Soil Erosion Assessment Using Vegetation Characterization & SWAT Modeling in Malatgao Dam Watershed in Narra, Palawan, Philippines

Prepared by:

Alyza Joy Pabillore
Adviser: Maurice A. Duka,Phd
MS in Agricultural Engineering
Major in Land and Water Resources Engineering
ajpabillore@up.edu.ph

University of the Philippines
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PRESENTATION OUTLINE

- Background of the Study
- METHODOLOGY & RESULTS
- SUMMARY & CONCLUSION
- RECOMMENDATIONS FOR FUTURE STUDIES

Background of the study

CHAPTER I

Background of the Study

- **Malatgao Dam Watershed,** a water resource for agriculture and water supply in Narra, Palawan. It has been experiencing degradation exacerbated by deforestation and land-use changes, including the expansion of oil palm plantations.
- This degradation has resulted in increased surface runoff, **soil erosion**, and sedimentation in river systems, highlighting the importance of understanding the forest's characteristics.
- Insufficient understanding among the local population about the importance of soil conservation has resulted in considerable human activity that has **accelerated soil loss.**

Figure 3: Malatgao River after heavy rainfall last Sept. 2024

Figure 4: Selective logging in the lower section of the forest in Malatgao Dam Watershed

Image Source: Thunder News Philippines.

Background of the Study

- **Malatgao Dam Watershed's** open forest is threatened by human disturbances like logging, burning, and charcoal production

- **Different land uses** within forest areas can significantly affect soil characteristics, influencing soil health and stability.

- The watershed's **steep terrain** make it highly susceptible to soil erosion.

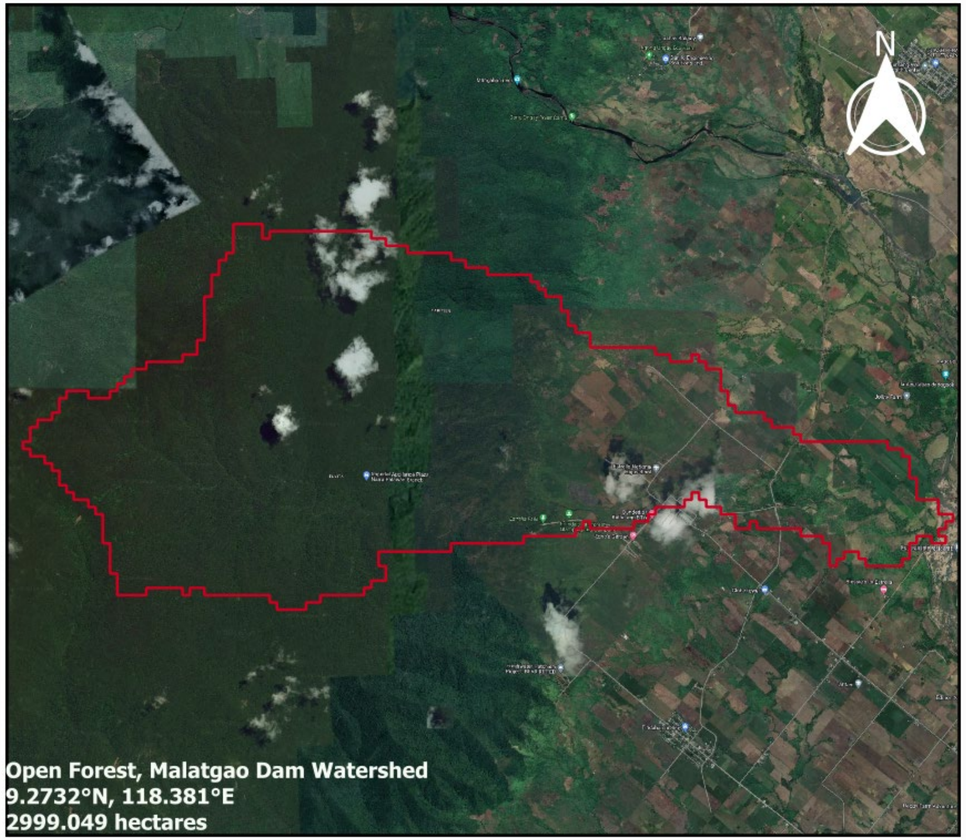
- Existing assessments acknowledge the watershed's susceptibility to erosion, there continues to be a **substantial deficiency** in research regarding the specific factors influencing soil erodibility in this area.

Charcoal Production

Selective Logging

Figure 5 : Existing Human Activities in the Open Forest of Malatgao Dam Watershed

Background of the Study



- **High Erosion Risk**: The steep topography and extreme rainfall patterns in the Malatgao Dam Watershed make it vulnerable to soil erosion, impacting water quality and the integrity of agricultural systems.

- **Inadequate Existing Research**: Current studies on watershed management have largely overlooked the specific factors influencing soil erosion in the Malatgao Dam Watershed particularly forest properties.

- **Integration with National Policies**: This study aligns with the goals of the Department of Environment and Natural Resources (DENR) regarding watershed management and could contribute to national strategies for climate change adaptation and mitigation.

Statement of the Problem

- **Open forest of Malatgao Dam Watershed** is subjected to unsustainable activities like selective logging, slash-and-burn farming, and charcoal production. These disturbances are likely altering the soil's structure and increasing its **vulnerability to erosion**.

- Current land management practices rely on generalized models that do not account for the specific **forest composition** or soil types found within the forest of the watershed.

- Despite the availability of the Soil and Water Assessment Tool (SWAT) for soil erosion studies, its application in the Malatgao Dam Watershed **lacks integration with field-based forest inventory** data.

Figure 6 :Open Forest in Malatgao Dam Watershed

http://minecraftservers.nu/improper-waste-disposal-in-the-philippines.html

Significance of the Study

Research Gap

- Addresses the limited integration of soil erodibility mapping with actual vegetation conditions in the Malatgao Dam Watershed.
- Fills the gap by linking vegetation data with erosion processes, supporting more precise watershed protection.

Scientific Merit

- Utilizes scenario-based SWAT modeling to assess the impact of land use and forest management on soil erosion, providing a flexible tool for evaluating environmental change.
- Integrates vegetation data with assumed forest activities (e.g., reforestation, selective logging, conservation) to simulate realistic, site-specific scenarios.

Environmental Impact

- Demonstrates how vegetation and land use changes influence erosion, guiding proactive management even in low-risk areas.
- Combines field vegetation data with SWAT simulations to support science-based erosion monitoring and early interventions.
- Promotes sustainable land use through targeted, site-specific erosion control strategies.

Research Objectives

GENERAL OBJECTIVE

Assess the soil erosion within the open forest of Malatgao Dam Watershed through vegetation characterization, soil erodibility mapping and SWAT modeling

SPECIFIC OBJECTIVES

- Assess the actual vegetation condition of the open forest of Malatgao Dam Watershed and its influence on soil erosion;
- Map soil erodibility (K-factor) using field-acquired values to support the assessment of vegetation influence on erosion patterns in the open forest of Malatgao Dam Watershed;
- Evaluate the impact of best management practices (BMPs) on soil erosion under different land use scenarios using the SWAT model

Scope and Limitations

SINGLE AREA-CENTRIC

This study focuses in the open forest of Malatgao Dam Watershed in Narra, Palawan Philippines

PARAMETERS USED

Measurement of canopy, basal area, and diameter at breast height (DBH) of trees across the open forest of the watershed

OBSERVATION PERIOD

Soil erodibility assessment and sediment collection was conducted over a one-month period with weekly sampling based on rainfall conditions.

RAINFALL DEPENDENCE

Reliance on natural rainfall during the observation period may limit the study's comprehensiveness regarding soil erosion processes

LAND COVER & SOIL MAP

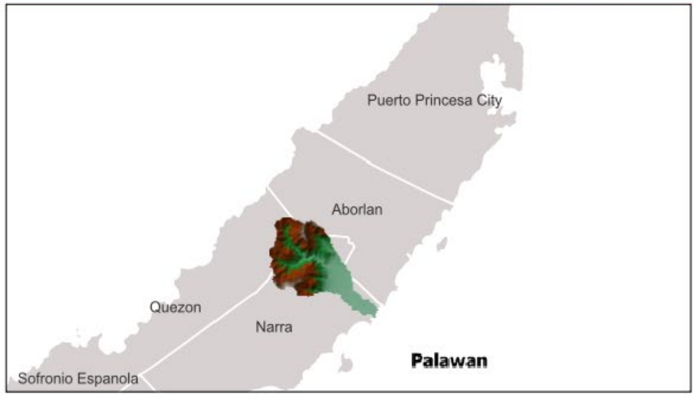
Land Cover and Soil type for Malatgao Dam Watershed were requested from NAMRIA and BSWM.

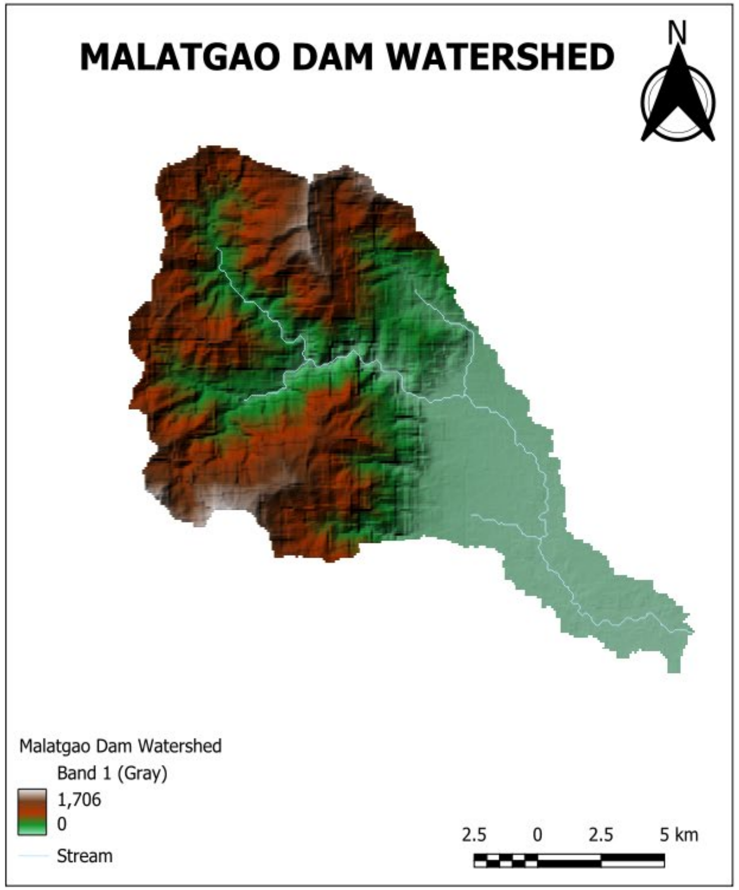
SOFTWARE

Recognized limitations due to the specific versions of software used: QGIS 3.22.1 and QSWAT 3.3

Time and Place of the Study

Name	Malatgao Dam Watershed
Location	Narra, Palawan Philippines
Coordinates	9°18'31.76" to 9°29'32.13" north latitude and 118°17'43.71" to 118°29'36.98" east longitude
Watershed Area	21,089 hectares
Open Forest Area	12, 128.9 hectares
Observation Period	September 2024 (1 month)





METHODOLOGY & RESULTS

CHAPTER III & IV

General Framework

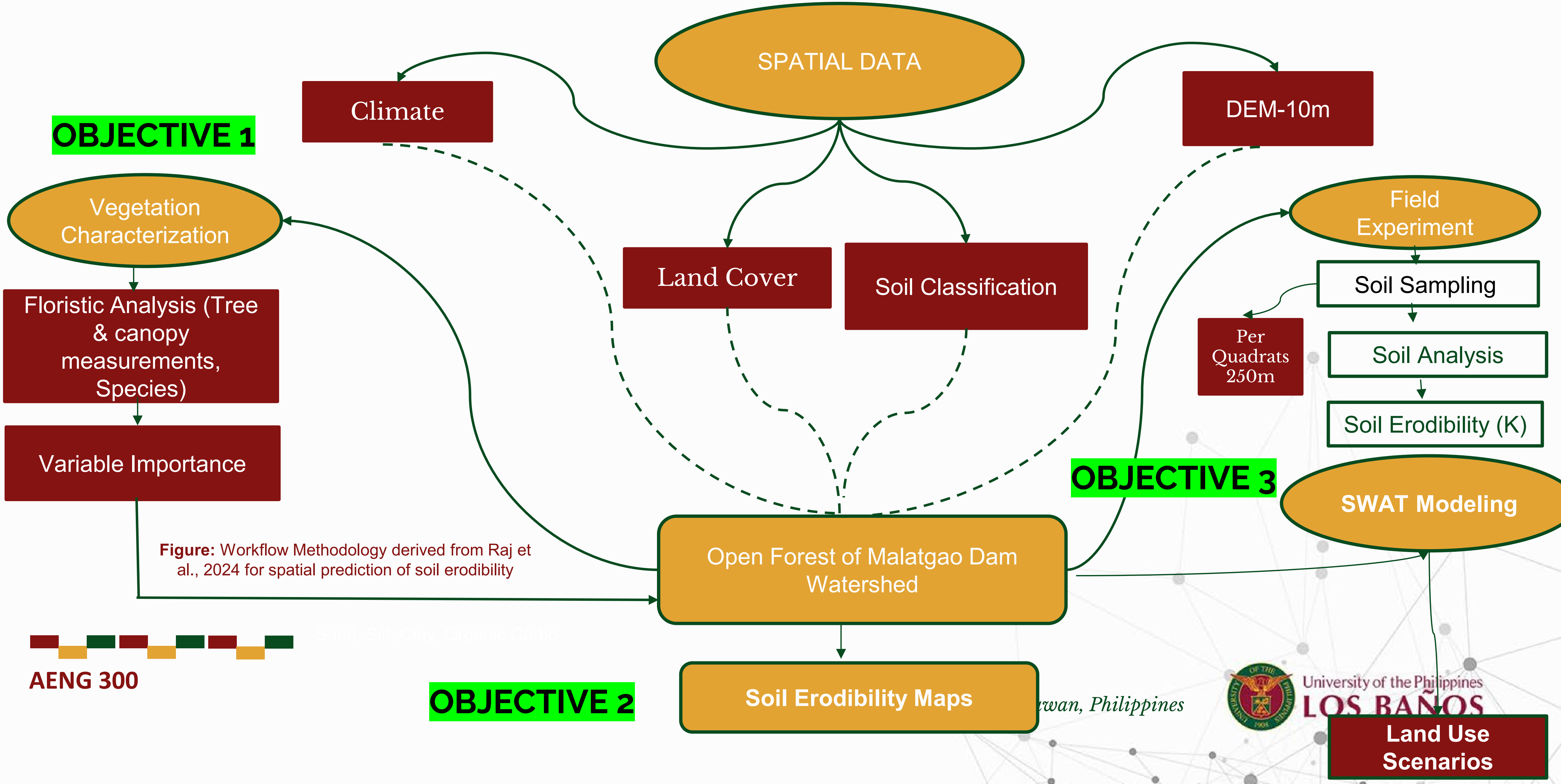


Figure: Workflow Methodology derived from Raj et al., 2024 for spatial prediction of soil erodibility

Method for Objective 1:Vegetation Characterization

Assess the actual vegetation condition of the open forest of Malatgao Dam Watershed and its influence on soil erosion;

MAP → 2 km- Transect → Eight quadrats → Distance of each Stand (250m) → Quadrat Placement & Location

Quadrat Placement & Location → Site 1 (Lower Section) / Site 2 (Mid Section)

Site 1 (Lower Section) → Accessible

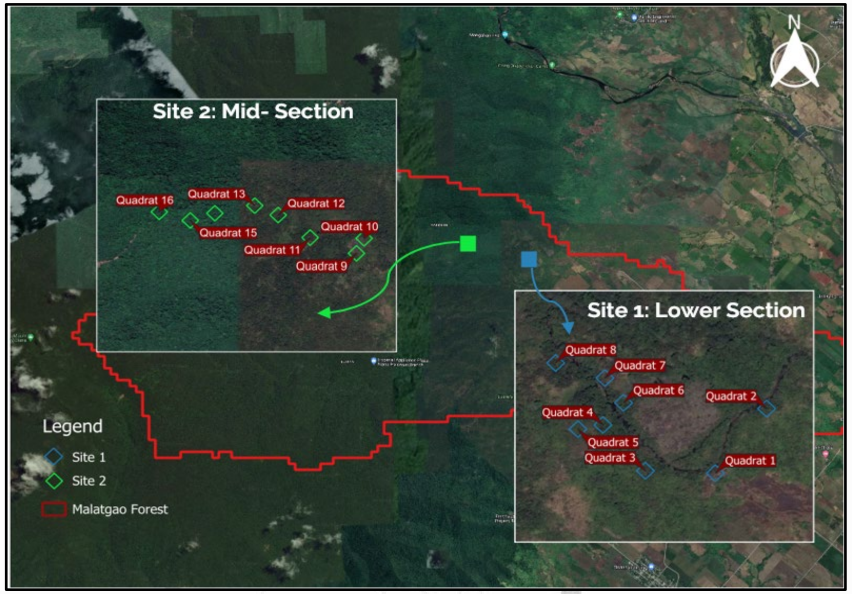
Site 2 (Mid Section) → Accessible / Inaccessible

Inaccessible → STOP

Accessible → Vegetation Characterization → Floristic Analysis

Floristic Analysis → Tree Measurement & Identification / Canopy Measurement

Tree Measurement & Identification → Vegetation Condition ← Canopy Measurement



Map of the Study Area

Method 1A: Ideal Quadrat Placement

A. Sampling Plot Establishment

- This study used the **Modified Belt Transect Method** (DENR Technical Bulletin 16-A) with a 2-km transect and 20m x 20m quadrats every 250 meters for tree species assessment and **vegetation litter** collection. This systematic sampling across elevation gradients captured forest variation. Vegetation litter biomass was calculated by multiplying the dry-to-wet mass ratio of samples by the total wet mass per plot.
- Site 2 (mid-section) of the study area was found to be **accessible**, allowing for the establishment of another 2-km transect. This second transect was set up to compare soil erosion between the lower and mid-sections of the forest.
- The gathered vegetation data was analyzed to assess its **role in soil erosion**, focusing on how forest characteristics influence erosion rates.

