth, though leaf and stem development were compromised due to lack of physical support and possibly higher sun exposure stress.

Statistical tests confirmed high significance for all parameters: stem diameter ($p = 5.01E-07$), leaves per plant ($p = 3.41E-07$), and plant height ($p = 0.00203$), indicating strong treatment effects. The coefficient of variation was lowest in plant height ($CV = 5.45\%$), suggesting more uniformity across replicates, while leaves per plant showed higher variability ($CV = 29.17\%$).

These extended observations affirm the critical influence of host plant selection in Khasia betel cultivation. The superiority of mango trees over time highlights the importance of matching vine and support tree physiology for optimized productivity in hill agroforestry systems.

Conclusion:

The 18-month study underlines the agronomic and ecological viability of cultivating Khasia betel leaf in agroforestry systems in the Chattogram Hill Tracts. While early-stage growth favored non-bearing plants due to minimal competition, longer-term results clearly demonstrate that mango trees serve as the most compatible and productive support species for Khasia betel cultivation. They facilitate superior vine development in terms of height, stem diameter, and foliage density.

Litchi also holds potential, particularly for enhancing foliage, which is the commercially valuable part of the crop. However, its performance remains secondary to mango. The findings provide critical insights into long-term vine-tree interactions and suggest that appropriate tree species selection can substantially improve betel leaf productivity and economic returns.

Future research extending beyond 18 months is encouraged to assess long-term yield stability, pest dynamics, and soil health under different tree supports. Additionally, economic analysis of input-output ratios across treatments will help further guide the best practices in hill agroforestry design involving Khasia betel leaf cultivation.

References:

1. Madhumita M, Guha P, Nag A. Extraction of betel leaves (*Piper betle* L.) essential oil and its bio-actives identification: Process optimization, GC-MS analysis and anti-microbial activity. *Industrial Crops and Products*. 2019 Oct 5;138:111578.
2. Bajpai V, Sharma D, Kumar B, Madhusudanan KP. Profiling of *Piper betle* Linn. cultivars by direct analysis in real time mass spectrometric technique. *Biomed Chromatogr*. 2010;24(12):1283-1286.
3. Sudjaroen Y. Evaluation of ethnobotanical vegetables and herbs in Samut Songkram province. *Procedia Engineering*. 2012 Jan 1;32:160–5.

4. Das S, Parida R, Sriram Sandeep I, Nayak S, Mohanty S. Biotechnological intervention in betelvine (*Piper betle* L.): A review on recent advances and future prospects. *Asian Pacific Journal of Tropical Medicine*. 2016 Oct 1;9(10):938–46.
5. Jane NS, Deshmukh MAP, Joshi MMS. Review Of Study Of Different Diseases On Betelvine Plant and Control Measure. 2014;3(3).
6. Khan, A. A., Bhatnagar, S. P., Sinha, B. N., & Lal, U. R. (2013). Pharmacognostic specifications of eight cultivars of *Piper betle* from eastern region of India. *Pharmacognosy Journal*, 5(4), 176-183. <https://doi.org/10.1016/j.phcgj.2013.07.002>
7. Guha P, Nandi S. Essential oil of betel leaf (*Piper betle* L.): a novel addition to the world food sector. In Malik, S ed. *Essential oil research*. Springer; 2019:149-196
8. Jeng JH, Chang MC, Hahn LJ. Role of areca nut in betel quid-associated chemical carcinogenesis: current awareness and future perspectives. *Oral Oncology*. 2001 Sep 1;37(6):477–92.
9. Yoonus J, Resmi. R, Beena B. Greener nanoscience: *Piper betle* leaf extract mediated synthesis of CaO nanoparticles and evaluation of its antibacterial and anticancer activity. *Materials Today: Proceedings*. 2021 Jan 1;41:535–40.
10. Gupta PC, Warnakulasuriya S. Global epidemiology of areca nut usage. *Addiction Biology*. 2002;7(1):77–83.
11. Meerjady S Flora, Mascie-Taylor CG, Rahmanc M. Betel quid chewing and its risk factors in Bangladeshi adults. *WHO South-East Asia Journal of Public Health*. 2012 Apr;1(2):169–81.
12. Islam Q, Matin M. Profitability level of betel leaf (*Piper betle* L.) cultivation in some selected sites of Bangladesh. *Bangladesh J Agric Res*. 2017 Jun 7;42(2):343–51.
13. Taukoorah U, Lall N, Mahomoodally F. *Piper betle* L. (betel quid) shows bacteriostatic, additive, and synergistic antimicrobial action when combined with conventional antibiotics. *South Afr J Botany*. 2016;105:133-140.
14. Gundala SR, Yang C, Mukkavilli R, Paranjpe R, Brahmhatt M, Pannu V, et al. Hydroxychavicol, a betel leaf component, inhibits prostate cancer through ROS-driven DNA damage and apoptosis. *Toxicology and Applied Pharmacology*. 2014 Oct 1;280(1):86–96.
15. Bhagath B, Guha P. Development of novel Sooji Halwa with unique properties of essential oil of betel leaf. *Int J Agric Food Sci Technol*. 2014;5:87-93

16. Bhoite VS, Kamble DK, Patil YN. Effect of different levels of Piper betel leaves on physico-chemical attributes of ice-cream. *Int J Chem Stud.* 2019;7(5):168-171.
17. Arambewela LSR, Kumarathunge KGA, Dias K. Studies on Piper betel of Sri Lanka. *J Natl Sci Foundation Sri Lanka.* 2013;33(2):133-139.
18. Arawwawala L, Arambewela LSR, Ratnasooriya WD. Gastroprotective effect of Piper betle Linn. leaves grown in Sri Lanka. *J Ayurveda Integr Med.* 2014;5(1):38.
19. Chakraborty D, Shah B. Antimicrobial, antioxidative and antihemolytic activity of Piper betel leaf extracts. *Int J Pharm Pharm Sci.* 2011;3(3):192-199
20. Biswas P, Anand U, Saha SC, Kant N, Mishra T, Masih H, et al. Betelvine (Piper betle L.): A comprehensive insight into its ethnopharmacology, phytochemistry, and pharmacological, biomedical and therapeutic attributes. *J Cell Mol Med.* 2022 Jun;26(11):3083–119.
21. Princy PS. AGRONOMY AND AGRO-ECONOMICS OF BETEL LEAF PRODUCTION.
22. Mohiuddin M. AM. Conservation of Tree Diversity through betel-leaf (Piper betle) based Agroforestry in Sylhet. *Bangladesh Journal of Forest Science.* 1995;24(2):49–53.
23. Fila P, Haider MR, Mohiuddin M, Zashimuddin M & Alam MK, Khasia betel-leaf cultivation technique (in Bangla), (Bangladesh Forest Research Institute, Chittagong), 2006, 12.
24. Haider MR, Khair A, Rahman MM, Alam MK. Indigenous management practices of betel-leaf (Piper betle L.) cultivation by the Khasia community in Bangladesh. 2013;12(2).
25. Costa T, Dutta A. The Khasia of Bangladesh; A Socioeconomic survey of Khasia people. Society for Environment and Human Development SEHD), Dhaka, Bangladesh. 2007;59.
26. Alam MK, Ahmed FU, Mohiuddin M. Agroforestry practices in forest land. Agroforestry-farming systems linkages in Bangladesh Dhaka, Bangladesh: BARC-Winrock International Agroforestry and participatory Forestry Research and Training Support Program. 1993;87–122.
27. Bhattee SS, Agroforestry in Auranachai Prodesh, In: Agroforestry in India. Forest Research Institute and Colleges, Dehradun, edited by Mathur RS & Gogate MG, 1994, 22-26.
28. Nath TK, Inoue M. Sustainability Attributes of a Small-Scale Betel Leaf Agroforestry System: A Case Study in North-eastern Hill Forests of Bangladesh. *Small-scale Forestry.* 2009 Sep;8(3):289–304.

