Soil Erosion Modeling in the Puyallup-White River Watershed: A GIS and RUSLE Approach

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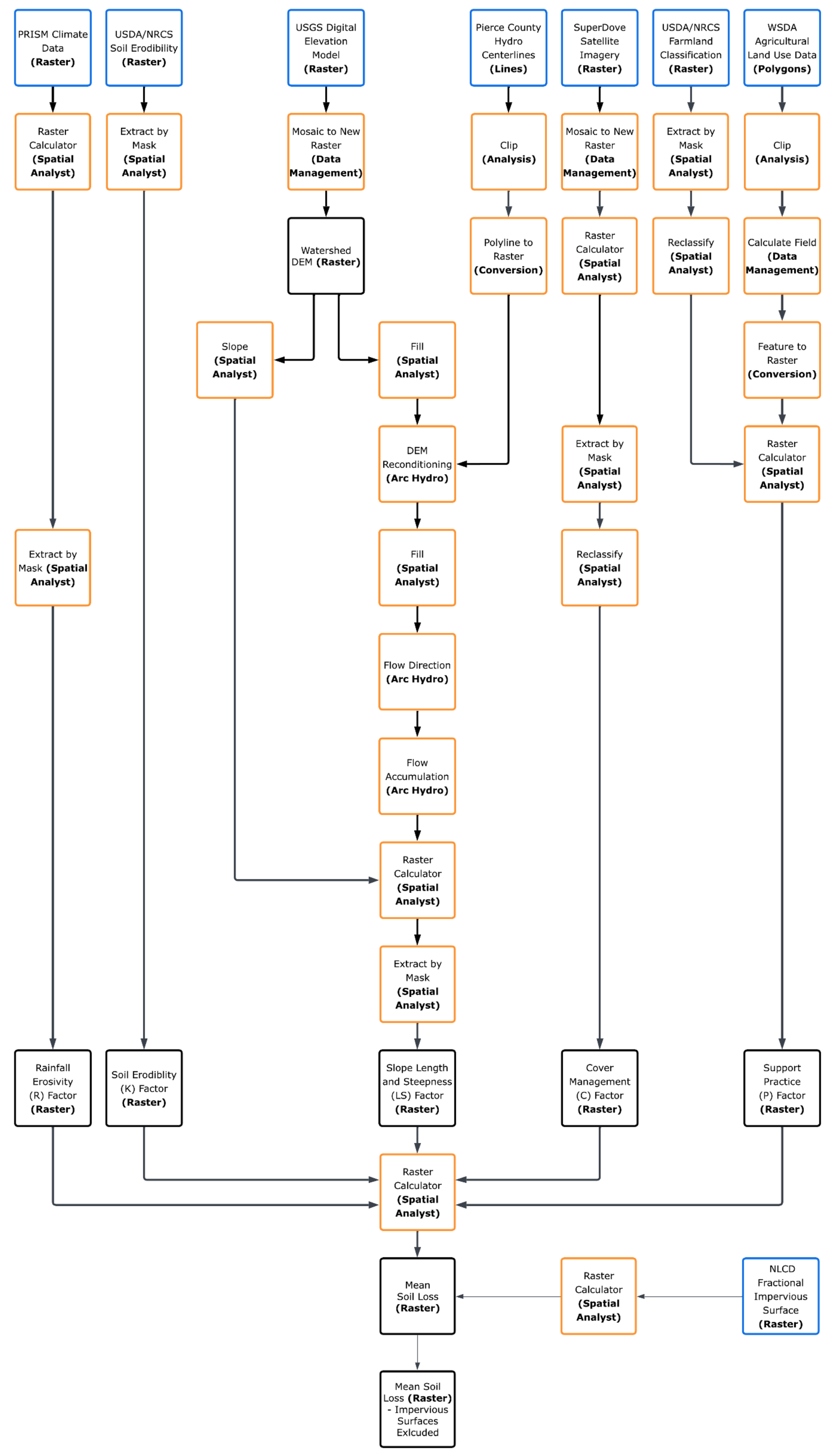
Introduction

- The Revised Universal Soil Loss Equation (RUSLE) serves as a practical model for estimating soil loss from sheet and rill erosion, integrating climatic, topographic, soil, and land-use variables to calculate a mean annual rate.
- Accelerated soil erosion causes land degradation and loss of soil fertility while also disrupting sediment transport, water quality, and ecosystem health[1].
- Developments in GIS technology have strengthened RUSLE modeling by improving the integration of spatial data and analysis[2].