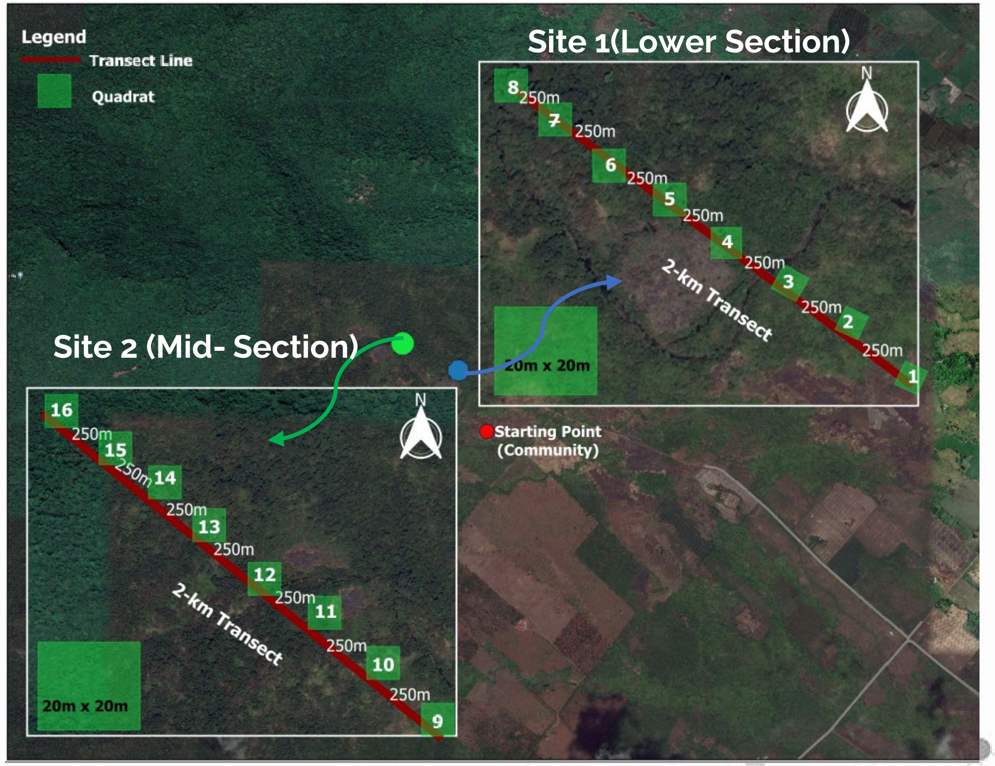


Figure: Ideal Quadrat Placement Along the 2-km Transect in the Open Forest of Malatgao Dam Watershed

Method 1B: Floristic Analysis

A. Tree Species Identification

- Tree measurements follow specific protocols for varying terrains and structures. On sloping ground, **measurements are taken on the uphill side at a height of 1.3 meters.**
- For leaning trees, measurements are conducted on the **leaning side at the same height**.
- In trees with buttresses over one meter, the **tip of the buttress is identified**, and an additional 0.3 meters is added before measuring the diameter at breast height (DBH).

B. Tree Species Measurement

▪ Trees were subjected to **taxonomic identification** and classification to accurately determine their species.

Figure :Documentation of Tree Species Identification And Measurement In the Open Forest of Malatgao Dam Watershed.

Method 1C: Floristic Composition Metrics

Floristic Composition – The types and number of plant species in an area.

Relative Dominance (RDo %) Space a species occupies based on tree size.	**Relative Frequency (RF%)** How often a species appears in different areas.	**Relative Density (RDe %)** Proportion of a species population in the forest.	**Importance Value (IV)** Measures a species' overall ecological importance
$\frac{\text{BA of all Species } i}{\text{Total BA of Species}} \times 100$ where: **Basal Area (BA)** = total cross-sectional area of tree trunks per unit area	$\frac{\text{Frequency species } i}{\text{Total Frequencies of all species}} \times 100$	$\frac{\text{No. of individual species } i}{\text{Total Densities of all species}} \times 100$ where: **Density** = $\frac{\text{No. of Individual Trees}}{\text{Area Sample (sqm)}}$	**RDo + RF + RDe**

Canopy Diameter The total width of a tree's branches and leaves.	**Diameter at Breast Height (DBH)** Tree trunk diameter measured at 1.3 meters above the ground.
$\frac{\text{Canopy Area of Tree}}{\text{Sampling Area}} \times 100$	

Results 1A: Actual Quadrat Location

A. Sampling Plot Establishment

- A **total of 16 quadrats** was established across two transect sites: Site 1 (Lower Section) and Site 2 (Mid-Section) of the forest.
- Data collected was used for computing **floristic analysis** which includes, **relative dominance (RDo), relative frequency (RFre): relative density (RDe) and importance value (Iv).**
- **Due to accessibility and terrain constraints**, the actual transect layout deviated slightly from a perfectly linear path, as shown in the previous slide. This adjustment ensured that the selected sites accurately represented the forest conditions while maintaining logistical feasibility for field data collection.

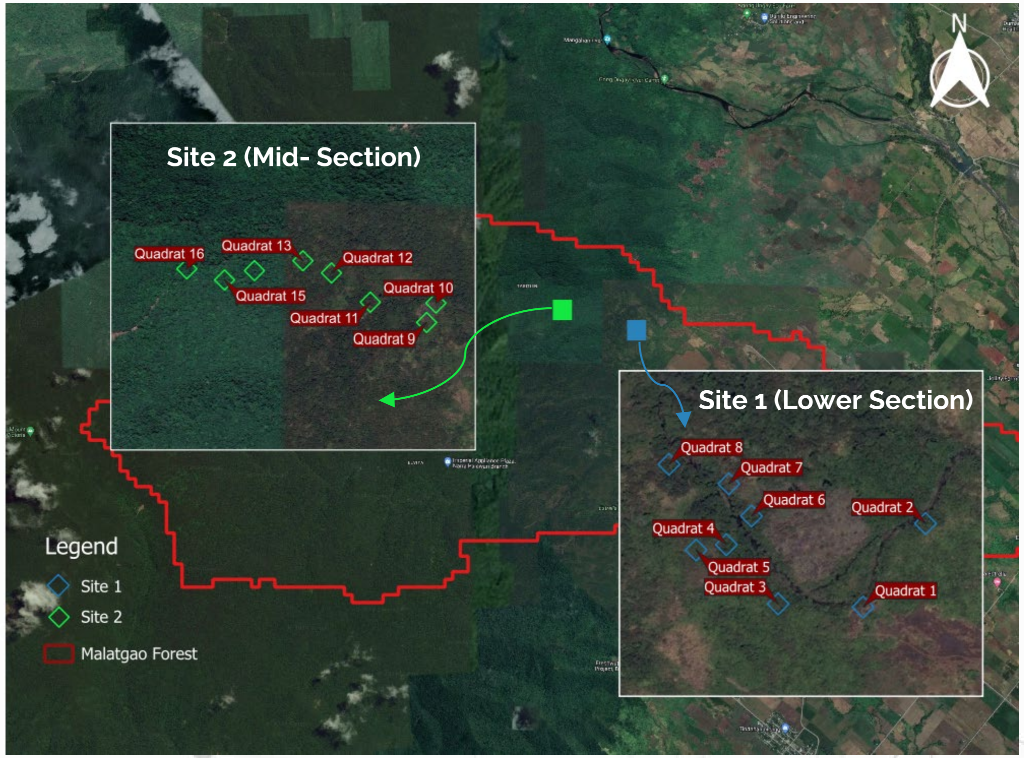


Figure :Sampling Location both in Site 1/ Lower Section and Site 2/Mid-Section of the Forest

Result 1B: Floristic Analysis: Trees Species Identified

- ***Garcinia venulosa*** (IVI = 98) is the most dominant species, with high Relative Density (40%) and Relative Dominance (44.29%), indicating numerous individuals and large basal area. Its dominance may limit light availability, affecting understory vegetation.
- ***Koordersiodendron pinnatum*** (IVI = 37) is species with significant Relative Dominance (19.77%), indicating it has large individual trees but a low population (10%).
- ***Gnetum gnemon*** (IVI = 34) is a widely distributed species (14.29% frequency) with moderate size and population, aiding in forest regeneration, especially in disturbed areas.
- ***Terminalia pellucida*** (IVI = 26) is a common species (14.29% frequency) found across the area, but with smaller trees (1.51% dominance).
- ***Terminalia calamansanai*** (IVI = 22): is a species that helps stabilize soil and form the canopy, with moderate tree size (5.11% dominance), often found alongside T. pellucida.

Species	RDo(%)	RF (%)	RDe (%)	IV (%)
1. *Garcinia venulosa*	44.29	14.29	40	98
2. *Koordersio Dendron pinna tum*	19.77	7.14	10	47
3. *Gnetum gnemon*	9.88	14.29	10	34
4. *Terminalia pellucida*	1.51	14.29	10	26
5. *Terminalia calamansanai*	5.11	7.14	10	22

Figure : Relative Density, Frequency, Dominance, and Importance Value percentages for top 5 plant species

Local Names:
1. Gatasan, 2. Amugis 3. Bago 4. Sakot 5. Malakalumpit

Result 1B: Floristic Analysis: Tree Measurement

- **Tree measurements** follow specific protocols for varying terrains and structures. On sloping ground, measurements are taken on the uphill side at a height of 1.3 meters. For leaning trees, measurements are conducted on the leaning side at the same height. In trees with buttresses over one meter, the tip of the buttress is identified, and an additional 0.3 meters is added before measuring the diameter at breast height (DBH).

Diameter at Breast Height (DBH)

- The Pareto chart shows most trees have smaller DBH (5-34 cm), with fewer large ones, forming a right-skewed distribution typical of secondary forests. The cumulative frequency confirms 80% of trees have DBH ≤34 cm, indicating limited canopy closure, which affects understory vegetation.

Figure: Trees found in the open forest of Malatgao Dam Watershed

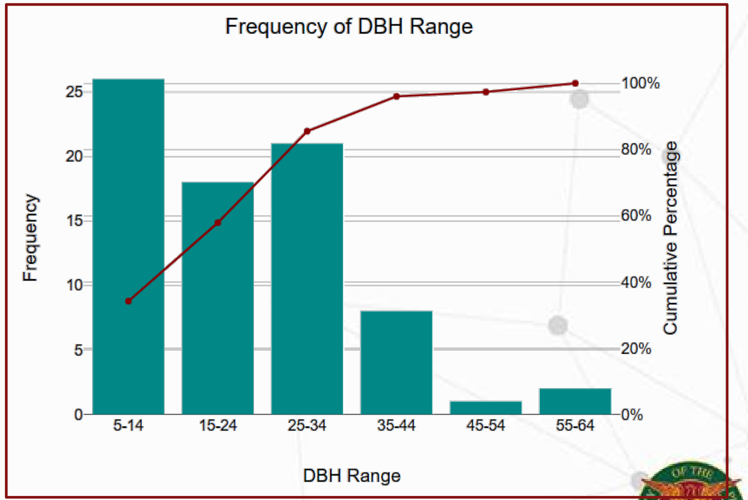


Figure : Frequency of trees within different Diameter at Breast Height (DBH) ranges

Result 1C: Metrics: Individual Trees & Canopy Cover Percentage (%)

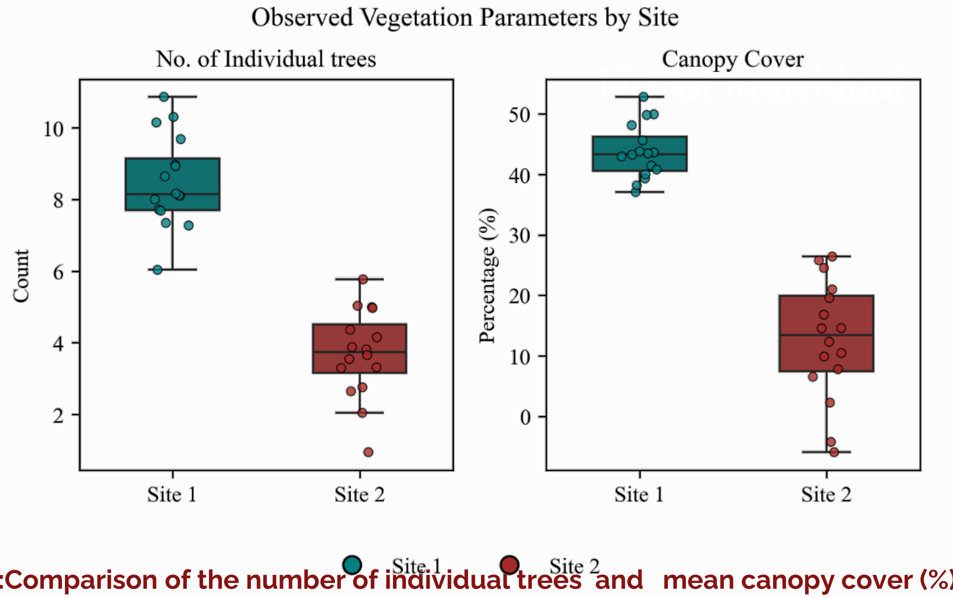
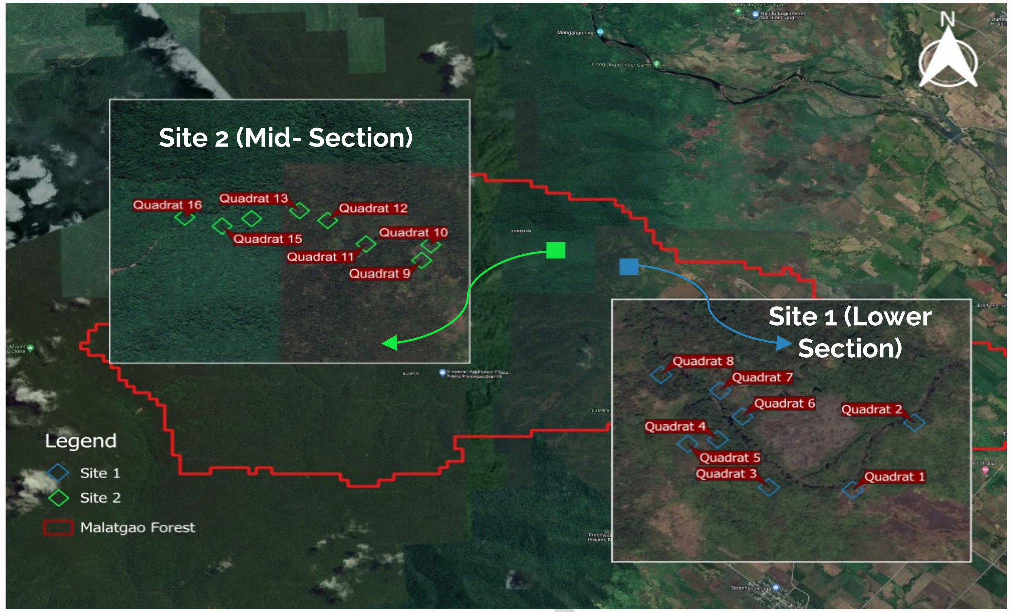


Figure :Comparison of the number of individual trees and mean canopy cover (%) across different sites in the Malatgao Dam Watershed.

