SPATIAL MODELING FOR SOIL EROSION ASSESSMENT IN THE PALOUSE REGION, WASHINGTON, IDAHO

By

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A COURSE PROJECT

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Or

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ABSTRACT

Soil degradation has been a major problem that regions around the globe face including several areas of the United States of America**.** Extensive researches were conducted to address the issue of soil erosion around the world and across the United States; however few focused on the visualization and quantification of the phenomenon despite available tools and methodologies. The purpose of this study is to estimate and map, on a yearly basis, the amount of soil loss, in the Palouse region, located between Washington and Idaho States. In fact, the area comes first over the whole country in terms of soil deterioration. In order to attain those objectives, the Universal Soil Loss Equation (USLE) (Wischmeier & Smith, 1978) was used into the ArcGIS environment. Digital Elevation Model (DEM) combined with factor maps such as rainfall and land use land cover as well as tabular data from published sources served as input to build the soil loss model. As a result, a map (see Map 10) showing the spatial distribution of soil loss was produced highlighting the Southeastern of Whitman, Eastern Spokane and Northern Latah Counties as the most hit. Also, five different classes of loss were set: 0-10, 11-20, 21-50 and 51-500 tons per hectare and per year. Despite the fact that most of the losses are comprised from 0 through 10 tons, significant amount are recorded between the 51-500 intervals particularly in the locations mentioned above. The findings are not contradictory to the 46 tons average that is given in literature. They suggest, however, that any generalization of one value for the entire region is to be avoided despite the relatively uniform distribution of the issue.

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INTRODUCTION

Palouse is an expanse of rolling hills boarded by the Channeled Scablands on the west, the Clearwater Mountains on the east, the Snake River to the south and the Spokane plains to the north. The semi-arid land has extremely fertile soils but in the same light the soil is comprised of loess, which is wind-deposited soil (Andrew P. Duffin, 2004). The geology in the area is made up of crystalline basement rock with an overlay of basalt flows and interbedded sediments. The basalt flows are the result of fluvial deposits. Basalt itself is from lava flows that entered the Palouse basin. In this region on most of the land the slopes average around five to fifteen degrees (Busacca et al 1993). The research article also states that in cultivated fields the steepness of the slopes can reach twenty-six degrees or more. The importance of the slopes degree allows water erosion rates to be measured. What is the importance of erosion or the importance of soil loss? Soil loss is measured using the universal soil loss equation. The fact that many factors such as rainfall erosivity, slope length and steepeness, soil erodibility, vegetation cover and conservation practice are accounted for makes the Universal Soil Loss Equation (USLE) a very famous, imposing and reliable tool in the academia.

Objectives

The objectives of doing the project are stated as follows:

- Map the soil loss in the Palouse region
- Quantify the amount of soil loss on a yearly basis

Significance

Some of the reasons that justify the selection of Palouse to conduct our study are presented as follows:

- Literatures place Palouse in first place when it comes to soil degradation in the United States of America.
- The Study will contribute in providing information over the region
- Despite the gravity of its degradation, it turns out that few articles are written on the soil loss quantification issue.
- The mapping and amount may help in decision-making.

METHOD

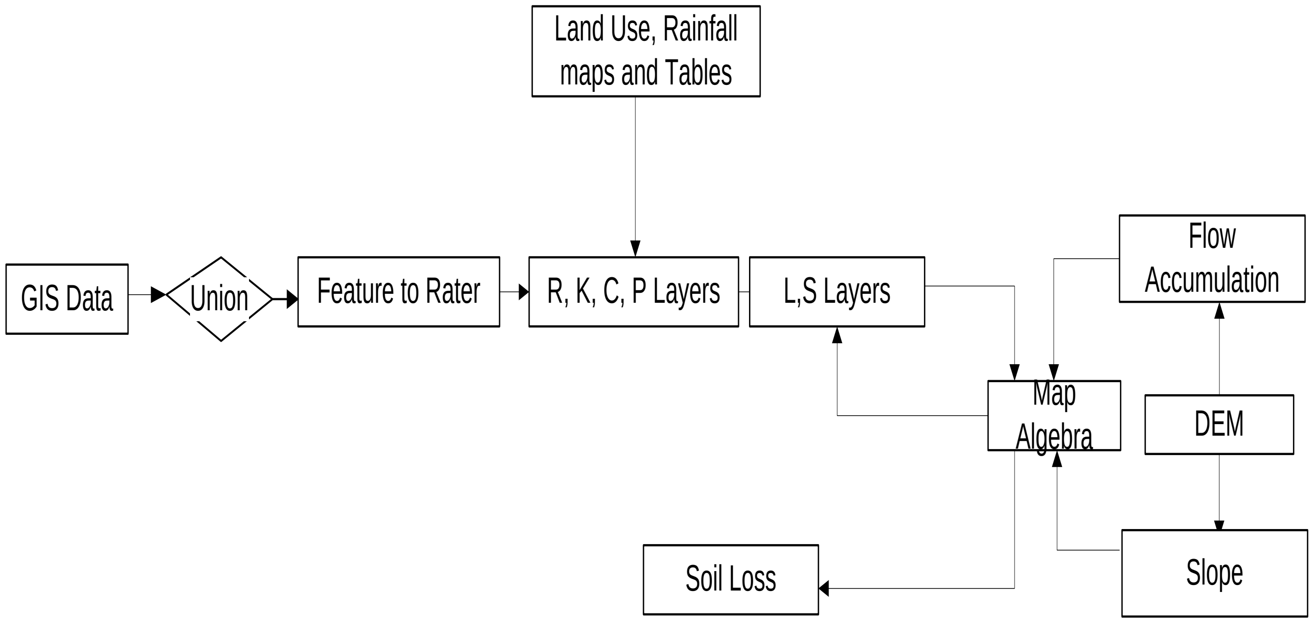
The following approach was designed and followed all along the study. It tries to encompass some of the characteristics of science such as being systematic, clear, verifiable or testable.

- ✓ Identify problem and study Area
- ✓ Formulate research topic
- ✓ Literature review
- ✓ Design model
- ✓ Data collection
- ✓ Data processing and analysis. The DEMs were mosaic before the counties could be extracted.
- ✓ Presentation of the results
- ✓ Conclusion and recommendations

Equations

The universal soil loss equation was applied to assess the erosion in the Palouse and it is written as follows: $A = R * L * S * K * C * P$

Where, A is the loss in ton/ha/year, R the rainfall and run-off erosivity factor in MJ*mm/ha/h/year, L the slope length factor, S the steepness factor, K the soil erodibility factor in t*h/MJ*mm, C the vegetation cover factor and P the conservation practice factor. All the factors are dimensionless with exception of R and K.



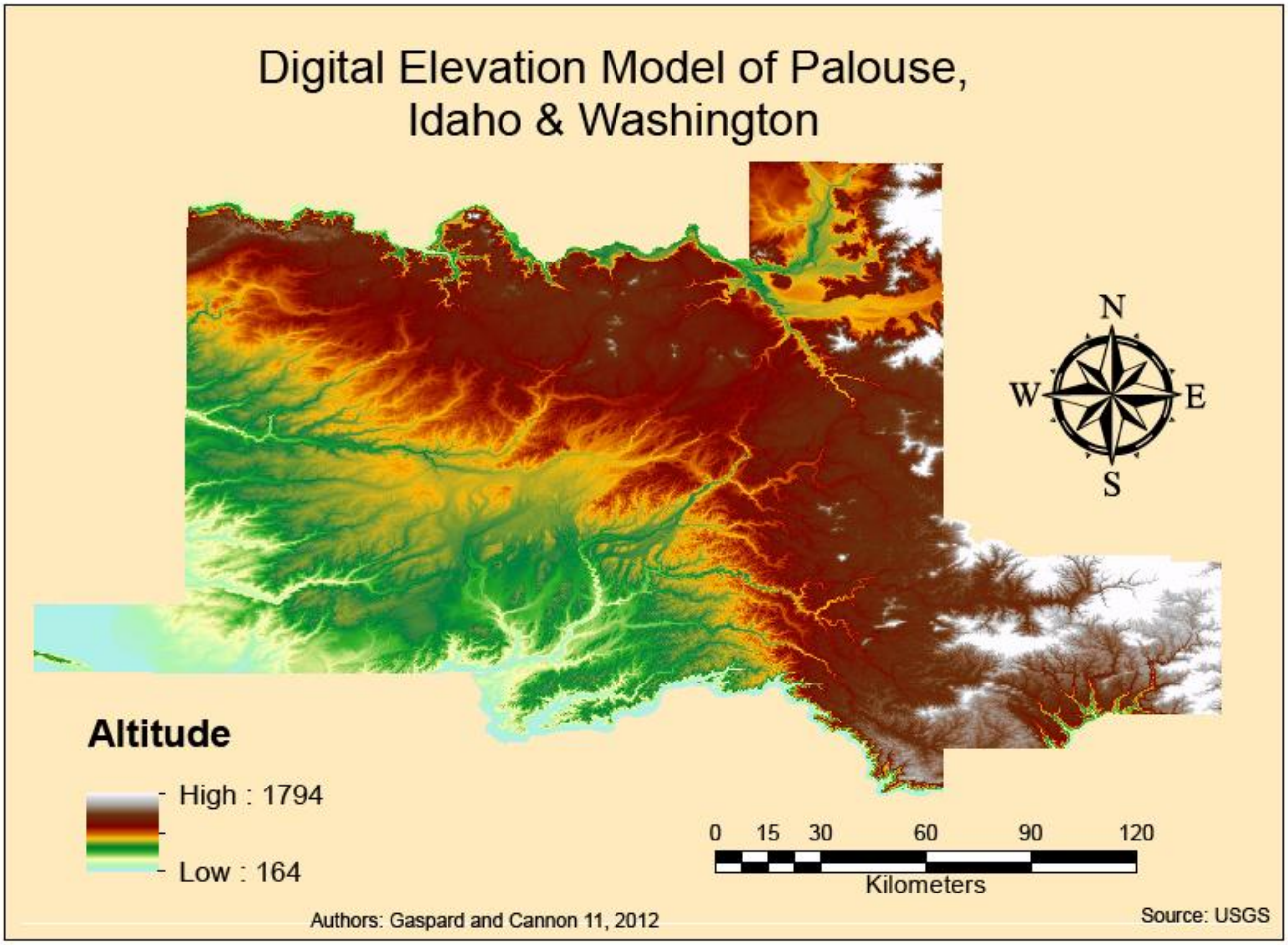
Graph 1. *Soil erosion loss model for Palouse. This flow chart gives the major steps taken in estimating soil loss using Digital Elevation Model,* GIS data, maps and tabular information issued from published sources.

