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Spatial analysis of soil erosion sensitivity using RUSLE model in Nyamasheke district, Rwanda

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OUTLINES

1. INTRODUCTION
2. METHODOLOGY
3. RESULTS
4. CONLUSION

1.INTRODUCTION

- *MOTIVATION*

Nyamasheke district annual soil loss was estimated to be 19t/year in 2015 (Karamage, Chi, Shao, Ndayisaba, & Kayiranga, 2016)

In addition, to fight the soil loss sustainably, the Nyamasheke district aims to conserve soil using terraces cultivation in highland areas in line with vision 2020 and Green growth and climate resilient strategy(GGCRS)

However, previous studies did not focus on spatial distribution of soil erosion sensitive areas in the district

Therefore, we have been stimulated to carry out this study in order to identify the areas where soil erosion is problematic, and provide evidence- based recommendations to decision makers and planners

1.INTRODUCTION

- **OBJECTIVES:**

Overall objective

- Analyze spatial soil erosion sensitivity change in Nyamasheke district, using Revised Universal soil loss equation (RUSLE) integrated with GIS, from 2008 to 2018.

Specific objectives

- Identifying the underlying factors contributing to the soil erosion change in the district from 2008 to 2018.
- Identify existing areas prone to soil erosion in the district, 2018
- Producing areas prone to soil erosion maps of average annual soil loss rates of Nyamasheke district in 2018
- Formulate recommendations to decision makers and planners in Nyamasheke district, accordingly to the research findings.

1.INTRODUCTION

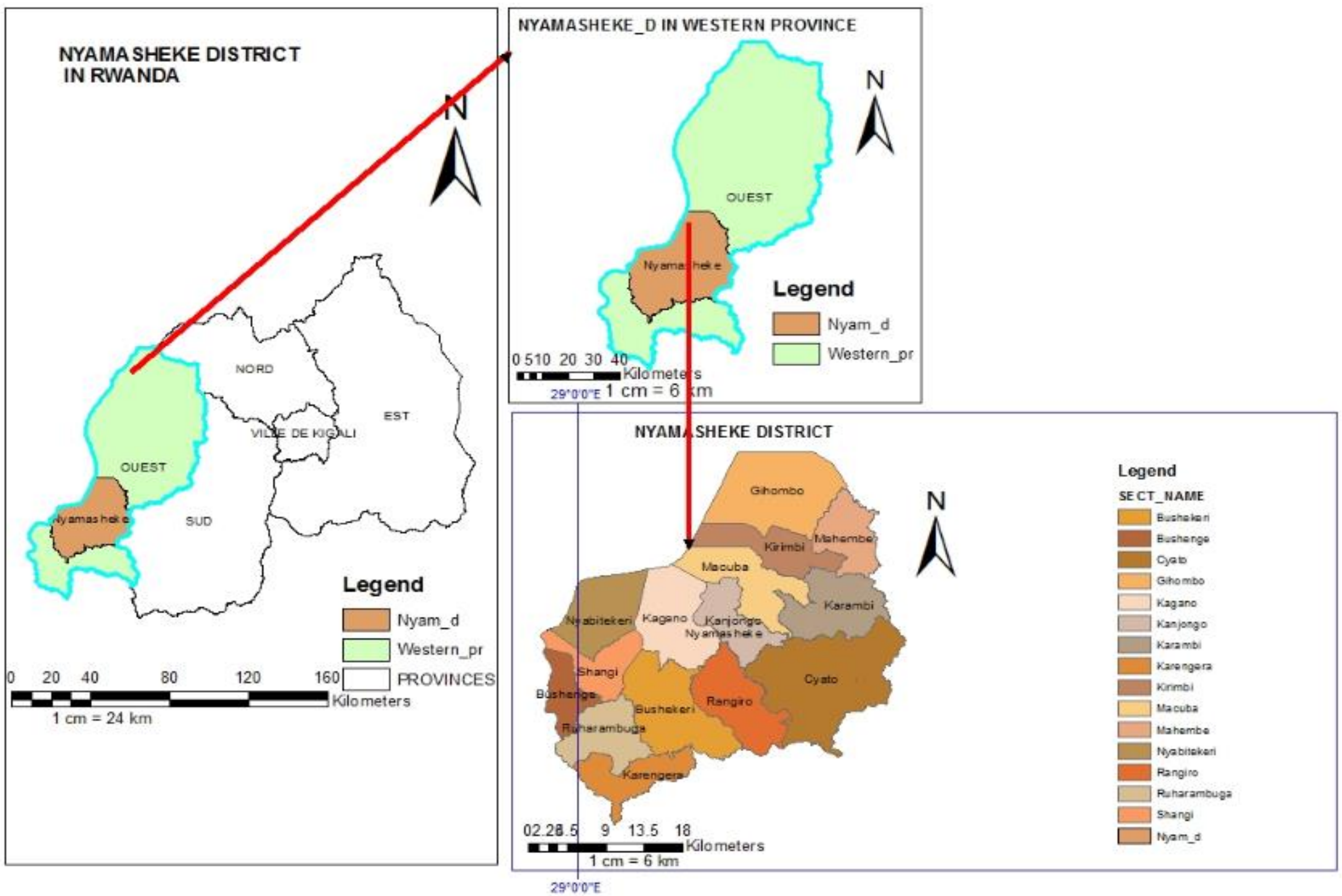
- RUSLE (Revised Universal Soil Loss Equation)