Individual data points (dots) represent unique sampling locations. Box boundaries show percentiles with median line; diamond shapes indicate mean values with dotted lines showing the confidence intervals.



Map of the Study Area

- **Site 1 (lower section)** generally has a **higher number of individual** trees and a much higher and more consistent percentage of canopy cover compared to Site 2.
- **Site 2 (Mid Section)** has **a lower number of individual trees** and a lower but more variable percentage of canopy cover.

Result 1C: Metrics: Canopy Diameter

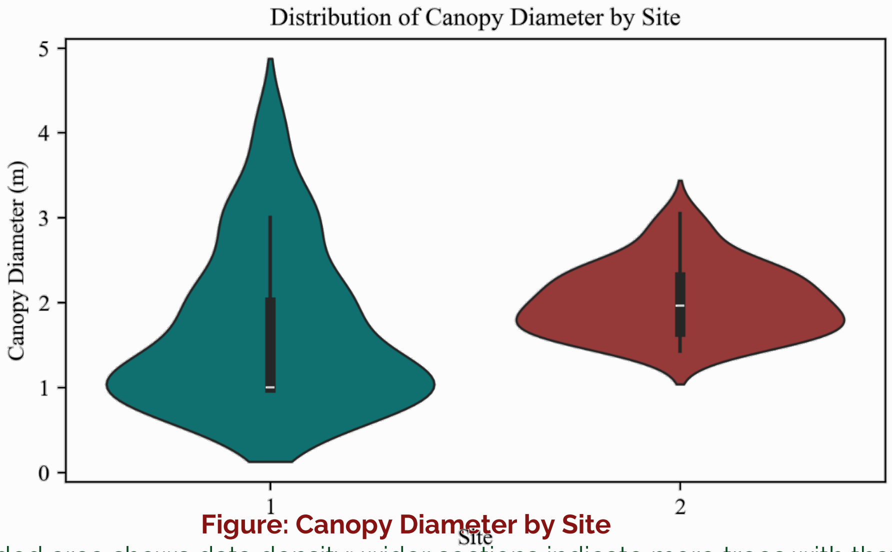
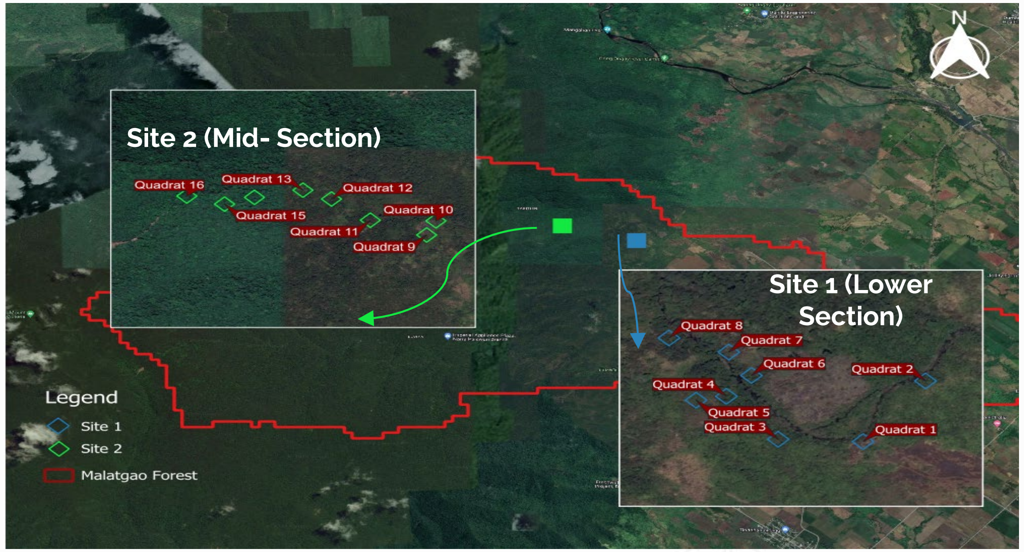


Figure: Canopy Diameter by Site

The shaded area shows data density; wider sections indicate more trees with that diameter. The embedded boxplot displays the median (thick line), interquartile range (box), and outliers (dots).



Map of the Study Area

Comparison	Test Statistic (W)	p-value	Interpretation
Site 1 vs Site 2	623.5	0.0207	Significant difference between groups

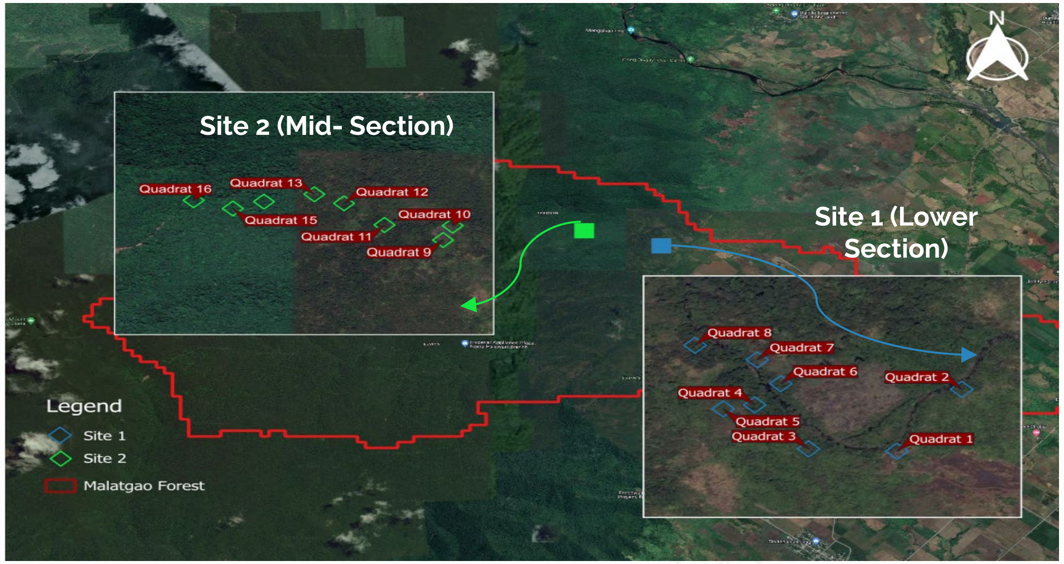
Figure: Wilcoxon Rank-Sum Test Result (Canopy Diameter)

❖ The Wilcoxon Rank-Sum Test ($W = 623.5$, $p = 0.02079$) indicated a statistically significant difference in canopy diameter between Site 1 and Site 2, reflecting true structural variation rather than random chance

- Both sites have a **similar median canopy diameter** (2m), but Site 2 (mid section) exhibits much greater variability in canopy size than Site 1.
- Canopy diameters in Site 1 (lower section) are **more concentrated** around smaller to medium sizes.
- **Site 2 (mid section**) has **a wider range of canopy diameters,** including significantly larger trees, indicating a more heterogeneous forest structure with some dominant large trees, whereas Site 1 (lower section) is more uniform in structure.

Result 1C: Metrics: Species Richness, DBH, Canopy Diameter

Site	Variable	Mean	SD	Median
1 (Lower Section)	Species	3.56	2.13	2
	DBH (cm)	75.72	34.63	76.5
	Canopy Diameter (m)	2.09	0.73	2
2 (Mid Section)	Species	3.23	1.74	3
	DBH (cm)	63.32	39.55	46.5
	Canopy Diameter (m)	1.41	0.67	1



Map of the Study Area

- **The Lower Section** tends to have **fewer species on average** but with some variability, larger and more consistently sized trees (larger DBH), and bigger canopy diameters.
- **The Mid Section** has a **slightly higher** and more consistent species count but smaller and more variable tree diameters and smaller canopies, indicating younger or less mature trees or a different forest structure.

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PCA biplots showing the relationship of Vegetation Parameters

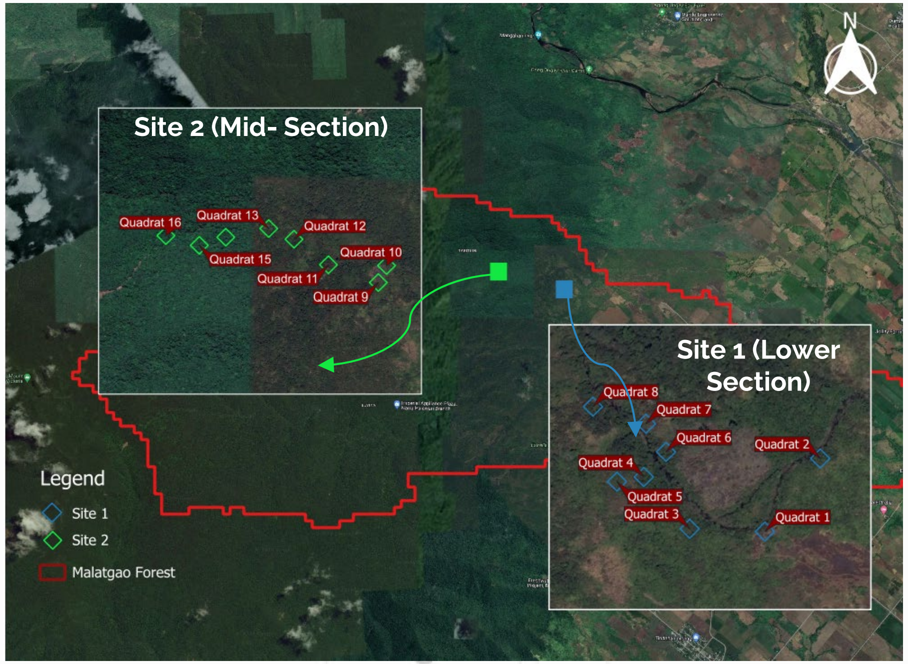
Result 1: Summary of Vegetation Condition & Soil Erosion Susceptibility

Site 1 (Lower Section)

- **Higher number of individual** trees increases root network density, helping bind soil and reduce erosion (Vovides et al., 2020)
- **Consistent canopy cover** reduces rainfall impact on soil, minimizing splash erosion (Shu Wei et al., 2024).
- **Smaller, uniform canopies** provide moderate but consistent shade and rainfall interception (Nakamura,2017).
- **Dominance of smaller to mid-sized** trees suggests recovering forest; moderate erosion control (Deb Raj Aryal et al., 2024)

Site 2 (Mid Section)

- **Lower tree density** results in weaker root systems, leading to higher susceptibility to erosion (W. Vannoppen et al. 2024).
- **Lower and variable canopy** cover leaves soil more exposed to raindrop impact, increasing erosion risk (Pedroza-Parga et al., 2022).
- **Wide variation**, with gaps between large trees allowing erosion-prone open patches.
- **Presence of large trees with** open spaces between them reduces overall ground cover, increasing erosion vulnerability (Vovides et al., 2020)



Map of the Study Area

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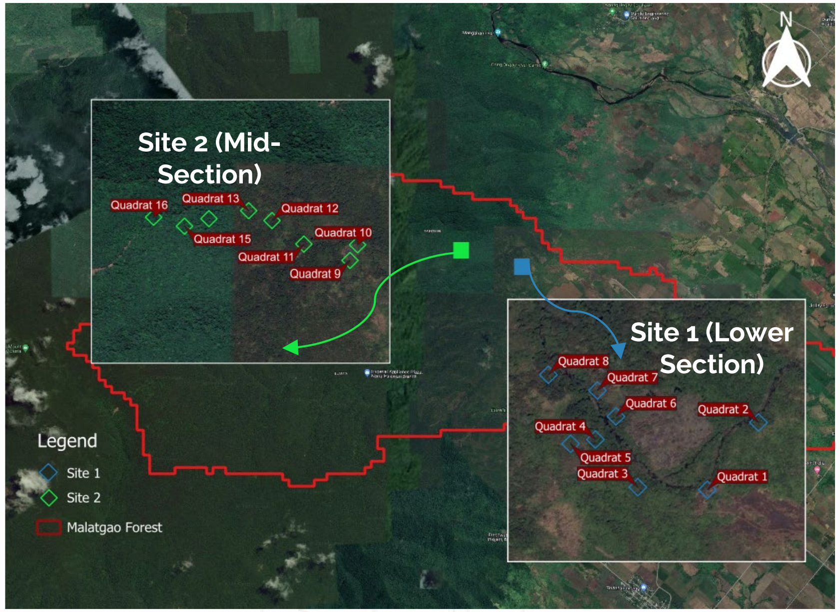
Result 1: Summary of Vegetation Condition & Soil Erosion Susceptibility

Site 1 (Lower Section)	Site 2 (Mid Section)
▪ ***Garcinia venulosa*** was identified as the dominant species in both sites, having a high Importance Value Index (IVI = 98). ▪ **Soil erosion susceptibility** is lower in Site 1 (lower section) because of more effective natural erosion barriers and better soil stability. ▪ **Finer soils with higher organic matter** content improve cohesion and reduce erosion.	▪ **Similar species present**, but structural disturbance limits their erosion-mitigating effect. ▪ **Soil erosion susceptibility** is higher in Site 2 areas with less protective vegetation cover and a disrupted forest structure that leaves soil exposed to erosion. ▪ **Coarser soils with lower OM** content are more prone to detachment and transport.



Map of the Study Area

- Overall, **the open forest is a regenerating secondary forest** with fragmented canopy. Areas with lower vegetation cover and inconsistent tree structure (Site 2/mid section) are **more prone** to soil erosion than Site 1/lower section.

