Soil Erosion Analysis of the Monroe County's watersheds in Indiana

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Introduction

- ❑ Monroe County is a county located in the U.S. state of Indiana
- ❑ Monroe has a total area of 411.32 square miles (1,065.3 km^2), of which 95.91% is land and 4.09% is water

Fig. 1. Location of Monroe County in Indiana
Source: www.co.monroe.in.us

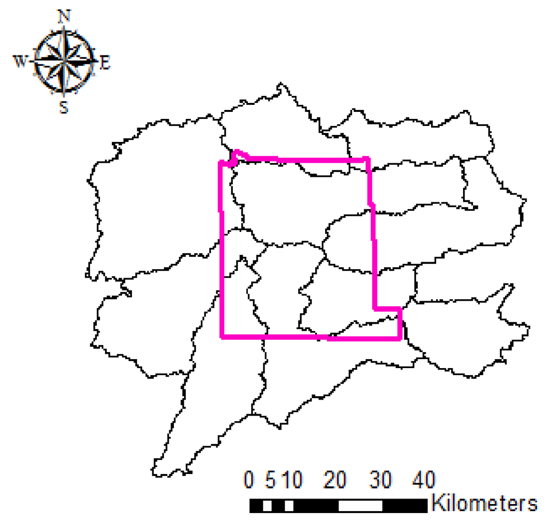

Fig. 2. Watersheds located in the Monroe County
Data source: Geospatial Data Gateway
Map developed by Danielli Moura

AREAACRES	AREASQKM	STATES	HUC10	NAME
59878	242,32	IN	0512020116	Indian Creek
106932	432,74	IN	0512020806	North Fork Salt Creek
172729	699,01	IN	0512020202	Fish Creek-White River
111032	449,33	IN	0512020203	Plummer Creek
65582	265,4	IN	0512020804	South Fork Salt Creek
66083	267,43	IN	0512020117	Butler Creek-White River
57393	232,26	IN	0512020807	Lake Monroe-Salt Creek
130349	527,5	IN	0512020808	Salt Creek
123349	499,18	IN	0512020201	Beanblossom Creek
110342	446,54	IN	0512020809	Indian Creek

Fig. 3. Attribute table of the watersheds

- ❑ Soil erosion is a process of physical degradation of the landscape over time
- ❑ Water and wind are the main agents responsible for soil erosion

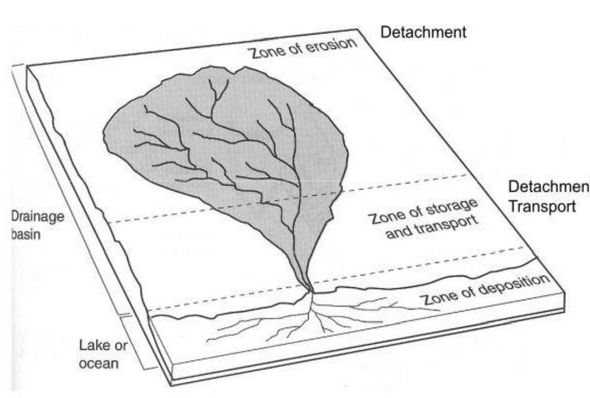

Fig. 4. Soil erosion sequence
Source: Iowa Stormwater Runoff Control, n.d

- ❑ A combination of the Revised Universal Soil Loss Equation (RUSLE) with the computer capabilities of a GIS was done in order to calculate an average annual soil loss (also called factor A) throughout watersheds in the Monroe County
- ❑ The RUSLE equation is an accepted method worldwide for soil erosion prediction

A (tons/ha/year) = R * K * LS * C * P

A – Annual soil loss, in tons ha^{-1} $year^{-1}$

R – Rainfall erosivity factor, an erosion index for the given storm period in MJ.mm/(ha.hr.year)

K – Soil erodibility factor, the erosion rate for a specific soil in continuous fallow condition on a 9% slope having a length of 22.1m in ton.ha.hr/(MJ.mm.ha)

LS – Topographic factor which represent the slope length and slope steepness (dimensionless).

