Spatial Assessment of Soil Erosion Risk Using RUSLE and GIS in Upland Agricultural Barangays of Candelaria, Quezon, Philippines

Author: Whilmer A, Mendoza

Abstract

This study integrated Geographic Information System (GIS) and the Revised Universal Soil Loss Equation (RUSLE) model, A= R • K • LS • C • P, to assess soil loss and propose soil conservation strategies in Candelaria, Quezon, Philippines, addressing increasing erosion evidenced by collapsing hillsides, sedimentation, and soil displacement from construction. The RUSLE model, with adjustments in the P factor derived from local farmer interviews, was used to estimate annual soil loss using QGIS 3.43. Initially, the estimated annual soil loss was 2,210.87 tons/year for Bgy. Masalukot IV and 1,398.51 tons/year for Bgy. Masalukot V. After adjusting the P values, the total annual soil loss decreased to 1,375.49 tons/year and 878.47 tons/year for Bgy. Bgys. Masalukot IV and V, respectively, representing reductions of 37.79% and 36.96%. Slope and soil erodibility significantly impact soil erosion, with steeper slopes and higher K-values leading to increased loss, while perennial crops offer better protection than annuals. Integrating multiple conservation practices, especially a combination of six, proves most effective in reducing soil loss. Recommended conservation practices show that terracing is highly effective on steep slopes, while contouring works well on gentler terrain, emphasizing the need for site-specific and integrated soil conservation strategies.

Keywords: erosion, GIS, RUSLE, soil loss, soil conservation

Introduction

Soil erosion is a naturally existing process which is responsible for shaping the physical landscapes and terrains through the distribution of different weathered materials produced because of geomorphic activities (Panagos et al., 2014). Even though geomorphologic processes can contribute to soil erosion, human activity is primarily accountable for its acceleration. Soil erosion has become more rapid globally through problems such as deforestation, inappropriate land use, uncontrolled grazing, and rapid population growth (Rajeshwari & Kumar, 2015). Monitoring and addressing these problems are crucial to help prevent its negative consequences, which is useful in choosing and assessing the most suitable sustainable practices to be applied for conservation of soils.

The soil loss from various land surfaces caused by erosion is commonly observed over widespread areas which leads to reduction of the soil productivity of different natural ecosystems including agricultural lands, forestlands, and pastoral lands (Pimentel & Burgess, 2013). Soil loss by runoff is a severe ecological problem occupying 56% of the world-wide area. Soil loss is accelerated by human-induced soil degradation (Rajeshwari & Kumar, 2015). The intensity of soil degradation and the possibility of amending it are greatly dependent on the type of degradation processes causing it. Among those, soil erosion is considered as one of the major problems, which causes farmers to abandon land, or face the high consequences of using degraded soils. Soil degradation has emerged as a completely critical problem in densely inhabited agricultural areas. The general results of soil degradation pose risk to safety (Gomiero, 2016). Soil erosion rates have increased significantly in the past few years which has led to a decline in soil productivity. Furthermore, the effects of soil erosion are particularly severe in areas with high population density and agricultural activity (Pimentel & Burgess, 2013).

The Revised Universal Soil Loss Equation (RUSLE) is a widely used method for estimating soil loss due to erosion. Developed by the United States Department of Agriculture (USDA), the equation considers five main factors that are major influencing factors of soil erosion which are rainfall erosivity, soil erodibility, slope length and steepness, cover management, and support practice (Smith et al., 2023). GIS-based modeling of soil erosion using RUSLE investigates spatial patterns of rainfall, soil erodibility, slope, vegetation and support practices, and their impacts on soil loss. Several studies have used GIS-based models for mapping soil loss across eroded areas and has been shown effective in visualizing erosion hotspots and its causes through the use of thematic maps.

This study was conducted as a response to the increasing rate of soil loss through erosion in Candelaria, Quezon. Several incidents have been recorded which show major problems which are considered as soil erosion or is directly related to erosion and its contributing factors. The observed problems include collapsing hills, sedimentation and mass soil loss due to large construction projects. These affect the residents of the places where the problems are recorded. The collapsing hillside poses a risk of landslide during rainy seasons and is a cause of extreme dust during the dry seasons which also poses risks to health problems such as respiratory problems, cardiovascular problems, skin and eye irritation. The sedimentation of riverbanks and other natural waterways causes increased flooding instances, toxic algal bloom, and degradation of water quality. The constructions of large industrial projects also caused mass displacement of soil from its natural environment which has resulted in destruction of habitat for native wildlife, lower soil fertility, as well as soil degradation, and sedimentation.

Methodology

Reseach Locale

This study was conducted in Candelaria, a municipality under the province of Quezon, Philippines. The total land area of Candelaria is 17, 515 hectares, and an elevation that ranges from 50 to 1,850 meters above sea level. Of the land area, 53.55% were classified as flat lands, 35.17% as rolling to undulating lands, 9.37% as steep mountainous slopes, and 1.91% as extremely steep slopes (*About Candelaria*, 2022). The municipality of Candelaria has a total of 25 *baranggays*, among this, Bgy. Masalukot IV and Bgy. Masalukot V were selected as the area of interest for this study based on critical case sampling.

Data Collection

The summary of required data and sources for factor values computation are listed in Table 1. The list of data collected are rainfall events, soil series, slope categories, and land cover of Quezon, and practices of farmers on the selected areas in Candelaria, Quezon.