Discussion for Results 1

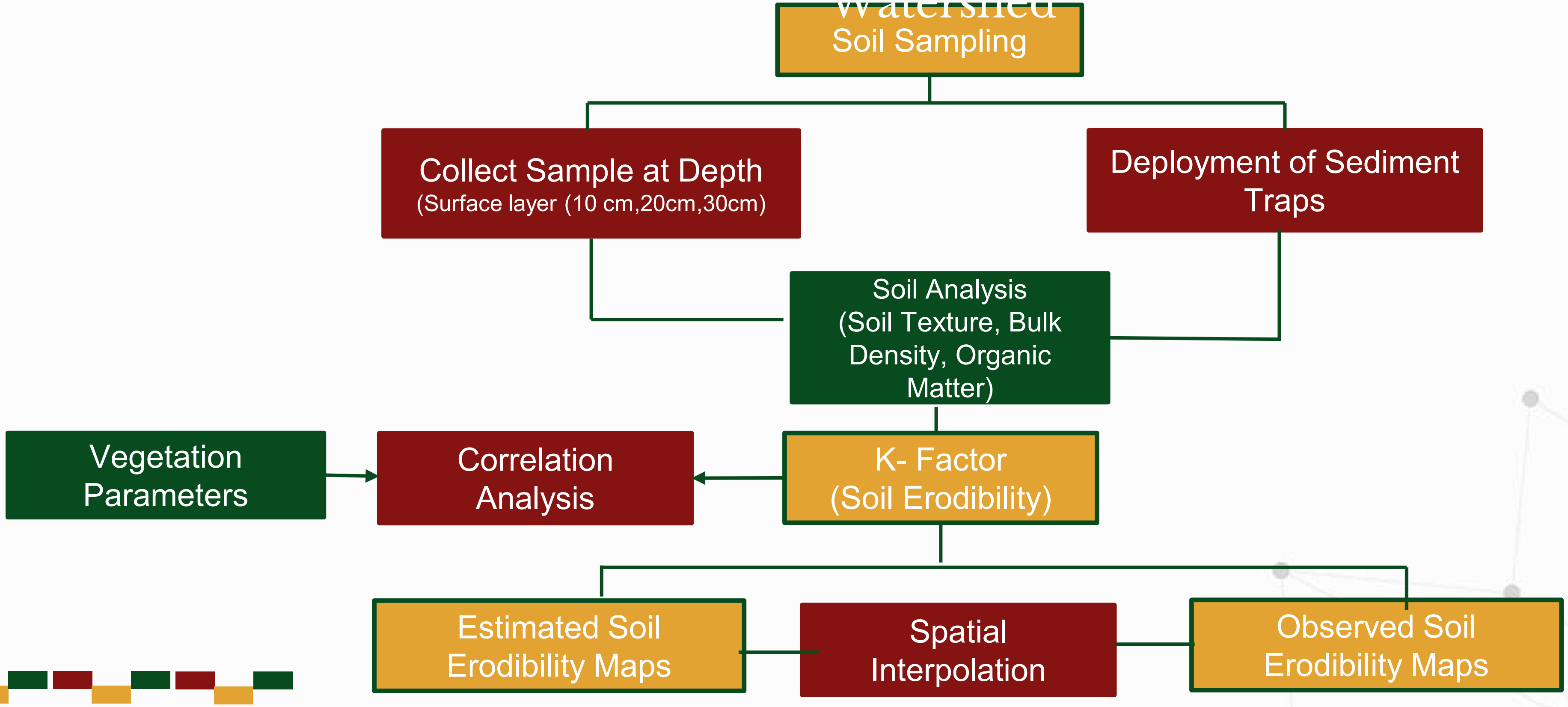
Study Findings	Support from Existing Literature
Higher DBH (Site 1 mean: 75.72 cm vs Site 2 mean: 63.32 cm) corresponds to lower erosion susceptibility	▪ Gyssels et al. (2005) showed that **trees with larger DBH have more extensive root systems**, which increase soil cohesion and reduce erosion rates by 50-90%. ▪ Zhou et al. (2008) found that every 10% increase in average DBH is associated with a 15-20% decrease in soil erosion potential.
Greater canopy diameter (Site 1 mean: 2.09 m vs Site 2 mean: 1.41 m) improves erosion resistance	▪ Montgomery (2007) stated that **canopy diameter directly affects rainfall interception**. Trees with canopy diameters greater than 2 meters can reduce raindrop impact energy by up to 60%, greatly lowering splash erosion. ▪ Zuazo & Pleguezuelo (2008) reported that broader canopies form a multi-layered protective barrier against rainfall erosivity..
Higher species richness (Site 1 mean: 3.56 vs Site 2 mean: 3.23) enhances ecological resilience	▪ Pohl et al. (2009) found that each additional tree species in **a forest plot increases erosion resistance by about 8-12%** because of complementary root systems. ▪ Stokes et al. (2014) showed that **higher species diversity** offers better erosion protection due to varied root depths and structures, with mixed-species forests experiencing 30-40% less erosion than monocultures.

Discussion for Results 1

Study Findings	Support from Existing Literature
Greater number of individual trees (Site 1) creates more effective soil protection	▪ Casermeiro et al. (2004) found that soil erosion rates **decreased exponentially with increased tree density**; areas with more than 5 trees per 100 m^2 showed 70% lower erosion rates. ▪ Wang et al. (2013) demonstrated that in **similar tropical forest conditions, soil loss decreased** by approximately 18% for each additional tree per sampling plot.
Visual satellite imagery sometimes contradicts ground measurements	▪ Vrieling (2006) highlighted that **relying solely on remote sensing for erosion assessment can be inaccurate, with ground-truth data showing 15–40% discrepancies** compared to satellite-based visual assessments. ▪ Metternicht et al. (2010) showed that **visual assessments of canopy cover from aerial imagery can be misleading** due to seasonal changes and perspective limitations.

Method for Objective 2: Soil Erodibility Maps

Map soil erodibility (K-factor) using field-acquired values to support the assessment of vegetation influence on erosion patterns in the open forest of Malatgao Dam Watershed



Method 2A: Soil Sampling

A. Depth

Two soil samples were collected from each of the three standard depths—10 cm, 20 cm, and 30 cm—using a 5 cm diameter, 30 cm long soil sampler.

B. Soil Texture Analysis

Soil texture was analyzed to determine the proportions of sand, silt, and clay, which directly affect water retention, infiltration, and erosion resistance.

C. Soil Bulk Density

To assess soil compaction and porosity, which influence water infiltration, root penetration, and susceptibility to erosion it will be computed as

$$\text{Soil Bulk Density } (g/cm^3) = \frac{\text{oven-dry sample mass } (g)}{\text{sample volume } (m^3)}$$

D. Soil Organic Matter

decomposed remains of plants, animals, and microorganisms in the soil or on the forest floor

$$\text{OM \%} = \frac{\text{Weight Before Ignition (g)} - \text{Weight After Ignition (g)}}{\text{Weight Before Ignition}}$$

Figure : Two Soil Samples Collected for Soil Textural and Organic Matter Analysis

Figure: Soil Particle Size Analysis Using the Hydrometer Method

Method 2B: Observed Soil Erodibility from Sediment Traps

- This study deployed **2x2 meter sediment traps** made of sack trapal, standing **1 foot tall**, in each quadrats to collect sediments for observed soil erodibility. Sediment collection and monitoring was conducted over a one-month observation period."
- The **observed soil erodibility** was computed by combining the concepts of Kinetic Energy of Raindrops, Cumulative Kinetic Energy, and Soil Detachment (Alemu, 2022). This approach allowed for quantifying soil susceptibility to erosion based on rainfall impact and soil particle detachment.

Figure : Deployment of Sediment Traps

Soil Erodibility Due to Rain Impact

$$F = 16.4 * K * R$$

F = soil detached (g/m^2)

K = soil erodibility factor

KE = kinetic energy of the rainfall.

Method 2B: Estimation of Soil Erodibility from K Equation

- The **estimated soil erodibility** values were derived from soil samples collected at specific depths to capture vertical variation in soil properties.
- Estimation of soil erodibility were computed using a specific equation and soil analysis on various soil samples, based on the formula used by Alemu (2022).

$$K = \left(0.2 + 0.3 * \exp\left[-0.0256 * m_s * \left(1 - \frac{m_{silt}}{100}\right]\right) * \left(\frac{m_{silt}}{mc+silt}\right)^{0.3} * \left(1 - \frac{m_{silt}}{orgC + exp[\,3.72 - 2.95 * orgC\,]}\right) * \left(1 - \frac{m_{silt}}{\left(1-\frac{1}{100}\right) + exp\left[-5.51 + 22.9 * \left(\frac{m_{silt}}{\left(1-\frac{m_{silt}}{100}\right)}\right)\right]}\right) * 0.1317$$

where **ms, msilt, mc and organic carbon** are sand, silt, clay and organic carbon content (Sharpley et al., 1990).

Figure: Soil Samples Collected in different Depths

Method 2C: Spatial Interpolation

To interpolate both observed and estimated soil erodibility values in unsampled areas based on measured data points

Method Used	Sample Size Consideration	Expected Output
Inverse Distance Weighting (IDW) A deterministic method that assumes values closer to the prediction location have more influence than those farther away.	**Suitable for small to moderate datasets (e.g., 16 samples)** This sample size is appropriate when detailed, resource-intensive measurements are required, or when the population under study is limited.	▪ Continuous raster surface showing estimated K-factor values ▪ Spatially interpolated map representing gradual changes in soil erodibility between sampled locations.

Method 2D: Correlation Analysis

- **Correlation analysis** will explore the **strength and direction** of relationships between vegetation characteristics and soil erodibility. As an exploratory approach, this analysis will help identify which vegetation factors contribute most significantly to reducing soil erodibility, thereby providing insights for erosion control and sustainable watershed management strategies. Additionally, the results of the correlation may guide reforestation or vegetation management plans aimed at mitigating soil degradation in the watershed.

Canopy Diameter

Total Basal Area & DBH

Vegetation Litter

Figure: Vegetation Characteristics

Result 2A: Soil Texture

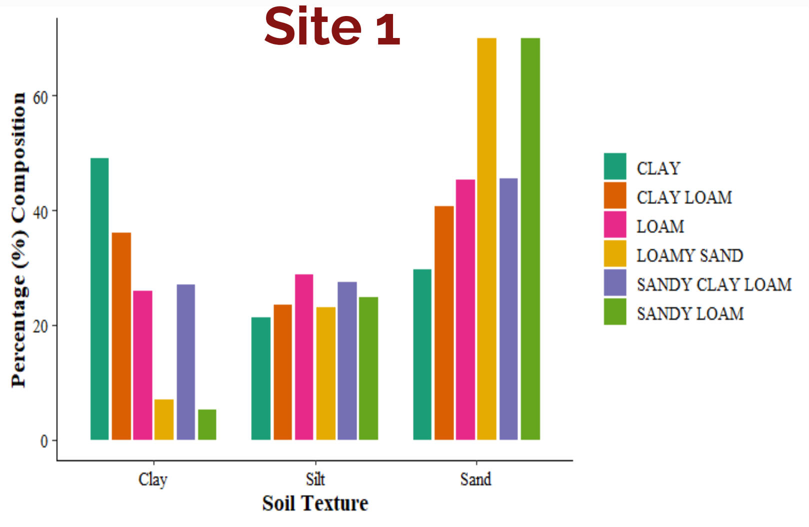
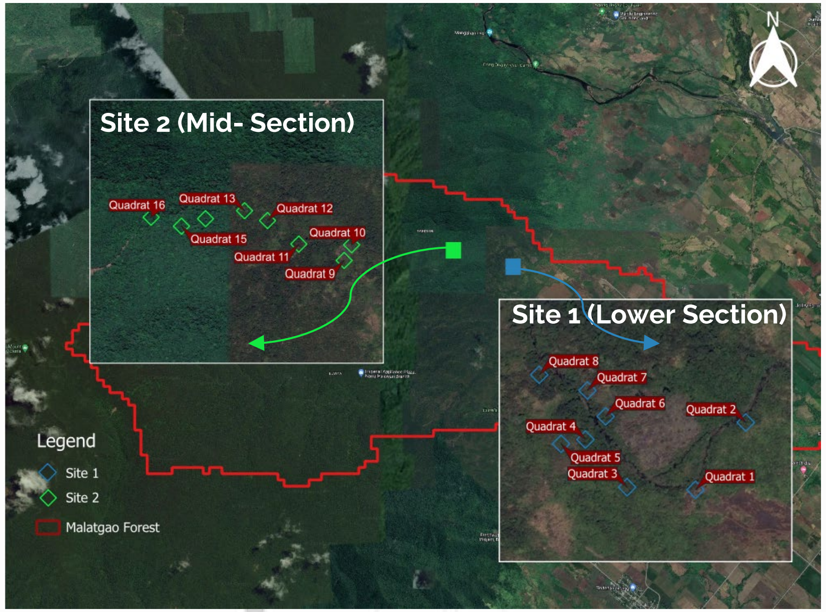


Figure: Particle Size Distribution of Site 1

Figure: Particle Size Distribution of Site 2



Map of the Study Area

- **Site 2 generally has higher sand content**, especially in Sandy Loam and Sandy Clay Loam, even in its "Clay" sample.
- **Site 1 shows higher clay content**, particularly in its true Clay sample.
- **Silt content** varies across both sites with no clear trend.
- Loam samples at **both sites are balanced**, slightly leaning toward sand.
- Site 2 shows **more extreme textures**, especially in Sandy Loam.

Result 2A: Soil Organic Matter

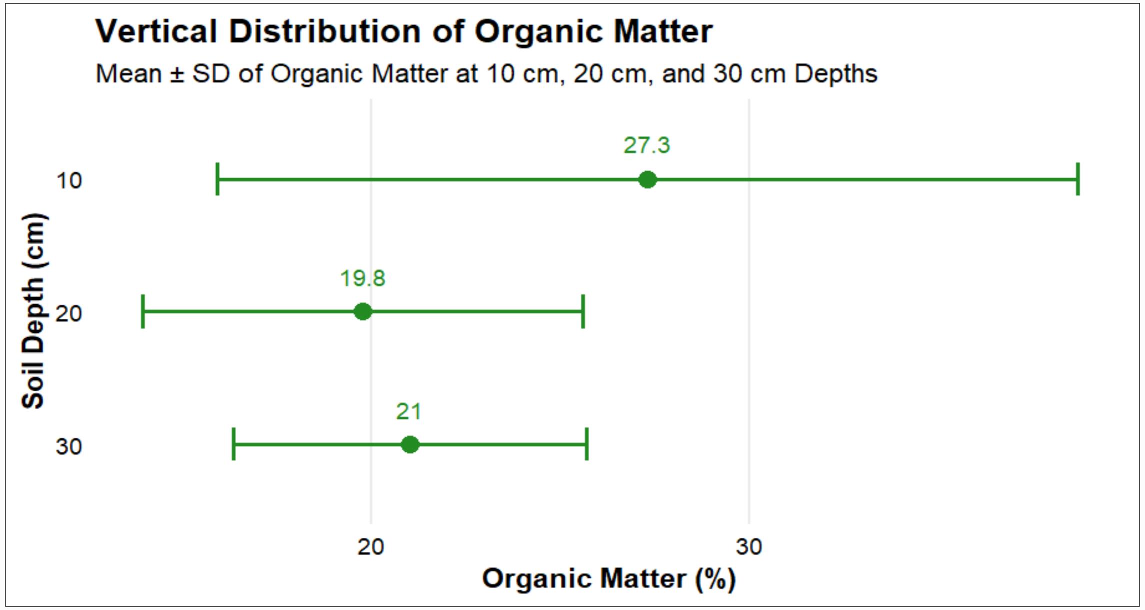


Figure 20: Profile of Soil Organic Matter

- Pairwise comparisons of mean organic matter content were conducted.
- The p-values presented in the table are adjusted for multiple comparisons.
- The adjustment method is likely a Bonferroni correction (or similar) to control the family-wise error rate given the three comparisons.

Comparison	p-value (adj)
10-20cm vs 0-10cm	0.1136
20-30cm vs 0-10cm	0.0147
20-30cm vs 10-20cm	0.0750

- Organic matter content is **highest in the topsoil** (10 cm) with a mean of 27.3%.
- There's a notable **decrease in mean organic matter** to 19.8% at the 20 cm depth.
- There is a **significant difference** in organic matter between the 0-10cm and 20-30cm depths.
- There is also no significant difference between 10-20cm and 20-30cm depths, although the difference is close to being significant.

Result 2B: Table of K Values

Soil ID	Observed Soil Erodibility	Estimated Soil Erodibility
1	0.01416	0.1385
2	0.1413	0.1369
3	0.1215	0.1198
4	0.1228	0.1251
5	0.1372	0.1354
6	0.1465	0.1421
7	0.1291	0.1258
8	0.1193	0.1165
9	0.1441	0.1419
10	0.1366	0.1332
11	0.1388	0.1345
12	0.1325	0.1302
13	0.1269	0.1238
14	0.1225	0.1211
15	0.1302	0.1264
16	0.1233	0.1207

- The table presents a **point-by-point comparison** between measured (observed) and estimated (predicted) K-factor values.
- **Differences between observed and estimated** values are **relatively small**, indicating a low prediction error and reasonable accuracy of the IDW method.
- This supports the **reliability of the interpolated** continuous K-factor surface used for erodibility mapping.