Geographic Information System (GIS) Workflow



- Rainfall erosivity (R) was calculated using the mathematical relationship between erosivity and average annual precipitation[3].
- SSURGO soil data were extracted via spatial mask to assess erosion susceptibility (K) based on intrinsic soil properties.
- Slope length and steepness (LS) was calculated using an empirical equation incorporating flow accumulation and slope gradient[4].
- Cover management (C) was approximated by developing a Normalized Difference Vegetation Index (NDVI)[5].
- Support practices (P) were estimated by integrating farmland classifications with current irrigation methods.

RUSLE Analysis

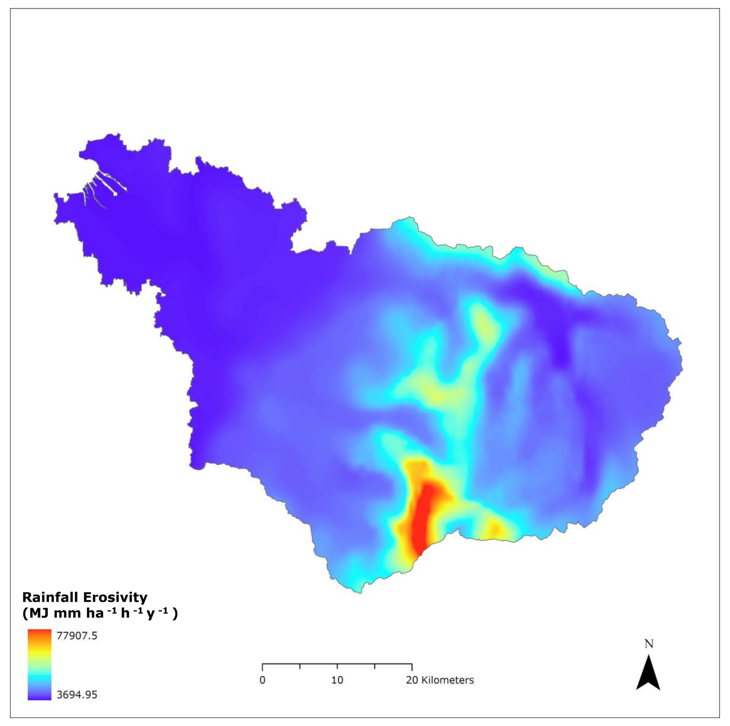


Figure 1. Rainfall erosivity factor (R) in the Puyallup-White River Watershed, calculated from PRISM 30-year climate normals (1991–2020). This factor represents the physical potential for rainfall to detach soil.

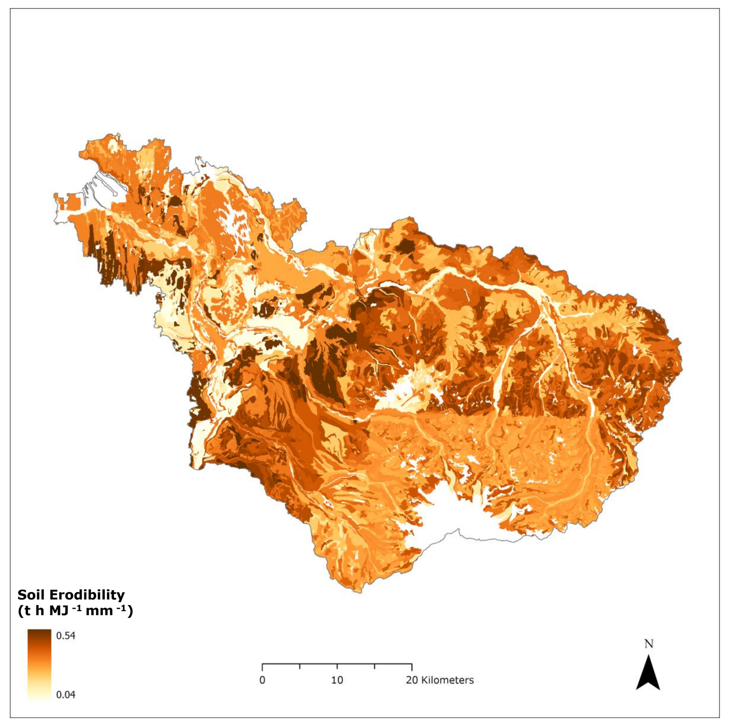


Figure 2. Soil erodibility factor (K) in the Puyallup-White River Watershed, based on pre-computed USDA/NRCS SSURGO raster data. Quantifies the inherent susceptibility of soils to erosion.