C – Cover management factor, which represents the protective coverage of canopy and organic material in direct contact with the ground (dimensionless).

P – Support practice factor which represents the soil conservation operations or other measures that control the erosion (dimensionless).

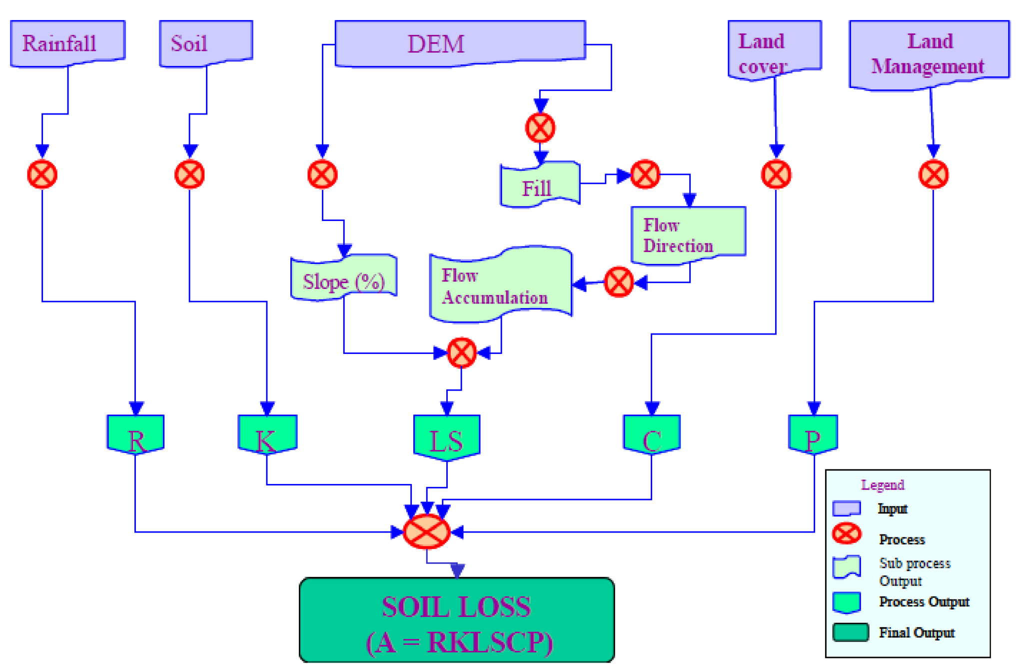

Fig. 5. Flow chart showing analysis of soil loss based on GIS application
Source: Bizuwerk et al. (2008)

Methodology

Rainfall erosivity factor (Factor R)

- ❑ Renard and Fremund (1994) developed a function to estimate the rainfall erosivity as a function of the mean annual precipitation (mm) in the Continental U.S.:

$R = 0.04830 * P^{1.51}$ Unit: MJ.mm/(ha.hr.year)

- ❑ Data source: 1981-2010 Annual Average Precipitation from USDA/NRCS - National Geospatial Center of Excellence (UTM NAD83 16N, meters).
- ❑ The factor R was calculated and added to the attribute table of the precipitation polygons. After that, it was used the tool "Polygon to Raster" to generate the Factor R.

FID	Shape *	PREC_mm	factorR
0	Polygon	914,4	1429,759
1	Polygon	939,8	1490,152
2	Polygon	965,2	1551,384
3	Polygon	990,6	1613,443
4	Polygon	1016	1676,319
5	Polygon	1041,4	1740,002
6	Polygon	1066,8	1804,482
7	Polygon	1092,2	1869,749
8	Polygon	1117,6	1935,796
9	Polygon	1143	2002,613
10	Polygon	1168,4	2070,191
11	Polygon	1193,8	2138,522
12	Polygon	1219,2	2207,6

Fig. 6. Precipitation data and factor R

Soil erodibility factor (Factor K)