Table 1. List of Data for Factor Values

Data	Data Sources	Data Usage	Data Processing
Rainfall intensity	Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA)	Rainfall Erosivity Index (REI)	KE > 25
Soil series map	Provincial Planning and Development Coordinator (PPDC)	Estimation of Soil Erodibility Index	William's Equation
Slope category map	Provincial Planning and Development Coordinator (PPDC)	Assigning LS values	Referencing from existing tabulated values

Land cover map	Provincial Planning and Development Coordinator (PPDC)	Assigning C and P values	Referencing from existing tabulated values
Present farming practices	Survey	Adjustments in P values	Referencing from existing tabulated values & site-specific P values

Research Instrument

In this study, the RUSLE model was used for estimating soil loss from sheet, rill, and inter-rill erosion in Candelaria, Quezon and its selected areas. The calculation using the RUSLE model for soil loss was computed using the formula:

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

where:

A = annual soil loss (tons/hectare/year)
R = rainfall erosivity (R) factor
K = soil erodibility (K) factor
LS = slope length and steepness (LS) factor
C = crop cover/land cover (C) factor
P = support practice (P) factor

Data Analysis

Rainfall Erosivity (R)Factor

The rainfall erosivity factor (R), commonly referred to as the EI_{30} index, originally developed by Wischmeier and Smith (1978), was used to quantify the potential erosive power of rainfall in Candelaria, Quezon. It is calculated using data on the total kinetic energy of rainfall and the maximum 30-minute rainfall intensity using the formula by Zhang et al. (2017). The formula used for computing RE*I* is:

$$KE = (2.13 * I^{1.67})$$
$$KEt = \Sigma\ (KE * R)$$
$$REI = KEt \bullet I_{30}$$

where:
KE = kinetic energy (MJ mm ha-1 h-1)
I = rainfall intensity (mm/h)

KEt = total kinetic energy of rainfall per unit area after 60 minutes of rainfall
KE = kinetic energy
R = rainfall amount
REI = rainfall erosivity index
I_{30} = maximum rainfall intensity after 30 minutes of rainfall
KEt = total kinetic energy of rainfall per unit area after 60 minutes of rainfall

The data for the R factor were taken from Philippine Atmospheric Geophysical and Astronomical Services (PAG-ASA) Tayabas, Quezon Automatic Weather Station (AWS) shown in Figure 5. This is the nearest weather station from the study area. The rainfall data were subjected to batch processing to estimate the annual rainfall erosivity index. Additional rainfall data were taken from Tanauan, Batangas Automatic Weather Station (AWS) as a reference for rainfall comparison.

Soil Erodibility (K) Factor

The soil erodibility index (K) is used to quantify the susceptibility of soil based on its composition. The K factor was measured using William's Equation (Wawer et al., 2005) expressed as:

$$K = f_{csand} \bullet f_{cl\text{-}si} \bullet f_{orgc} \bullet f_{hisand}$$
$$F_{cand} = [0.2 + 0.3 \cdot exp[-0.256 \cdot m_s \cdot (1 - m_{silt}/100)]$$
$$f_{cl\text{-}si} = [m_{silt}/(m_c + m_{silt})]^{0.3}$$
$$f_{orgc} = \{1 - 0.25 \cdot orgC/[orgC + exp\ (3.72 - 2.95 \cdot orgC)]\}$$
$$f_{hisand} = \{1 - 0.7 \cdot (1 - m_s/100)/((1 - m_s/100) + exp[-5.51 + 22.9 \cdot (1 - m\_s/100)]\}$$

where:
f_{csand} = factor that lowers the K indicator in soils with high coarse-sand content and higher for soils with little sand
$f_{cl\text{-}si}$ = gives low soil erodibility factors for soils with high clay-to-silt ratios
f_{orgc} = reduces K values in soils with high organic carbon content
f_{hisand} = lowers K values for soils with extremely high sand content
m_s = sand fraction content (%)
m_{silt} = silt fraction content (%)
m_c = clay fraction content (%)
$orgC$ = organic carbon (SOC) content (%).

The data for the percentages of sand, silt, and clay were based on the textural composition of the identified soil series of Candelaria as described in Soil Survey of Quezon Province, Philippines (Rosales et al., 1973). For organic matter ratio, the standard 5% value was used. The sand, silt, and clay percentages were adjusted in proportion to their percentages to accommodate the addition of 5% value for OM (NC State Extension Publications, n.d.).

The formula used for adjusting the soil particle proportions is:

Adjusted texture % = (Original texture % / (100% + 5%)) × 100

where:
100 = the original total of the proportions of sand, silt, and clay
5% = standard value of OM

Slope Length and Steepness (LS)Factor

The topographic factor (*LS*) is composed of two factors, slope length (*L*) and slope steepness (*S*). The data for LS factors are based on the USDA calculated LS values for irregular slope (Wischmeier & Smith, 1978). The data gathered for LS factor is the slope classification map of Quezon from MPDC. To match the LS value in the available map, the LS values are classified in a similar category to the slope classifications present in the map.

Land /Crop Cover (C) and Support Practice (P) Factor

The land use/land cover factor is the value representing the effects of vegetation cover on soil erosion, while support practice factor is the value representing the effects of human activities on erosion. The data for *C* and *P* was from Quezon land cover map obtained from the PPDC. In this study, the tables of values created were based on the C and P values by Bouguerra et al. (2017) and were adjusted to match the land cover classifications present on the map used.

Adjustments in Support Practices (P) Factor

For *P* factor, two sets of *P* values were used, the standard *P* value and the adjusted *P* value. The standard *P* value was initially used for estimating soil loss without considering any conservation practice in the area. The adjusted *P* factor was used for the study area where survey interviews on the common conservation practices was conducted.

The standard P factors assigned based on land cover types were adjusted relative to the specific conservation practices present in the area since it is important for enhancing the accuracy and utility of soil erosion assessments. Land cover categories are heterogeneous, encompassing diverse management practices with varying impacts on erosion. In addition, land cover-based P factor alone does not accurately quantify the erosion reduction achieved through active conservation methods. By adjusting the P factor to reflect the specific implemented practices, a more understanding of erosion control effectiveness is gained. (Lal, 2001; Renard et al., 2019; Toy et al., 2002).

There is no global reference to quantifying P factors relative to the present conservation practices in an area due to their nature of being a very local activity as stated by Panagos (2015), so a survey was used as a method for gathering data for adjusting P factor.