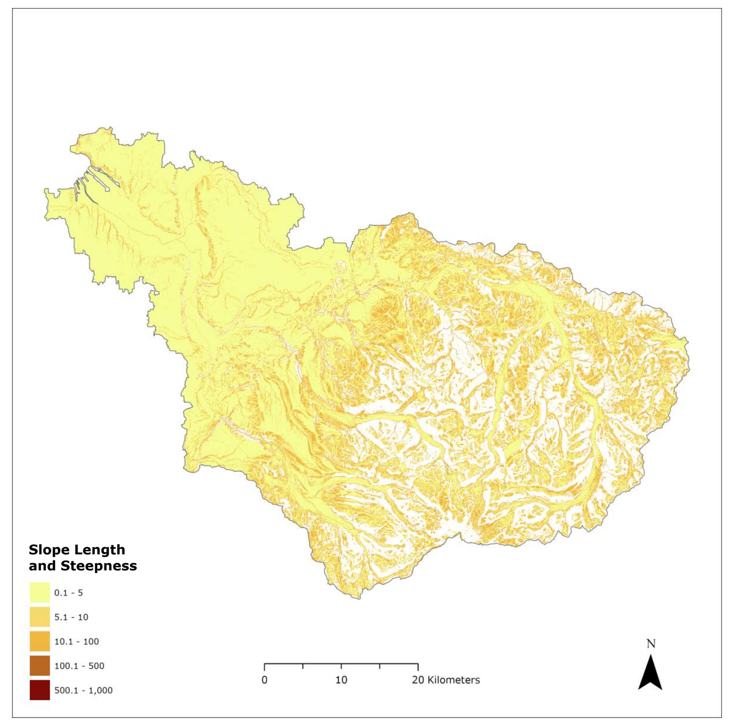


Figure 3. Slope length and steepness factor (LS) in the Puyallup-White River Watershed, calculated from USGS 30-meter digital elevation models (DEMs). This topographic factor quantifies the combined effect of slope gradient and flow accumulation on soil erosion potential.

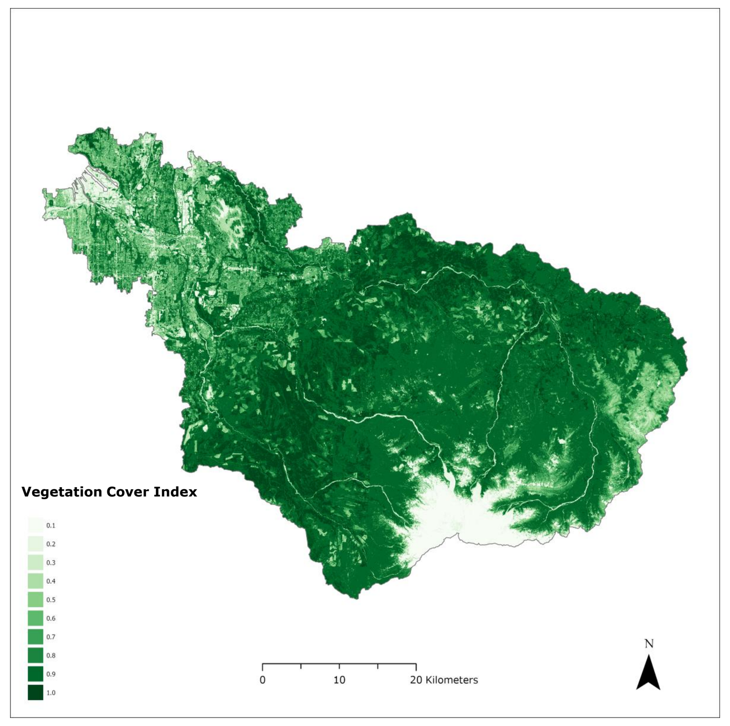


Figure 4. Cover management factor (C) in the Puyallup-White River Watershed, derived from Planet Labs SuperDove satellite data (June 30 2025). Quantifies the effect of vegetation and land cover on soil erosion risk.