A = R x K x LS x C x P

- A is the average annual soil loss per unit area (t/ha.year);
- R is the rainfall-runoff erosivity factor (MJmm/ha.h.year);
- K is the soil erodibility factor (t.h/MJ.mm);
- LS is the slope length (L) and the slope steepness (S) factor (dimensionless);
- C is the cover and management factor (dimensionless);
- P is the support and conservation practice factor (dimensionless).

2.METHODOLOGY

○ STUDY AREA MAPPING



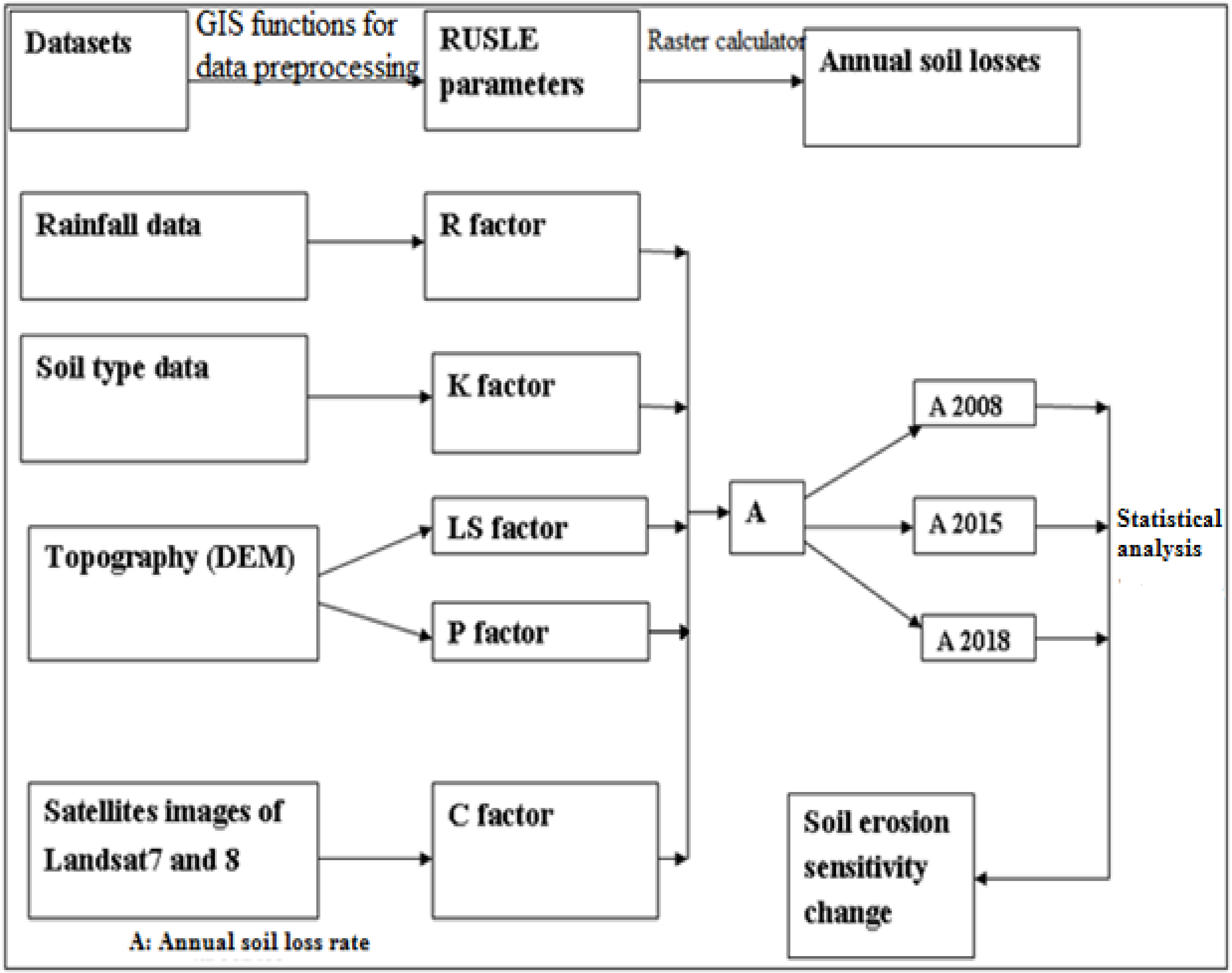
2. METHODOLOGY

- DATASETS AND SOURCES

Data type	Data source
Digital elevation model (DEM)	Rwanda Land Management and Use Authority (RLMUA)
Monthly precipitation Data	Meteo Rwanda
Soil type map	Downloaded from: The FAO Digital soil map of the world (DSMW).
Satellite imageries of Landsat7/ETM+ and Landsat8/OLI	Downloaded from Earth explorer/USGS)

2.METHODOLOGY

- METHODOLOGY FLOWCHART DIAGRAM

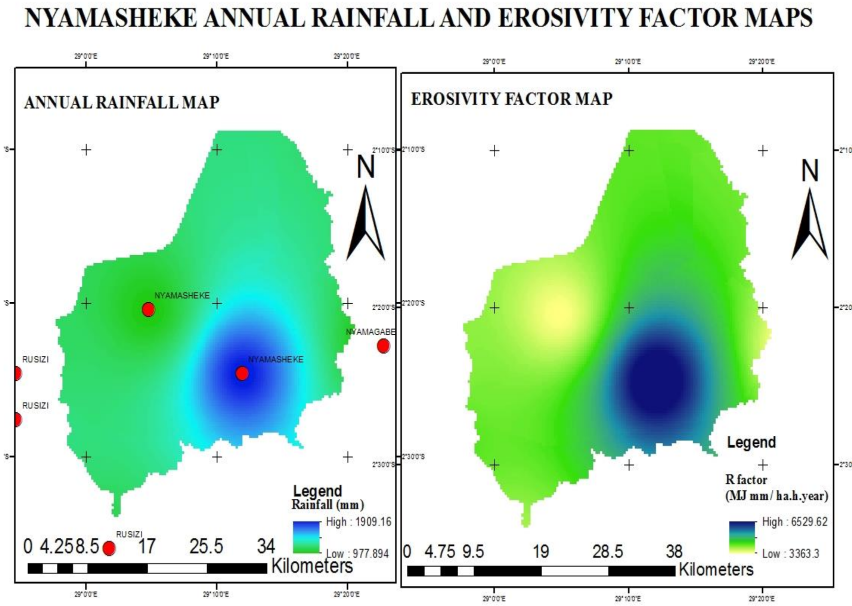


2. METHODOLOGY:RUSLE Parameters' estimation + mapping

Rainfall run off erosivity factor(R-factor) in MJ mm/ ha.h.year

- The rainfall erosivity factor (R) reflects the effect of rainfall intensity on soil erosion, and requires detailed, continuous precipitation data for its calculation (Ganasri & Ramesh, 2016).
- **An empirical equation to determine R factor**
- **R= [38.46 + (3.4*P)]: Tropical rainfall estimation equation**
- **P Average annual precipitation map in mm, produced by Inverse distance weighing (IDW) interpolation method**
- **R factor map production: Raster calculator GIS function**

Mapping annual rainfall and erosivity factor in Nyamasheke District.



2. METHODOLOGY:RUSLE Parameters' estimation + mapping

Soil Erodibility Factor (K) estimation

- Soil erodibility is a measure of a soil's resistance to the erosive powers of rainfall energy and runoff (Ndolo, 2015) that accounts for soil texture, structure, organic matter, and even permeability.
- Empirical equations according to Willium (Wawer, Nowocieñ, & Podolski, 2005):

F_{c-sand} is a factor that lowers the K indicator in soils with high coarse-sand content and higher for soils with little sand

$F_{cl-silt}$ 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,

$F_{hill-sand}$ lowers K values for soils with extremely high sand content.

ms – the sand fraction content (0.05-2.00 mm diameter) [%];

$msilt$ – the silt fraction content (0.002-0.05 mm diameter) [%]

mcl – the clay fraction content (<0.002mmdiameter [%];

$orgC$ –The organic carbon (SOC) content [%].