Study Area

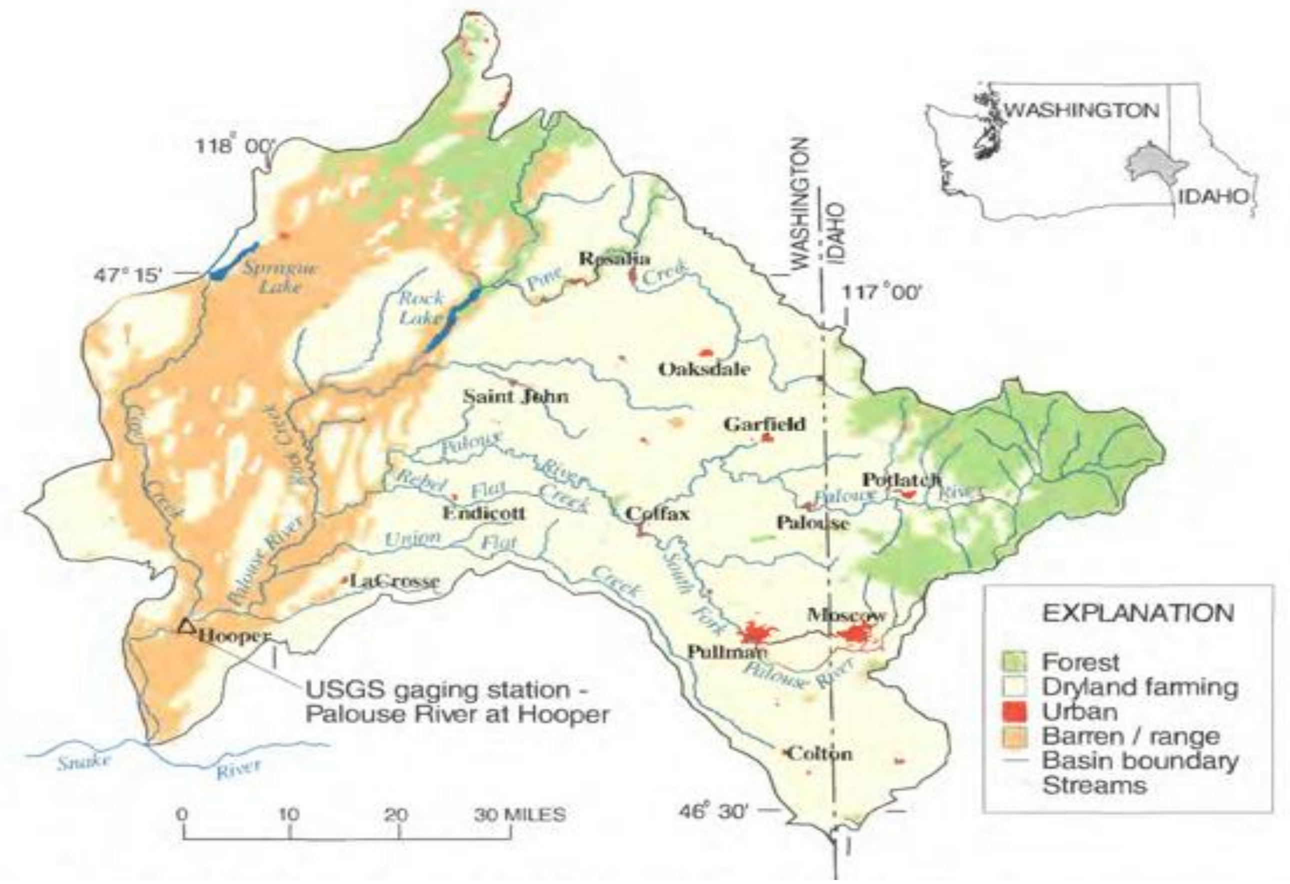
The Palouse region of eastern Washington and northern Idaho is one of the most productive regions in the world for dry land agriculture, such as wheat. The local communities of Pullman, Colfax and Palouse in Washington and Moscow, Idaho are located within the region (Alyssa A. Douglas et al, 2006). The land was first used for cattle grazing in the mid eighteen hundreds. As the population increased from new settlers the land became more agriculturally based. Agriculture and farming was the ending point for free-range cattle grazing. Terrain is commonly accepted as one of the key factors leading to soil erosion. The average rate of soil erosion in this area is one of the highest in the United States (Busacca et al, 1993). The severe erosion is caused by a combination of sheet and rill processes and tillage soil movement. Wheat fields were commonly tilled by a moldboard plow. This plow would dig deep into the ground loosening the soils so water could penetrate the ground. Managing fields this way disturbed the soil and eventually contributed to the beginning of soil erosion. Duffin noted that erosion began in the 1870's and 1880's, which was due to the land being tilled numerous times during the year for seedbed preparation and weed control. The effects of erosion in the Palouse region such as crop loss and decreased water quality were noted as early as 1901. Currently within the Palouse Basin, non-irrigated agriculture is the predominant land use. Agriculturally used land comprises of 53.5% of the land, or 269,602 acres, which is used for cropland. The major crops include wheat, barley, peas, and lentils. Forested areas consist of 31.1% of the land, which is 157,241 acres; rangeland covers 10.5% of the land, 52,966 acres. Only a small percentage, 4.9, or 23,720 acres, of the basin is developed with rural residential and low intensity urban areas. Less than 1% of the basin is open water or wetland with 2,117 acres (NLCD 2001).

STEEP (Solution to Environmental and Economic Problems) is a government program that has funded experimental research in the Palouse region. The emphasis on the research was to develop and utilize new and improved system of management in which the crops would be able to flourish. Crop residue management is one of the principal areas of concern (Papendick). Later it was discovered in the high-precipitation zone of the Palouse (>450 mm annually), a grain legume crop, usually a dry pea or a lentil was commonly grown before the winter wheat. Legumes have the ability to increase the yield potential for the winter crop. They can also produce a residue that can result in less than thirty percent residue ground cover. A minimum plant residue groundcover of thirty to fifty percent is recommended for protection against erosion (Guy & Cox, 2002).

Climate also plays a role in soil erosion. According to Fritz Fiedler, PhD, a faculty member at the University of Idaho, a considerable amount of erosion takes place in the spring with runoff from rapid snowmelt events. Fiedler also states, the Palouse climatic conditions vary both spatially and temporally. Spatially, precipitation increases with elevation from west to east. The lowest precipitation occurs near Colfax, WA (elevation 1,960ft with 18 inches mean annual ppt). The highest precipitation occurs on top of Moscow Mountain (elevation 4,988ft with 50 inches mean annual ppt). Temperature shows the opposite relationship, the trend decreases to the east. This area has hot, dry summers with very little precipitation and a high evaporation rate. Winters are cool and wet. Precipitation can occur as both rain and snow. Linus Andersson, from Lund University did a minor field study in Tunisia. His study was based on the estimated sol loss based off the USLE and GIS approach through small catchments. He gives an example of a farmer, planting cactus in rows, in order for the plants to root. The purpose is eventual growth from the plant will form a vegetated rock strip, consolidated with roots and deposited soil, effectively stopping runoff and eroded sediments can be deposited (Andersson, 2010).



Map1. *Digital Elevation Model showing the Palouse area. The region includes four Washington counties: Spokane, Whitman, Adams, Lincoln and Latah for Idaho.*



Map2. *This map show the distribution of land use and land cover over the Palouse area.*