- ❑ K factor is soil erodibility factor which represents both susceptibility of soil to erosion and the rate of runoff, as measured under the standard unit plot condition. Unit: t*ha/MJ*mm
- ❑ Soils high in clay ➡ low K values(0.05 to 0.15) ➡ resistant to detachment.
- ❑ Coarse textured soils (e.g. sandy soils) ➡ low K values (0.05 to 0.2) ➡ because of low runoff even though these soils are easily detached.
- ❑ Medium textured soils (e.g. silt loam soils) ➡ moderate K values(0.25 to 0.4) ➡ because they are moderately susceptible to detachment and they produce moderate runoff.
- ❑ Soils having a high silt content ➡ high k values (> 0.4) ➡ most erodible of all soils and easily detached; tend to crust and produce high rates of runoff.

Soil unit symbol	sand % topsoil	silt % topsoil	clay % topsoil	OC % topsoil	OM %	K factor
LC	64,3	12,2	23,5	0,63	1,0836	0,2
LO	76	9,9	14,1	0,41	0,7052	0,05
AO	53,6	15,8	30,6	2,25	3,87	0,2

Fig. 7. Soil percentages and k factor values
Source: DSMW(soil percentages)

Textural Class	Spanish Texture Class	Soil composition			Mean K (based on % organic material)		
		Sand	Silt	Clay	unknown	< 2%	≥ 2 %
Clay	Arcilloso	0-45	0-40	40-100	0.22	0.24	0.21
Sandy Clay	Arcilloso arenoso	45-65	0-20	35-55	0.2	0.2	0.2
Silty Clay	Arcilloso limoso	0-20	40-60	40-60	0.26	0.27	0.26
Sand	Arenoso	86-100	0-14	0-10	0.02	0.03	0.01
Sandy Loam	Franco arenoso	50-70	0-50	0-20	0.13	0.14	0.12
Clay Loam	Franco - arcilloso	20-45	15-52	27-40	0.3	0.33	0.28
Loam	Franco	23-52	28-50	7-27	0.3	0.34	0.26
Loamy Sand	Franco arenoso	70-86	0-30	0-15	0.04	0.05	0.04
Sandy Clay Loam	Franco arenso arcilloso	45-80	0-28	20-35	0.2	0.2	0.2
Silty Clay Loam	Franco limoso arcilloso	0-20	40-73	27-40	0.32	0.35	0.3
Silt	Limoso	0-20	88-100	0-12	0.38	0.41	0.37
Silty Loam	Franco limoso	20-50	74-88	0-27	0.38	0.41	0.37

Fig. 8. Estimating soil erodibility (factor K) based on soil texture and organic material content
Source: Roose (1996)

Topographic factor (Factor LS)

- ❑ The effect of topography on soil erosion is accounted for by the LS factor in RUSLE.

The equation is shown below:

$LS = (X/22.1)^m * (0.065+0.045*S+0.0065*S^2)$

Where:

X – slope length (m)

S – slope gradient (%)

The values of X and S can be derived from Digital Elevation Model (DEM).

To calculate the X value, Flow Accumulation was derived from the DEM after conducting Fill and Flow Direction processes in ArcGIS.

X=Flow accumulation * Cell size

m value	Slope (%)
0.5	>5
0.4	3-5
0.3	1-3
0.2	<1

Fig. 9. m value for LS factor
Source: Ministry of Natural Resources and Environment of Malaysia, 2010)

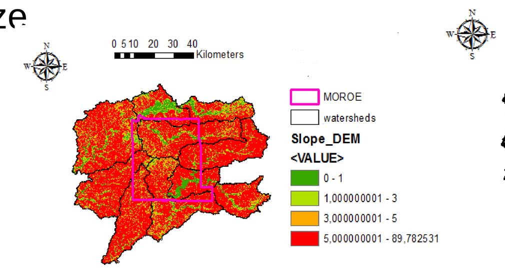

Fig. 10. Slope (%)