Equations:

$$K = K_{USLE} \times 0.1317$$

$$K_{USLE} = F_{c\text{-}sand} \times F_{cl\text{-}silt} \times F_{orgC} \times F_{hill\text{-}sand}$$

$$F_{c-sand} = \left(0.2 + 0.3 \times \exp\left[-0.256 \times ms \times \left(1 - \frac{msilt}{100}\right)\right]\right)$$

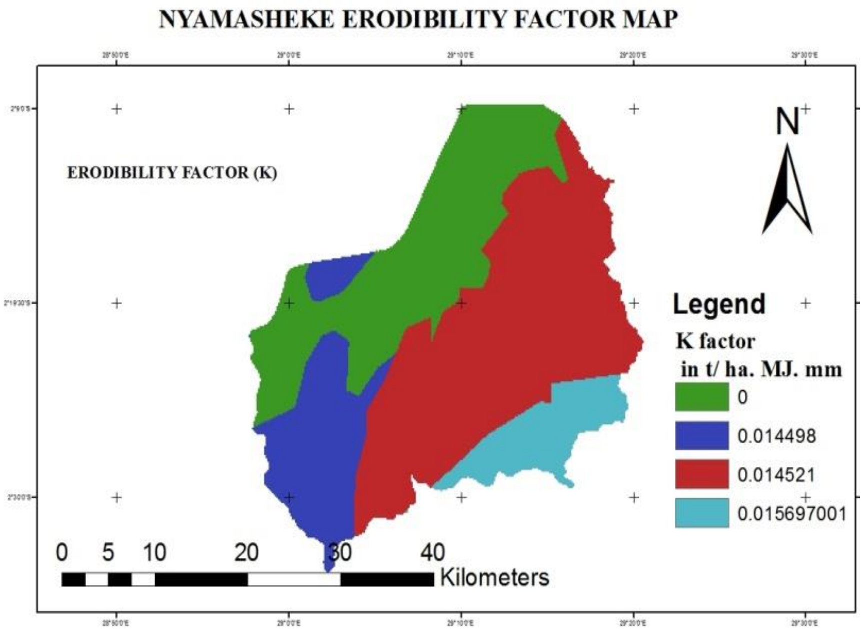
$$F_{cl-silt} = \left(\frac{msilt}{mcl + msilt}\right)^{0.3}$$

$$F_{orgC} = \left(1 - \frac{0.25 \times orgC}{orgC + \exp[3.72 - 2.95 \times orgC]}\right)$$

$$F_{hill-sand} = \left(1 - \frac{0.7\left(1 - \frac{ms}{100}\right)}{\left(1 - \frac{ms}{100}\right) + \exp\left[-5.51 + 22.9\left(1 - \frac{ms}{100}\right)\right]}\right)$$

2. METHODOLOGY:RUSLE Parameters' estimation + mapping

K FACTOR MAP



SOIL PROPETIES & K VALUES FROM EXCEL SHEETS

SOIL PROPERTIES

Soil type unit	Soil unit symbol	sand % topsoil	silt % topsoil	clay % topsoil	OC % topsoil
Humic Ferralsol	Fh	12.8	21.6	65.5	3.49
Distric nitosol	Nd	38.9	17.6	43.6	1.57
Humic cambisol	Bh	55.2	21	23.8	3.86

K FACTOR VALUES

Fc-sand	Fcl _silt	F _org	F _hisand	K
0.22299	0.658159	0.7501	1	0.014498
0.200082	0.688063	0.800959	0.999911	0.014521
0.200004	0.796677	0.75003	0.997294	0.015697

2. METHODOLOGY:RUSLE Parameters' estimation + mapping

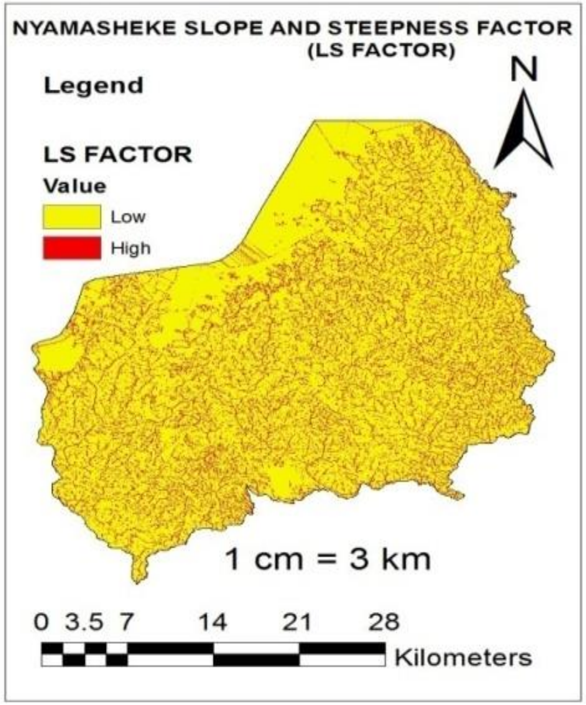
Topographic factor (LS) estimation

- The Topographic factor represents a ratio of soil loss under given condition to that at a site with the "standard" slope steepness of 9% and slope length of 22.6 m (Ganasri & Ramesh, 2016).
- The slope length factor (L) and the steepness factor (S) constitute the topographic factor and account for the effects of topography on soil erosion modelling in RUSLE (Ndolo, 2015).