Source: James C. Ebbert, USGS, and R. Dennis Roe, USDA

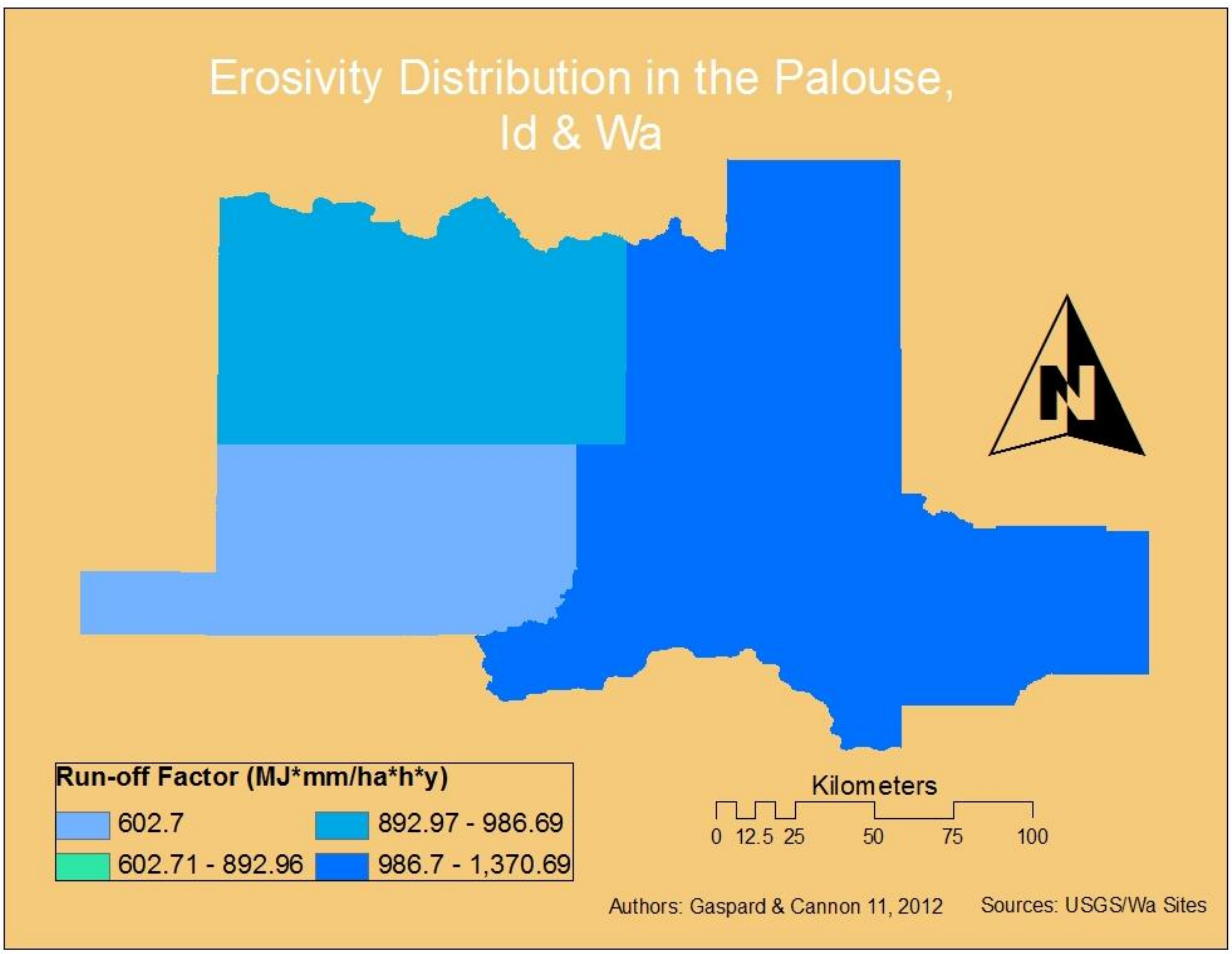
Data

To perform this project, a 10 meters resolution Digital Elevation Model was used for five counties that cover the Palouse area. The GRID data has one band with GCS_North_American_1983 as spatial reference. The pixel type is floating point with 32 bit depth. The elevation data was downloaded from the United States Geological Survey (USGS) website. In addition, Spokane, Lincoln, Whitman, Adams and Latah Counties and subdivisions were downloaded in shapefile format from the Environmental Systems Research Institute (ESRI). They are of the same spatial reference as the DEM where the angular unit is in degrees.

Procedures

Rainfall and Run-off Factor

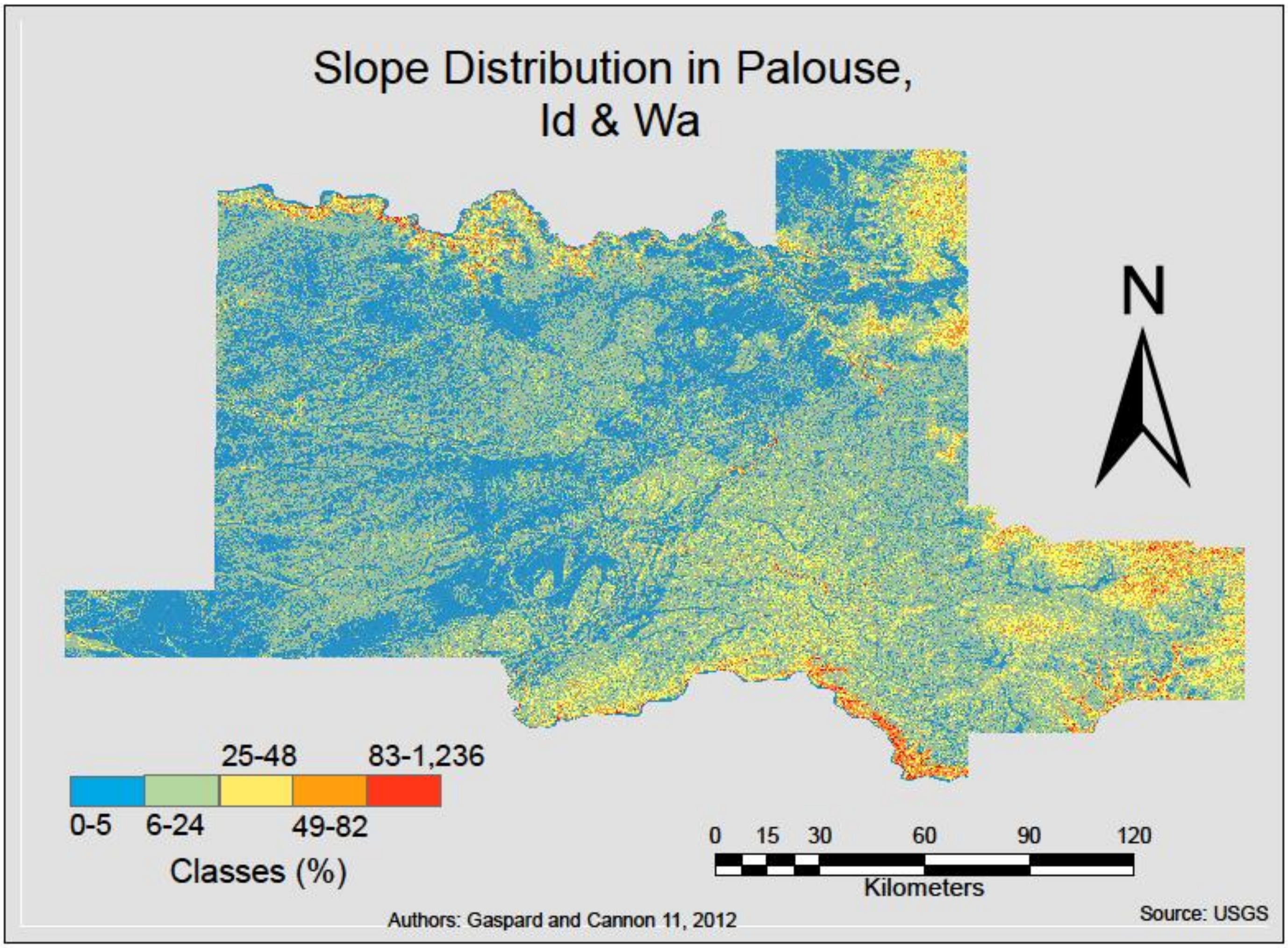
The erosivity factor or R factor is a function of the amount of rain that fall over in a area, the intensity of that and rain and the energy generated by that rain through run-off. To perform erosivity calculation, a map showing the average annual rainfall for the Washington was was used. The values were converted from inches into millimeters and inserted under a rainfall field. Then, the erosivity was calculated from the rainfall values using the following equation $R = 0.4669X - 12.1415$ (Ongsomwang, Thinley 2009) where X is the rainfall in millimeter and R the run-off factor in $\frac{megajoule * millmeter}{hectare * hour * year}$. The equation has been tested in comparison to the values provided by federal agencies and available in published sources before validation.



Map3. *This map displays the erosivity distribution over the study area. The map is derived from the average annual rainfall for the region.*

Slope

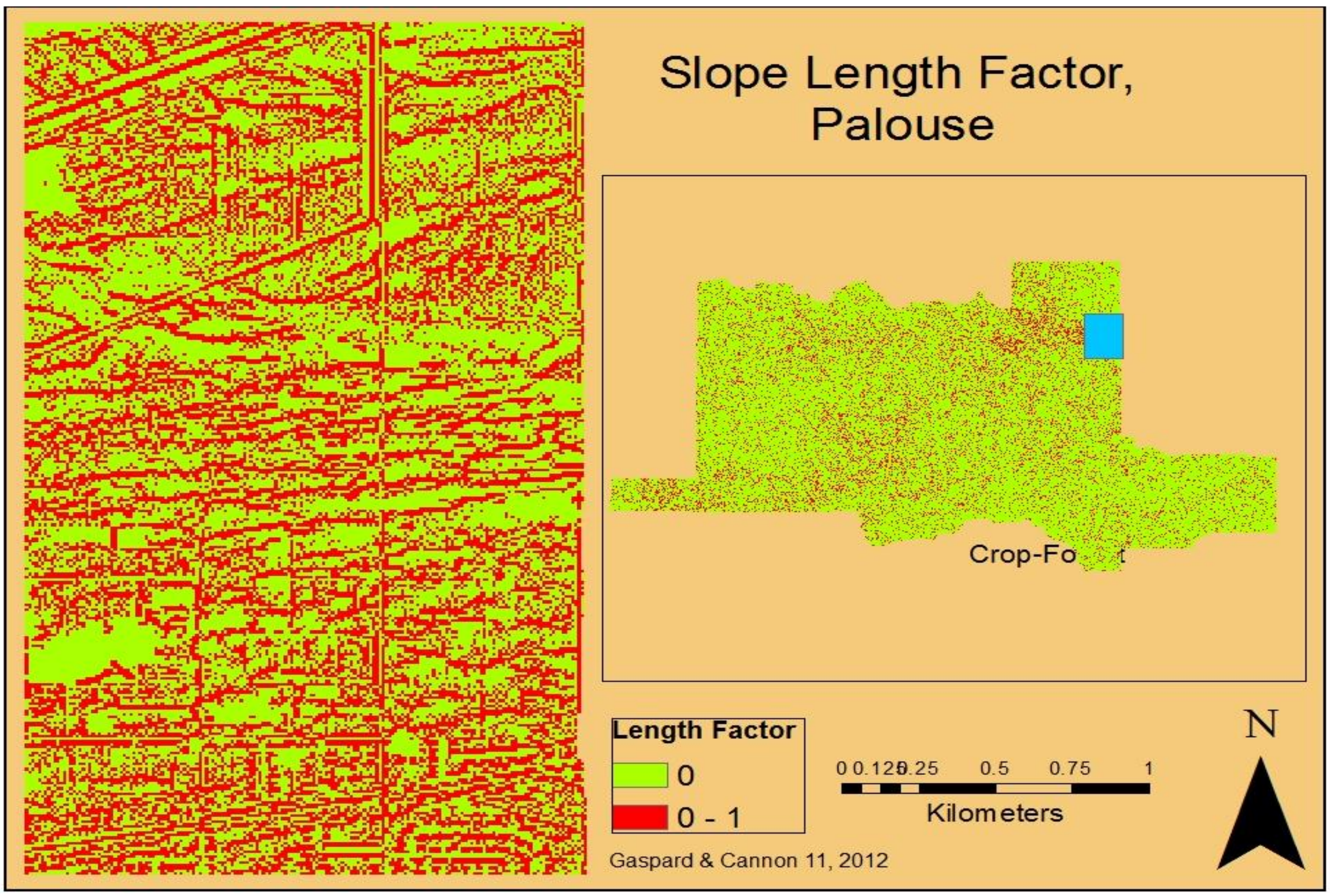
Slope, per se, is not part of the USLE which we are using. However, it was calculated so we can see where erosion is most likely to occur and use it to derive the steep factor. In fact, it is obvious that Palouse has very high slopes especially in southeastern, eastern and northeastern parts. The values are given in percent and are classified into five categories. The Palouse region is located between 46 and 48 degrees latitude north which falls between 40 and 50 therefore a z factor 0.0000125 were interpolated and assigned to the DEM in order convert the units into meters. The slopes are the highest and tend towards infinite particularly for the regions mentioned above (see Map 4).