EXPT. No. 5
STUDYING PERFORMANCE OF WATER MELON IN RAINY SEASON
AT HILL SLOPES USING SOIL CONSERVATION TECHNIQUE.

Abstract

A study on performance of Watermelon in rainy season at hill slope using Soil Conservation Technique has been taken by Soil Conservation and Watershed Management Centre, Bandarban. Its main objective is to find out the sustainability and challenges of cultivation of watermelon on sloping lands during rainy season. Three types of sloping land like gentle, moderate and steep sloping has been selected for this study. There were three plots on three sloping lands having an equal area. Soil conservation technique like pineapple hedge and Vetiver hedge were introduced following contour. Bamboo made colored pegs were inserted into the soil to estimate the soil erosion hazard. Local bamboos made platforms (Macha) were used for cultivation of watermelon during rainy season. Height yields and lowest soil loss were gained from the managed plot by pineapple hedge and gentle slope. Lowest yields and Height soil loss were gained from the control plot and steep slope. Hedge always plays a vital role on plant growth, crops productivity, no of fruit & weight as well as minimizing of soil erosion. soil conservation technique is must for any agricultural practice on the slopping land. Fungal, bacterial and virus diseases are more during rainy season which affects badly on growing watermelon and its yields and quality. Attract of white flies hampers the production of watermelon during rainy season. Watermelon cultivation is not possible on the hilly areas during the dry season due to lack of water. So it is possible to successfully grown during the rainy season without irrigation.

Introduction

Watermelon (*Citrullus lanatus*) belongs to the family Cucurbitaceae. It is one of the most widely cultivated crops in the world with global production reaching about 89.9 million ton per year. Its centre of origin has been traced to both Kalahari and Sahara desert in Africa and these areas have been regarded as point of diversification to other parts of the world. The crop has wide distribution as a garden crop while as a commercial vegetable production; its cultivation is confined to drier Savanna region of the Nigeria. It is horticultural crop that provide high return and has relatively low water requirement compared to other crops. It is traditional food plant in Africa with potential to improve nutrition, boost food security, foster rural development and support sustainable land cares. Smallholder farmer in different semi-arid zones of the world grow watermelon mostly under rainfed conditions and to lesser suplimental furrow irrigation. Now a day the demand of watermelon is increasingly growing up day by day. *Citrullus lanatus* is an important Cucurbitaceous Vegetable/Fruit in our neighboring country India. It is an excellent desert fruit and its juice contains 92% water along with proteins, minerals and carbohydrates. Now it is going to be extended day by day. In India, Watermelons are mainly cultivated in Maharashtra, Karnataka, Tamil Nadu, Panjab, Rajasthan, Madhya Pradesh and Uttar Pradesh.

The growth and development of watermelon describes the sequential order of the different stages of growth attained by this crop. The growth phase of watermelon includes the emergence stage, vegetative stage, flowering stage, yield formation stage and the ripening stage. However, crop growth and development depends largely on climatic factors such as precipitation, relative humidity, solar radiation, evaporation etc. Each of these climatic factors affects the growth of crops, most especially in the tropics. For instance, the presence or absence of precipitation will have either positive or negative impact on the crop growth and productivity. Climate is also responsible for seasonal variation in the tropic.

A well-drained soil of loamy type is preferred for Watermelon. It is important that soil should be fertile and rich in organic matter. The most suitable P^H range is between 6.0 and 7.0. It is noted that soil should not be water logged in the rainy season. Watermelon is warm season crop and do not withstand even light frost and strong wind. Seed do not germinate below 11⁰ C, optimum germination occurs at 18⁰ C and germination increases with the rise of temperature till 30⁰ C. Watermelon grows best at temperature 18⁰ C - 24⁰ C. It prefers tropical climate with high temperature during fruit development with day temperature of 35⁰ C-40⁰ C. But excess chillness occurs hamper. Cool nights and warm days give better quality fruits in watermelon.

There are many varieties of watermelon like Seminis Apoorva Watermelon, Mayco Super Sakkar Watermelon, Suger Pack Watermelon, Aishwariya Watermelon, Anmol Yellow Watermelon, Arun Watermelon, Dragon King Watermelon, Black Magic Watermelon, NS 292 Watermelon, Jaguar F1 Watermelon etc. The crop duration ranges from 55 days to 120 days depending on the varieties.

Chittagong Hill Tracts Comprising the three districts of Bandarban, Rangamati and Khagrachari has an area of 13,181 Sq. Km. endowed with natural beauty and high economic potentiality. The tribal along with the Bengali people are living there for long maintaining their district socio-cultural identities and harmony. The area is hilly with mild to very steep (15% to over 70%) often breaking or ending cliffs. More than 90% of the area is covered by hills with only 1'29'000 ha. of cropped land. About 87% of the land is covered with forest mostly owned by the Government (Dasgupta and Ahmed. 1998). According to Banglapedia (2009) about 20,000 hectares of land are being brought under jhum cultivation each year.

Jhum cultivation, sloppiness, heavy rainfall and improper management of soil enhanced nutrients depletion through erosion. Accelerated soil erosion is the greatest hazard for the long term maintenance of soil fertility. Gafur *et al.* (2003) carried out a research to find out runoff and losses of soil and nutrients from a small watershed under shifting cultivation in CHT. Borggaard *et al.* (2003) carried out a study to analyze the sustainability the sustainability appraisal of shifting cultivation in CHT. Dewan (2008) conducted a survey work to analyze the socio-economic status of jhum cultivators. The Chittagong Hill Tract region is of great importance for

various crops which are different from the plains. But unfortunately, few eco-friendly sustainable practices for CHT has so far been developed.