Calculation of LS:

- Step1: calculate flow direction from DEM (ArcGIS 10.2.2.),
- Step2: calculate flow accumulation from flow direction,
- Step3: calculate slope in degree from DEM,
- Step4: raster calculation of LS using equation below:

LS FACTOR MAPP



m=0.5, for slopes of 5% or more

$$LS = \left(flow\ accumulation \times \frac{Resolution}{22.1}\right)^m (0.065+0.0455S+0.0065S^2)$$

2. METHODOLOGY:RUSLE Parameters' estimation + mapping

C Factor

- The Cover Management Factor (C) represents the effect of vegetation, soil cover, below ground biomass, cropping, soil-disturbing activities and management practices on soil erosion.
- STEPS:

1. Calculate NDVI from Landsat7/ETM+ (2008)and Landsat8/OLI(2015&2018).

$$\mathrm{NDVI} = \frac{(\mathbf{NIR} - \mathbf{RED})}{(\mathbf{NIR} + \mathbf{RED})}$$

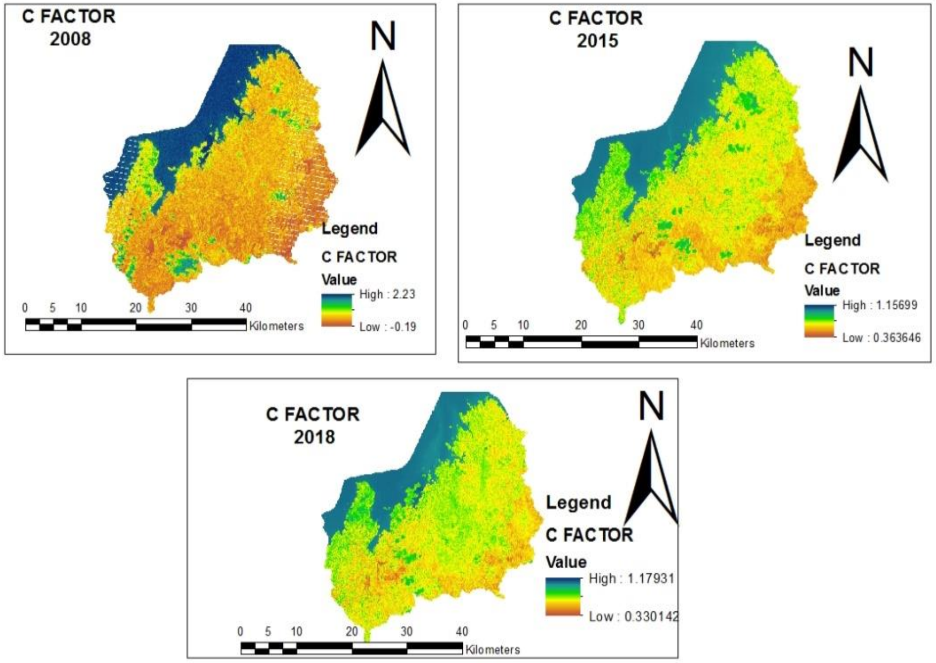
2. Calculate C factor 2008, 2015&2018.

$$\textbf{C factor} = \mathbf{1.02 - 1.21 \times NDVI}$$

3. GIS function: Raster calculator

C factor Maps

NYAMASHEKE COVER MANAGEMENT FACTOR MAPS (C FACTOR MAPS)



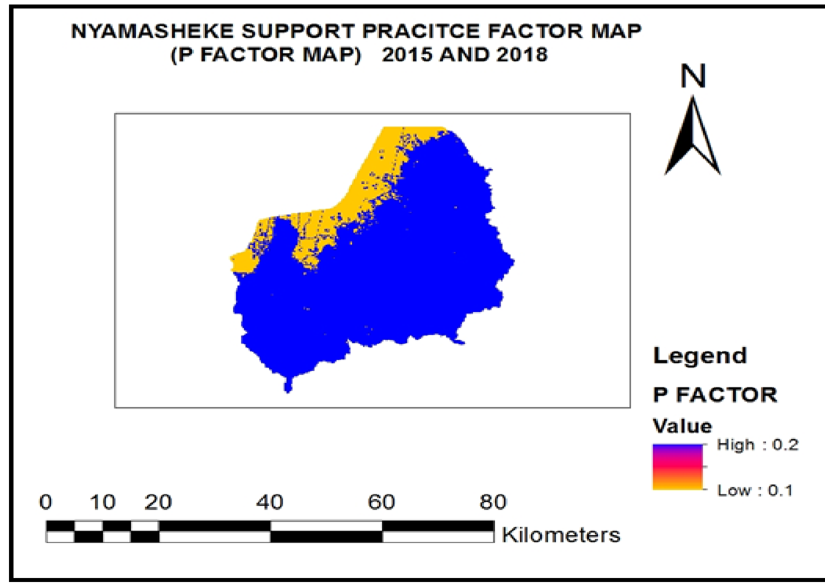
Band 3 & Band 4 for Landsat7 and Band 4&band 5 for Landsat 8 were considered to calculate NDVI