Map4. *This map shows the different slope classes and distribution across Palouse.*

Slope Length Factor

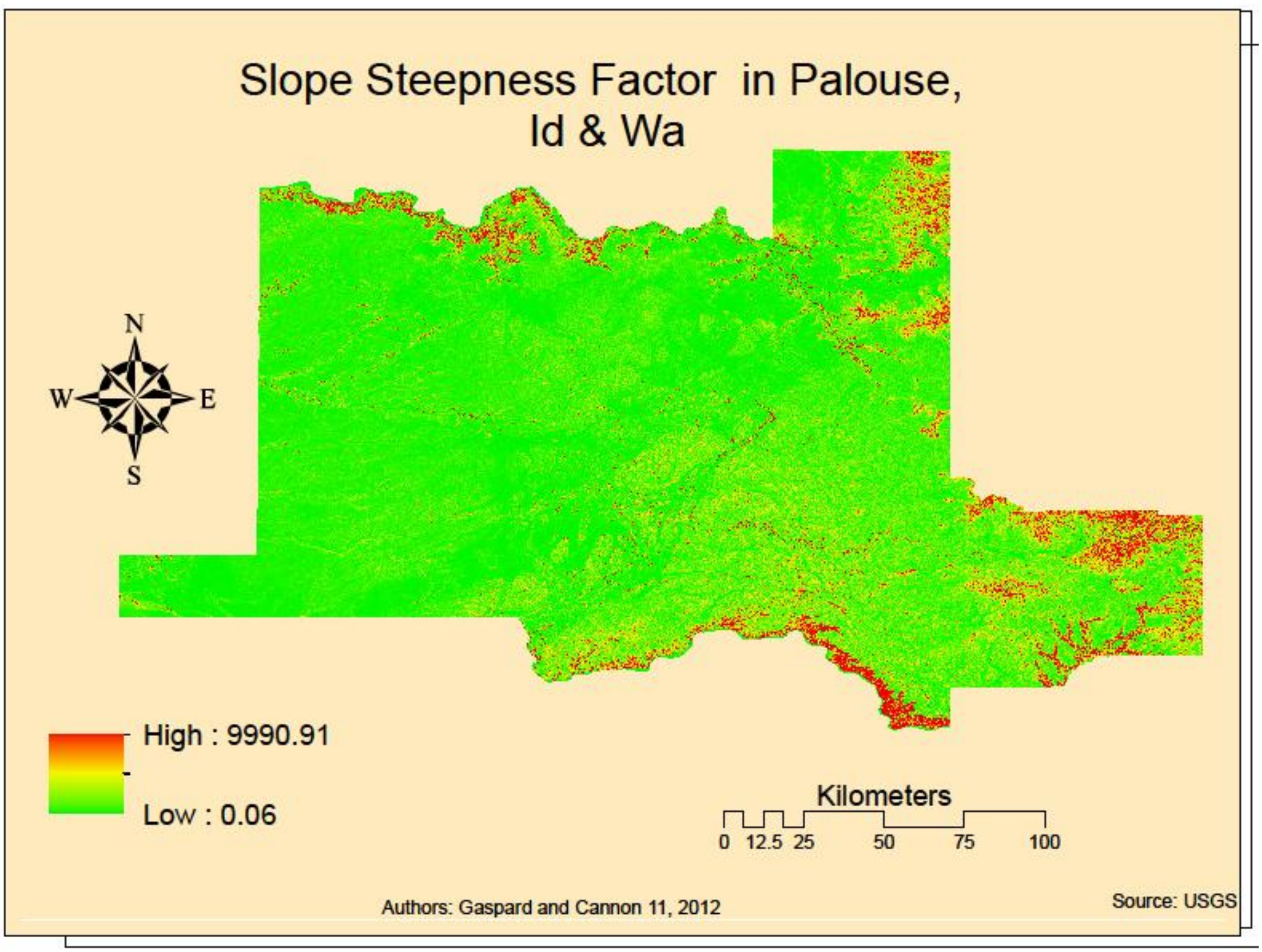
The slope length factor is one among all the factors that make up the USLE method. After deriving the flow accumulation from the original DEM, the slope length factor was calculated using *Map Algebra* and the following equation: $L = \frac{FlowAccumulation * Cellsize}{22.13^{0.3}}$ (Desmet & Govers, 1996; cited by ANGHEL & TODICĂ, 2008). That formula with power 0.3 was in place of 0.4 because the spatial resolution for the DEM is 10 meters which is less than 100 meters. The values found for L factor varies from zero to one as shown in Map 5.



Map5 *showing the slope length factor for Palouse,Washington and Idaho.*

Steep Factor

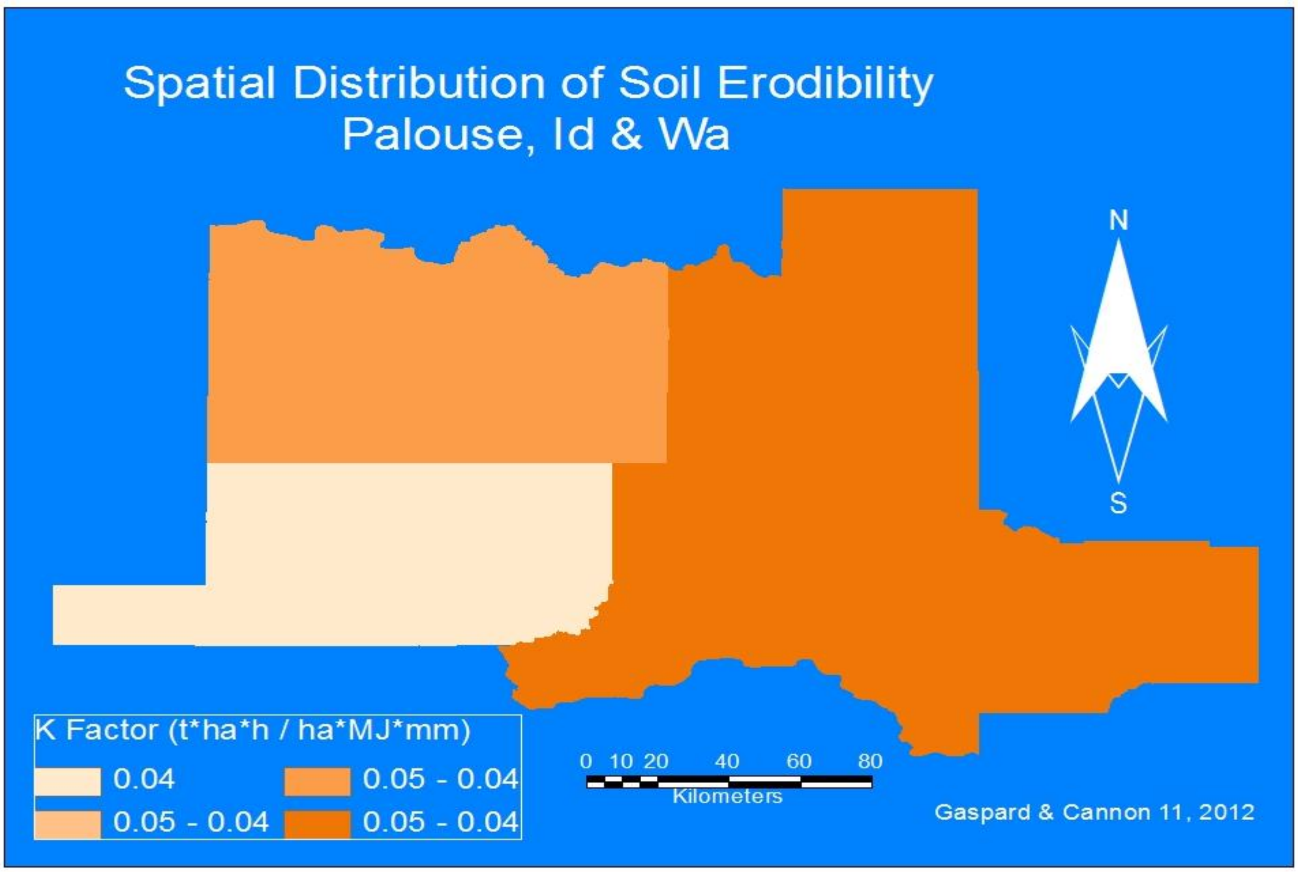
In addition to length, steepness is the second slope factor that intervenes in the universal soil loss equation. Like the length layer, the steep layer was determined using *Map Algebra* and the slope through this equation: $S = \frac{\left[0.43 + 0.30Z + 0.043Z^{2}\right]}{6.613}$ where Z is the slope in percent and S the steep factor which is a dimensionless value and which fluctuates between 0.06 and 9990.91 (Map 6).