Land degradation is one of the major ecological issues of the world. Land degradation means loss in the capacity of given land to support growth of useful plants on a sustained basis (Singh, 1994). Erosion hazard caused by water in the rainy season is one of the mostly responsible for land degradation in Bangladesh. In the hilly region of Bangladesh received huge amount of rainfall in this time. This amount of excess rainfall drains out along with eroded soil materials through numerous channels, canals and rivers of the hilly regions without natural or artificial obstacle. Thus following heavy downpour of the rainy season, the area suffers from severe draught and water scarcity in the dry season. Vegetation and land use play an important role controlling the intensity and frequency of overland flow and surface erosion (Mitchel, 1990; Gafur et al 2001b). Cultivation of watermelon in the rainy season using hedge of different species established across the slope could be introduced to mitigate the demand of food, to improve the socio-economic status of the hill dwellers and to minimize the land degradation.

In these circumstances, a very little scientific effort has been taken in hand to study the performance in cultivation of watermelon in the rainy season using soil conservation technique at the Research Area of Soil Conservation and Watershed Management Centre, SRDI, Bandarban. If the challenges along with other difficulties can be overcome, it would be a mile stone of eco-friendly sustainable agriculture of this hilly region.

Objectives:

- a. To find out the suitability of water melon without irrigation (rainy season) at hill slopes.
- b. To compare soil loss, runoff and nutrient mining under different hedge species & different slopes.
- c. To find out a significant source of income.

Materials and Methods

The research was conducted at the Research Area of Soil Conservation and Watershed Management Centre (SCWMC), SRDI under Bandarban Sadar upazila, Bandarban. Three types of slopping land like Gentle, Moderate and Steep Slopes were selected for this research to have comparative data. There are 3 plots in every individual slopping land having an area of 100 m² (5m x 20 m) for each plot. Total area of each slopping land was 300 m². The experimental plots were selected in such a way that the area individually can be treated as a micro watershed. Prior to selection of the plots, the area was cleaned. Jungles were removed. Slope percentage of the

land was measured by Abney's level. To conduct the study, 3 plots of 100 m² (5m x 20 m) in each slopping land were selected for applying different soil conservation technique. Among the three plots- one was controlled and remaining others two were pineapple hedge and vetiver hedge. Slope gradient of the selected three types of sloping lands were: 12%, 26% and 36% respectively. Each plot is separated by plot boundary in such a way that runoff from one plot cannot enter to another plot. On 25th of April-2021, Pineapple and Vetiver hedge in single row were established following contour at 5.0 m horizontal interval in each plot. There are four lines of hedge row in each plot. A number of bamboo made pegs painted by different colors were inserted in to the soil plot to determine the soil loss.

seeds of watermelon placed in soil filled poly packet for germination and to have seedlings. Prior to Digging up pits, composite topsoil samples were collected from each plot has been collected for physical, chemical and mineralogical analysis to compare the soil nutrients status. Pit size was 15"x15" having 1'-0" depth. During preparation of pits, at least one kg of dried cow dung along with 100 gr. TSP and 50 gr. MOP (Murat of Potash) were applied in each pit. Hill method or raised bed was practiced to avoid excess amount of water which causes root rot diseases. Two seedlings were planted in each pit/bed. In the rainy season, weeding is very necessary as this season promotes weed growth and the incidence of pest and diseases. When 25 to30 days has passed after plantation of the seedling, 2nd dose of fertilizer @50 gr. urea, 100 gr. TSP and 50 gr. MOP was applied in each pit.

Intercultural operation was done when necessary. Mulching practice around the plant was applied to prevent the rainwater from splashing soil onto the plants, reducing the chance of bacterial or fungal infection that might come from the soil. Bamboo made platform (Mancha) was placed for climbing up the plants and to protect melon bursting for excess water. During the fruiting time of the watermelon 3rd dose of fertilizer @ TSP 125 gr. and MOP 50 gr. in each pit was applied.

To estimate the soil loss on different slopping land under different treatment peg method was followed. In this practice, each plot was divided into three parts namely- Upper part, middle part and lower part. At the beginning of the monsoon, 9 nos. bamboo made pegs having marked by different color of paint were inserted in the soil for each part. Soil loss near each peg was measured by using leveling instrument and recorded. Average of nine pegs was calculated for each part. Insecticides, Pesticides and fungicides were applied depending upon the symptom of the plants at 3rd week, 5th week, 7th week, 9th week and 11th week after planting. When the fruits were in growing stage, those were supported to hang from the platform by using cotton made net bags.

Results and discussion

. Maximum soil loss 20.734 ton/ha.y⁻¹ ,17.920 ton /ha y⁻¹ , 22.680 ton /ha y⁻¹ & 23.50 ton /ha y⁻¹ were recorded at controlled plot on steep slope in the years of 2021-22, 2022-23, 2023-24 & 2024-25 whereas minimum soil loss was 8.834 ton/ha.y⁻¹ , 7.322 ton /ha y⁻¹ , 9.464 ton /ha y⁻¹ & 8.34 at pineapple hedge plot on gentle slope in the years of 2021-22, 2022-23 , 2023-24 & 2024-25. On field yield data was recorded. Only the ripen watermelon those were collected from field was included in yield data. Maximum number of fruits with maximum weight was recorded on pineapple hedge plot on gentle slope. On the other hand, minimum number of fruits with average minimum weight was recorded at controlled plot on steep slope. Maximum yield was.12.844, 14.040, 15.252 & 16.13 ton/hac. y⁻¹ at pineapple hedge plot on gentle slope and minimum yield was 8.505, 7.680, 6.441 & 5.94 ton/hac.y⁻¹ at controlled plot on steep slope or the years of 2021-22, 2022-23 ,2023-24 & 2024-25.

Table-01: Soil Loss under the cultivation of Watermelon in different treatments & different slope for the year 2021-22.

Year.	Slope Class	Treatments	Average soil loss in each row (mm)			Average Soil Loss of all row (mm.)	Total soil loss (ton/hac)
			Upper Row	Middle Row	Lower Row		
2021-22	Gentle	Pineapple	0.585	0.623	0.685	0.631	8.834
		Vetiber	0.600	0.684	0.720	0.668	9.352
		Controlled	0.690	0.75	0.810	0.750	10.500
	Moderate	Pineapple	0.695	0.790	0.840	0.775	10.850
		Vetiber	0.780	0.864	0.914	0.853	11.942
		Controlled	1.000	1.100	1.20	1.100	15.400
	Steep	Pineapple	1.140	1.200	1.260	1.200	16.800
		Vetiber Hedge	1.190	1.243	1.32	1.251	17.514
		Controlled	1.410	1.470	1.563	1.481	20.734

Table-02: Soil Loss under the cultivation of Watermelon in different treatments & different slope for the year 2022-23.

Year.	Slope Class	Treatments	Average soil loss in each row (mm)			Average Soil Loss of all row (mm.)	Total soil loss (ton/ hac)
			Upper Row	Middle Row	Lower Row		
2022-23	Gentle	Pineapple	0.443	0.516	0.610	0.523	7.322
		Vetiber	0.510	0.605	0.715	0.610	8.543
		Controlled	0.649	0.694	0.760	0.701	9.820
	Moderate	Pineapple	0.695	0.790	0.840	0.775	9.459
		Vetiber	0.780	0.864	0.914	0.853	10.386
		Controlled	0.924	1.013	1.108	1.015	14.210
	Steep	Pineapple	0.942	1.086	1.200	1.076	15.064
		Vetiber Hedge	1.06	1.125	1.220	1.135	15.890
		Controlled	1.160	1.270	1.410	1.280	17.920

Table-03: Soil Loss under the cultivation of Watermelon in different treatments & different slope for the year 2023-24.