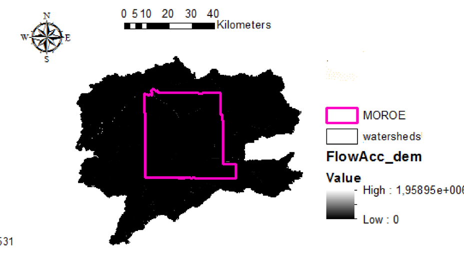

Fig. 11. Flow Accumulation

Cover management factor (Factor C)

- ❑ The Cover Management Factor (C) represents the effect of vegetation and management on the soil erosion rates.
- ❑ Data needed: Cropland Data Layer obtained from USDA/NRCS - National Geospatial Center of Excellence

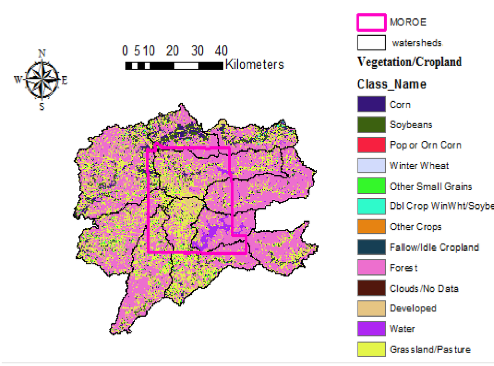

Fig. 12. Cropland Data Layer

OBJECTID *	Value	Count	Class_Name	factor_C
2	1	198744	Corn	0,35
3	5	178178	Soybeans	0,35
4	13	178	Pop or Orn Corn	0,7
5	24	584	Winter Wheat	0,25
6	25	96437	Other Small Grains	0,5
7	26	9516	Dbl Crop WinWht/Soybeans	0,35
8	44	1	Other Crops	0,2
10	61	29024	Fallow/Idle Cropland	1
11	63	255430	Forest	0,001
12	81	537	Clouds/No Data	1
13	82	65656	Developed	0,1
14	83	127276	Water	0,01
16	176	124922	Grassland/Pasture	0,1

Fig. 13. Attribute table – Factor C

Practice	Average annual C-factor
Bare soil	1.00
Forest or dense shrub, high mulch crops	0.001
Savanna or prairie grass in good condition	0.01
Overgrazed savanna or prairie grass	0.10
Maize, sorghum or millet; high productivity; conventional tillage	0.20–0.55
Maize, sorghum or millet; low productivity; conventional tillage	0.50–0.90
Maize, sorghum or millet; high productivity; chisel ploughing into residue	0.12–0.20
Maize, sorghum or millet; low productivity; chisel ploughing into residue	0.30–0.45
Maize, sorghum or millet; high productivity; no or minimum tillage	0.02–0.10
Cotton	0.40–0.70
Meadow grass	0.01–0.025
Soya beans	0.20–0.50
Wheat	0.10–0.40
Rice	0.10–0.20
Groundnuts	0.30–0.80
Palm trees, coffee, cocoa with cover crops	0.10–0.30
Pineapple on contour; residue removed	0.10–0.40
Pineapple on contour; with surface residue	0.01
Potatoes; rows downslope	0.20–0.50
Potatoes; rows across slope	0.10–0.40
Cowpeas	0.30–0.40
Strawberries; with weed cover	0.27
Pomegranate; with weed cover	0.08
Pomegranate; clean-weeded	0.56
Ethiopian tef	0.25
Sugar cane	0.13–0.40
Yams	0.40–0.50
Pigeon peas	0.60–0.70
Mungbean	0.04
Chilli	0.33
Coffee: after first harvest	0.05
Plantains: after establishment	0.05–0.10
Papaya	0.21

Source: after Wischmeier and Smith (1978), Roose (1977), Singh et al. (1981), El-Swaify et al. (1982), Hurni (1987), Hashim and Wong (1988).