Map6. *The map displays the spatial distribution of the slope steepness across the study are**a.***

Erodibility Factor or K factor

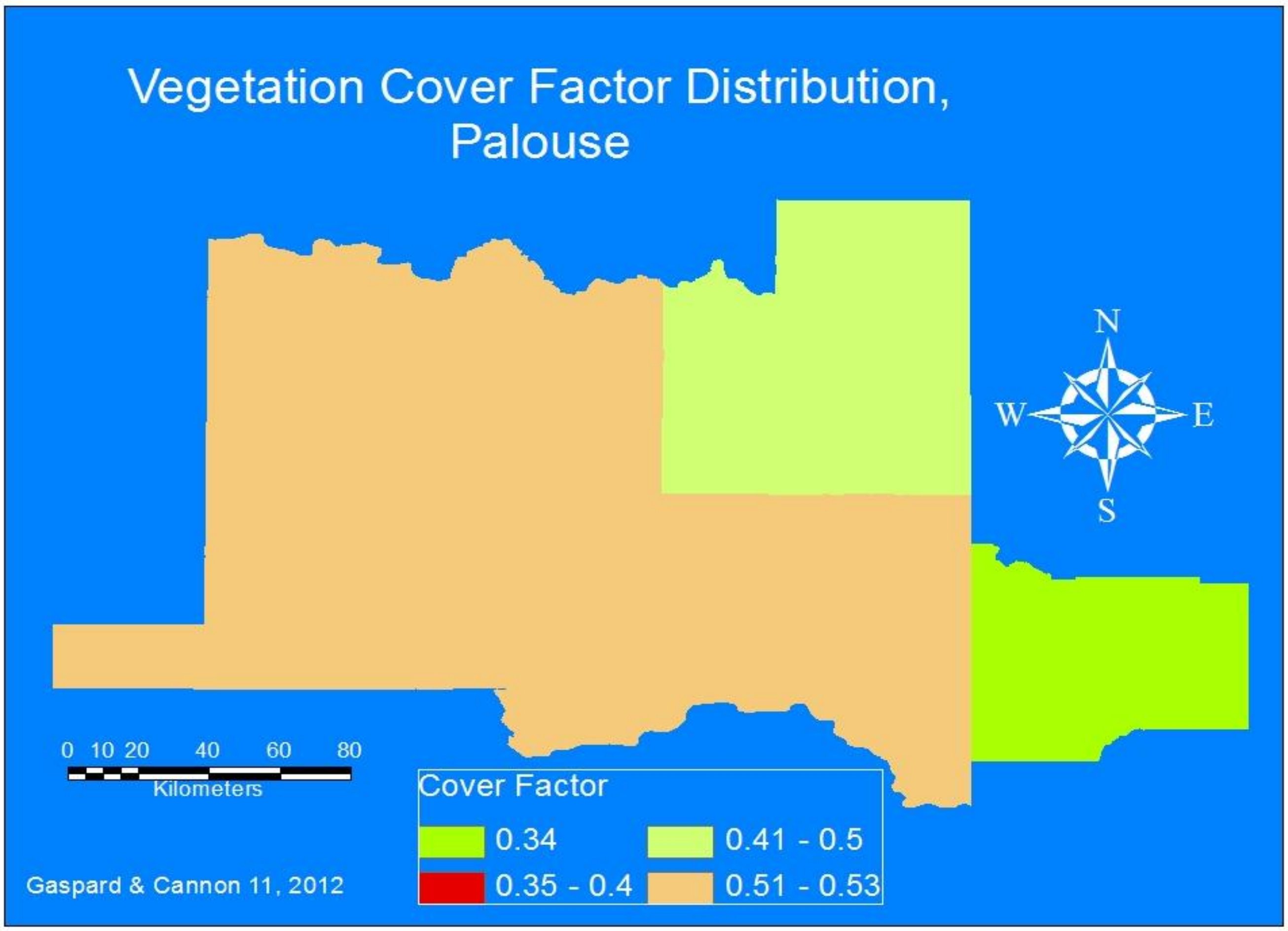
The susceptibility of the soil to be eroded defines the soil erodibility factor or K factor. The value of 0.32 is given for the Palouse region (Ward & Trimble, 1995) in U.S. units. The value was inserted as a field into the shapefile attribute table of for area. Then they are converted into international metric system (SI: $\frac{metricton * hectare * hour}{hectare * magajoule * millmeter}$) by multiplying by 0.1317. Then, the field was converted into raster using *Feature to Raster* tool. The final layer contains K values for the different counties with the highest values attributed to Latah and Spokane counties where there are some thin forest formations.



Map7. *This map shows the K factor for different counties forming the Palouse region.*

Vegetation Cover Factor

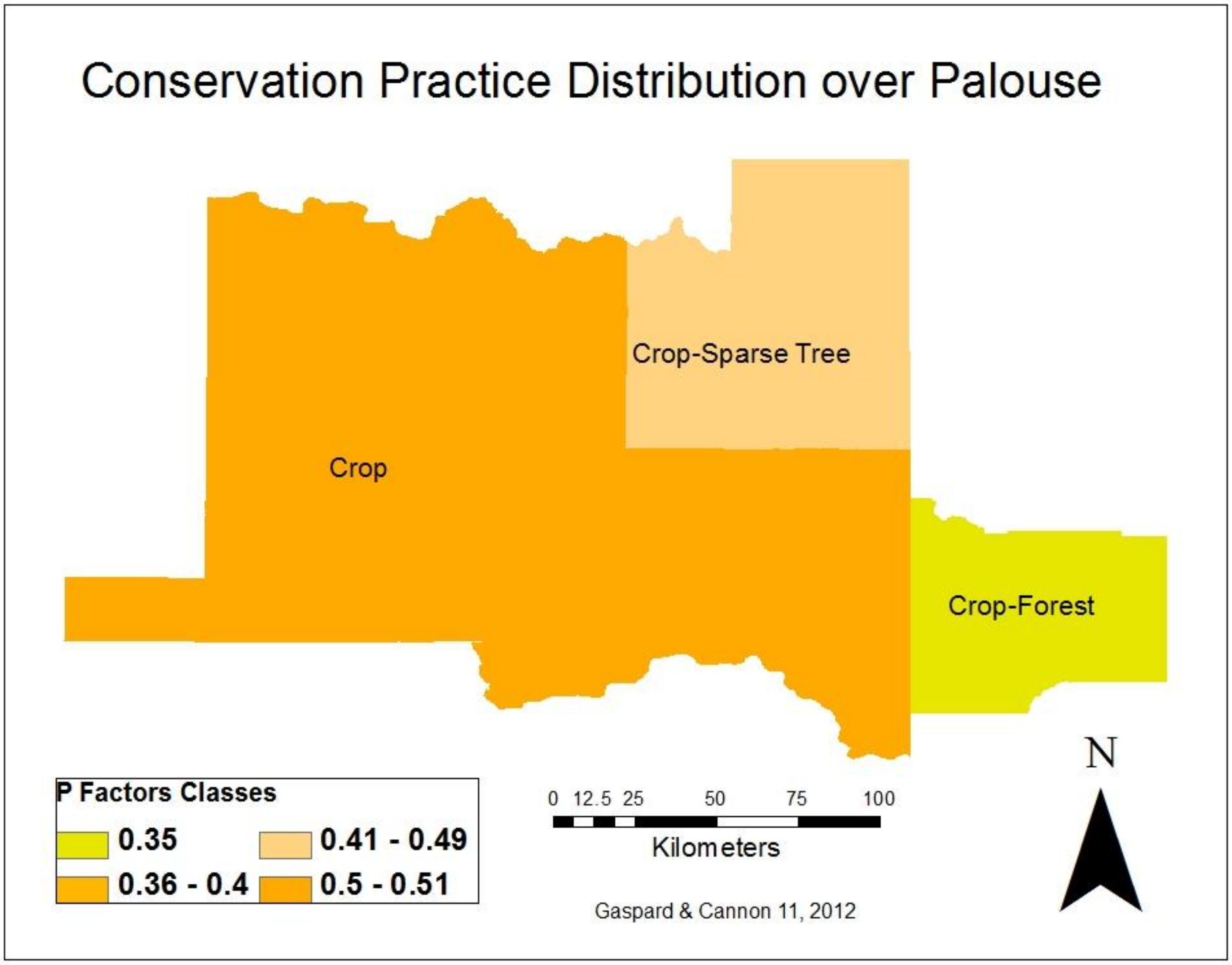
The vegetation cover factor or C factor refers to the type of land cover encountered on the area. The Palouse area is practically covered by crop farming with some forest in Spokane and Latah counties therefore values around 0.5 were assigned to the area where crops are dominant and 0.30 to 0.40 to zones where some remaining forests still exist. At that point, the field is converted into the raster model under the *Feature to Raster* tool (see the result presented in Map8). The C factor has no dimension and will contribute as a layer to determination of the total soil loss once combined to the other factors.



Map8 *providing the cover factor the area of interest*.