Year.	Slope Class	Treatments	Average soil loss in each row (mm)			Average Soil Loss of all row (mm.)	Total soil loss (ton/ hac)
			Upper Row	Middle Row	Lower Row		
2023-24	Gentle	Pineapple	0.582	0.657	0.788	0.676	9.464
		Vetiber	0.624	0.738	0.810	0.724	10.138
		Controlled	0.775	0.914	1.023	0.904	12.656
	Moderate	Pineapple	0.700	0.850	0.916	0.822	11.508
		Vetiber	0.850	0.900	0.980	0.910	12.740
		Controlled	0.950	1.250	1.300	1.167	16.338
	Steep	Pineapple	1.100	1.250	1.280	1.210	16.940
		Vetiber Hedge	1.250	1.285	1.395	1.310	18.325
		Controlled	1.350	1.600	1.910	1.620	22.680

Table-04: Soil Loss under the cultivation of Watermelon in different treatments & different slope for the year 2024-25.

Year.	Slope Class	Treatments	Average soil loss in each row (mm)			Average Soil Loss of all row (mm.)	Total soil loss (ton/hac)
			Upper Row	Middle Row	Lower Row		
2024-25	Gentle	Pineapple	0.493	0.585	0.714	0.597	8.34
		Vetiber	0.583	0.680	0.792	0.685	9.59
		Controlled	0.742	0.864	0.937	0.847	11.87
	Moderate	Pineapple	0.650	0.722	0.813	0.728	10.20
		Vetiber	0.789	0.841	0.896	0.842	11.79
		Controlled	0.911	0.990	1.210	1.037	14.20
	Steep	Pineapple	0.989	1.198	1.267	1.151	16.12
		Vetiber Hedge	1.211	1.200	1.388	1.266	17.73
		Controlled	1.289	1.533	2.213	1.678	23.50

Table-05: Yield of the Watermelon in different treatments in financial year 2021-22

Sl. No.	Slope Class	Treatments	Number of fruits (Nos.)	Av. weight per fruit (Kg)	Yield per plot (Kg.)	Yield per hectare (Ton)
1	Gentle	Pineapple hedge	76	1.69	128.44	12.844
		Vetiver Hedge	75	1.65	123.75	12.375
		Controlled	73	1.61	117.53	11.753
2	Moderate	Pineapple hedge	74	1.64	121.36	12.136
		Vetiver Hedge	72	1.62	116.64	11.664
		Controlled	70	1.56	109.20	10.920
3	Steep	Pineapple hedge	74	1.50	111.00	11.100
		Vetiver Hedge	73	1.45	105.85	10.585
		Controlled	63	1.35	85.05	8.505

Table-06: Yield of the Watermelon in different treatments in financial year 2022-23

Sl. No.	Slope Class	Treatments	Number of fruits (Nos.)	Av. weight per fruit (Kg)	Yield per plot (Kg.)	Yield per hectare (Ton)
1	Gentle	Pineapple hedge	78	1.80	140.40	14.040
		Vetiver Hedge	76	1.73	131.48	13.148
		Controlled	69	1.54	106.26	10.626
2	Moderate	Pineapple hedge	78	1.62	126.36	12.636
		Vetiver Hedge	75	1.61	120.75	12.075
		Controlled	71	1.45	102.65	10.265
3	Steep	Pineapple hedge	72	1.48	106.56	10.656
		Vetiver Hedge	69	1.47	101.43	10.143
		Controlled	60	1.28	76.80	7.680

Table-07: Yield of the Watermelon in different treatments in financial year 2023-24

Sl. No.	Slope Class	Treatments	Number of fruits (Nos.)	Av. weight per fruit (Kg)	Yield per plot (Kg.)	Yield per hectare (Ton)
1	Gentle	Pineapple hedge	82	1.86	152.52	15.252
		Vetiver Hedge	80	1.85	148.00	14.000
		Controlled	68	1.49	101.32	10.132
2	Moderate	Pineapple hedge	79	1.75	138.25	13.825
		Vetiver Hedge	76	1.64	124.64	12.464
		Controlled	72	1.30	93.60	9.360
3	Steep	Pineapple hedge	69	1.46	100.74	10.074
		Vetiver Hedge	66	1.45	95.70	9.570
		Controlled	57	1.13	64.41	6.441

Table-08: Yield of the Watermelon in different treatments in financial year 2024-25

Sl. No.	Slope Class	Treatments	Number of fruits (Nos.)	Av. weight per fruit (Kg)	Yield per plot (Kg.)	Yield per hectare (Ton)
1	Gentle	Pineapple hedge	84	1.92	161.28	16.13
		Vetiver Hedge	82	1.89	154.98	15.50
		Controlled	67	1.39	93.13	9.31
2	Moderate	Pineapple hedge	80	1.80	144.00	14.40
		Vetiver Hedge	77	1.69	130.13	13.01
		Controlled	73	1.25	91.25	9.12
3	Steep	Pineapple hedge	66	1.45	95.70	9.57
		Vetiver Hedge	63	1.42	89.46	8.94
		Controlled	54	1.10	59.40	5.94

Conclusion

Watermelon cultivation is not possible on the hilly areas during the dry season due to lack of water. So it is possible to successfully grown during the rainy season without irrigation. Hedge always plays a vital role on plant growth, crops productivity, no of fruit & weight as well as minimizing of soil erosion. Height yields and lowest soil loss were gained from the managed plot by pineapple hedge and gentle slope. Lowest yields and Height soil loss were gained from the control plot and steep slope. soil conservation technique is must for any agricultural practice on the slopping land.

Refferences

1. Schipper RR (2000), African Indigenous Vegetables, An Overview of the Cultivated Species, N.R/ACO, EU pg no. 56-60, Chatthan, UK.
2. Ufoegbune GC, Fadip OA, Belloo NJ, Eruola AO, Makinde AA and Amori AA, Department of Water Resources Management and Agrometeorology, Federal University of Agriculture, Abeokuta, Nigeria. Journal of Climatology Forecasting: Development of Watermelon in Response to Variation of Rainfall.

3. FAO (2003) World Agriculture towards 2015/2030. Summary Report, Rome.
4. Jarret B, R Bill, W Tom and A Garry (1996), Cucurbits Germplasm Report, Watermelon National Germplasm System, Agricultural Service, page no. 29-66, U.S.D.A.
5. Anons (2006), Nasarawa State Agricultural Development Programme, Annual Crop Area and Yield Survey (CAYS), Lafia, Nasarawa State.
6. Dane F, Lui J, Zhang C (2007) Phylogeography of the bitter apple, *Citrulus Colocythis*, Genet. Resour. Crop Evol. 54, 327-336.
7. Toth Z, Gyulai G, Szabo Z, Horvath L, Heszky L (2007), Watermelon (*Citrulus lanatus*) Production in Hungary from the Middle ages (13th Century). Hungarian Agric. Res. 4, pg. no. 14-19.
8. Wang Y, Xie ZK, Lim F, Zhang Z (2004). The effect of Supplemental Irrigation on Watermelon (*Citrulus lanatus*) production in gravel and sand mulched fields in the loess Plateau of north China Agric. Water Manage. 69; pg. no. 29-41.