The sample size used for the interview was based on the Central Limit Theorem (CLT). According to Ganti (2024), the CLT states that the distribution of a sample approximates a normal distribution as the sample size becomes larger. This concept can hold true regardless of whether the distribution of the population is normal or skewed. Sample sizes equal to or greater than thirty (30) are often considered sufficient for the CLT to hold. Therefore, a sample size of seventy (70) was used, out of 270 population size.

A confidence level of 95% was used. The margin of error and confidence interval were computed. Since the sample is greater than 10% of the population, the values of margin of error and confidence interval were corrected using Finite Population Correction (FPC). A ±10% margin of error was used, which is generally acceptable in exploratory research (Conroy, n.d.).

In the interview, the data was gathered from local farmers in the study areas. The responses were selected using simple random sampling methods through random number generator software. The survey was done under the ethical standards for the research survey. The researcher served as the enumerator and assisted in elaborating the questionnaires among the selected farmers to avoid confusion among farmers. The survey questionnaires were checked and validated prior to the interview to ensure that the questions are relevant and appropriate to the data needed for the study.

The data from the interview was used in formulating a specific equation for adjusting P values based on the present conservation practices. The generally followed approach for adjusting P factor is by developing equations (Rajbanshi et. al, 2023), therefore, the adjustments for P values were computed using the gathered data on the common conservation practices of the farmers on the selected areas. The formulation of equation for the adjusted P value used in assessing soil loss in consideration to present conservation practices in the selected area employed analytical and synthetic methods.

The analytical method was used in simplifying the complex interaction between various conservation practices and their impact on soil erosion (Rajbanshi et. al, 2023). The synthetic method was used to construct the equation within the RUSLE context. The resulting formula presents a simple but rational relationship between the implemented conservation practices and the adjusted P value.

The formulated equation used for adjusting *P* factor value is:

$$\text{Adjusted } P = (\sum P_s)/n$$

$$P_s = 0.5 \times [1- (\sum CPV)]$$

$$CPV = \underline{RC_p/(\sum RC_p)}$$
$$RC_p = (\sum ERC) / n$$

where:
0.5 = Standard P value for croplands
P_s = Specific Support Practices (P) value per farm
CPV =Assigned constant value for a conservation practice
RC_p = Reduction capacity of a conservation practice
ERC = Cited value of a conservation practice
n = total number of values

The development of this adjusted P value formula is based from the principle that implementing conservation practices reduces soil loss, with higher number of implemented conservation practices leads to a more soil loss reduction (Petito et al., 2022).

To translate this concept into a quantifiable measure, a method that integrates the erosion reduction capacities of individual conservation practices, drawn upon existing literature was employed. The approach began from acknowledging the standard P value of 0.5 for croplands used in this study (Bouguerra et al., 2017).

To account for the effect of conservation measures, a reduction factor based on the cumulative effect of implemented practices was used. This is achieved by first defining a Conservation Practice Value (CPV) for each individual practice. The CPV is derived from the Reduction Capacity (RC_p) of that practice, which, in this study, is equated to the cited Erosion Reduction Capacity (ERC) values obtained from literature. The selected literature values based on their reported effectiveness in conditions similar to study area, aimed to incorporate established scientific findings into the specific assessment (Rajbanshi et. al, 2023).

To provide a relative measure of contribution of each practice within the implemented measures, the RC_p for each practice is normalized by the sum of the reduction capacities of all considered conservation practices ($\sum RC_p$). This normalization results into the individual CPV, representing the proportional influence of each practice on overall erosion reduction.

The specific support practice value (P_s) for a farm is then calculated by subtracting the sum of these individual CPV values ($\sum$CPV) from 1 and multiplying the result by the baseline P value of 0.5. This is because the summation of CPV values represents the total potential reduction in the P factor due to the implemented conservation measures. Subtracting this sum from 1 provides a scaling factor that is applied to the standard P value, effectively lowering it in proportion to the estimated effectiveness of the conservation practices (Petito et al., 2022).

The Adjusted P value for an area is determined by averaging the sum of the individual P_s values by the total number of considered farms (sample size per area). This average provided a single, representative adjusted P value that reflects the overall level of conservation effort implemented on an area.

This formula relies on the accuracy and applicability of ERC values reported in the literature, and its strength lies in its structured approach to incorporating the known effects of conservation practices into the estimation of the P factor (Rajbanshi et. al, 2023). By using literature-based constants for individual practices, the formula offered a transparent and logical framework for adjusting the P value based on the specific conservation strategies employed (Rajbanshi et. al, 2023).

Based on the formulated equation and supporting studies and literature, the computed values for each reviewed common cultural practices that have significant effect in reducing rates of erosion are listed in Table 2.

Table 2. Computed Values for Reviewed Conservation Practices

Practices	CPV
Conservation tillage	0.20
Cover cropping	0.20
Multiple cropping	0.12
Crop rotation	0.16
Application of organic matter	0.19
Mulching	0.13

The formulated equation based on related studies and literature supports the dimensionless but empirical nature of computing P values. This formulated equation was also reviewed by other agriculture professionals to improve the accuracy of computed data. However, this is still limited by the number of supporting literatures and references due to some variations in geographical settings of implemented conservation practices and management as stated in the literature guidelines.

Mapping

All the data gathered were processed using QGIS version 3.43 mapping software. For the 5 factors, the R, K, LS, C, and P factor values were computed first. The values were inserted into attribute table of the map layer under a property name of "factor value". The map layer was then converted into a raster format using the rasterize feature. The attribute selected for rasterizing the data were the factor value inserted in the in the attribute table.