Conservation Practice Factor

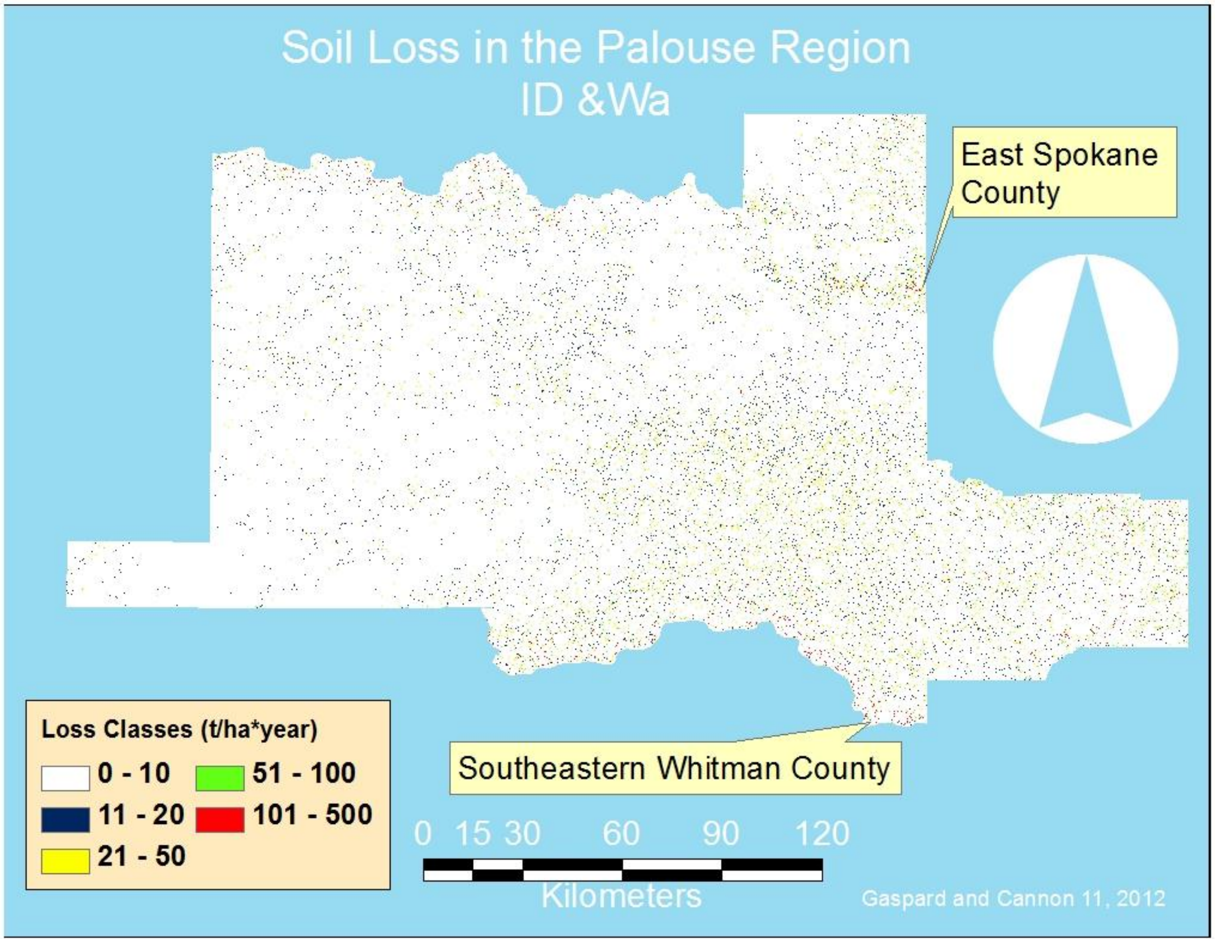
The conservation Practice factor of P factor, like the C factor, is closely related to the type of land use as a protection practice. Normally, a value of 1 is given to P when there is no conservation practice and whenever field crops are grown (Ongsomwang & Thinley, 2009). In our case, the P factor was assigned values around 0.5 because the crops are cultivated along contours lines and that there is presence of some forests. The value values also account for the different slopes.



Map9. *The map presents the P factor for the entire Palouse region.*

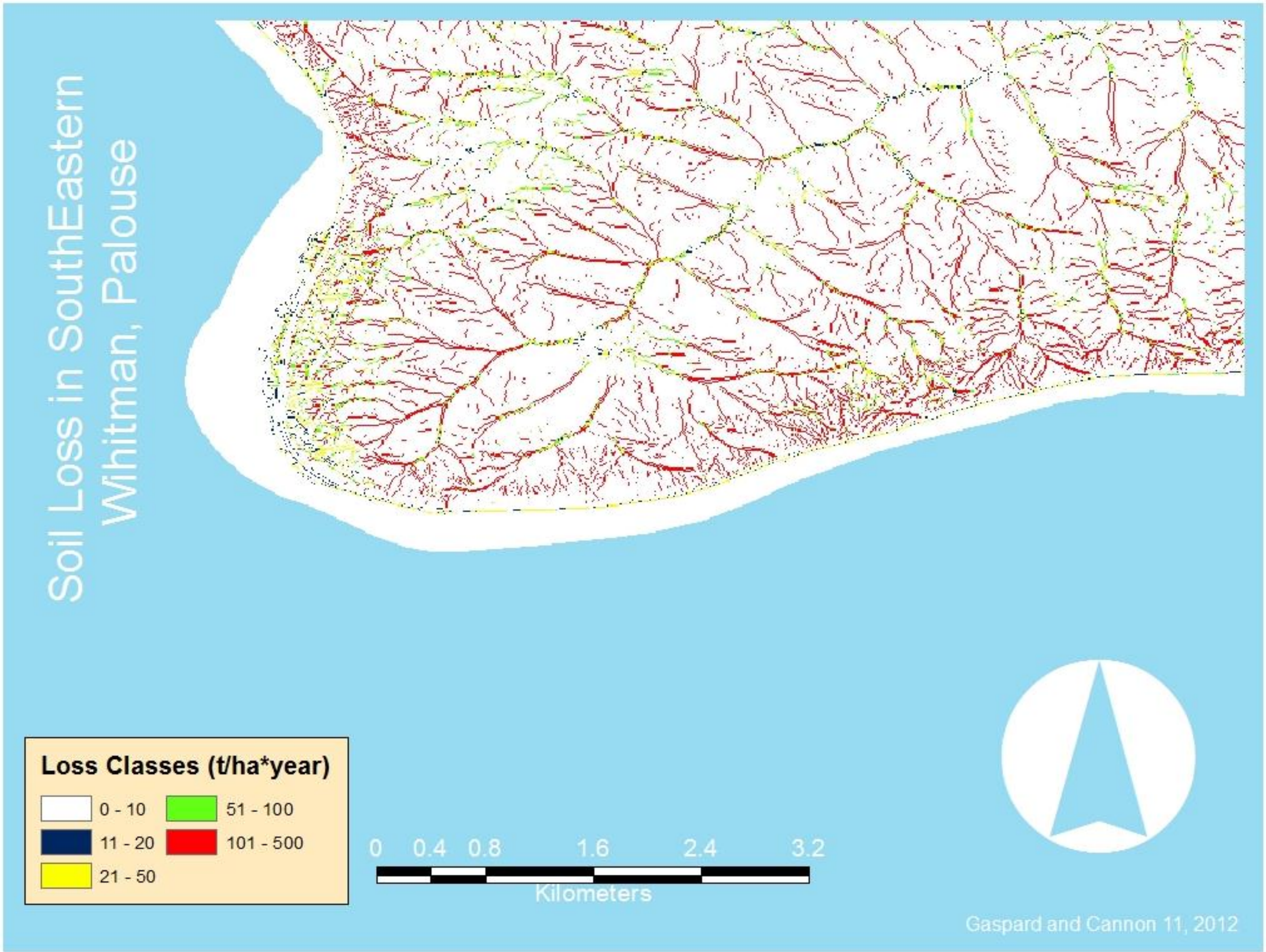
RESULTS AND DISCUSSION

Finally, all the factor layers, being in raster format, were overlaid to produce the soil map that contains the classes of losses. In fact, the erosion loss is categorized into five classes. These are 0-10, 11-20, 21-50, 51-100 and 101-500 which are expressed in tons per hectare times year (Map 10). The findings suggest reveals a high variation in the distribution of loss, from zero to over five hundred tons. Based on Map10, one may assume that the all the losses are uniformly distributed and that they vary inside the 0-10 class. However, looking closely, the results indicate that soil losses are severe in the Southeastern Whitman County (Map11) and East Spokane, North Latah and Northwestern of Palouse. Effectively, It has been proven that the losses are consistent with the all the factors and mapped.