EXPT. No. 6

EFFECT OF NATURAL VEGETATIVE STRIP (NVS) FOR MINIMIZING SOIL EROSION IN CULTIVATION OF BITTER GOURD AND SNAKE GOURD AT MODERATE HILL SLOPES.

Abstract

Soil erosion on sloping lands of the Chittagong Hill Tracts poses a major threat to sustainable agriculture, particularly under high-intensity monsoon rainfall. This study evaluated the effectiveness of Natural Vegetative Strips (NVS) in reducing soil loss and improving crop productivity under bitter gourd (*Momordica charantia*) and snake gourd (*Trichosanthes cucumerina*) cultivation on hill slopes in Bandarban. The experiment was laid out in a randomized complete block design with and without NVS treatments. Results showed that NVS reduced soil loss by approximately 60% and monsoon runoff by 25–30% compared to control plots. Bitter gourd and snake gourd yields increased by 12.5% and 9.8%, respectively, with significant improvements in fruit number, size, and weight. These benefits were achieved without external inputs, as NVS relied on naturally regenerating grasses. Despite occupying 10–15% of land area, the strips effectively preserved 14–16 t ha⁻¹ yr⁻¹ of topsoil, contributing to long-term soil fertility and income stability. The study concludes that NVS is a low-cost, farmer-friendly, and climate-resilient approach to soil conservation and productivity enhancement, and should be widely promoted in upland farming systems.

Introduction

CHT covers an area about 13,181 km² and occupies about 76% of total 12% upland areas of the country (Khisa,2006) endowed with natural beauty and economic potentiality. Jhum, the dominant form of land use in CHTs, widely practiced by tribal communities and remain as major source of livelihood for most of the hill people. About 1.0 million peoples in CHT of which 13 different ethnic groups are directly or indirectly depend on Jhum (Shoaib,2000).Generally, after one year harvest in general, sometimes two year, the land was left fellow for 20-30 years, which at present has been shorten to 3-4 years (DANIDA,2000).It is estimated that 1,02,468 areas (4.3 percent area of the CHT) is cleared every year for jhum cultivation.Gafuret *al.*(2003) cited approximately 2.5% area of CHT remains under jhum in each year. Soil erosion is an important social and economic problem and an essential factor in assessing ecosystem health and function. When runoff occurs, less water enters the ground, thus reduces the crop productivity. Soil erosion also reduces the levels of the basic plant nutrients needed for crops, trees and other plants and decreases the diversity and abundance of soil organisms(Olson et al.1999;Schumacher et al.1999; Irvine and Kirkby2004). Effective control of soil erosion lies in reducing direct impact

of rain drops, maintaining maximum soil infiltrability by decreasing surface sealing, increasing the surface storage, improving soil structure and decreasing the velocity and transport capacity of runoff, which can only be achieved through good land use management. Joshi et al.(2004) reported that the grass cultivation on barren terraces and bund of agriculture land proved effective in reducing erosion hazards for hill farming to maintain the nutrient balance under different land use systems.

Natural Vegetative Strips (NVS) represent a critical soil conservation strategy for hill slope agriculture, particularly relevant for cucurbit crops like bitter melon and snake melon cultivated on moderate slopes. These strips function as semipermeable barriers that intercept runoff and sediment while providing multiple ecosystem services (Angima, 2020). The effectiveness of NVS becomes particularly important in hill slope agriculture where conventional mechanical conservation measures may be cost-prohibitive or technically challenging to implement (Sudhishri et al, 2008).

NVS control erosion through several interconnected physical processes. Vegetative barriers provide protection from rainfall impact and create semipermeable barriers that reduce water flow velocity. The vegetation shields soil surfaces from overland flow and decreases the erosive capacity of water by reducing flow velocity (Angima, 2020). Research demonstrates that vegetative strips create enhanced flow depth regions upstream, with the backwater effect resulting in deposition of up to 95% of sediment in experimental conditions (Ghadiri et al, 2006)

The root systems of vegetative strips contribute significantly to soil stabilization through mechanical binding and improved soil structure. Studies show that grass barriers with fibrous root systems and strong lateral vegetative spread are particularly effective (Jiao et al, 2007). Additionally, the vegetation contributes to nutrient cycling and organic matter accumulation, with some studies reporting enhanced organic carbon accumulation in soils protected by vegetative barriers (Sudhishri et al, 2008).

Research on slopes ranging from 11% to 25% demonstrates substantial effectiveness of vegetative strips. On 11% slopes, sambuta and vetiver barriers reduced runoff and soil loss by 63.4% and 68.6% respectively (Sudhishri et al, 2008). Studies on 17% slopes showed vegetative buffers reducing soil loss by 28-88% depending on strip width and species selection (Jin et al, 2009). For slopes up to 25%, hedgerow measures maintained high effectiveness in water and soil conservation (Wang & Cai, 2007)

The effectiveness of vegetative strips varies with slope gradient, with research indicating that effectiveness decreases with increasing slope steepness. However, vegetative measures remain viable on slopes up to 25%, beyond which conversion to forest land is recommended. On slopes exceeding 25%, soil erosion increases dramatically, limiting the effectiveness of vegetative conservation measures (Wang & Cai, 2007).

Vegetative strips effectively reduce nutrient losses that are particularly important for cucurbit production. Research shows reductions in nitrogen losses by 10-54%, phosphorus by 7-24%, and potassium by 11-21% (Jin et al, 2009). For cucurbit crops that require substantial nutrient inputs, this conservation effect translates to reduced fertilizer requirements and improved soil fertility maintenance.

Vegetative strips should be established along contour lines to maximize their effectiveness in intercepting runoff (Angima, 2020). The spacing between strips depends on slope gradient, soil type, and erosion risk, typically ranging from 100-300 meters depending on local conditions (Juo et al, 1997). Integration with other conservation practices enhances overall effectiveness.

Studies demonstrate that properly established vegetative strips maintain their effectiveness over multiple years. Research spanning 4.5 years showed consistent performance of grass vegetation strips in reducing runoff and soil loss (Ghosh et al, 2012). The sustainability is enhanced when strips are integrated with appropriate management practices including organic amendments and minimum tillage systems.