Result 2C: Observed & Estimated Soil Erodibility Maps

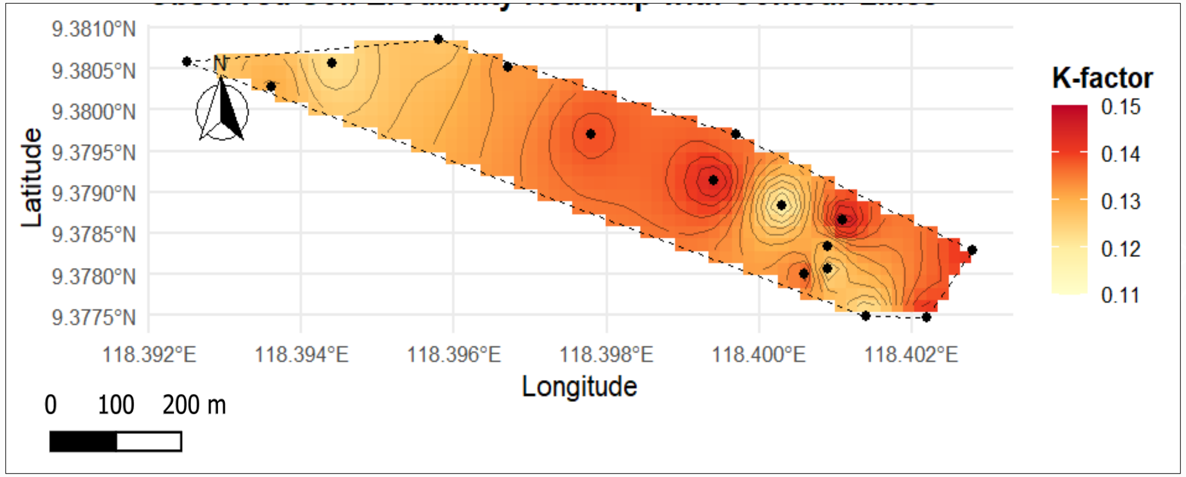


Figure : Spatially Interpolated Soil Erodibility Map Based on Observed K-Factor Values (Mg h MJ−1 mm−1)

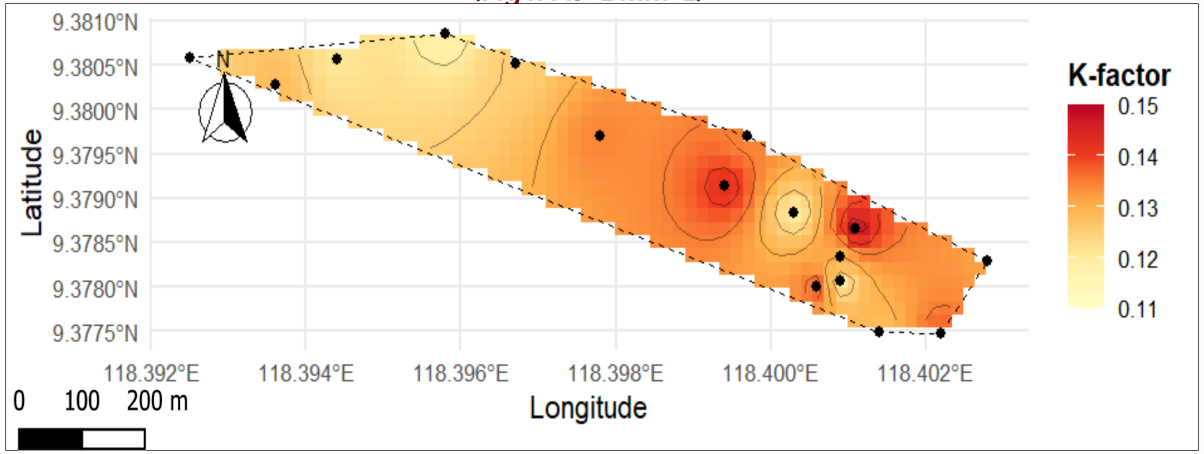
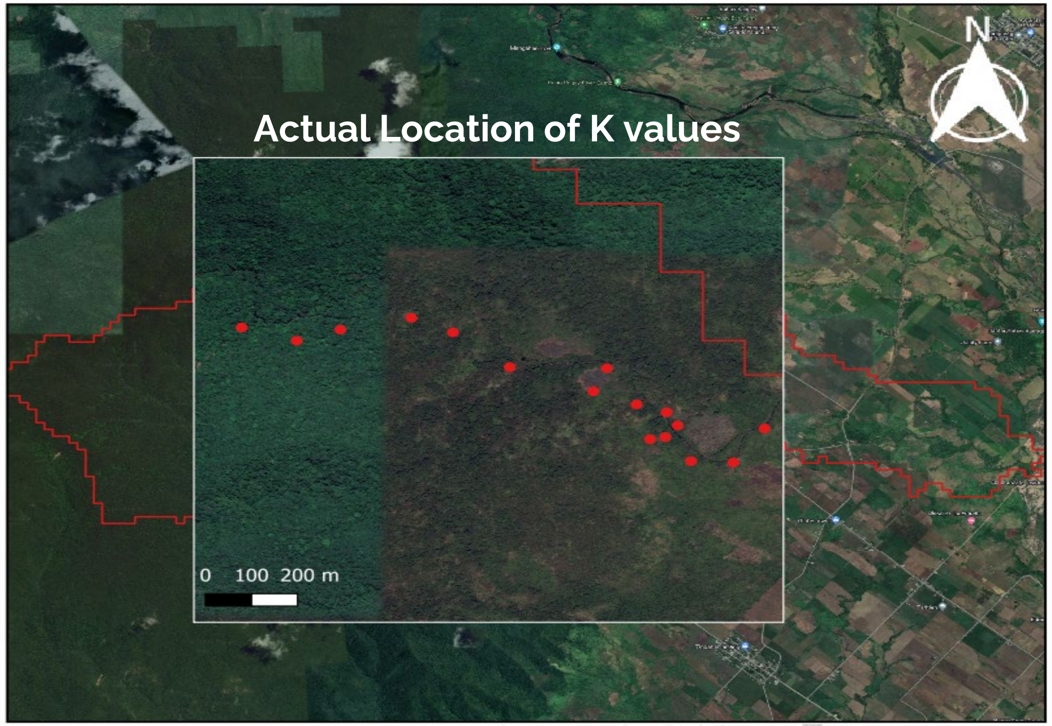


Figure : Spatially Interpolated Soil Erodibility Map Based on Estimated K-Factor Values (Mg h MJ−1 mm−1)



Soil Erodibility

The estimated K-Factor map captures the general pattern of soil erodibility but shows differences in the precise location of high-risk areas, particularly with fewer high-risk zones in the northeastern area.

AE

Result 2C: Difference Map

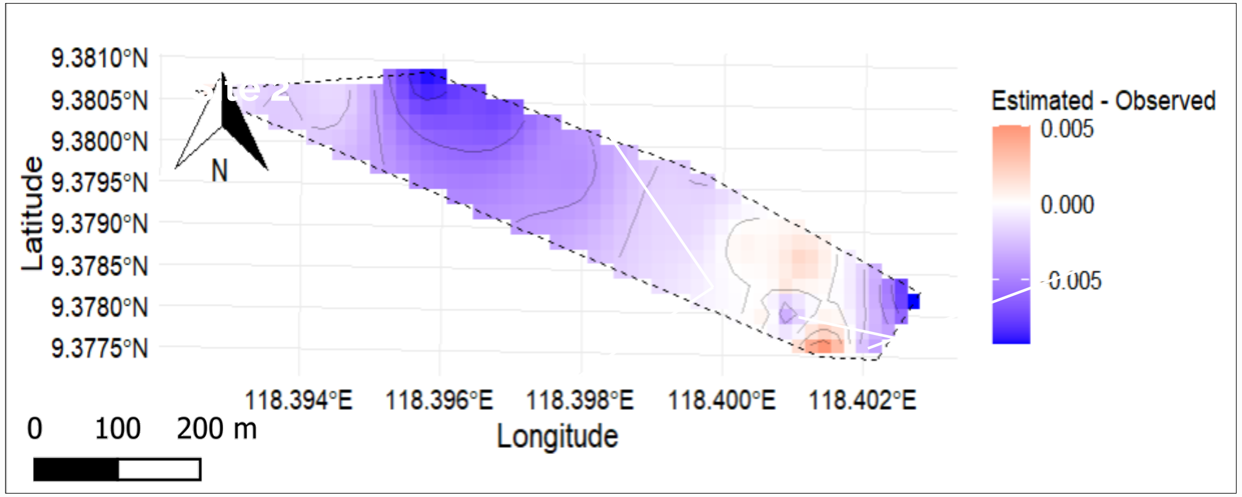


Figure : Spatial distribution of critical soil erosion zones based on soil erodibility (K-factor).

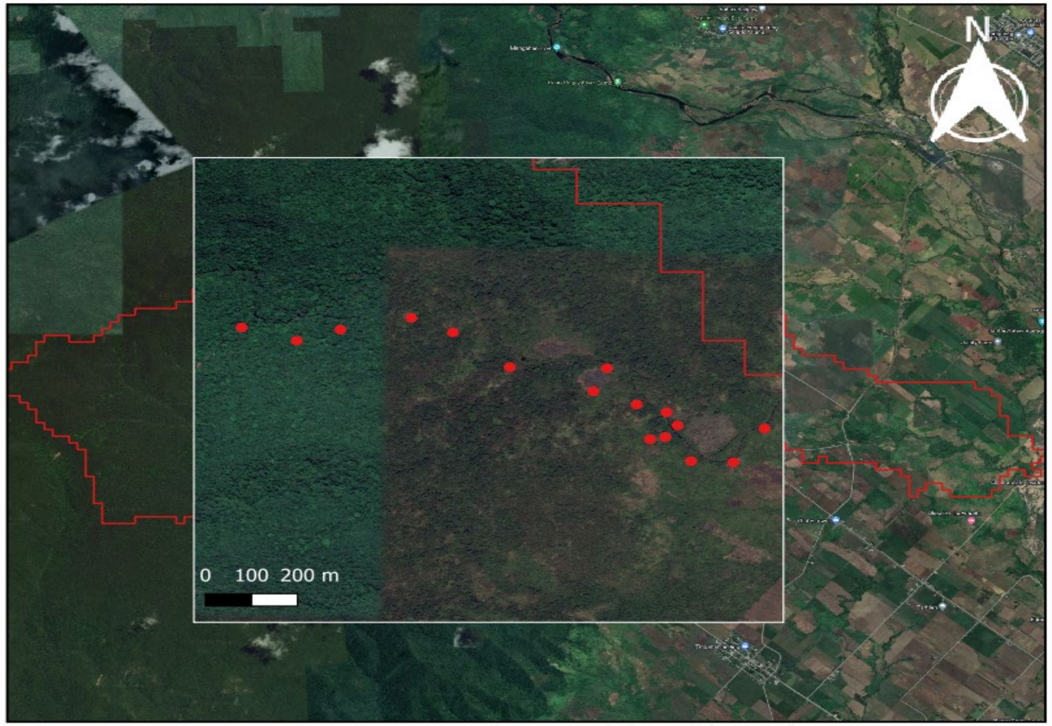


Figure :Study area showing actual location of K-Factor

- **Estimated K > Observed** in SE due to fine soil, but litter reduces erosion.
- **Observed K > Estimated** in N & central due to compaction and disturbance.
- White areas show good match, stable and uniform conditions.

Result 2D: Vegetation Parameters VS Soil Erodibility (K)

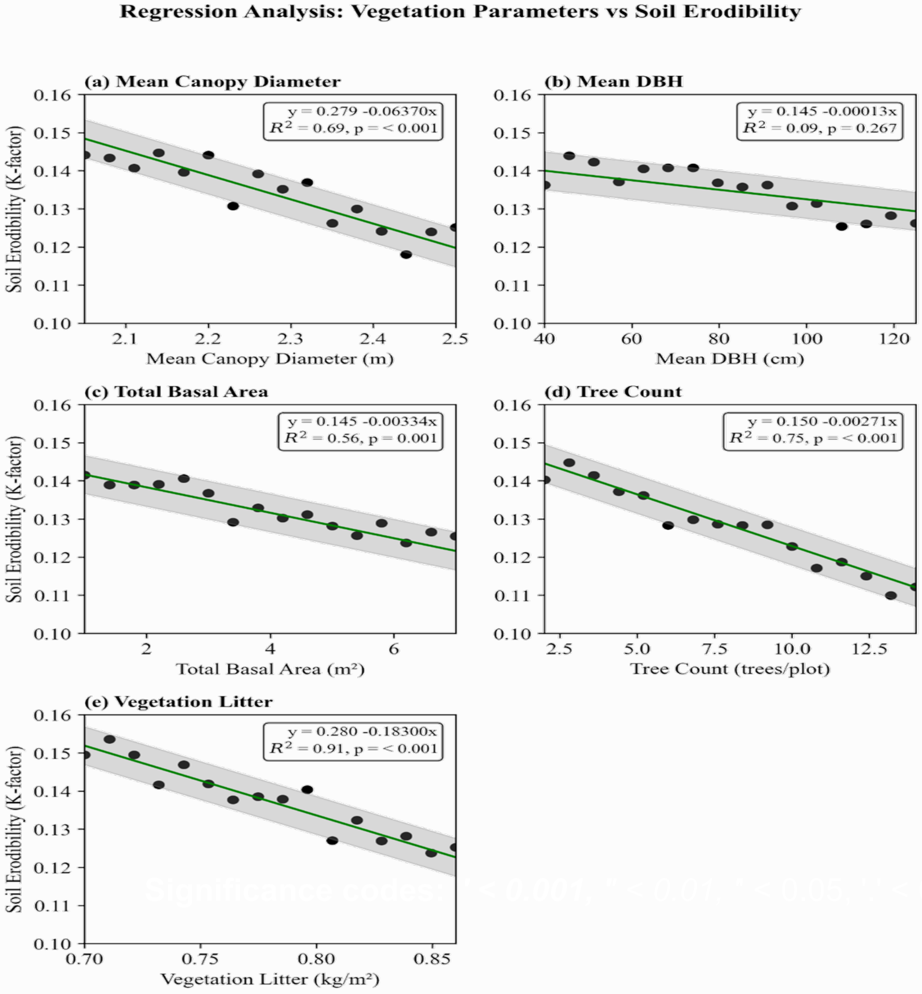


Figure 17:Correlation Matrix of Vegetation Parameters and Soil Erodibility (Factor)

- **Vegetation Litter Significantly Lowers K Factor:**
  A high amount of forest floor cover is the strongest predictor of a reduced K factor.

- **Dense Tree Cover Substantially Decreases K Factor:**
  A greater number of trees is strongly associated with a lower K factor.

- **Larger Tree Canopies contribute to lower K Factor:**
  Wider average tree crown diameters are linked to a considerable reduction in the K factor.

- The data indicates a general tendency for **increased vegetation** (in terms of litter, canopy, and tree density) to be associated with a decrease in the K factor.