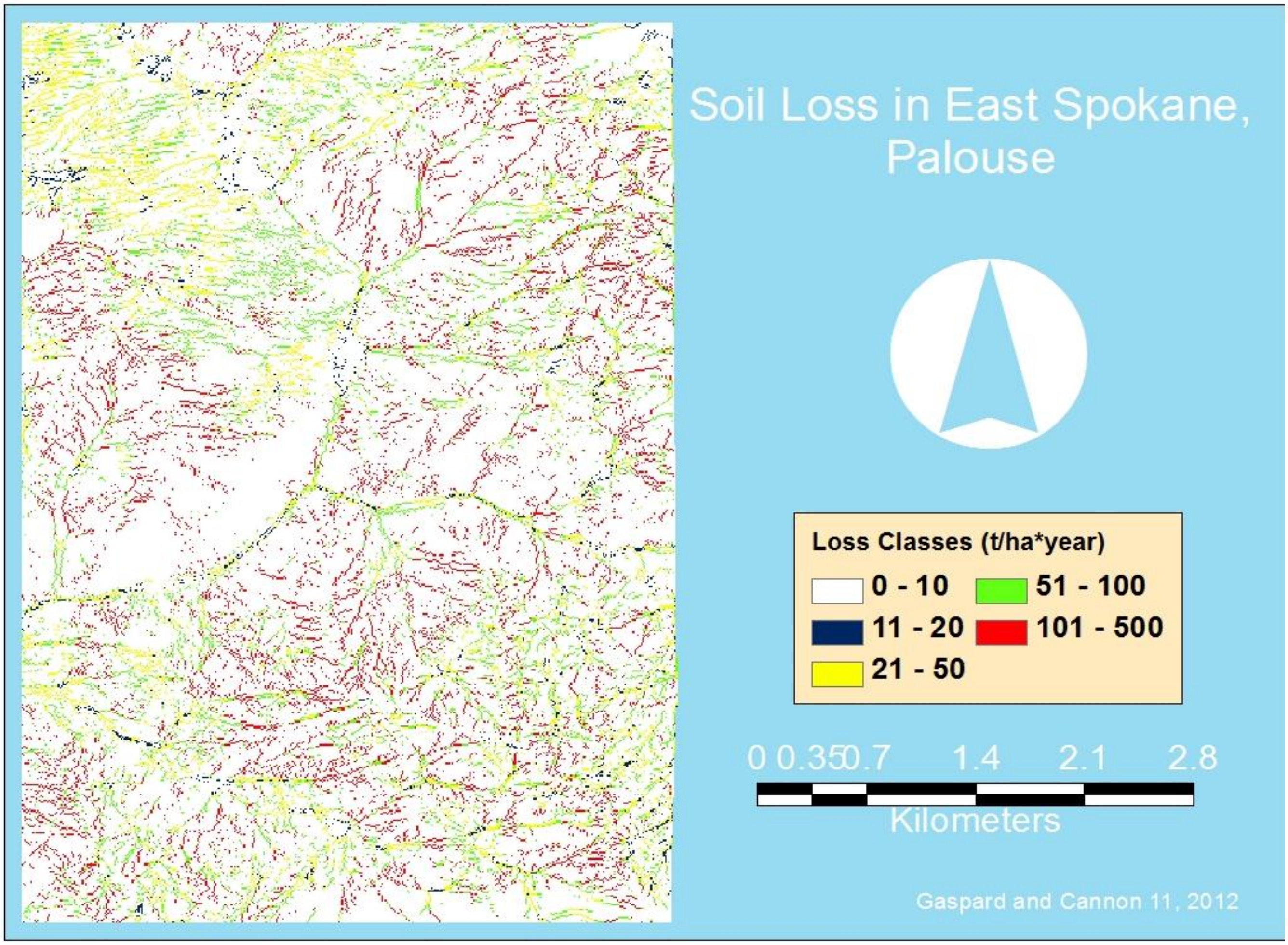


Map10. *This map shows the quantification of soil erosion loss in Palouse*

The results reinforce the robustness of the Universal Soil Loss Equation where both natural factors (rainfall erosivity, relief, soil erodibility, and vegetation cover in part) as well as human factors (cultivation and conservation practices) are accounted for. As a matter of fact, Palouse is naturally exposed to soil erosion but the intensive crop farming on such a vulnerable land worsens the harm. Despite the fact that the farming practices are taking place along contour line which practice is supposed to reduce the erosion rate, it remains obvious and true that the losses are still way beyond all expectancies.



Map11. *This map shows to insights about soil loss severity in Southeastern of Whitman County, Palouse.*



Map12. *This map shows more details about soil loss gravity in Eastern Spokane, Palouse.*

CONCLUSION

In summary, it has been confirmed that soil degradation continues climb over the Palouse region. In spite of the fact that the area is naturally exposed to erosion, considering its topography and geologic formation, ongoing inadequate agricultural practices are under way there. The results have shown that significant losses, one hundred on to five hundred metric tons, occur in the highest points of the Palouse region. That leaves us to the conclusion that human factors, as well, play a key role in the lowering of soil thickness in the location. Feeding the population is a need, so is protecting the environment that supports and provide the food. There is no question that actual practices on contour lines help, the necessity to find better compromises between feeding and protecting are a sine qua non. Still far from ideal, agroforestry practices prove to be an efficient common ground inside the eternal farming and forestry conflict.

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http://cloud.insideidaho.org/webMaps/flash/tiledownload/index.html?collection=elevation&layerName=1999_30m_Idaho&footprint=true

http://www.idwr.idaho.gov/GeographicInfo/gisdata/gis_data.htm

http://mepas.pnnl.gov/mepas/formulations/source_term/5_0/5_33/5_33.html

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http://fortress.wa.gov/dnr/app1/dataweb/dmmatrix.html

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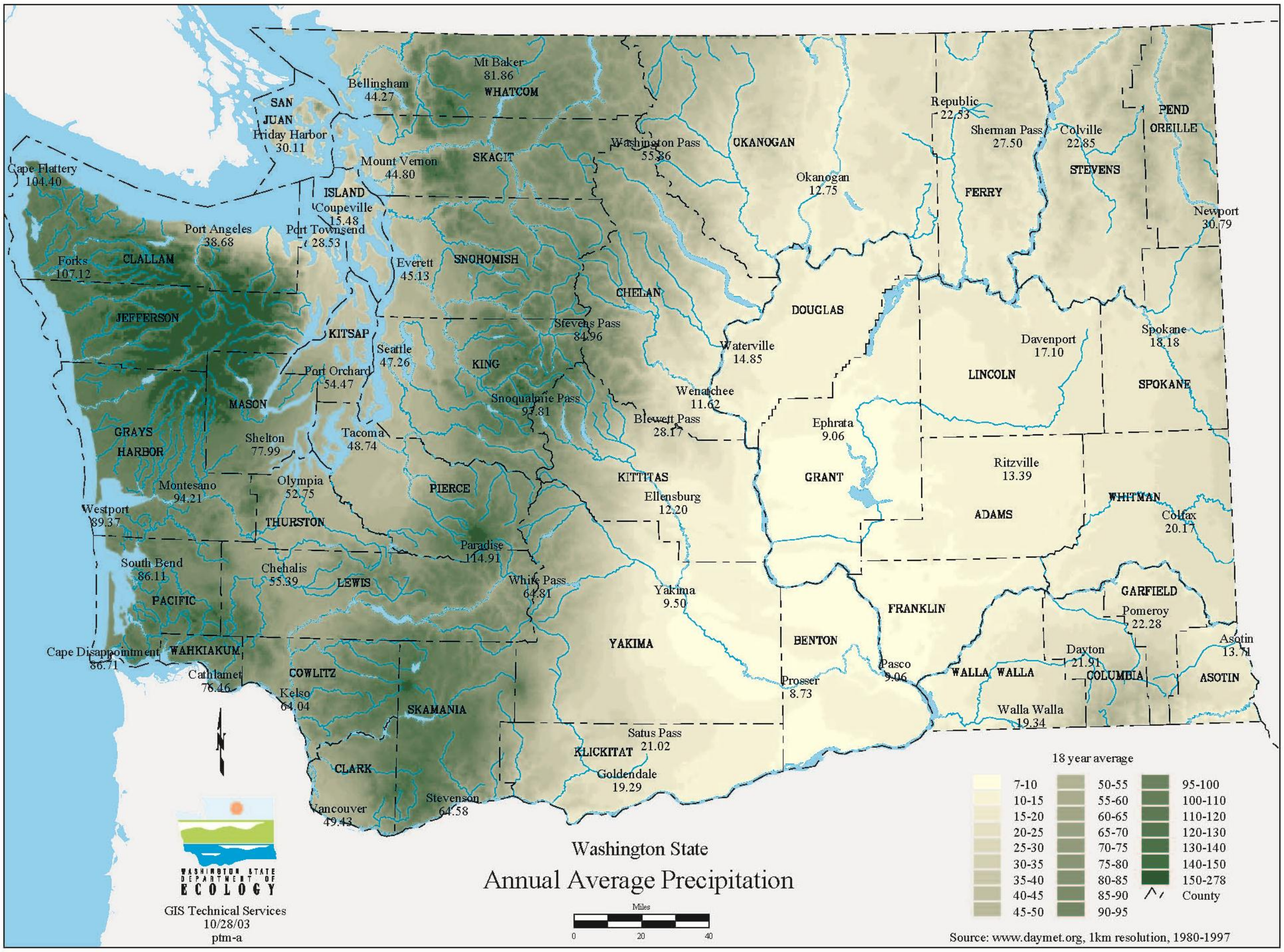
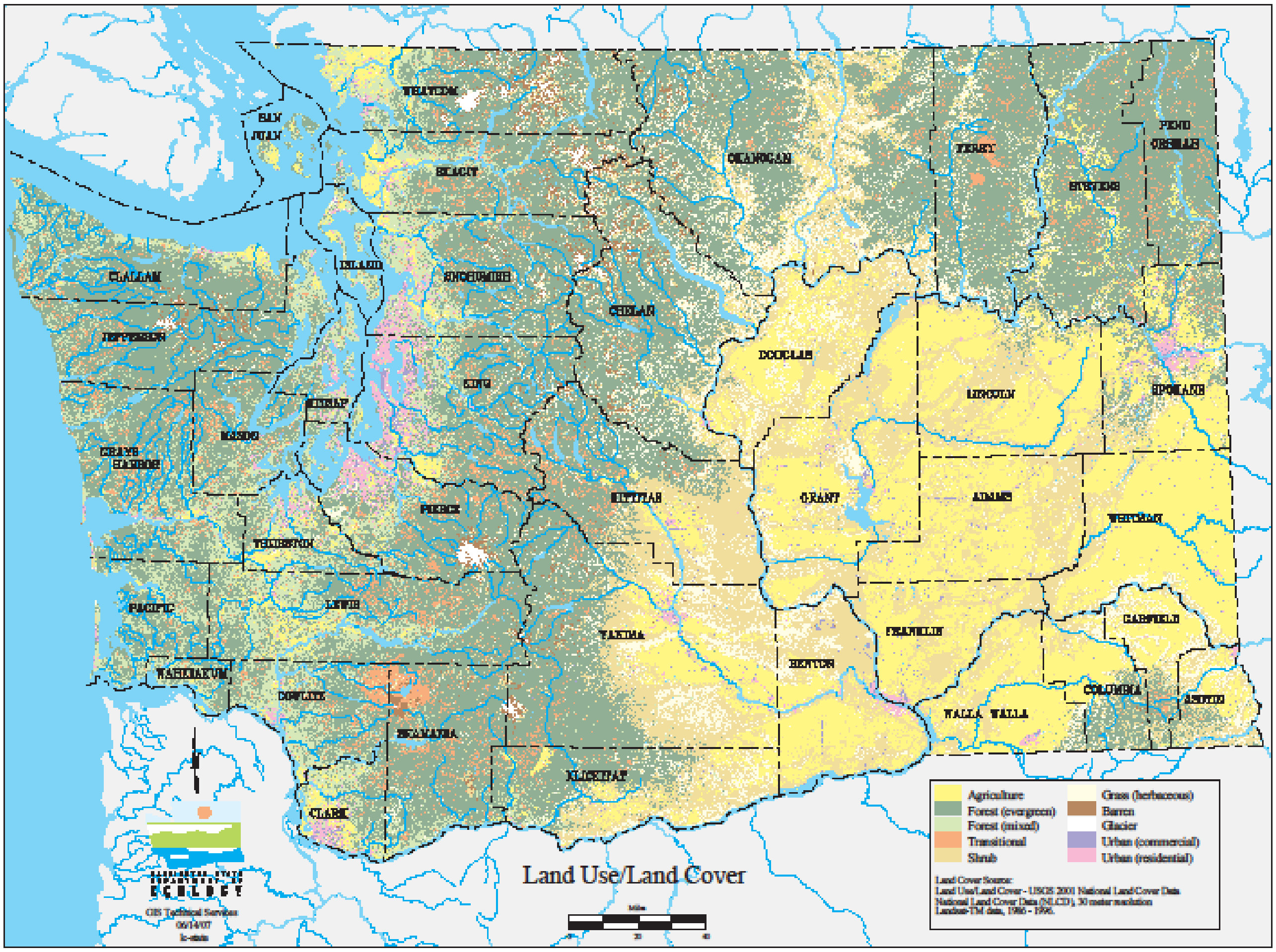
Latitude	Z factor (in meters)	Z factor (in feet)
0	0.00000898	0.00000273
10	0.00000912	0.00000278
20	0.00000956	0.00000291
30	0.00001036	0.00000316
40	0.00001171	0.00000357
50	0.00001395	0.00000425
60	0.00001792	0.00000546
70	0.00002619	0.00000798
80	0.00005156	0.00001571