Comprehensive research in the Indian sub-Himalayas demonstrated that grass vegetation strips significantly reduced soil loss and runoff over a 4.5-year period. The palmarosa+ system (combining palmarosa strips with organic amendments) achieved mean soil loss of only 3.4 t/ha compared to 7.1 t/ha without strips, while also improving crop yields. (Ghosh et al, 2012)

Minimization of soil through (NVS) is an indigenous technology which used by the hill dwellers since time immemorial. In the rural areas the poor, who struggle for survival, cannot be expected to pay heed to the conservation strategy unless their daily needs of food, fiber and fuel are met. Still a more urgent need is for assured and full employment for all the peoples. Though soil erosion in Chittagong Hill Tract is a great threat for crop cultivation, the practice of Natural Vegetative Strip application is still very limited. In this manner a land use system should be developed to control soil erosion and sustain crop productivity and aware the people as well as the peoples who involved develop the people of this remote area. So, the specific objectives of the present study were as follows:

- ❖ To examine the effect of NVS on the maintenance of soil fertility and reducing soil erosion in moderate hill slope.
- ❖ To examine the effect of NVS on Bitter gourd and Snake gourd productivity in hill slope.

Materials and Methods

The experiment was conducted in the experimental farm of the Soil Conservation and Watershed management Center (SCWMC); Soil Resource Development Institute (SRDI), Bandarban. The site was located in south-southeast hilly region of Bangladesh. The location of the site is between 22°09'16 to 22°10'32 north latitude and 92°11'17 to 92°11'34 east longitudes

with an elevation 92-133 m above mean sea level (SRDI,2005). The experiments were set up on the 26% hill slope areas. The climate of the experimental site is sub-tropical characterized by heavy rainfall during May to September and scanty rainfall during rest of the year. The area has an erratic monsoon climate, with periodic flooding in the valleys and drought in the mountains, hot rainy summer and a pronounced dry season in the cooler months. January is the coolest month of the year and April is the warmest one. The detail records of air temperature, humidity and rainfall for the study period were collected from meteorological station of Soil Conservation and Watershed Management Center, Bandarban. The mean annual rainfall of the study site was 3000 mm and monthly mean air temperature ranged from 25 to 34 °c and mean relative humidity was 79.3%.

The test crops of the experiment were Bitter gourd and Snake gourd. There were four treatments and these were as: T₁ = Bitter gourd in Natural vegetative strip, T₂ Bitter gourd in control (no NVS), T₃= Snake gourd in Natural vegetative strip, T₄ = Snake gourd in Control (no NVS). The experiment was laid out in Randomized Complete Block Design (RCBD) with 3 (three) replications. The treatments were randomly allotted in each block. The dimension of each plot was 20m x 5m (100 m²). The seeds were sown in following dibbling method. Necessary agronomic management practices for all crops were followed. Plots were prepared manually. Intercultural operations like weeding and fertilizer application were done equally in all treatments to get better results. In every plot after 4 meter intervals a 1 m width NVS were made naturally. So, there were four NVS in each plot. In Natural Vegetative Strips area there were different types of shrubs and grasses, which were germinated and developed naturally. The area of NVS was kept just to leave the cultivated area in cropping time without cleaning.

Soil erosion was measured through Spike layout method. In every plot, four spikes were inserted-two were near upper side (top of the plot) and another two were near bottom side of the plots. The spikes were made by mule bamboo and these were colored by normal paints. These bamboo spikes were divided into two parts by using two different colors (red and white).

Different intercultural operations like –weeding, insect and disease control, harvesting were done properly and timely for successful completion of the experiments.

Composited Soil samples were collected and just before land preparation to determine the physical and chemical properties of the experimental field. Soil samples were also collected treatment-wise after the final harvest of the crop. The collected samples were air-dried, grained and passed through a 2 mm sieve for physical and chemical analysis. Soil samples were analyzed following standard analysis method in central laboratory of SRDI.

Results and Discussion

Table 1. Initial soil fertility status and fertility status after crop harvest.

Parameter	Year	pH	OM (%)	N (%)	P	K	S	Zn	B	Ca	Mg	Cu	Fe	Mn
					meq/100g soil			µg/g soil		meq/100g soil	µg/g soil			
NVS Bitter gourd	2024	6.7	2.09 M	0.15 5	26.81 VL	0.30 O	0.00 3	1.5 2	0.30 L	3.4 2	0.6 9	0.8 2	80.6 2	42.1 1
	2025	6.1	2.6 H	0.18 0 L	30.57 VH	0.37 H	7.58 L	6.4 8	0.30 L	2.7 8	1.1 1	2.7 7	37.1 6	18.5 0
Control Bitter gourd	2024	6.3	2.16 M	0.15 8 L	17.89 O	0.38 H	0.30 VL	1.6 0	0.23 L	5.2 9	1.1 6	0.8 1	67.9 0	37.6 8
	2025	4.0	2.6 H	0.18 0 L	5.20 VL	0.43 H	11.5 9	0.5 2	0.03 VL	2.6 7	1.3 9	0.4 0	40.4 5	16.6 1
NVS Snake gourd	2024	6.1	2.50 H	0.17 5	0.54 VL	0.54 VH	31.6 9	1.7 1	0.26 L	4.8 0	1.3 3	0.7 7	63.9 0	42.3 2
	2025	4.0	3.0 H	0.20 0	2.02 VL	0.9 VH	4.38 VL	0.3 9	0.30 L	3.1 2	1.8 1	0.3 8	55.6 7	17.2 3
Control Snake gourd	2024	5.9	2.70 H	0.18 5	9.08 L	0.50 VH	7.99 L	1.9 1	0.35 M	4.2 1	1.2 5	0.7 3	66.2 3	41.5 6
	2025	4.0	3.2 H	0.21 0	1.73 VL	0.86 VH	3.60 VL	0.4 8	0.14 VL	3.3 6	1.9 4	0.3 5	41.2 8	13.3 7

Note: VL=very low; L=low; M= medium; O=optimum; VH=very high

Table-2: Soil Texture

Particulars	Soil Textural Class	Sand	Slit	Clay
		%		
NVS Bitter gourd	Silt Loam	23	59	18
Control Bitter gourd	Silt Loam	22	60	18
NVS Snake gourd	Silt Loam	20	62	18
Control Snake gourd	Silt Loam	23	59	18

Table 3: Soil loss under the cultivation of Bitter gourd in Natural vegetative strips

Treatments	Average soil loss in mm	Total soil loss (ton/ha)
Bitter gourd in NVS	0.7028 b	9.14 b
Bitter gourd in Control	1.796 a	23.35 a
CV (%)	26.04	2.98
CD (0.05)	1.40 mm	4.79 t ha ⁻¹

In a column means having dissimilar letter(s) differ significantly as per 0.05 level of probability. CV- Coefficient of Variation, CD – Critical Difference

Table 4: Soil loss under the cultivation of Snake gourd in Natural vegetative strip.

Treatments	Average soil loss in mm	Total soil loss (ton/ha)
Snake gourd in NVS	0.7756 b	10.08 b
Snake gourd Control	1.9326 a	25.12 a
CV (%)	11.32	5.31
CD (0.05)	0.62	8.67

In a column means having dissimilar letter(s) differ significantly as per 0.05 level of probability. CV- Coefficient of Variation, CD – Critical Difference

Table 5: Run off under the cultivation of Bitter gourd & Snake gourd in Natural vegetative strip in 2024-25.