Discussion for Results

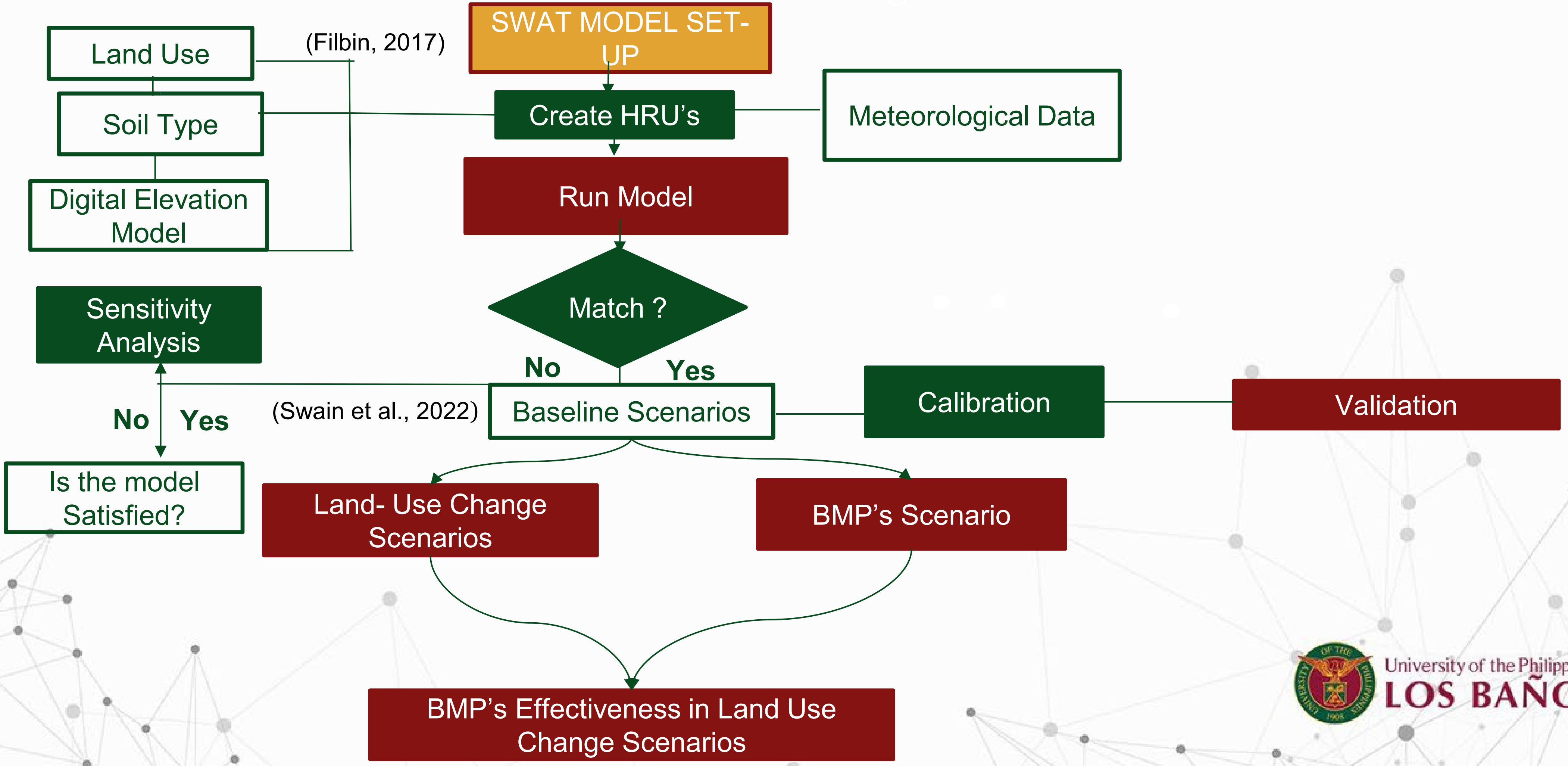
Study Findings	Support from Existing Literature
Site 2 Shows Higher Sand Content and Greater Erosion Susceptibility	▪ Site 2, with >60% sand content, **exhibits significantly higher erosion susceptibility**—Wang et al. (2013) reported 2.5–3× greater erodibility in sandy soils, Romkens et al. (2002) found K-factors 30–45% higher in sandy loams than clay-rich soils, and Wischmeier & Mannering (1969) confirmed that **erodibility peaks in soils high in sand and silt**. ▪ Site 1, characterized by >35% clay content, shows much lower erosion risk—Reichert & Norton (2013) noted 50–70% reduced erodibility, Bissonnais et al. (2005) highlighted improved aggregate stability, and Guerra (1994) **reported erosion rates 3–5× lower than sandy soils under similar rainfall.**
Observed vs. Estimated K-Factor Maps Show Discrepancies in High-Risk Areas	▪ Hessel et al. (2017) found models **underestimated erosion by 15–30% in high-risk zones.** ▪ Dai et al. (2001) noted that IDW offers computational **simplicity and reliable performance**, particularly when trends are locally driven rather than regionally consistent.

Discussion for Results

Study Findings	Support from Existing Literature
Critical Erosion Zones Clustered in Central and Eastern Areas	▪ Zingg et al. (2011), Teng et al. (2018), and Boardman (2006) showed that erosion risk is not random **but clusters along geomorphic patterns, flow paths, and hotspot convergence zones.**
Vegetation Parameters	▪ Gyssels et al. (2005) and Zuazo & Pleguezuelo (2008) found that **forest litter and root biomass can reduce soil erosion** by up to 100%, highlighting the protective role of ground cover. ▪ Panagos et al. (2015) and Alewell et al. (2019) showed that **higher tree density and canopy cover significantly lower erosion rates** by minimizing rainfall impact and runoff. ▪ Nanko et al. (2011) and Geißler et al. (2013) demonstrated that broader tree crowns and canopy structures reduce raindrop force and soil detachment, improving soil stability.

Methods for Objective 3: SWAT Modeling

Evaluate the impact of best management practices (BMPs) on soil erosion under different land use scenarios using the SWAT model



University of the Philippines
LOS BAÑOS

Method 3: SWAT Modeling

MUSLE	Model Performance Indicators
SWAT estimates daily sediment yield using the MUSLE equation: **$S = 11.8 \times (Q \times qpeak \times A)^{0.56} \times K \times C \times P \times LS$** Where: S = Sediment yield (metric tons) Q = Surface runoff volume (mm) $qpeak$= Peak runoff rate (m^3/s) A = Area of HRU (hectares) K = Soil erodibility factor C = Crop management factor P = Conservation practice factor LS = Topographic factor (slope length and steepness)	**a) Nash-Sutcliffe Efficiency (NSE):** Measures the predictive accuracy of a model compared to observed data; values closer to 1 indicate better performance. **b) Coefficient of Determination (R^2):** Indicates the proportion of variance in observed data explained by the model; ranges from 0 to 1, with higher values showing better fit. **c) Percent Bias (PBIAS):** Assesses the average tendency of model predictions to overestimate or underestimate observed values; values near 0% indicate minimal bias.

Method 3: SWAT Model Input & Land Codes

INPUT	DESCRIPTION	SOURCE
DEM	30 m	IFSAR
Base Map	Administrative Boundaries	NAMRIA
Land Cover	Land Classification	NAMRIA, Geoportal, ESRI
Soil Map	Soil Texture Data	Bureau of Soils and Water Management (BSWM)
Weather Data	daily records of rainfall (mm) and temperature (°C)	PAG-ASA

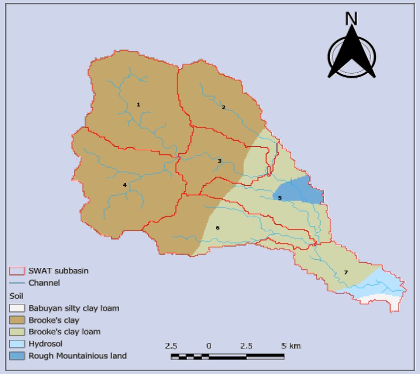
Defining Watershed Boundaries and HRUs Using Input Data

SWAT Code	Classification
FRST	Open Forest
BARR	Barren Land
PAST	Pasture
AGRL	Agriculture
URBN	Built Up
RNGE	Grasslands
WATR	Water
WETL	Wetlands
FRSE	Close Forest

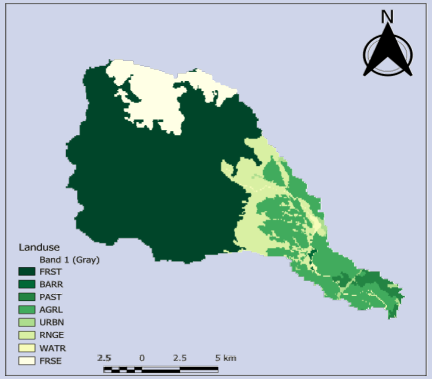
SWAT Land Cover Codes and Corresponding Classifications

Method 3: SWAT Model Setup & HRU Delineation

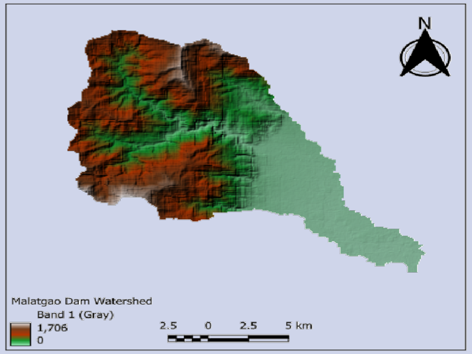
Input	Output



Soil Map



Landcover Map



Digital Elevation Model (DEM)

Hydrologic Response Unit (HRU)
- The smallest modeling unit in SWAT, representing unique combinations of land use, soil type, and slope.

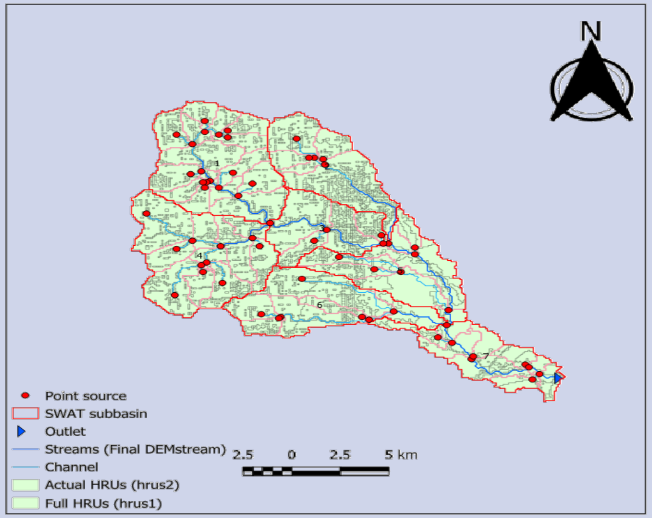


Figure :Subbasins & Hydrologic Response Units in SWAT

Total HRUs: 126
Number of Sub-basins: 7
Watershed Total Area: 21, 086 ha

Method 3: Run Model: SWAT Configuration

Model Component	Description
Simulation Period	2011–2017 (baseline run)
Land Cover Input	2020 land cover map
Warm-up Period	1 year to stabilize conditions
Model Platform	QSWAT+ 3.0.3
Outputs	sediment yield and other hydrological components

Figure : Summary of Key Components and Configuration Settings in the Hydrological Model Simulation

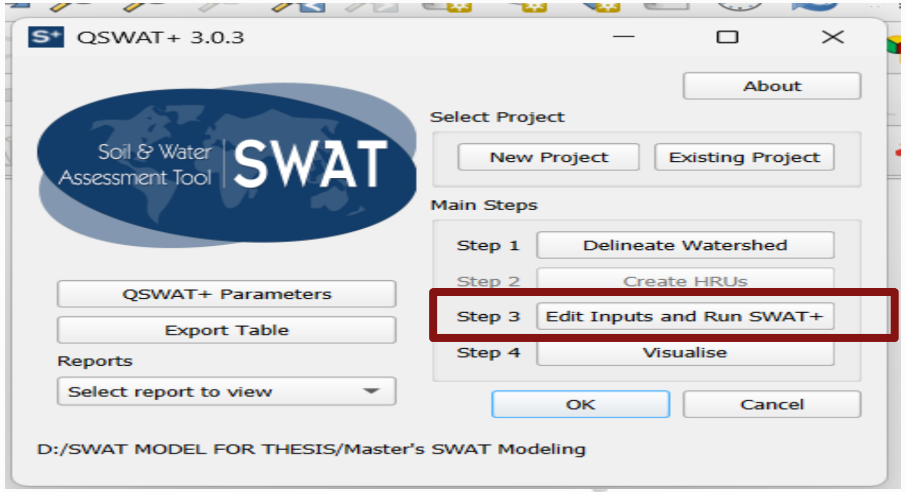


Figure : QSWAT+ 3.0.3 Interface

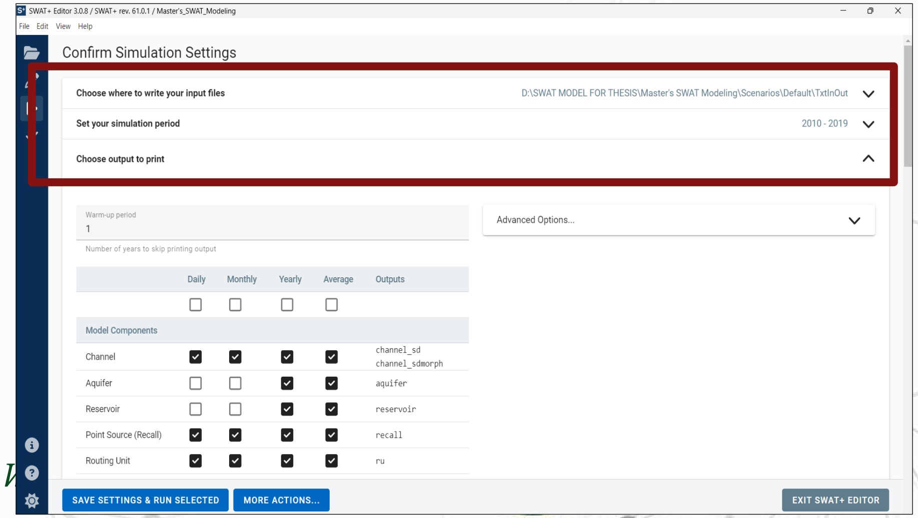


Figure :Simulation Configuration in QSWAT+

Method 3: SWAT Parameters for Sensitivity Analysis

Parameters	Description	Changes Applied
ESCO	Soil evaporation factor	Set between 0 - 1
CN2	Curve number	Varied by ±20% and -40%
OV_N	Surface roughness	±30%
CN3_SWF	Wet condition runoff adj.	±30%
SURLAG	Runoff delay	Set between 1 - 10
ALPHA_BF	Baseflow Factor	Set between 0.01 - 0.99
REVAP_CO	Soil-to-Plant Water Transfer	Set between 0.02 - 0.2
REVAP_MIN	Minimum Depth for Plant Uptake	Set between 0.02 - 0.2
USLE_K	Soil Erodibility Factor	Varied by ±25%
k	Hydraulic Conductivity	Varied by ±25%

Pre-Calibration Sensitivity Analysis

- Sensitivity analysis conducted before adjusting model parameters to fit observed data

Result 3: Sensitivity Ranking and NSE Response of Parameters

Ranking	Parameter	Sensitivity Value (Higher = More Sensitive)	Best Sensitivity Value
1	surlag	1.23	1.28
2	cn2	0.20	6.87
3	esco	0.12	0.84
4	cn3_swf	0.06	1.87
5	revap_co	0.00007	0.10

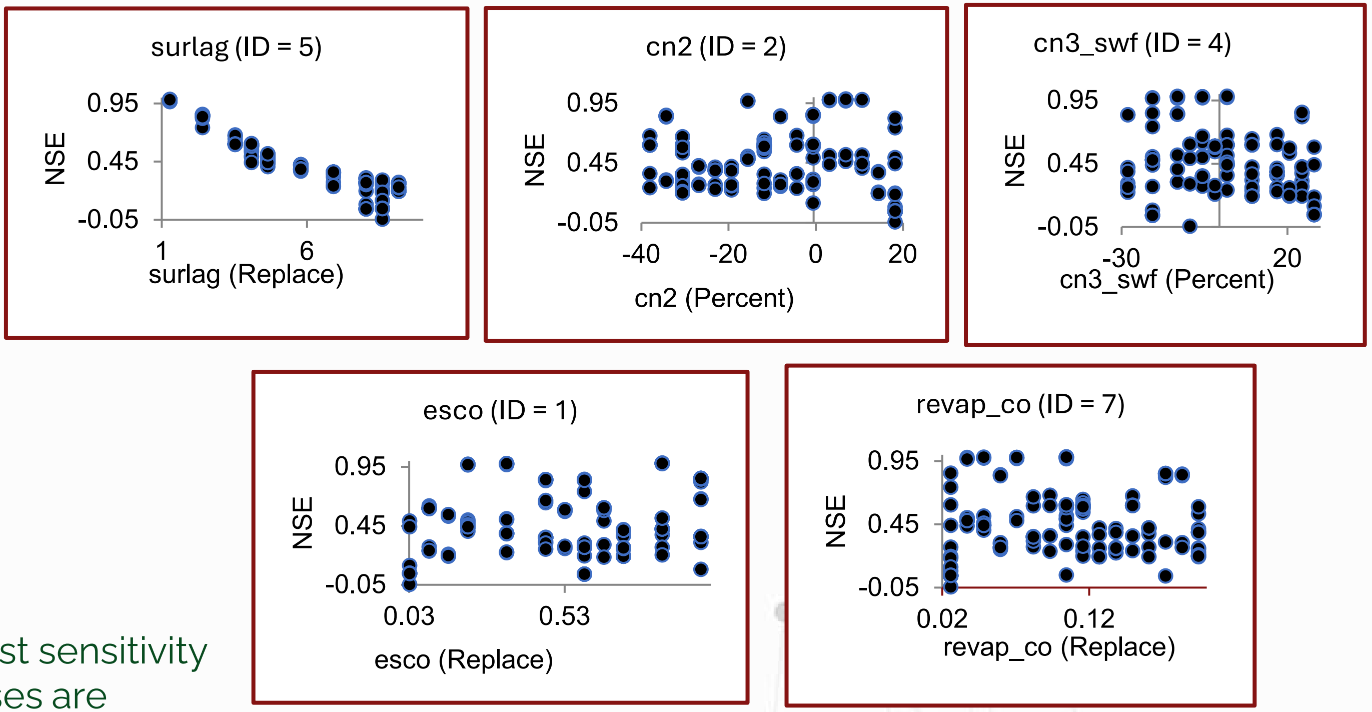
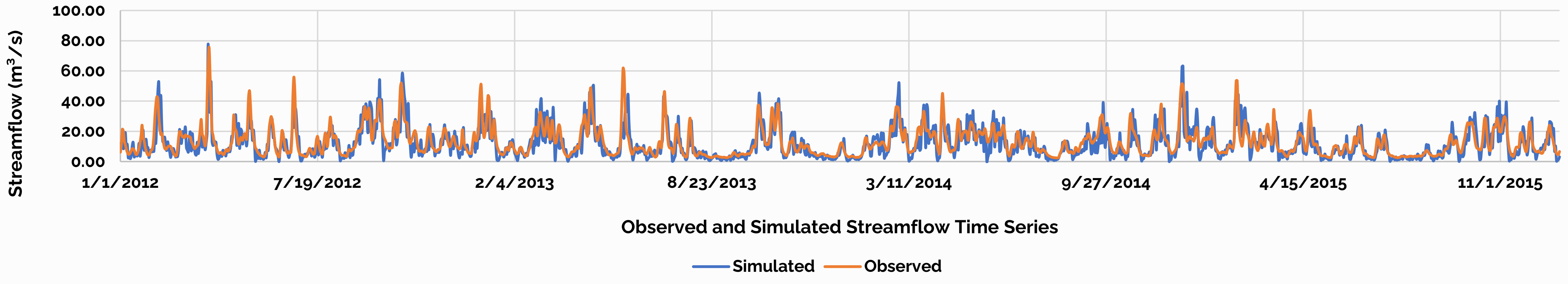