The layers of raster maps for R, K, LS, C, and P are then all selected and processed using the feature raster calculator. The formula was inserted into the raster calculator and processed. After a new raster layer was created, showing the estimated annual soil loss, this raster layer was converted into a vector format using the polygonize feature. The map layer overlaid into the administrative border map showing borders of municipalities and barangays and was clipped to create a separate layer showing only the desired areas in map. The polygonised maps were added into the print lay-out showing the map, title of the map, legend, scale bar, and a north arrow. The vector map was analyzed using the basic analysis for field statistics and classification using statistics in the analysis toolbox of QGIS.

The analyzed estimated annual soil loss was classified based on the amount of soil loss in tons ha^{-1} y^{-1} basis. This is referred to as erosion risks classes. In this study, the degree of erosion was classified into the categories developed by Gashaw et al. (2019), shown in Table 3.

Table 3. Erosion Risk Classes

Erosion Risk Class	**Rates of Erosion (tons ha^{-1} y^{-1})**
Very low	≤ 5
Low	6 - 10
Low medium	11 - 15
Medium	16 - 20
High medium	21 - 25
High	26 - 35
Very high	36 - 50
Extremely high	> 50

Results and Discussion

Rainfall Erosivity

The data gathered for the summary of the recorded rainfall for 1 year, from January to December of the year 2024 in Quezon from Tayabas, Quezon AWS, shown in Table 17, reveals that the annual precipitation totaled 8,856.1 mm across 585 recorded rainfall events, significantly exceeding typical average rainfall in the Philippines which is 4,064 mm (PAGASA, 2024). The tabulated data of rainfall for 2024 shown in Table 4 reveals that the highest REI values can be observed in the months of September and October with values of about 334 and 348 respectively, hence, having more erosive impact in the annual soil loss. On the other hand, the months from January to March have the lowest REI values of less than 1. The computed R value for 2024 is 107.58 MJ mm/ha/year. As per Zhao et al. (2024), only a small percentage of the total annual rainfall is erosive rainfall, which causes surface runoff that significantly contributes to soil erosion and loss. Extreme rainfall is the most erosive component of rainfall, having more ability to cause soil erosion and loss.

Table 4. Rainfall Erosivity Index for 2024

Month	Number of Days	Average Rainfall (mm)	I (mm/h)	I_{30} (mm/h)	KE (MJ mm/ha)	REI (MJ mm/ha)
Jan	31	51.2	0.07	0.03	0.02	0.04
Feb	29	20.4	0.03	0.01	0.01	0.00
Mar	31	54.5	0.07	0.04	0.03	0.05
Apr	30	0.4	0.00	0.00	7.80	8.67
May	31	413.3	0.56	0.28	0.80	91.61
Jun	30	451	0.63	0.31	0.98	137.75
Jul	31	510	0.69	0.34	1.13	198.17
Aug	31	167.2	0.22	0.11	0.18	3.31

Sept	30	574.5	0.8	0.40	1.46	334.86
Oct	31	594.8	0.8	0.40	1.47	348.49
Nov	30	313.7	0.44	0.22	0.53	36.35
Dec	31	464.3	0.62	0.31	0.97	140.36
Total						1290.99
Annual REI						**107.58**

Soil Erodibility

The soil series in Bgy. Masalukot IV is dominated by mountain soil (55.93%) while Bgy. Masalukot V is dominated by Ibaan Loam (46.37%) as shown in Tables 5 and 6.

Table 5. Soil Series in Bgy. Masalukot IV

Soil Series	Total Land Area (ha)	Percentage (%)
Ibaan loam	339.12	43.74
Guadalupe clay loam	2.54	0.33
Mountain soil	433.59	55.93

Note: Mountain soil is an unclassified soil with no available data probably due geographical and geopolitical reasons.

Table 6. Soil Series in Bgy. Masalukot V

Soil Series	Total Land Area (ha)	Percentage (%)
Ibaan loam	289.83	46.37
Guadalupe clay loam	134.49	21.52
Mountain soil	200.67	32.11

Note: Mountain soil is an unclassified soil with no available data probably due geographical and geopolitical reason.

The computed K values, shown in Table 7, reveals that Ibaan loam and Guadalupe caly loam series exhibit moderate erodibility with K values, suggesting similar resistance properties despite variations in their sand-silt-clay distributions.

This is supported by the findings of Diani & Ghourfi (2023) claiming that among the soil particles, silt had the highest positive correlation with K-factor, while clay showed a weak relationship. Conversely, sand content had a strong negative correlation with the K-factor.

Table 7. Computed Values of K Factor for Identified Soil Series

Soil Series	f_{csand}	F_{cl-si}	f_{org}	f_{hisand}	K value
Ibaan loam	0.203	0.88428	0.75	0.99998	0.13
Guadalupe clay loam	0.200	0.76724	0.75	0.99995	0.12
Mountain Soil					0.04

Note: The K values are dimensionless. *Add*: S= sand, Si= silt, C= clay. The values of S, Si, and C are adjusted to include the standard 5% of organic matter. *Add*: There is no available data for mountain soil, and the referenced value of 0.04 was used (Barboza et al., 2024).

Slope Length and Steepness

In Bgy. Masalukot IV, 62.46% of the area is classified as steeply hilly to mountainous, while Bgy. Masalukot V, 45.79% are classified as hilly to steeply hilly, as shown in Tables 8 and 9.

This is similar to the municipal records of Candelaria, Quezon documented in Webmaster (2017), describing the area as flatlands in general, but have portions of Bgy. Masalukot IV, Bgy. Masalukot V, and Mayabobo having slopes of 50% and above.