Particulars	Month wise runoff (%)											
	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec
Bitter gourd in NVS	-	-	-	-	-	30.16	58.30	37.47	38.40	15.37	-	-
Bitter gourd in Control	-	-	-	-	-	48.50	70.14	52.36	60.17	23.80	-	-
Snake gourd in NVS	-	-	-	-	-	43.14	52.79	49.45	35.98	28.23	-	-
Snake gourd in Control	-	-	-	-	-	44.79	56.22	51.66	39.49	33.17		

1 Effect of Natural Vegetative Strips (NVS) on soil-loss under bitter gourd

Average soil detachment on the 26 % slope dropped from 1.80 mm yr⁻¹ (23.35 t ha⁻¹) in the untreated control to 0.70 mm yr⁻¹ (9.14 t ha⁻¹) where 1 m-wide NVS were installed at 4 m vertical intervals (Table 3). The 60.7 % reduction exceeded the critical difference at $P \leq 0.05$, confirming that the improvement was statistically robust. A coefficient of variation (CV) of 26 % is acceptable for on-farm erosion trials on steep land and indicates that the treatment effect, rather than plot-to-plot noise, drove the response. The finding corroborates earlier work in Oregon, USA, where vegetative filter strips lowered sediment load in runoff by 68 % (Colquhoun et al, 2008). The markedly lower soil loss can be attributed to (i) interception of overland flow at the strip face, (ii) rapid re-infiltration of ponded water, and (iii) greater micro-roughness created by the strip vegetation, all of which curtail the transport capacity of stormflow.

2 Effect under snake gourd

A nearly identical pattern emerged for snake gourd (Table 4): mean soil removal fell from 1.93 mm yr⁻¹ (25.12 t ha⁻¹) in the bare control to 0.78 mm yr⁻¹ (10.08 t ha⁻¹) with NVS—a 59.6 % decline that again exceeded the least significant difference ($LSD_{0.05} = 0.62$ mm). Because snake gourd produces a sparser early-season canopy than bitter gourd, a slightly higher absolute loss persisted even with strips. Nevertheless, the proportional benefit of NVS remained stable, underscoring the technique’s crop-independent efficacy on similar edaphic and topographic settings. Comparable cross-crop consistency was reported by Aziz et al. (2023), who found that

vetiver hedgerows curtailed sediment export by 55–72 % across three vegetable species on 20–30 % slopes.

3 Seasonal runoff dynamics during the monsoon

Runoff percentages (Table 5) mirrored the soil-loss trends. In bitter-gourd plots, cumulative wet-season runoff fell from 255 % of monthly rainfall (control total) to 168 % with NVS, a mean monthly reduction of ~30 %. The greatest absolute benefit occurred in July–August, when rainfall intensity peaks in Bandarban. Snake gourd displayed a smaller yet meaningful 7 % average decline, reflecting its sparser foliage and the larger proportion of exposed inter-row ground early in the season.

The tight correspondence between runoff and sediment export confirms that overland flow is the principal driver of soil displacement on these quartzitic sandy-loam hillsides; therefore, any measure that attenuates runoff peaks will have an outsized effect on total soil loss. The strips also lengthened runoff-arrival time at the downslope boundary (visual field notes), lending further support to their hydraulic buffering role.

Mean performance of NVS on yield & yield component of Bitter gourd & Snake Gourd

Table 6: Mean performance of NVS on yield & yield component of Bitter gourd

Treatments	Fruit per pit	Fruit length, (cm)	Fruit diameter (cm)	Av.Weight/ Fruit (gm)	Yield /Plot (Kg)	Yield (t/ha)
Bitter gourd in NVS.	45.07 a	24.45 a	5.30 a	325.45 a	143.5 a	14.35 a
Bitter gourd in Control	39.30 b	22.52 b	4.70 b	298.32 b	127.5 b	12.75 b
CV %	8.3	4.1	5.2	6.8	5.5	5.5
CD (0.05)	4.5 fruits	1.1 cm	0.5 cm	22 g	12.6 kg	1.26 t ha ⁻¹

In a column means having dissimilar letter(s) differ significantly as per 0.05 level of probability.

CV- Coefficient of Variation, CD – Critical Difference

Table 7: Mean performance of NVS on yield & yield component of Snake gourd

Treatments	Fruit per pit	Fruit length, (cm)	Fruit diameter (cm)	Av.Weight/ Fruit (gm)	Yield /Plot (Kg)	Yield (t/ha)
Snake gourd in NVS.	48.20 a	34.52 a	4.2 a	442.42 a	153.12 a	15.31 a
Snake gourd in Control	43.36 b	31.25 b	3.7 b	410.24 b	139.54 b	13.95 b
CV %	6.5	3.5	5.0	7.0	5.5	5.5
CD (0.05)	3.0 fruits	1.8 cm	.4 cm	30 g	12.5 kg	1.25 t ha ⁻¹

In a column means having dissimilar letter(s) differ significantly as per 0.05 level of probability. CV- Coefficient of Variation, CD – Critical Difference

Yield response of bitter gourd to Natural Vegetative Strips (Table 6)

Installation of 1 m-wide NVS at 4 m vertical intervals lifted every recorded yield component of bitter gourd. Fruit number per plant rose from 39.3 to 45.1 (+14.7 %), average fruit weight from 298 g to 325 g (+9.1 %), and marketable yield from 12.8 t ha⁻¹ to 14.4 t ha⁻¹ (+12.5 %). Because each gain exceeded its respective critical difference (CD_{0.05}) while coefficients of variation stayed below 9 %, the enhancement can be attributed confidently to the strip treatment rather than to experimental noise. Agronomically, three processes are at work: (i) better soil-moisture retention within the cropped alleys after storms, (ii) reduced leaching and physical loss of soluble and particulate nutrients, and (iii) a slightly cooler, less wind-eroded micro-climate in the lee of the strips. The net result is fuller fruit set and larger fruit size, outcomes that translate directly into farm-gate revenue.

Yield response of snake gourd to Natural Vegetative Strips (Table 7)

Snake gourd showed the same positive pattern, though the percentage increments were marginally smaller. Fruit number climbed by 11 %, fruit length by 10 %, and overall yield by 9.8 % (from 14.0 t ha⁻¹ to 15.3 t ha⁻¹). Every difference again surpassed the CD_{0.05}, with coefficients of variation ≤7 %, indicating a stable treatment effect across replications. The slightly reduced magnitude relative to bitter gourd is consistent with snake gourd's more open canopy: early-season soil shading and micro-climatic buffering are therefore weaker, so the crop cannot exploit the improved edaphic environment quite as fully. Nonetheless, a 10 % yield bump on steep hill-slope land is agronomically meaningful and economically attractive, especially where landholdings are small and per-unit-area returns drive household income.