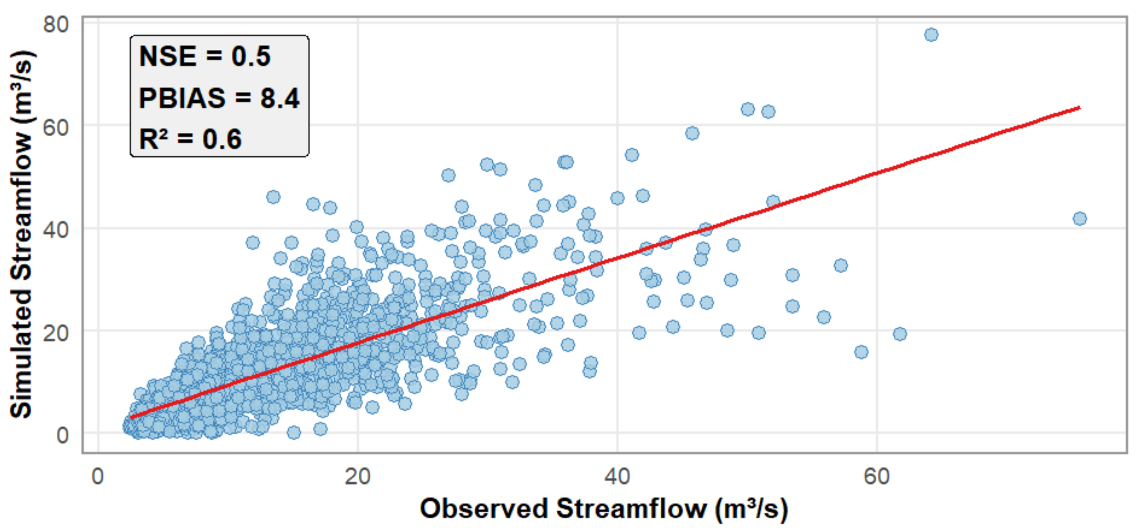
Figure: NSE Response to Variation in Top 5 Most Sensitive SWAT Parameters

- **Runoff-related parameters (SURLAG, CN2)**, having the highest sensitivity values, are the most influential, meaning surface flow processes are dominant in this watershed.
- **Evapotranspiration (ESCO)** shows a moderate sensitivity, influencing water balance but to a lesser extent than runoff parameters. Baseflow (ALPHA) and groundwater movement (REVAP_CO), with low sensitivity values, have minimal impact on surface runoff compared to groundwater.

Result 3: Calibration

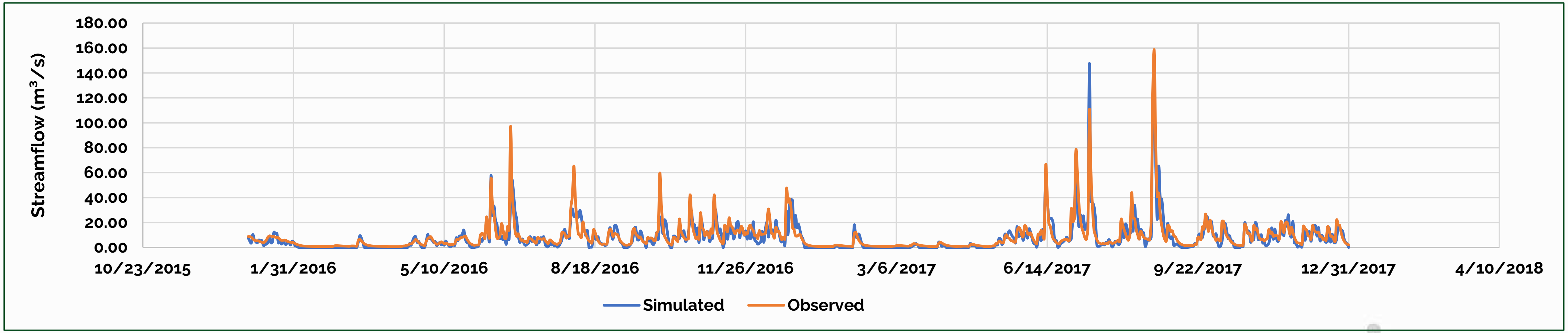


Observed and Simulated Streamflow Time Series

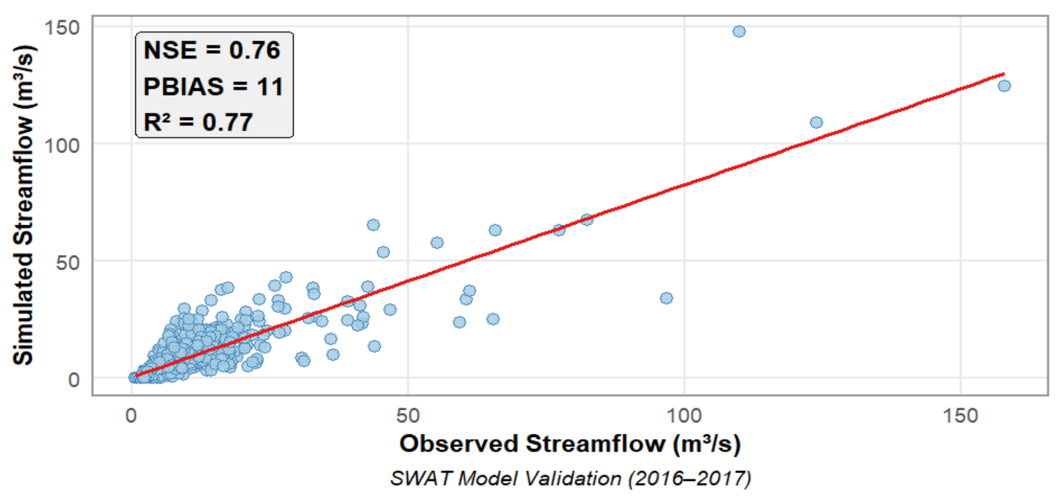


Simulated Streamflow vs. Observed Streamflow during Calibration

Result 3: Validation



Observed and Simulated Streamflow Time Series



Simulated Streamflow vs. Observed Streamflow during Calibration

Result 3: Run off VS Sediment Yield

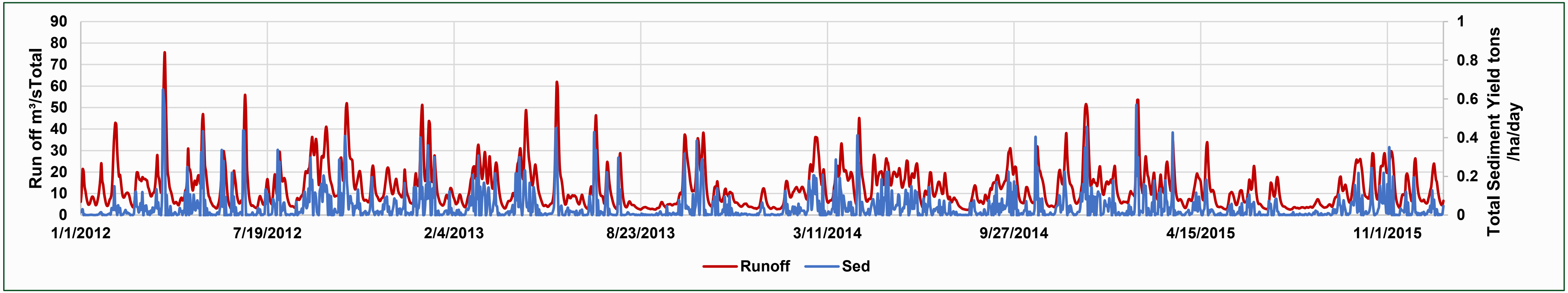


Figure: Sediment Yield Response to Runoff Events

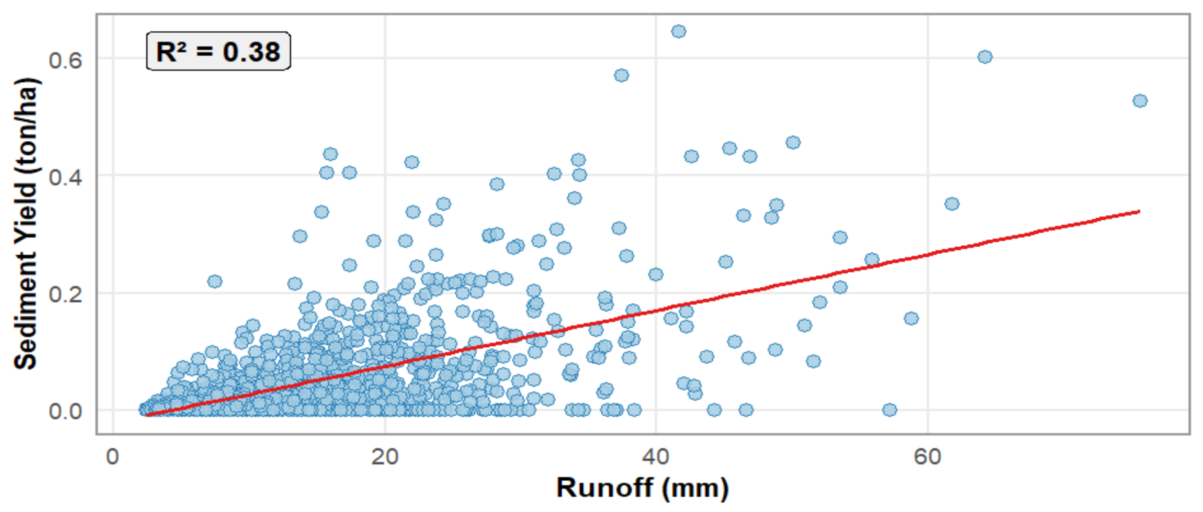
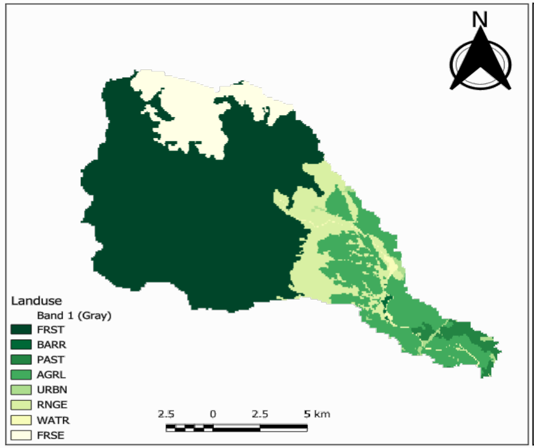


Figure: Correlation between runoff and sediment yield.

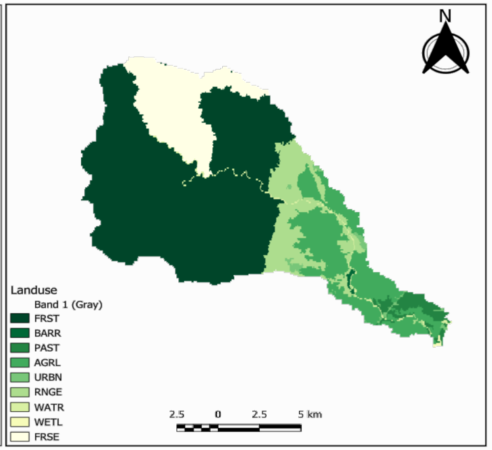
Result 3: Land Use Scenarios

Scenario No.	Description of Land Use Scenarios
0	Baseline
1	Partial Forest Conversion to Agriculture (15%) with Forest Cutting
2	Increased Agricultural Expansion (20%) with Forest Cutting

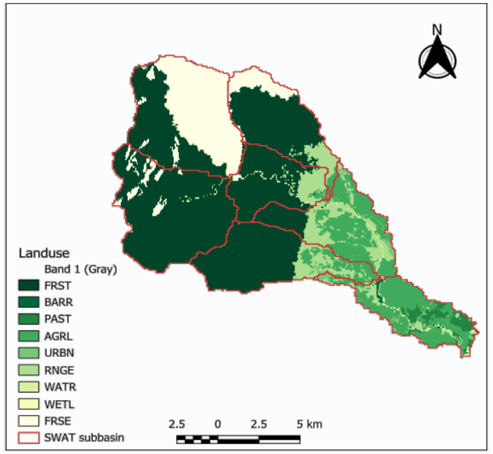
Forest Conversion and Agricultural Expansion Scenarios in Malatgao Dam Watershed



2010 (NAMRIA)



2015 (Geoportal)

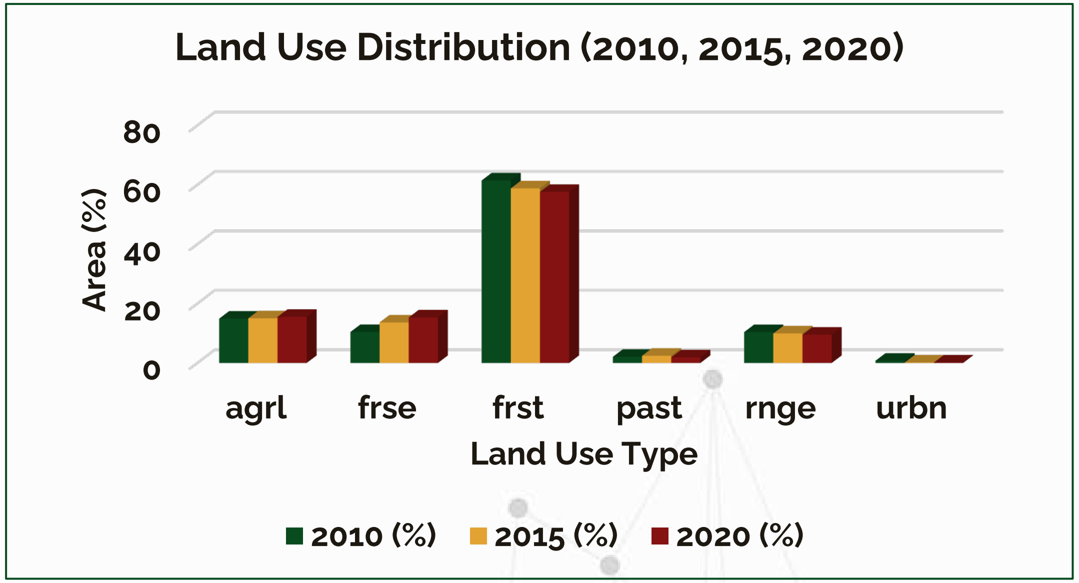


2020 (Geoportal)

- The **transformation of land cover continues** to impact land surface properties and the functions of ecosystem services. Gaining insights into historical land cover changes and their interactions with environmental processes is key to improving land-use planning and management.