2. METHODOLOGY:RUSLE Parameters' estimation + mapping

P factor estimation

- The ratio of soil loss with a specific support practice to the corresponding soil loss with straight row upslope and down slope tillage (Kim H. , 2006).
- For this study P factor was taken as 1 in 2008(no soil conservation control and 0.2 in 2015&2018(terraces implemented from 2012 till now at about 3.04%).
- **Procedure:**
- Calculate slope in percentage from surface tool in spatial analyst tools (ArcGIS 10.2.2).
- Classify slope map based on slope intervals specific to agriculture method P values
- Convert raster map to polygon in conversion tools
- Open attribute table
- Select by attribute ''grid code".
- Sort by ascending grid code
- Open Editor Tool then start editing and merge for all unique values. For Nyamasheke watershed only 2 classes were observed. This means that Nyamasheke slopes are less than 7% and greater than 26.8%.

P factor map



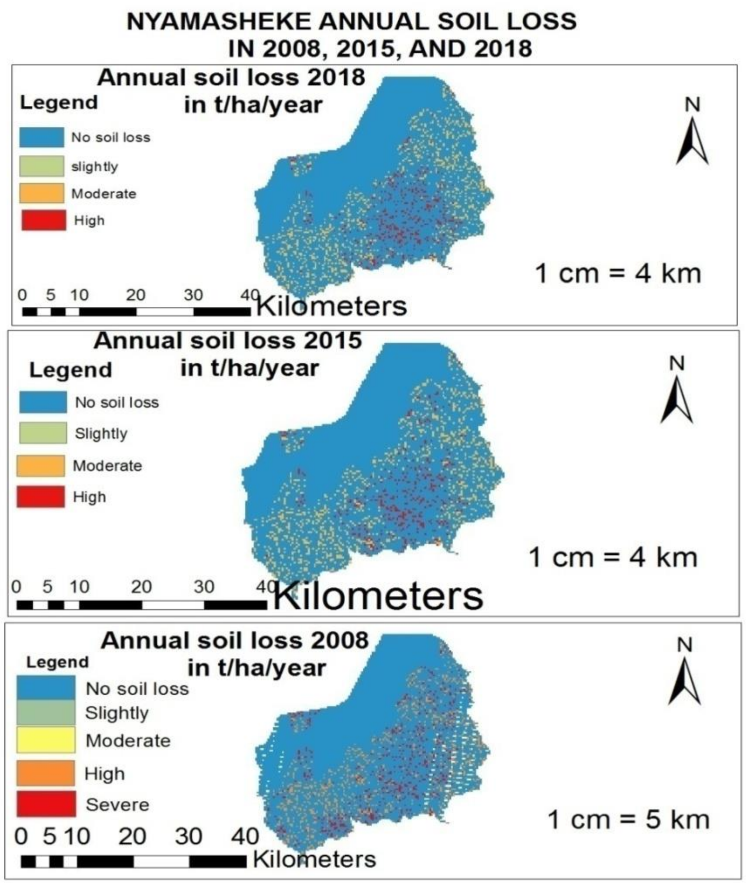
Slope interval (%)	Terracing
0-7	0.1
7-11.3	0.12
11.3-17.6	0.16
17.6-26.8	0.18
26.8>	0.2