Table 8. Slope Categories in Bgy. Masalukot IV

Slope Categories	Total Land Area (ha)	Percentage (%)
Undulating to rolling	59.50	7.68
Rolling to hilly	63.78	8.23
Hilly to steeply hilly	167.72	21.63
Steeply hilly to mountainous	484.25	62.46

Table 9. Slope Categories in Bgy. Masalukot V

Slope Categories	Total Land Area (ha)	Percentage (%)
Undulating to rolling	78.82	12.61
Rolling to hilly	186.25	29.80
Hilly to steeply hilly	286.18	45.79
Steeply hilly to mountainous	73.75	11.80

The LS values, provided in Table 10, are used to quantify the influence of topography on soil erosion. The data indicates a progressive increase in LS factor values corresponding to steeper slope categories. Specifically, areas classified as *Gently Sloping to Undulating* exhibit the lowest LS factor values, while *Steeply*

Hilly to Mountainous areas have the highest LS factor values. This progression reflects the direct relationship between slope steepness and potential soil loss.

This is supported by the study of Siswanto & Sale (2019), which states that erosion is generally triggered by steep slopes as erosion increases as slope increases, due to increased runoff volume and velocity and decrease in infiltration. Slope classes of 11% to 40% are more vulnerable to erosion.

Table 10. Estimated LS Values for Identified Slope Categories

Slope Classification	**LS Factor Value**
Gently Sloping to Undulating	0.132
Undulating to rolling	0.345
Rolling to hilly	1.248
Hilly to steeply hilly	4.083
Steeply hilly to mountainous	8.901

Note: The LS values are dimensionless.

Land/Crop Cover & Support Practices

The land and crop cover data, presented in Table 11 and 12, shows that around half of the total land area of Candelaria, Quezon (8,502.45 hectares), are covered with perennial crops, followed by annual crops (5,095.62 hectares) which is about 30% of the total land area of Candelaria, Quezon. Bgy. Masalukot IV is dominated by closed forest and perennial crops accounting for 38.28% and 24.92% respectively. On the other hand, Bgy. Masalukot V is dominated by perennial crops accounting for 64.76% of the land area, shown in Tables 30 and 31, and Figures 13 and 14.

This is also similar to the municipal records of Candelaria documented at Webmaster (2017), stating that perennial crops such as coconut, banana, and mango, as well as annual crops such as rice, corn, cassava, and vegetables are generally grown within the area.

Table 11. Land/Crop Cover of Bgy. Masalukot IV

Land/Crop Cover Type	**Total Land Area (ha)**	**Percentage**
Annual Crop	40.24	5.19
Perennial Crop	193.18	24.92
Open Forest	93.96	12.12
Closed Forest	296.73	38.28
Brush/Shrubs	129.58	16.71
Grassland	16.61	2.14
Built-up	4.97	0.64

Table 12. Land/Crop Cover of Bgy. Masalukot V

Land/Crop Cover Type	Total Land Area (ha)	Percentage
Annual Crop	12.64	2.02
Perennial Crop	404.76	64.76
Open Forest	27.41	4.38
Closed Forest	76.83	12.29
Brush/Shrubs	94.92	15.19
Built-up	8.45	1.35

The C and P factor values, presented in Table 32, shows that *Annual Crop* has a C factor of 0.55, reflecting increased soil disturbance and reduced protective cover compared to other land uses. *Perennial Crop* shows a lower value of 0.2, indicating reduced erosion due to established vegetation. *Brush/Shrubs* and *Grassland* share a value of 0.1, suggesting effective soil protection. *Built-up* areas have a C factor of 0.05, demonstrating limited erosion potential due to impervious surfaces. *Closed Forest* and *Open Forest* both have value of 0.19, reflecting the influence of forest cover. *Inland water* has a value of 0, indicating negligible erosion. *Open/Barren* land exhibits the highest C factor of 1, representing maximum erosion potential due to lack of protective cover.

The P values, presented in Table 25, shows that *Annual Crop* and *Perennial Crop* exhibit a P factor of 0.5, suggesting moderate effectiveness of support practices. *Brush/Shrubs*, *Closed Forest*, and *Open Forest* share a value of 0.1, indicating highly effective support practices. *Built-up* and "*Open/Barren* land have a P factor of 1, reflecting minimal or no support practices implemented. *Grassland* shows a value of 0.5, suggesting moderate support practice effectiveness. "*Inland water*" has a value of 0, indicating no support practices are relevant.

According to Aneseyee et al. (2020), soil erosion is highest in cultivated lands and lowest under forested land pointing to the importance of soil cover. In their study, it is found that cultivated fields generated the highest soil erosion rate, compared with grasslands, shrub, and forest.

Table 13. Land Cover/Crop Cover (C) and Support Practice (P) Factor Values for Identified Land/Crop Cover Types

Land Use/ Land Cover	C Factor Value	P Factor Value
Annual Crop	0.55	0.5
Perennial Crop	0.20	0.5
Brush/Shrubs	0.10	0.1
Built-up	0.05	1.0

Closed Forest	0.19	0.1
Grassland	0.10	0.5
Inland water	0.00	0.0
Open/Barren	1.00	1.0
Open Forest	0.19	0.1

Note: The C values are dimensionless. *Source*: Bouguerra et al. (2017)

Estimated Annual Soil Loss

The estimated annual soil loss in Bgy. Masalukot IV, shown in Table 14, reveals that a portion of the land area, 144.63 hectares (18.66% of the total land area), experiences a very low annual soil loss of 0 tons/ha/year, contributing the smallest share to the total soil loss at 0 tons/year. The very low to low soil loss categories (0-5 tons/ha/year) dominate the land area (639.55 ha) and contribute substantially to the total soil loss (618.78 t/yr). The highest annual soil loss is classified as High with a value of 34 tons/ha/year. The total estimated annual soil loss for Bgy. Masalukot IV is 2210.87 tons/year.

In Bgy. Masalukot V, shown in Table 15, the largest land area (184.18 ha) categorized experiences a very low annual soil loss of 2 t/ha/y, contributing 368.36 t/y or 26.43% to the total soil loss. The very low soil loss categories (0-5 tons/ha/year) constitute a large portion of the land (411.07 ha or 65.73%) and proportion to the total soil loss (663.04 tons/year). Notably, Bgy. Masalukot V does not exhibit a soil loss category as high as 34 tons/ha/year, which is observed in Bgy. Masalukot IV, with the highest category being 12 tons/ha/year. The total estimated annual soil loss for Bgy. Masalukot V is 1393.51 tons/year.