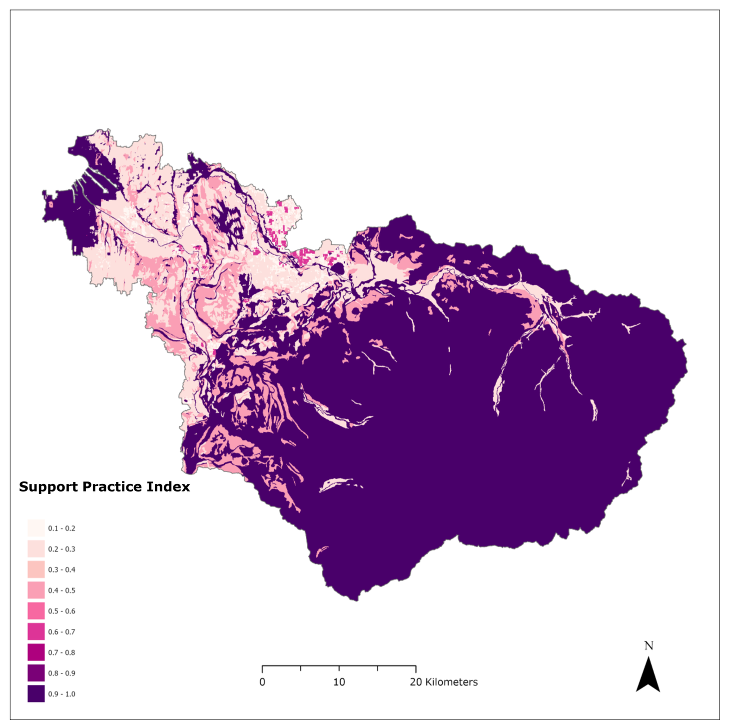


Figure 5. Support practice factor (P) in the Puyallup-White River Watershed. Values are derived from USDA/NRCS farmland classification data and WSDA irrigation method assessments, reflecting practices that influence soil erosion potential.

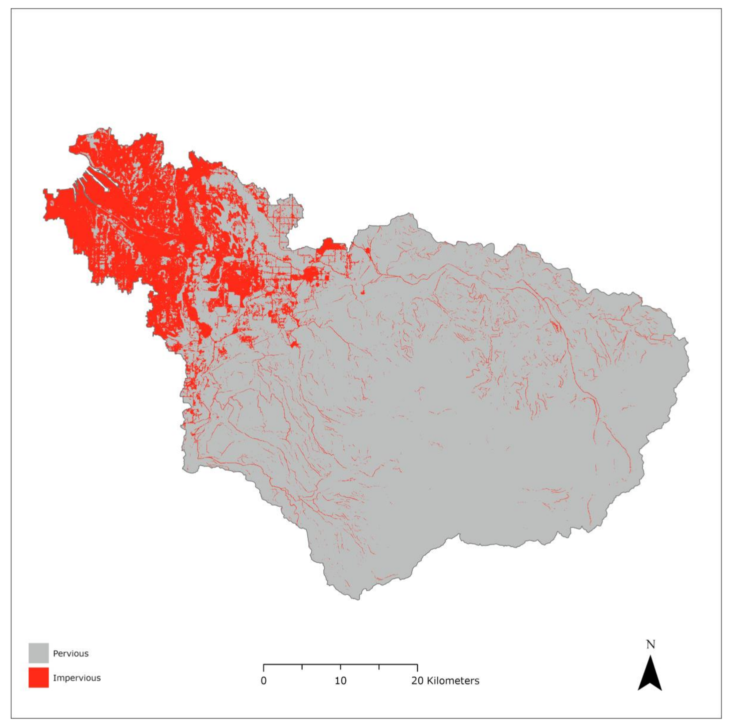


Figure 6. Impervious and permeable surface classification in the Puyallup-White River Watershed, using data from the (2024) Annual National Land Cover Database (NLCD). A >5% imperviousness threshold was applied to reclassify surfaces, accounting for heterogeneity of features.