3. RESULTS: Annual soil loss (A)

SOIL EROSION ESTIMATION

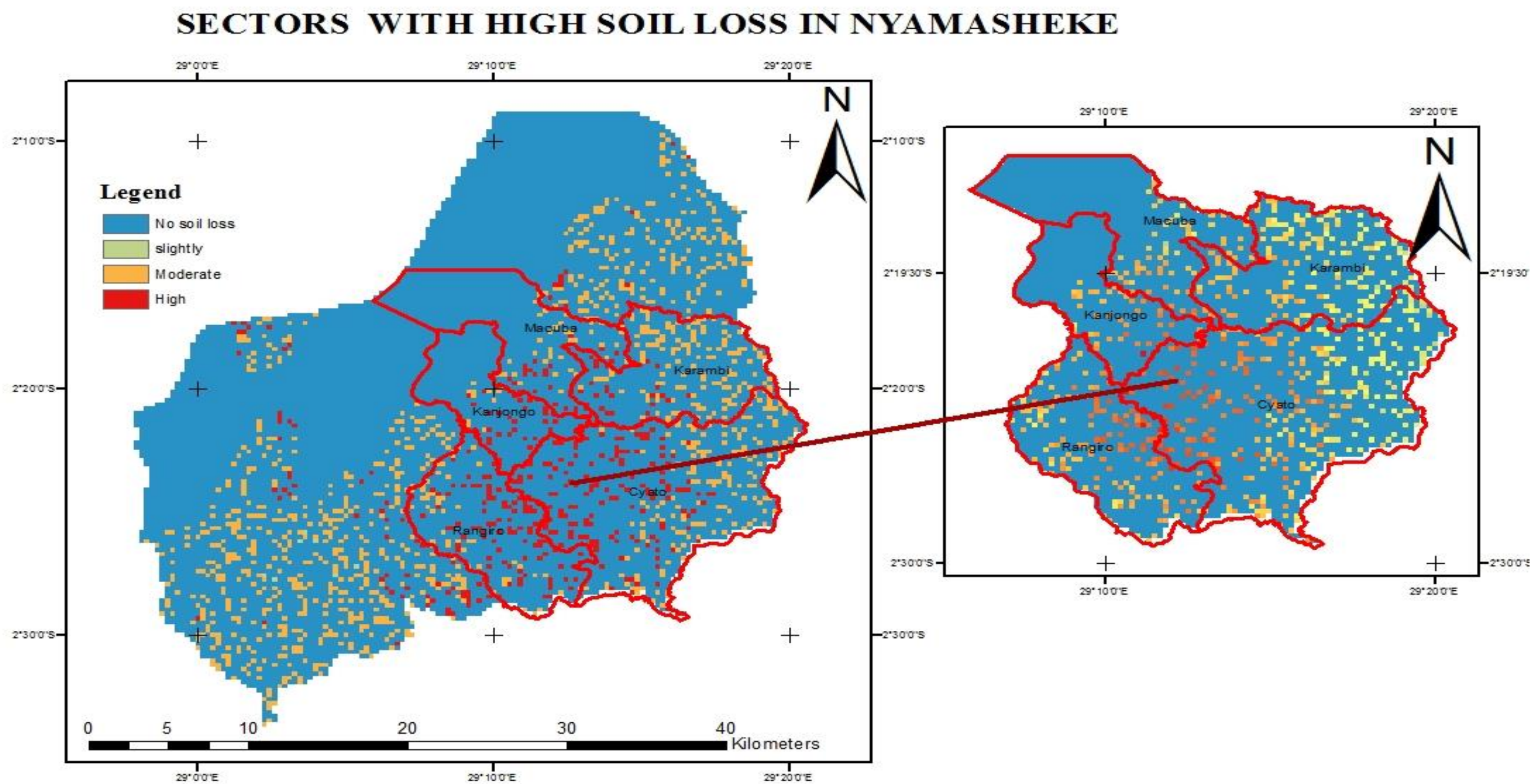
- Average annual soil erosion (tons/ha/year)
- A = R x K x LS x C x P.
- GIS function : Raster calculator.
- Annual soil loss was classified into 5 classes:
- No soil loss (0t/ha/year),
- slightly soil loss (0-5t/ha/year),
- moderate soil loss (5-10t/ha/year),
- high soil loss (10-40t/ha/year),
- severe soil loss (40-95t/ha/year).
- **High soil loss area** was identified in Kanjongo, Cyato, Rangiro, and Karambi sectors at about 3020.01ha corresponding to 2.57% in 2018 while it was 2.25% in 2015, 6.54% as **high soil loss area** and **3.325% severe soil loss area in 2008** of the total surface area of the district.