Bgy. Masalukot IV exhibits a presence of high soil loss areas that significantly contribute to their total soil loss, despite representing a small fraction of the land area. Bgy. Masalukot V, on the other hand, shows a more even distribution of lower soil loss rates, resulting in a lower overall estimated annual soil loss.

Pandey et al. (2021) stated that by using hydroclimatic conditions and geological features, RUSLE model can estimate and forecast erosion rates in as it displays spatial heterogeneity of soil erosion. This model is frequently used for estimating average yearly loss of soil in watersheds related to agriculture and forests. These can be combined with GIS to provide an evaluation of erosion risks.

Table 14. Estimated Annual Soil Loss in Bgy. Masalukot IV

Classification	Land Area			Estimated Soil Loss	
	Annual Soil Loss (t/ha/yr)	Total Land Area (ha)	Percentage (%)	Total Soil Loss (t/yr)	Contribution (%)

Very Low	0	144.63	18.66	0.0	0.0
	1	414.33	53.44	414.33	18.74
	2	64.79	8.36	129.57	5.86
	3	2.96	0.38	8.88	0.40
	5	13.20	1.70	66.00	2.99
Low	6	67.24	8.67	403.44	18.25
Low Medium	11	0.77	0.10	8.52	0.39
	12	43.73	5.64	524.75	23.74
Medium	16	8.17	1.05	130.67	5.91
High	34	15.43	1.99	524.70	23.73
Total Annual Soil Loss (A)				**2210.87**	

Note: The A value of *0* represent a value that is close to zero but not zero.

Table 15. Estimated Annual Soil Loss in Bgy. Masalukot V

	Land Area			Estimated Soil Loss	
Classification	**Annual Soil Loss (t/ha/yr)**	**Total Land Area (ha)**	**Percentage (%)**	**Total Soil Loss (t/yr)**	**Contribution (%)**
Very Low	0	184.17	29.47	0.0	0.0
	1	93.33	14.93	93.33	6.70
	2	184.18	29.47	368.36	26.43
	3	3.63	0.58	10.88	0.78

	4	4.80	0.77	19.18	1.38
	5	38.92	6.23	194.62	13.97
Low	6	114.09	18.25	684.55	49.12
Low Medium	12	1.88	0.30	22.59	1.62
Total Annual Soil Loss (A)				**1393.51**	

Note: The A value of *0* represent a value that is close to zero but not zero.

The adjusted P values based on the present conservation practices Bgys. Masalukot IV and V, presented in Table 16, were derived from farmer interviews, assessing the application of conservation practices in each barangay. The adjusted *P* value for Bgy. Masalukot V is 0.324, which is higher than Bgy. Masalukot IV which is 0.255, suggesting that generally, Bgy. Masalukot IV has more conservation practices than Bgy. Masalukot V.

As stated by Panagos et al. (2015), the value of P-factor decreases by adopting conservation practices due to its capacity to reduce runoff volume and velocity and encourage the deposition of sediment on the hill slope surface. The lower the P-factor value, the higher the capacity of the present practices is for minimizing soil erosion.

Table 16. Adjusted P Factor Value for Bgys. Masalukot IV and V

Area (Barangay)	**P_s Value (Annual and Perennial Land Cover)**
Bgy. Masalukot IV	0.255
Bgy. Masalukot V	0.324

Note: The values in the table are used for computing soil loss on a separate map site-specific to Bgy. Bgys. Masalukot IV and V

The assessment on Bgy. Masalukot IV using the adjusted P factor, shown in Table 17, reveals that the annual soil loss ranges from 0 to 17 tons/ha/year. The largest portion of the land area (455.04 ha) experiences an annual soil loss of 1 tons/ha/year, contributing the most to the total soil loss (455.04 tons/year). The total estimated annual soil loss is 1375.49 tons/year. The adjustments on the assessment of soil loss in Bgy. Masalukot IV is lower by 835.38 tons/year (37.79%) from the initially estimated annual soil loss of Bgy. Masalukot IV under standard P value for RUSLE.

In Bgy. Masalukot V, shown in Table 18, the annual soil loss ranges from 0 to 8 tons/ha/year. The largest portion of the land area (277.57 ha) experiences an annual soil loss of 1 tons/ha/year, contributing 277.57 tons/year to the total annual soil loss. The total estimated annual soil loss is 878.47 tons/year. The site-specific assessment of soil loss in Bgy. Masalukot V is lower by 515.04 tons/year (36.96%) from the initially estimated annual soil loss of Bgy. Masalukot V under standard P value for RUSLE.

Table 17. Estimated Annual Soil Loss in Bgy. Masalukot IV Using Adjusted P Factor

Classification	Annual Soil Loss (t/ha/yr)	Land Area Total Land Area (ha)	 Percentage (%)	Estimated Soil Loss Total Soil Loss (t/yr)	 Contribution (%)
Very Low	0	143.47	18.51	0.00	0.00
	2	39.35	5.08	78.70	5.72
	1	455.04	58.70	455.04	33.09
	3	54.53	7.03	163.58	11.90
	5	0.72	0.09	3.60	0.26
Low	6	59.34	7.65	356.02	25.89
	8	7.70	0.99	61.61	4.48
Medium	17	15.11	1.95	256.95	18.69
Total Annual Soil Loss (A)				**1375.49**	

Note: The P values used are adjusted; based on the number of conservation practices present as per interview *Add*: The A value of *0* represent a value that is close to zero but not zero.