9 linking erosion control and productivity

Tables 3–7 together demonstrate that the same vegetative strips which halved soil loss and cut monsoon runoff by up to 30 % also generated a 9–15 % yield dividend across two cucurbit crops. Conservation therefore need not trade off against production; rather, it underpins it. On the 26 % slopes typical of Bandarban, retaining an extra 14–16 t ha⁻¹ yr⁻¹ of topsoil preserves nutrient capital roughly equivalent to 150–200 kg ha⁻¹.

Conclusion

Natural Vegetative Strips (NVS) reduced soil loss by about 60% and runoff by up to 30% on 26% hill slopes in Bandarban. Both bitter gourd and snake gourd showed significant yield increases—12.5% and 9.8% respectively—when NVS was used. These benefits came without extra cost, as the strips were formed from naturally growing grasses. Although NVS takes up about 10–15% of the land, the increase in yield and improvement in soil condition more than make up for it. Overall, NVS is a simple, low-cost, and effective method for controlling erosion and improving crop production on sloping land, and should be encouraged in similar hill farming areas.

References

1. Angima, S. D., 2020. Erosion and Sediment Control: Vegetative Techniques. <https://doi.org/10.1201/9780429346255-65>
2. Atta-krah, A.N. and J.E.Submerg, 1988 Studies with *Glericidiasepum* for crop-livestock production system in West Africa, *agroforestry systems* 6:97-118.
3. Attah-krah,A.N.,J.E.Sumberg.and L.Reynolds.1986.In potential of forage legume in farming System of Sub Saharan,Africa.InI.haque,S.Jutzi and P.J,H Neate (eds) 307-329.ILCA,ADDIS ABABA.
4. Aziz, S. and Islam, M.S., 2023. Erosion and runoff reduction potential of vetiver grass for hill slopes: A physical model study. *International Journal of Sediment Research*, 38(1), pp.49-65.
5. Colquhoun, J., Lins, R. and Cole, C., 2008. *Vegetative filter strips near surface water in the Pacific Northwest*. EM 8876-E. Reprinted August 2008. Oregon State University Extension Service.
6. DANIDA, 2000 Interim Planning Mission, Watershed Development Project, Chittagong Hill Tracts (CHT), Bangladesh (draft).
7. Gafur,A,O,KBorggaard,J.R.Jensen and L.Petersen.2000.Changes in soil nutrient content under shifting cultivation in the Chittagong Hill Tracts Of Bangladesh. *Danish J.Geogr.*100:37-46.

8. Ghadiri, H., Hussein, J., Yu, B., & Rose, C. W. (2006). The mechanism of flow retardation and erosion control by vegetated buffer strips on sloping lands.
9. Ghosh, B. N., Dogra, P., Bhattacharyya, R., Sharma, N. K., & Dadhwal, K. S. (2012). Effects of grass vegetation strips on soil conservation and crop yield under rainfed conditions in the Indian sub-Himalayas. *Soil Use and Management*, 28(4), 635-643
10. Irvine, B and M.Kikby, 2004, Land Degradation risk and off site impact of soil erosion at the European scale. *Geophy. Res. Abstracts* 6 (03669).
11. Jiao, J., Tzanopoulos, J., Xofis, P., Bai, W., Ma, X., & Mitchley, J. (2007). Can the study of natural vegetation succession assist in the control of soil erosion on abandoned croplands on the Loess Plateau, China? *Restoration Ecology*, 15(3), 391-399. <https://doi.org/10.1111/J.1526-100X.2007.00235.X>
12. Jin, Y., Lee, J., Lee, G., Hwang, S., Zhang, Y., Park, C., Seo, M., Ryu, J., Jeong, J., & Chung, I. (2009). Effects of Vegetative Buffers on Reducing Soil Erosion and Nutrient Loss of Highland Field in Korea.
13. Joshi, B.K., P.K. Verma and B.P. Kothiyari. 2004. Erosion studies under different land use systems in Bhetagad watershed of central Himalayas. *Indian J. Soil Cons.* 32(2):139-142.
14. Juo, A. S. R., Pacific Region, T. T. E., & Thurow, T. L. (1997). Sustainable technologies for use and conservation of steep lands.
15. Kang, B.T.H. Grimme and T.L. Lawson. 1985. *Plants and Soils* 85:267-276.
16. Khisa, S.Kanti, J.U.M Shoaib, and K.N.Ahmed. 2006. Selected natural resources conservation approaches and technologies in Chittagong Hill Tracts Bangladesh. *Bangladesh Conservation Approaches and Technology (BANCAT)*.
17. Miah, M.G. 1993. Performance of selected multipurpose tree species and field crops grown in the association as affected by tree branch pruning. A Ph.D dissertation research (Crop Science-Agronomy). CLSU. Philippines.
18. Nair, P.K.R. 1990. The prospect of Agro forestry in the tropics. (ed. P.K.R. Nair). Kluwer Academic Publisher London, pp.12-18.
19. Olson, K.R., Mokma, D.L.R. Lal, T.E. Schumcher and M.J. Lindstrom. 1999. Erosion impacts on crop yield for selected soils of the North Central United States. In: R. Lal (ed.) *Soil Quality and Soil Erosion*, CRC Press, Boca Raton, FL. pp.259-283.
20. Sudhishri, S., Dass, A., & Lenka, N. K. (2008). Efficacy of vegetative barriers for rehabilitation of degraded hill slopes in eastern India. *Soil and Tillage Research*, 99(1), 98-107. <https://doi.org/10.1016/J.STILL.2008.01.004>
21. Wang, X., & Cai, Q. (2007). Water and Soil Conservation Measures for Different Slope Land in Red-Earth Hilly Region. *Resources Science*, 29(6), 85-91.

Proposed Programme (2025-2026)

EXPT. No. 1

Growth and Yield Performance of Year-Round Moringa (*Moringa oleifera*) on Hill Slopes for Sustainable Cultivation

Objectives:

1. To assess the seasonal growth performance of year-round Moringa on hill slopes.
2. To evaluate the seasonal yield variation of year-round Moringa cultivated on hill slopes.

EXPT. No. 2

Integrated Assessment of Liming and Hedge-Based Soil-Erosion Control on Growth Performance of *Carica papaya* in Acidic Slopes of Bandarban .

Objectives:

1. To evaluate the combined effects of liming and hedge species barriers (e.g., vetiver, pineapple) on soil erosion control and soil fertility improvement in acidic hill slopes of Bandarban.
2. To assess the growth and yield performance of *Carica papaya* under integrated soil management practices involving liming and hedge-based erosion control measures.

EXPT. No. 3

SPATIO-TEMPORAL ASSESSMENT OF LAND USE/LAND COVER CHANGE DYNAMICS IN BANDARBAN THROUGH GOOGLE EARTH ENGINE–BASED MACHINE LEARNING APPROACHES

Objectives:

1. To prepare multi-temporal LULC maps of Bandarban using Google Earth Engine and machine learning techniques.
2. To analyze and quantify the patterns and trends of LULC change in Bandarban over time for better land management planning.