ANNUAL SOIL LOSS CHANGE MAPPING



3. RESULTS: Annual soil loss (A)

SECTORS WITH HIGH SOIL LOSS MAPPING

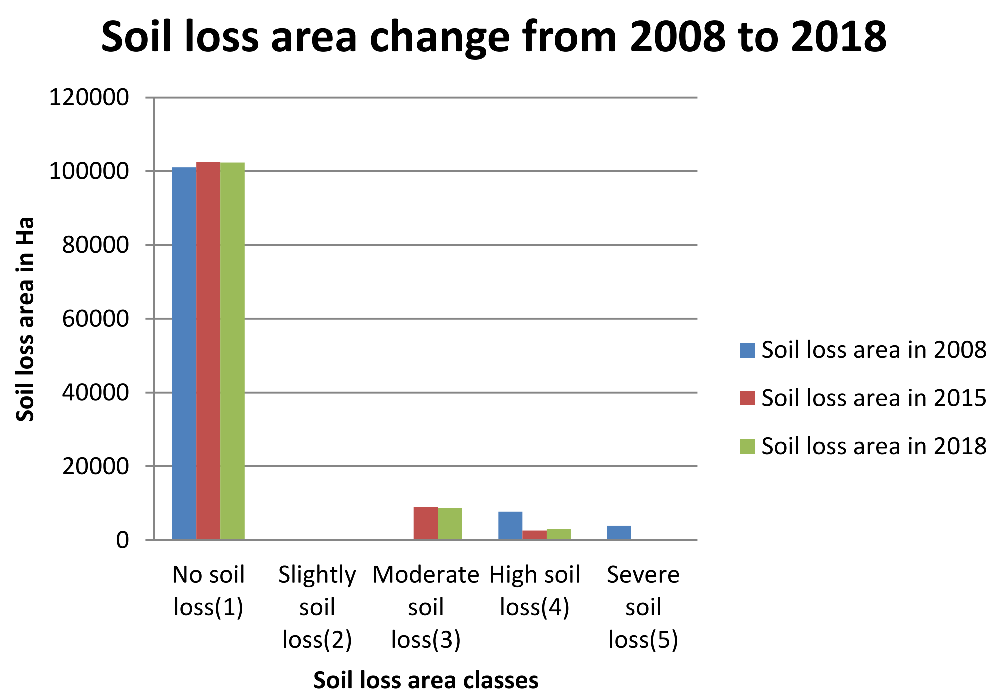


RESULTS: Erosion sensitivity change analysis in Nyamasheke District

Statistical comparison

- Statistical analysis by a comparison between soil loss areas calculated from annual soil loss maps in 2008, 2015 and 2018 in terms of soil loss area classes, showed a decease of susceptibility to soil erosion of Nyamasheke watershed from 2008 to 2018.

Histogram of comparison

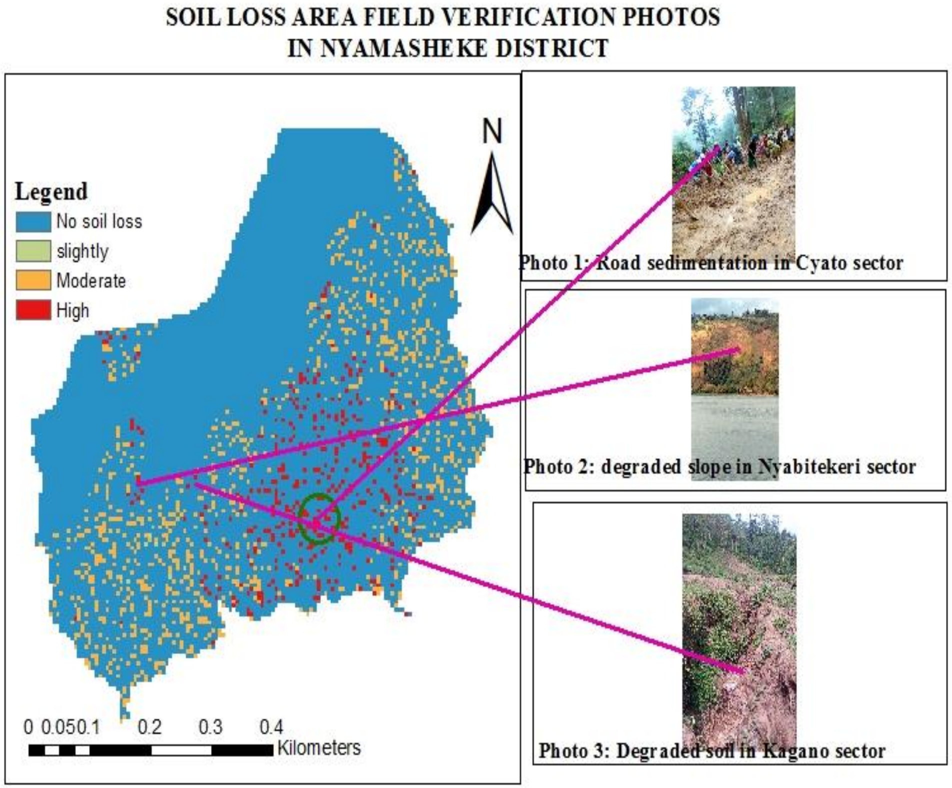


3.Results validation

Field based Validation

- The field survey investigation confirmed the success of our method for soil erosion prone areas identified.
- This is because no experimental data were available in the watershed.

Validation map



3.Results: Key factors contributing to soil erosion sensitivity in area identified

- High **slope steepness**, **high rainfall** and **low vegetation cover** that contribute more significantly to soil erosion sensitivity in the vulnerable area identified in 2018 and actually now.
- In addition this area recognizes a high erodibility factor compared to other areas in the district

4.Conclusion

- Nyamasheke District shows a decreasing sensitivity to soil erosion from 2008 to 2018 significantly.
- Field based Rwanda’s soil erosion data are needed to facilitate future researchers.

THANK YOU!