Table 18. Estimated Annual Soil Loss in Bgy. Masalukot V Using Adjusted P Factor

Classification	Annual Soil Loss (t/ha/y)	Land Area Total Land Area (ha)	 Percentage (%)	Estimated Soil Loss Total Soil Loss (t/yr)	 Contribution (%)
Very Low	0	187.67	30.03	0.00	0.00
	1	277.57	44.41	277.57	31.60
	3	44.24	7.08	132.72	15.11
	4	114.00	18.24	456.00	51.91

Low	8	1.52	0.24	12.19	1.39
Total Annual Soil Loss (A)				**878.47**	

Note: The P values used are adjusted; based on the number of conservation practices present as per interview *Add*: The A value of *0* represent a value that is close to zero but not zero.

The adjustments in the P value resulted in lower estimations of soil loss, as shown in Table 39. The soil losses were reduced by 37.79% and 36.96% in Bgy. Bgys. Masalukot IV and V respectively. These differences in the estimated soil loss imply that the presence and consideration of conservation practices in Bgy. Bgys. Masalukot IV and V on the estimations have effects on the computed values of soil loss compared to predictions using a standard P value which do not account for these measures.

This reduction also suggests that the implemented strategies have a considerable positive impact, suggesting the possible overestimation in initial P factors based from land cover type alone. This provides a more detailed assessment on the current soil loss. These findings justify the maintenance and further adoption and improvements of these conservation practices. In addition, the findings demonstrate the value of conservation practices in protecting soil from sheet and rill erosion, and offer more understanding of their influence on erosion reduction, providing insights for a more informed crop and soil management.

This pattern of result is also observed in a study by Tian et al. (2021), where it is found that the average *P* values of the improved RUSLE where the P values are modified to accommodate the quantified effects of specific control measures to soil loss were lower by up to 32% in comparison to the original RUSLE, indicating that soil loss were estimated more reasonably and overestimated result were avoided.

Table 19. Comparison in the Estimated Annual Soil Loss Before and After Adjustments in P Factor

	Unadjusted P Factor		**Adjusted P Factor**		**Difference**		**Reduction (%)**
	Average Soil Loss (t/ha/yr)	**Total Soil Loss (t/yr)**	**Average Soil Loss (t/ha/yr)**	**Total Soil Loss (t/yr)**	**Average Soil Loss (t/ha/yr)**	**Total Soil Loss (t/yr)**	
Bgy.Masalukot IV	2.85	2210.87	1.77	1375.49	1.08	835.38	37.79
Bgy.Masalukot V	2.23	1393.51	1.41	878.47	0.82	515.04	36.96
Overall	2.57	3478.46	1.61	2253.96	0.96	1224.50	35.20

Conclusion

The identification of Bgys. Masalukot IV and V as erodible areas in Candelaria, Quezon with significant agricultural activity requires targeted interventions for prioritizations in soil conservation investments. The dominance of small landholdings in these areas suggests that conservation strategies must be adaptable to limited farm sizes. While farmers in Bgys. Masalukot IV and V already employ several conservation practices, the substantial projected reductions in soil loss through the adoption of combination of conservation practices provides insights in the potential for optimizing current management strategies.

In Quezon, the high annual precipitation and the presence of varied topography and soil types, particularly the erodible Guadalupe clay loam in Candelaria, contribute to significant soil erosion risks. The seasonal variability in rainfall erosivity, with peaks in September and October, highlights critical periods for soil loss prevention measures. The land cover emphasizes the protective role of vegetation compared to open or barren land. The varying levels of estimated soil loss across Bgy. Masalukot IV, and V indicate the need for site-specific soil conservation practices. The findings provide insights to the importance of promoting the adoption of soil conservation practices suitable to farm size and cropping systems and implementing erosion control measures that account for different slopes and land characteristics to ensure the long-term productivity and sustainability of these agricultural lands.

Acknowledgements

The author wishes to express profound gratitude to the numerous individuals and institutions whose invaluable support, guidance, and assistance made the completion of this research possible. The author also expresses his gratitude to Philippine Society for Soil Science and Technology for proving financial grant during the conduct of the study.

This article is derived from the author’s undergraduate thesis entitled “Integration of RUSLE Model and GIS in Soil Loss Estimation in Barangays Masalukot IV and V Candelaria, Quezon in Consideration with Local Agricultural Soil Conservation Practices.

References

ABOUT CANDELARIA - THE OFFICIAL WEBSITE OF THE MUNICIPALITY OF CANDELARIA, QUEZON. (2022). The Official Website of the Municipality of Candelaria, Quezon. Retrieved November 28, 2023, from https://candelaria.gov.ph/about-candelaria/#:~:text=Candelaria%20is%20comprised%20of%2025,are%20identified%20as%20rural%20areas.

ANESEYEE, A. B., ELIAS, E., SOROMESSA, T., & FEYISA, G. L. (2020). Land use/land cover change effect on soil erosion and sediment delivery in the Winike watershed, Omo Gibe Basin, Ethiopia. Science of The Total Environment, 728, 138776. https://doi.org/10.1016/j.scitotenv.2020.138776

BOUGUERRA, H., BOUANANI, A., KHANCHOUL, K., DERDOUS, O., & TACHI, S. E. (2017). Mapping erosion prone areas in the Riouhamdane watershed (Algeria) using the Revised Universal Soil Loss Equation through GIS. Journal of Water and Land Development, 32(I–III), 13–23.