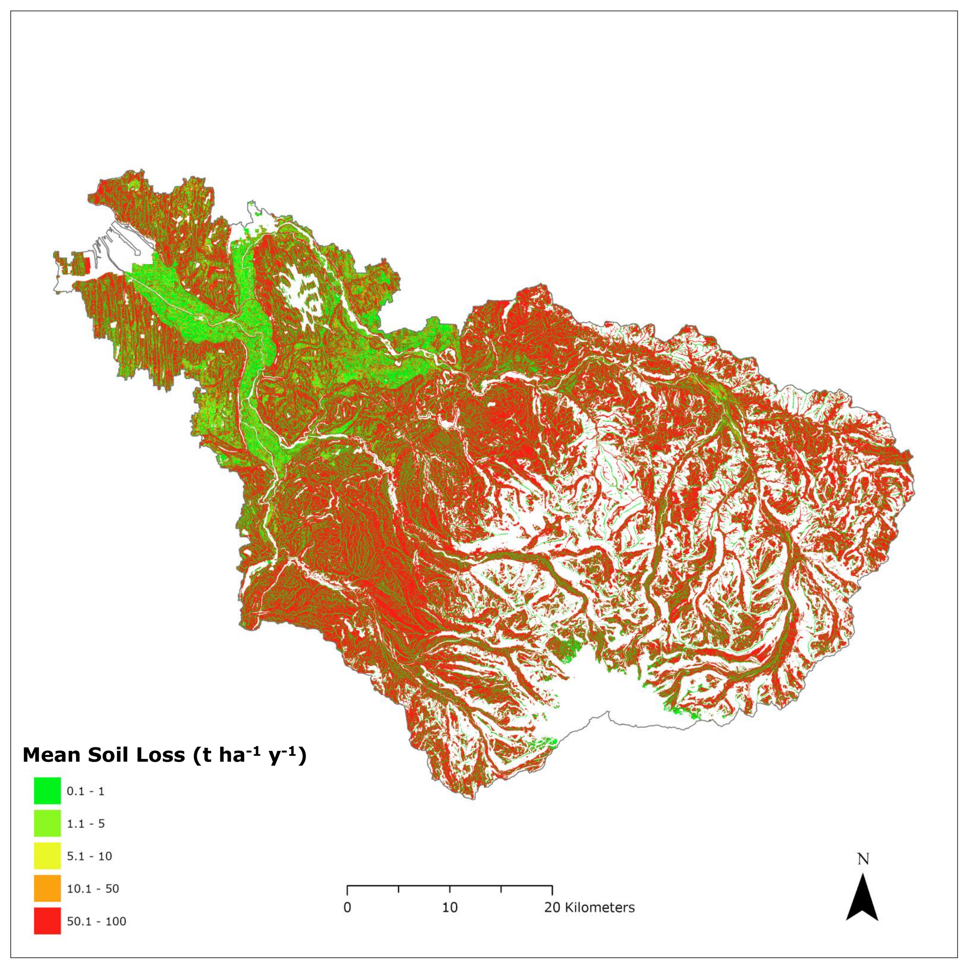


Figure 7. Mean annual soil loss in the Puyallup-White River Watershed, estimated using the Revised Universal Soil Loss Equation (RUSLE). Values represent long-term average erosion rates derived from rainfall erosivity, soil erodibility, slope length/steepness, cover management, and support practice factors.