Fig. 14. C factor values for RUSLE

Support practice factor (Factor P)

- ❑ The values of P factor were estimate by using Dawen et al. table and then were added to the attribute table of the cropland layer
- ❑ The Support Practice factor (P) represents the impact of support practices on the soil erosion rates.
- ❑ In this study only considers P values due to types of land cover, using values suggested by Dawen et al. (2003)

	P factor
Build up	1.0
Farmland	0.5
Cropland	0.5
Paddy land	0.5
Forest	1.0
Grassland	1.0
Wetland	1.0
Bare land	1.0
Water	1.0

Fig. 15. Support practice factor (P factor) values
Source: Dawen et al. (2003)

OBJECTID *	Value	Count	Class_Name	Factor_P
2	1	198744	Corn	0,5
3	5	178178	Soybeans	0,5
4	13	178	Pop or Orn Corn	0,5
5	24	584	Winter Wheat	0,5
6	25	96437	Other Small Grains	0,5
7	26	9516	Dbl Crop WinWht/Soybeans	0,5
8	44	1	Other Crops	0,5
10	61	29024	Fallow/Idle Cropland	0,5
11	63	255430	Forest	1
12	81	537	Clouds/No Data	1
13	82	65656	Developed	1
14	83	127276	Water	1
16	176	124922	Grassland/Pasture	1

Fig. 16. Attribute table – Factor P

Results and Discussions

Rainfall erosivity factor (Factor R)

- ❑ R represents the potential of the rain in a particular area to produce erosion. According to the department of agronomy of Purdue University, In Indiana, it is lowest in the northeast and highest in the southwest

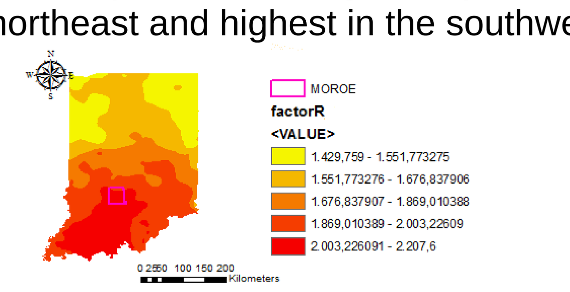

Fig. 17. Factor R in Indiana

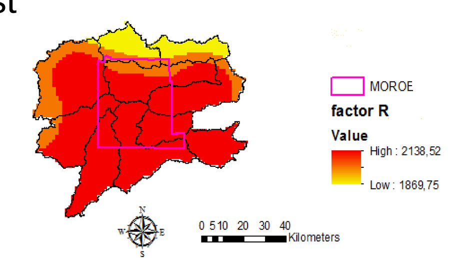

Fig. 18. Factor R in Monroe's watersheds

Soil erodibility factor (Factor K)

- ❑ Texture is the principal factor affecting K, but soil profile, organic matter and permeability also contribute.
- ❑ It varies from 70/100 for the most fragile soil and 1/100 for the most stable soil.
- ❑ Values of 0 – 0.6 are reasonable, while higher values should be given a critical look. For the case of Monroe County, k ranges from 0.05 to 0.20

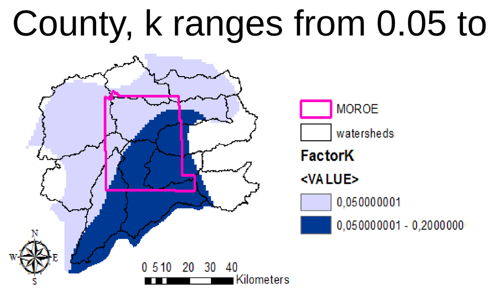

Fig. 19. Factor K in Monroe's watersheds

Cover management factor (Factor C) and Support Practice factor (Factor P)

- ❑ Factor C:

C =1 when the land has continuous bare fallow and have no coverage.

C < 1 when there is more coverage of a crop for the soil surface and less soil erosion.

- ❑ Factor P:

P =1 when the land is plowed on the slope directly – worst practice.

P<1 when the adopted conservation practice reduces soil erosion.