Charlie Frye, Esri Chief Cartographer


Washington State
Annual Average Precipitation
18 year average
7-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-95
95-100
100-110
110-120
120-130
130-140
140-150
150-278
County
Miles
0
20
40
Source: www.daymet.org, 1km resolution, 1980-1997
WASHINGTON STATE DEPARTMENT OF ECOLOGY
GIS Technical Services
10/28/03
ptm-a
Bellingham 44.27
Mt Baker 81.86
WHATCOM
SAN JUAN
Friday Harbor 30.11
Cape Flattery 104.40
Mount Vernon 44.80
SKAGIT
ISLAND
Coupeville 15.48
Port Angeles 38.68
Port Townsend 28.53
Forks 107.12
CLALLAM
Everett 45.13
SNOHOMISH
JEFFERSON
KITSAP
Seattle 47.26
Port Orchard 54.47
KING
MASON
GRAYS HARBOR
Shelton 77.99
Tacoma 48.74
Snoqualmie Pass 93.81
Montesano 94.21
Olympia 52.75
PIERCE
Westport 89.37
THURSTON
Paradise 114.91
South Bend 86.11
Chehalis 55.39
LEWIS
White Pass 64.81
PACIFIC
Cape Disappointment 86.71
WAHKIAKUM
Cathlamet 76.46
COWLITZ
Kelso 64.04
SKAMANIA
CLARK
Vancouver 49.43
Stevenson 64.58
Washington Pass 55.36
OKANOGAN
Okanogan 12.75
CHELAN
Stevens Pass 84.96
DOUGLAS
Waterville 14.85
Wenatchee 11.62
Blewett Pass 28.17
Ephrata 9.06
GRANT
KITTITAS
Ellensburg 12.20
Yakima 9.50
YAKIMA
BENTON
Prosser 8.73
KLICKITAT
Satus Pass 21.02
Goldendale 19.29
Republic 22.53
Sherman Pass 27.50
Colville 22.85
PEND OREILLE
STEVENS
FERRY
Newport 30.79
Davenport 17.10
LINCOLN
Spokane 18.18
SPOKANE
Ritzville 13.39
ADAMS
WHITMAN
Colfax 20.17
FRANKLIN
GARFIELD
Pomeroy 22.28
Pasco 9.06
WALLA WALLA
Dayton 21.91
COLUMBIA
Asotin 13.71
ASOTIN
Walla Walla 19.34


Land Use/Land Cover
Agriculture
Forest (evergreen)
Forest (mixed)
Transitional
Shrub
Grass (herbaceous)
Barren
Glacier
Urban (commercial)
Urban (residential)
Land Cover Source:
Land Use/Land Cover - USGS 2001 National Land Cover Data
National Land Cover Data (NLCD), 30 meter resolution
Landsat-TM data, 1986 - 1996.
WHATCOM
SAN JUAN
SKAGIT
OKANOGAN
FERRY
STEVENS
PEND OREILLE
CLALLAM
ISLAND
SNOHOMISH
CHELAN
JEFFERSON
DOUGLAS
KING
LINCOLN
SPOKANE
KITSAP
MASON
GRAYS HARBOR
KITTITAS
GRANT
ADAMS
WHITMAN
PIERCE
THURSTON
PACIFIC
LEWIS
YAKIMA
BENTON
FRANKLIN
GARFIELD
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GIS Technical Services
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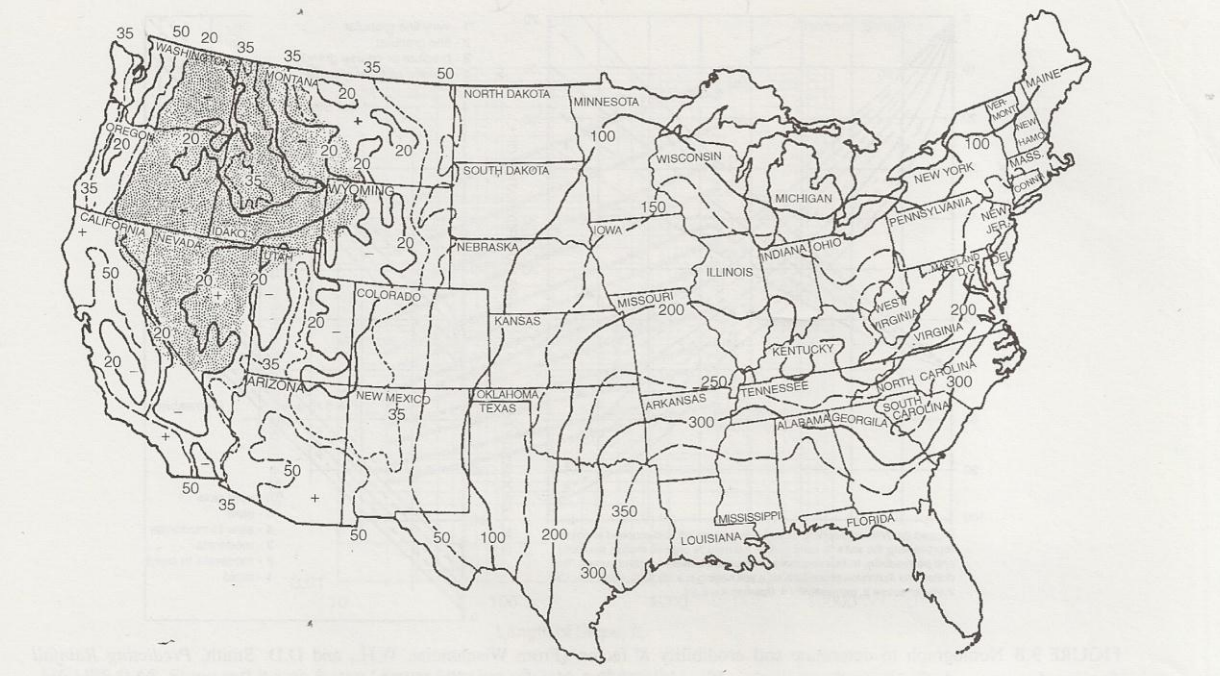

FIGURE 9.6 Rainfall and runoff erosivity index *R* distribution in the U.S. (From Wischmeier, W.H., and D.D. Smith, *Predicting Rainfall Erosion Losses — A Guide to Conservation Planning*. USDA Handbook 537, USDA–Science and Education Administration, Washington, DC, 1978. With permission.)

TABLE 9.1
Cover Management *C* Factors for Permanent Pasture, Rangeland, and Idle Land[a]

Vegetal Canopy: Type and Height of Raised Canopy[b]	Canopy Cover[c]	Type[d]	Cover that Contacts the Surface: Percentage Ground Cover 0	20	40	60	80	95–100
No appreciable canopy		G	0.45	0.20	0.10	0.042	0.013	0.003
		W	0.45	0.24	0.15	0.090	0.043	0.011
Canopy of tall weeds or short brush	25	G	0.36	0.17	0.09	0.038	0.012	0.003
(1.5 ft fall height)[b]		W	0.36	0.20	0.13	0.082	0.041	0.011
	50	G	0.26	0.13	0.07	0.035	0.012	0.003
		W	0.26	0.16	0.11	0.075	0.039	0.011
	75	G	0.17	0.10	0.06	0.031	0.011	0.003
		W	0.17	0.12	0.09	0.067	0.038	0.011
Appreciable brush or bushes	25	G	0.40	0.18	0.09	0.040	0.013	0.003
(6 ft fall height)[b]		W	0.40	0.22	0.14	0.085	0.042	0.011
	50	G	0.34	0.16	0.85	0.038	0.012	0.003
		W	0.34	0.19	0.13	0.081	0.041	0.011
	75	G	0.28	0.14	0.08	0.036	0.012	0.003
		W	0.28	0.17	0.12	0.077	0.041	0.011
Trees, but no appreciable low brush	25	G	0.42	0.19	0.10	0.041	0.013	0.003
(12 ft. fall height)[b]		W	0.42	0.23	0.14	0.087	0.042	0.011
	50	G	0.39	0.18	0.09	0.040	0.013	0.003
		W	0.39	0.21	0.14	0.085	0.042	0.011
	75	G	0.36	0.17	0.09	0.039	0.012	0.003
		W	0.36	0.20	0.13	0.083	0.041	0.011

[a] All values shown assume (1) random distribution of mulch or vegetation and (2) mulch of appreciable depth where it exists.
[b] Average fall height of waterdrops from canopy to soil surface.
[c] Percentage of total area surface that would be hidden from view by canopy in a vertical projection.
[d] G = cover at surface is grass, grasslike plants, decaying compacted duff, or litter at least 2 in. deep; W = cover at surface is mostly broadleaf herbaceous plants (as weeds) with little lateral root network near the surface or undecayed residue.

Source: Cooperative Extension Service and Ohio State University, *Ohio Erosion Control and Sediment Pollution Abatement Guide*, Columbus, OH, 1979.