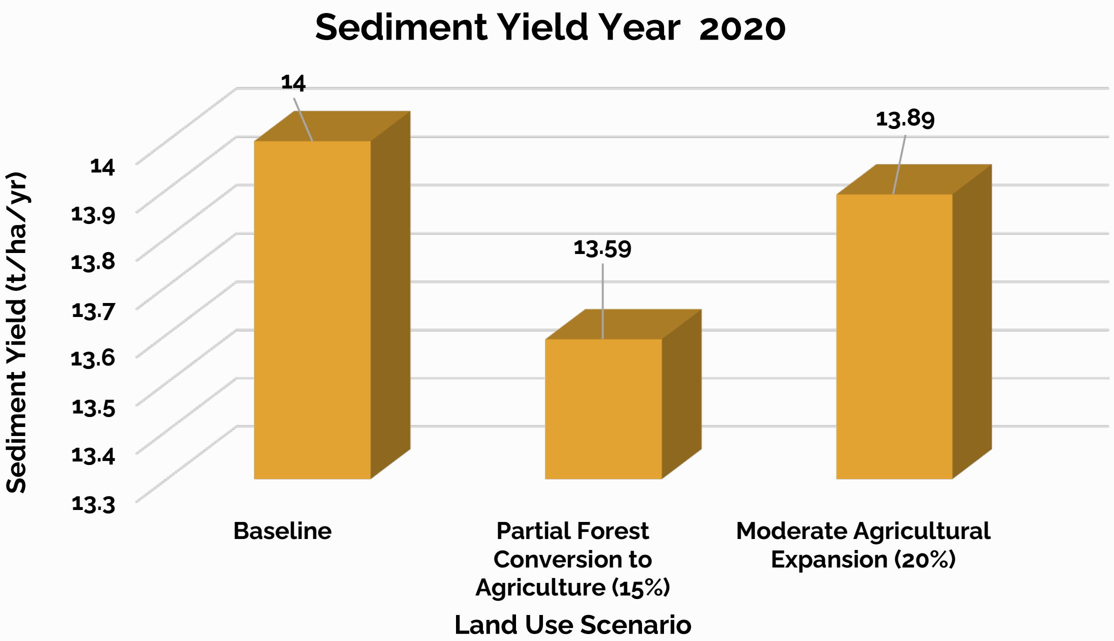
Result 3: Trend in Land Use

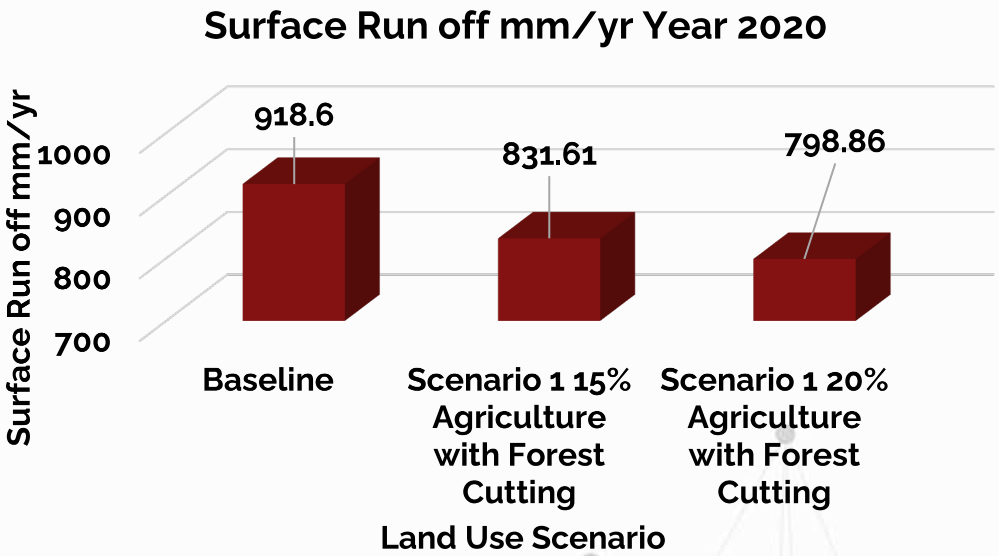
- **Open forest cover declined** from 61.45% in 2010 to 57.59% in 2020, indicating ongoing deforestation.
- **Agricultural land expanded slightly**, suggesting forest areas are gradually being converted to farmland.
- **Closed forest fluctuated**, with signs of recovery by 2020 possibly due to natural regeneration or reforestation.
- **Urban and pasture areas** remained stable, showing minimal development pressure within the watershed.



Trends in Land Cover for 2010, 2015, and 2020

Result 3:Sediment Yield Response to Land Use Scenarios





- **Sediment yield remained stable** across scenarios, indicating forest loss alone did not significantly increase erosion.
- **Surface runoff decreased with forest-to-agriculture conversion**, suggesting altered infiltration and evapotranspiration dynamics.
- 15% and 20% forest conversion scenarios resulted in lower runoff compared to the baseline (918.6 mm to 831.61 mm and 798.86 mm).
- Results reveal non-linear responses, highlighting that land use impacts are influenced by multiple factors like soil and topography.

Result 3: Best Management Practices (BMPs)

BMP No.	BMP
0	-
1	Contour Farming
2	Contour Farming + No Till
3	Strip Contour + Grass Waterway (Medium)
4	Strip Contour + Grass Waterway (High)

Implemented Best Management Practices

- The selected BMPs were **designed to reflect actual land management activities** observed in the open forest areas of the watershed, where tree cutting and subsequent conversion to upland farming are common.
- Practices such as contour farming, no-till methods, and the use of grassed waterways were incorporated to address soil disturbance, minimize erosion on sloping lands, **and simulate practical conservation measures aligned with current land use trends.**

BMPs Effectiveness calculates the percentage reduction achieved by BMPs. A higher percentage means BMPs were more effective in reducing erosion or improving conditions.

No BMPs = Sediment yield (or other parameter) without BMPs
With BMPs = Sediment yield (or other parameter) with BMPs

$$\textbf{Effectiveness (\%)} = \frac{(\text{No BMPs} - \text{With BMPs})}{\text{No BMPs}} \times 100$$

Result 3: BMP Effectiveness in Sediment Reduction

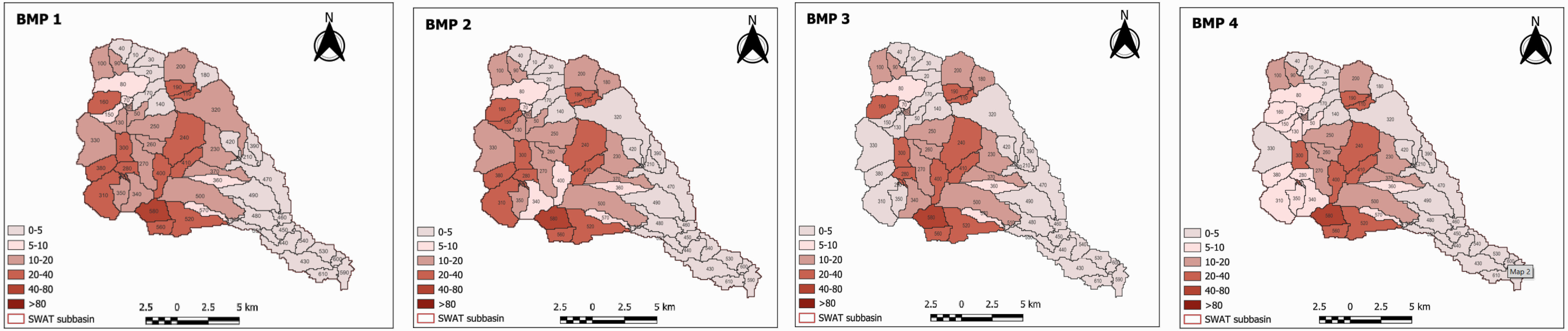


Figure: Annual spatial distribution of sediment yield (t ha^{-1}) across different BMP scenarios, with numbers representing SWAT sub-watersheds (2020)

- **In 2020 land cover**, areas that lost significant forest cover—particularly in the central and eastern parts of the watershed—correspond to zones with high sediment yield across all BMP scenarios.

- Among the BMPs, **BMP 4** performed best, effectively maintaining lower sediment yield, especially in downstream areas. However, while BMPs help reduce sediment yield, their effectiveness largely depends on the extent of land conversion and the presence of forest cover.

- **BMPs were most effective in areas** where some forest cover remained, emphasizing the importance of maintaining a balanced land-use approach. In contrast, in regions where agriculture expanded excessively (up to 40%), BMPs alone were insufficient to control erosion.

Discussion for Results 3

Study Findings	Support from Existing Literature
Highest sediment yield occurred in moderate agricultural expansion scenarios (20%)	▪ **Liu et al. (2019) identified a "disturbance threshold" where moderate land conversion** creates maximum erosion risk before stabilizing at higher conversion percentages. Rodríguez-Blanco et al. (2016) found similar non-linear relationships between land conversion percentages and sediment yield.
BMPs showed varying effectiveness across different land use scenarios	▪ Mhazo et al. (2016) demonstrated that BMP effectiveness is highly context-dependent and varies with landscape configuration. Wickham et al. (2022) confirmed that the same BMPs **perform differently across varied watershed** compositions, with effectiveness strongly linked to landscape patterns.

Summary & Conclusion

CHAPTER V

Objective 1

Summary	Conclusion
▪ **Most trees are small** (5–14 cm DBH) → recovering secondary forest. ▪ **Low canopy cover** (avg. 33%) limits light and understory growth. ▪ **Site 1: Denser**, uniform canopy and vegetation. ▪ **Site 2: Sparse**, disturbed, erosion-prone due to weak cover and roots.	**The forest is in a recovery phase, dominated by small trees and low canopy cover. Structural differences between sites reveal that Site 2 is more vulnerable to erosion due to its sparse vegetation and reduced root stability, highlighting the need for targeted conservation efforts.**

Vegatation Condition in Site 1

Vegatation Condition in Site 2

Objective 2

Summary	Conclusion
▪ **Soil texture significantly influences erosion risk**, with sandy soils showing higher susceptibility due to lower cohesion, while clay-rich soils provide greater stability and lower erosion rates. ▪ Vegetation, including litter layers, dense tree cover, and larger canopies, plays a significant role in **minimizing soil erodibility**, **reinforcing the importance** of sustaining healthy vegetation for erosion prevention.	**The spatial variation in soil erodibility within the study area is strongly influenced by soil texture and vegetation cover. Sandy soils are more prone to erosion, while clay-rich soils are more stable. Vegetation, particularly forest litter, dense tree cover, and large canopies, plays a critical role in reducing erosion risk by improving soil stability and minimizing raindrop impact.**

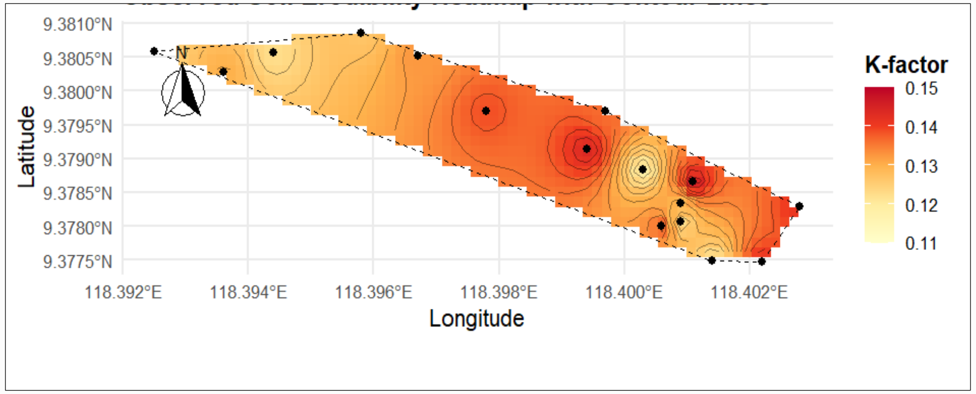


Figure : Spatially Interpolated Soil Erodibility Map Based on Observed K-Factor Values (t. ha.hr/ha.MJ.mm)

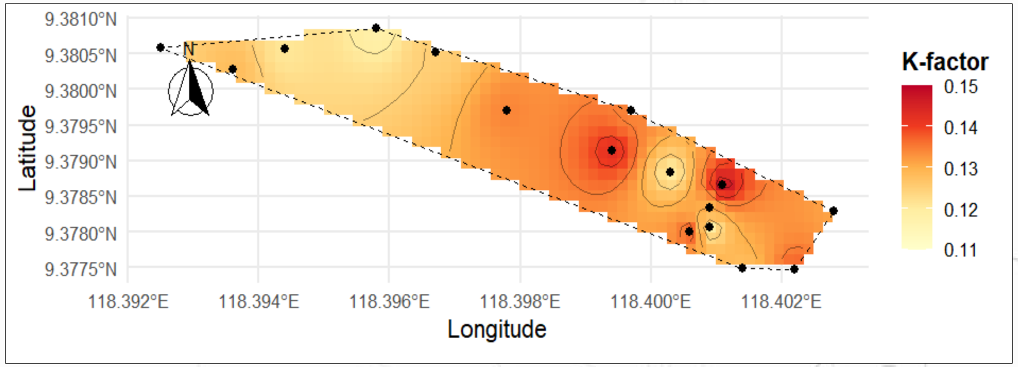


Figure : Spatially Interpolated Soil Erodibility Map Based on Estimated K-Factor Values (Mg h MJ−1 mm−1)

Figure : Spatially Interpolated Soil Erodibility Map Based on

Objective 3

Summary

- Initial disturbance effects stabilized over time due to soil and vegetation development captured by SWAT.
- Results suggest balanced land use and targeted BMPs are more effective than maximum forest cover for watershed protection.

Conclusion

SWAT simulations showed that agricultural expansion did not always increase erosion risk.

BMPs like Strip Contour + Grass Waterway were most effective in areas with 15–20% agricultural expansion, where initial sediment yield was higher.

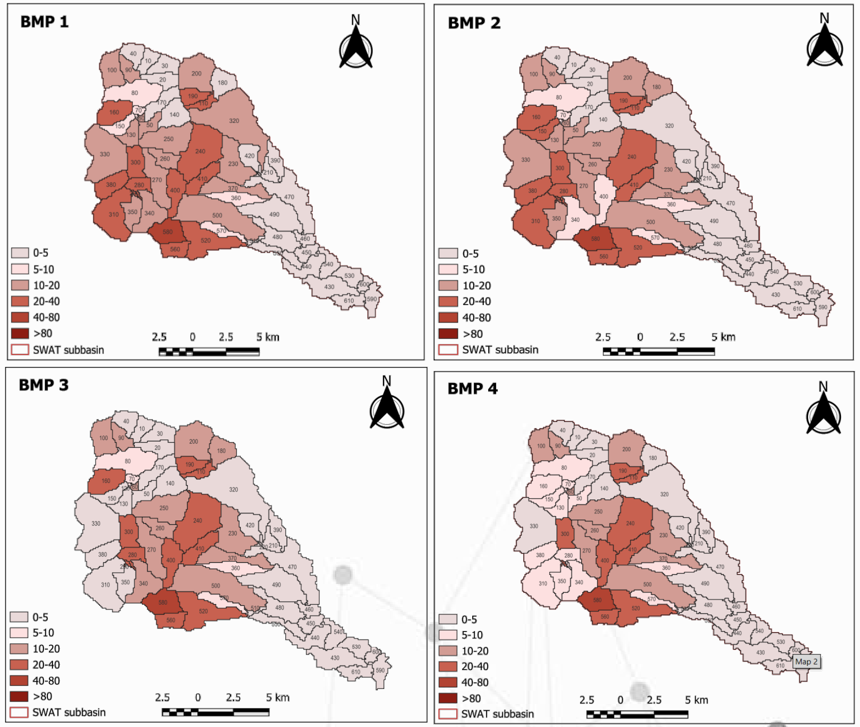


Figure: Annual spatial distribution of sediment yield (t ha^{-1}) across different BMP scenarios, with numbers representing SWAT sub-watersheds (2020)

Recommendation for Future Studies

- **Long-Term Monitoring**
  Extend the observation period for sediment traps and runoff to capture seasonal variability (wet vs. dry season dynamics).

- **Broader Spatial Coverage**
  Increase the number of sampling plots to improve spatial resolution and model accuracy.

- **Field Verification of BMPs**
  Implement and monitor Best Management Practices (BMPs) on the ground to assess actual effectiveness versus simulated results, particularly in critical erosion-prone areas.

Acknowledgement

- This research is supported by the Department of Science and Technology Engineering Research and Development for Technology (DOST-ERDT)

Thank you!

The floor is now open for questions.