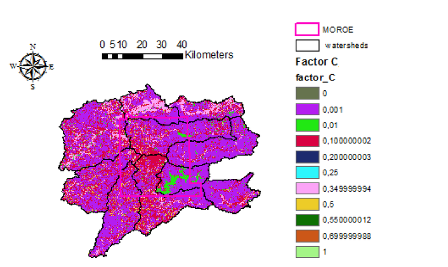

Fig. 20. Factor C in Monroe's watersheds

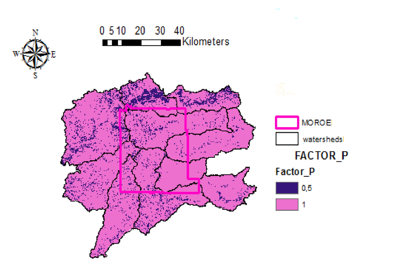

Fig. 21. Factor P in Monroe's watersheds

Topographic factor (Factor LS)

❑The equation:

$LS = (FlowAccumulation*cell\ size/22.1)^{0.5} * (0.065+0.045*Slope+0.0065*Slope^2)$

was used in the Raster Calculator.

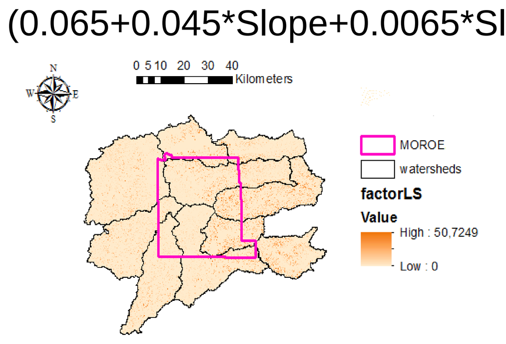

Fig. 22. Factor LS in Monroe's watersheds

Annual soil loss (Factor A)

The major part of Monroe has up to 2 tons/ha/year of soil loss in its watersheds. However, it also present spots of extremely high soil loss (i.e. values higher than 91 tons/ha/year).

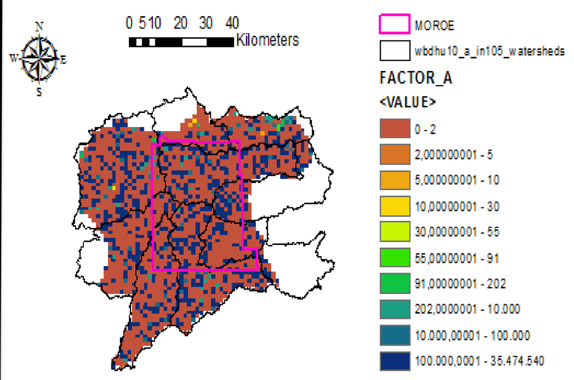

Fig. 22. Factor A in Monroe's watersheds

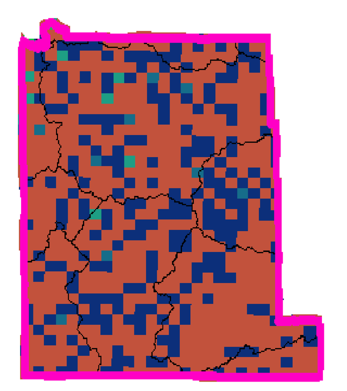

Fig. 23. Factor A in Monroe County

Soil erosion rate (ton/ha/year)	Erosion potential
0 – 5	Low
5 – 10	Moderate
10 – 30	High
30 – 55	Very high
55 - 91	Extreme
➢ 91	Extremely high

Fig. 24. Erosion Potential
Source: Ali and Hagos, 2016

Conclusions

- ❑ This study demonstrates that the RUSLE combined with GIS provides great advantage to analyze multi-layer of data spatially and estimates soil loss rate over areas
- ❑ The result of the analysis demonstrated that the soil loss rate in Monroe's watersheds ranges from 0 to 35,474,540.00 ton/ha/year
- ❑ The major part of Monroe County presents low erosion potential (up to 2 ton/ha/year, however there are spots of extremely high soil loss (i.e. values higher than 91 tons/ha/year)