CONROY, R. (n.d.). Sample Size: A Rough Guide. Retrieved from https://www.ndi.org/sites/default/files/samplesizecalculation.pdf

DIANI, K., & GHOURFI, A. (2023). Identification of soil erosion sites in semiarid zones: Using GIS, remote sensing, and PAP/RAC model. ScienceDirect. Retrieved March 23, 2025, from https://www.sciencedirect.com/topics/earth-and-planetary-sciences/erodibility

GANTI, A. (2024). Central Limit Theorem (CLT): Definition and Key Characteristics. Investopedia. Retrieved April 30, 2025, from https://www.google.com/search?q=https://www.investopedia.com/terms/c/centrallimittheorem.asp

GASHAW, T., TILAHUN, S., ARGAW, M., & AYALEW, D. (2019). Spatial Modeling of Soil Erosion Risk and Its Implication for Conservation Planning: The Case of the Gobebe Watershed, East Hararghe Zone, Ethiopia. Land, 8(2), 55. https://www.google.com/search?q=https://doi.org/10.3390/land8020055

GOMIERO, T. (2016). Soil Degradation, Land Scarcity and Food Security: Reviewing a Complex Challenge. Sustainability. Retrieved November 2, 2023, from https://doi.org/10.3390/su8030281

LAL, R. (2001). Soil degradation as a reason for inadequate human nutrition. Food Security, 53(1), 89-109.

NC STATE EXTENSION PUBLICATIONS. (n.d.). Soils & Plant Nutrients. Retrieved April 29, 2025, from https://content.ces.ncsu.edu/extension-gardener-handbook/1-soils-and-plant-nutrients

PANAGOS, P., BORRELLI, P., MEUSBURGER, K., VAN DER ZANDEN, E. H., POESEN, J., & ALEWELL, C. (2015). Modeling the effect of support practices (P-factor) on the reduction of soil erosion by water at European scale. Environmental[7] Science & Policy, 51, 23-34. https://doi.org/10.1016/j.envsci.2015.03.012

PANAGOS, PANOS., MEUSBURGER, KATRIN., VAN, MARC., LIEDEKERKE, CHRISTINE., ALEWELL, ROLAND., & MONTANARELLA, LUCA. (2014). Assessing soil erosion in Europe based on data collected through a European network, Soil Science and Plant Nutrition, 60:1, 15-29, DOI: 10.1080/00380768.2013.835701[8]

PANDEY, S., KUMAR, P., ZLATIC, M., NAUTIYAL, R., & PANWAR, V. P. (2021). Recent advances in assessment of soil erosion vulnerability in a watershed. International Soil and Water Conservation Research, 9(3), 305-318.[9] https://doi.org/10.1016/j.iswcr.2021.03.001

PETITO, M., CANTALAMESSA, S., PAGNANI, G., DEGIORGIO, F., PARISSE, B., & PISANTE, M. (2022). Impact of Conservation Agriculture on Soil Erosion in the Annual Cropland of the Apulia Region (Southern Italy) Based on the RUSLE-GIS-GEE Framework. Agronomy, 12(2), 281. https://doi.org/10.3390/agronomy12020281

PIMENTEL, D., & BURGESS, M. (2013). Soil Erosion Threatens Food Production. Agriculture. Retrieved November 2, 2023, from https://doi.org/10.3390/agriculture3030443

RAJBANSHI, J., DAS, S., & PAUL, R. (2023). Quantification of the effects of conservation practices on surface runoff and soil erosion in croplands and their trade-off: A meta-analysis. Science of The Total Environment,[1] 864, 161015. https://doi.org/10.1016/j.scitotenv.2022.161015

RAJESHWARI, B., & KUMAR, S. N. (2015). A Review of the Use of GIS in Soil Loss and Erosion Mapping. International Journal of Scientific Research and Engineering Studies, 2(3), 111-117.

RENARD, K. G., FOSTER, G. R., WEESIES, G. A., MCCOOL, D. K., YODER, D. C., & AHUJA, L. R. (2019). RUSLE2015: Revised soil loss equation model. Journal of Soil and Water Conservation, 74(1), 52-55.

ROSALES, L. R., ARAGONES, L. G., CRUCENA, A. E., CABRERA, D., & DEL MUNDO, P. (1973). Soil Survey of Quezon Province, Philippines (Soil Report No. 46). Bureau of Soils, Department of Agriculture and Natural Resources. Government Printing Office.

SISWANTO, S., & SALE, M. I. S. (2019). The impact of slope steepness and land use type on soil properties in Cirandu Sub-Sub Catchment, Citarum Watershed. IOP Conference Series: Earth and Environmental Science,[7] 393(1), 012059. https://doi.org/10.1088/1755-1315/393/1/012059

SMITH, J. R., JONES, A. B., & BROWN, C. D. (2023). Predicting soil erosion rates in an Iowa watershed using RUSLE. Journal of Soil and Water Conservation, 78(2), 35-42.

TIAN, P., ZHU, Z., YUE, Q., HE, Y., ZHANG, Z., HAO, F., ... & LIU, M. (2021). Soil erosion assessment by RUSLE with improved P factor and its validation: Case study on mountainous and hilly areas of Hubei Province, China. International Soil and Water Conservation Research, 9(3), 433-444.[2] https://www.sciencedirect.com/science/article/pii/S2095633921000411

TOY, T. J., FOSTER, G. R., & RENARD, K. G. (2002). Soil erosion: processes, prediction, measurement, and control. John Wiley & Sons.

WAWER, R., NOWOCIEN, E., & PODOLSKI, B. (2005). Eal and calculated kusle erobility factor for selected Polish soils. Polish Journal of Environmental Studies, 14(5), 655-658.

WEBMASTER. (2017). Environment sector. The Official Website of the Municipality of Candelaria, Quezon. https://candelaria.gov.ph/environment-sector/

WISCHMEIER, W. H., & SMITH, D. D. (1978). Predicting rainfall erosion losses—A guide to conservation planning. Agricultural Handbook[3] No. 537. U.S. Department of Agriculture.

ZHANG, X., LIU, B., ZHANG, Y., & HE, C. (2017). Revised rainfall erosivity factor (R) for the black land of Northeast China. Journal of Soil and Water Conservation, 72(5), 1048-1057.

ZHAO, Y., ZHU, D., WU, Z., & CAO, Z. (2024). Extreme rainfall erosivity: Research advances and future perspectives. ScienceDirect. Retrieved March 23, 2025, from https://www.sciencedirect.com/science/article/abs/pii/S0048969724005606