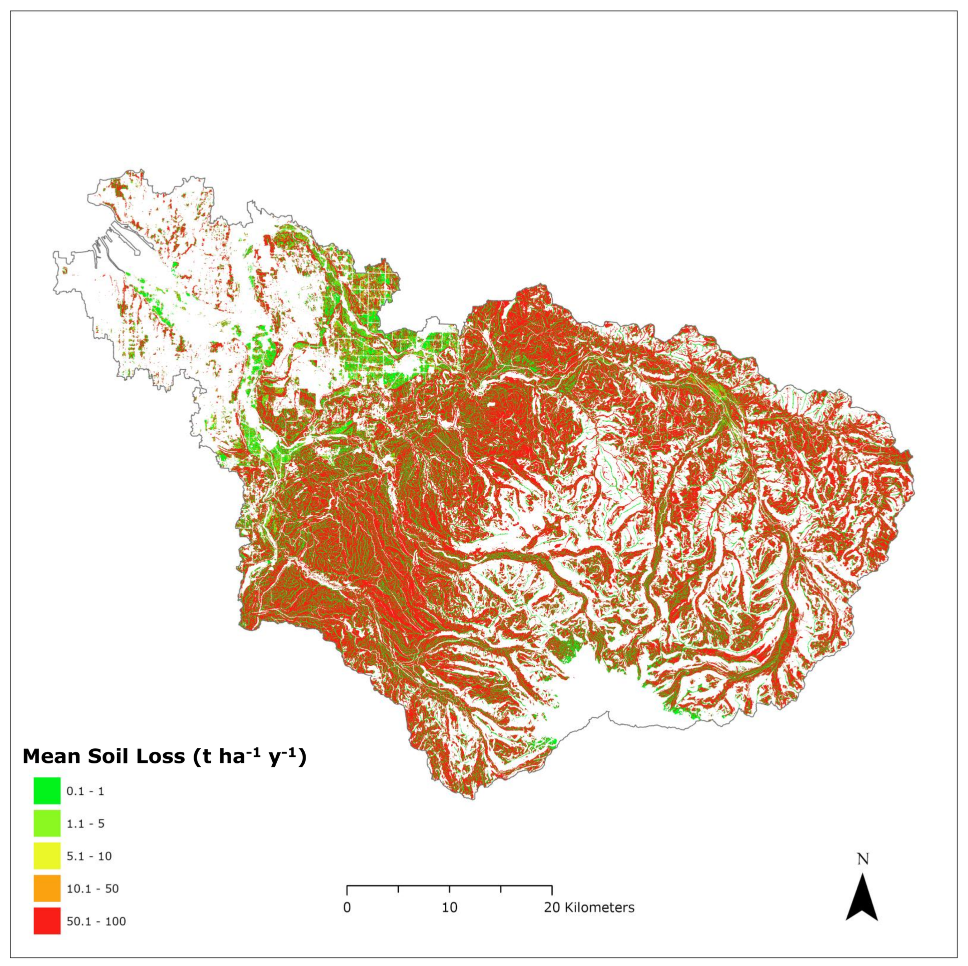


Figure 8. Mean annual soil loss in the Puyallup-White River Watershed. Areas with >5% impervious surface cover were masked out to exclude surfaces not applicable under the model.

Discussion

- The rainfall erosivity (R) factor corresponds geographically with annual precipitation patterns. The highest values occur at the watershed source because of orographic lift on precipitation.
- The slope length and steepness (LS) factor tends to be overestimated in regions with steep slopes and mountainous terrain.
- Areas with high-severe soil erosion risk (50–100 t/ha/yr) are most prevalent on steep, long slopes, aligning with the current overestimation of the LS factor.
- The effect of support practices on soil erosion is likely underestimated, as the analysis lacks direct data on agricultural practices.
- Soil loss rates were successfully measured for the watershed itself and key sites under the RUSLE model, (agricultural, logging, disturbed/reclaimed, and landfill areas). These findings can be used to mitigate the acceleration of erosion risks.

Continued Research

- Expand the temporal scope of the rainfall erosivity (R) and cover management (C) factors by incorporating retrospective data into the analysis. Assess the effects of climate change on rainfall and vegetation.
- The Modified Universal Soil Loss Equation (MUSLE) model can be applied to quantify runoff and sediment yield[6]. MUSLE implements a runoff erosivity factor, which integrates storm runoff volume (Q) and peak runoff rate (q_p).
- Incorporating a higher-resolution digital elevation model (DEM) to refine the slope length and steepness (LS) factor calculation by accounting for micro-topographic variations.
- To better align with the heterogeneous terrain of a mixed-use watershed, (LS) factor equation(s) can be applied conditionally. This may involve incorporating a multiple-flow direction algorithm[7] to account for variations in topography.
- Integrate forest-specific best management practices (BMPs) into the support practice (P) factor.
- Shift analysis to sub-watersheds, sub-basins, or other known high-risk erosion sites.

References & ArcGIS StoryMap