Universal Soil Loss Equation (USLE)

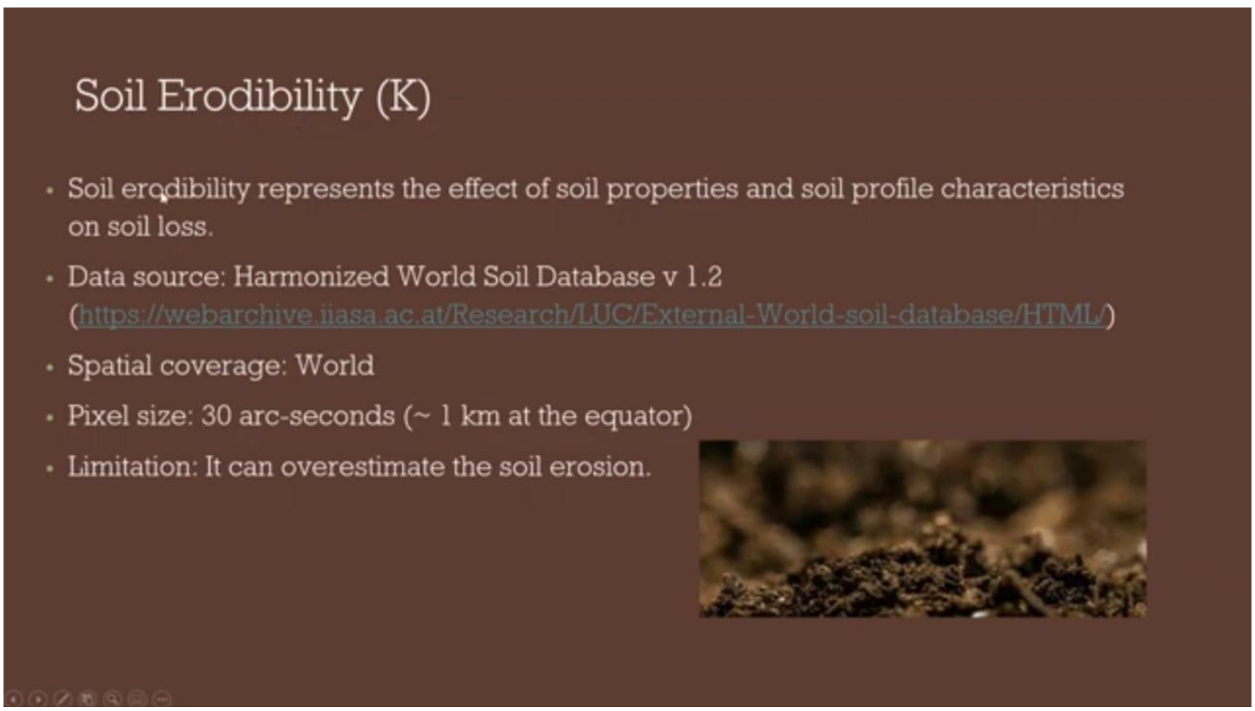
Introduction

The Universal Soil Loss Equation (USLE) is a widely used mathematical model that describes soil erosion processes.

$$\boldsymbol{A = R \times K \times LS \times C \times P} \left(\boldsymbol{metric}: \frac{\frac{\boldsymbol{tonnes}}{\boldsymbol{ha}}}{\boldsymbol{yr}} \right)$$

- ✓ R - rainfall Erosivity
- ✓ K - soil erodibility;
- ✓ L - slope length;
- ✓ S -slope steepness;
- ✓ C - cover and management;
- ✓ P - support practice.

This tutorial uses the K factor, derived from HWSD v1.2 database soil properties.



2. Data Acquisition

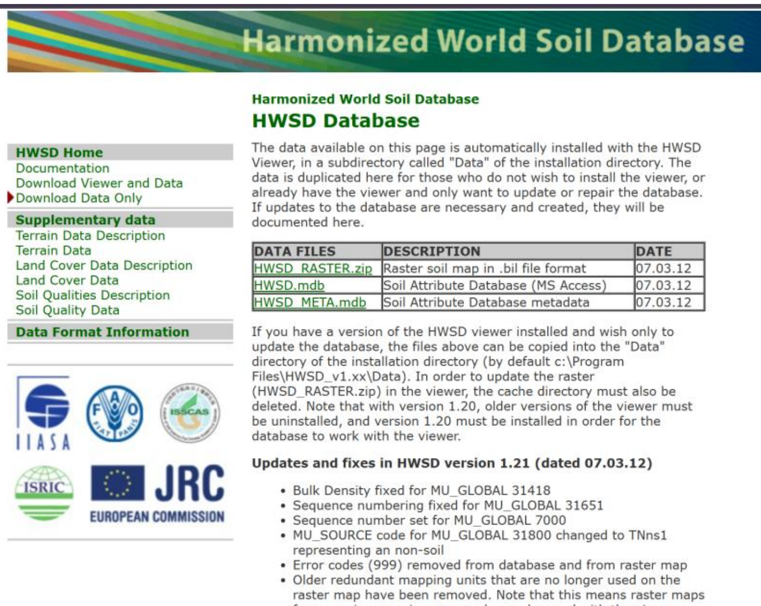
Step 1: Download HWSD Dataset

Go to: Harmonized World Soil Database v1.2

In the left sidebar, click on "Download data only"

Download:

- ✓ hwsd_raster.zip (holding raster file)
- ✓ hwsd.mdb (Microsoft Access metadata file)



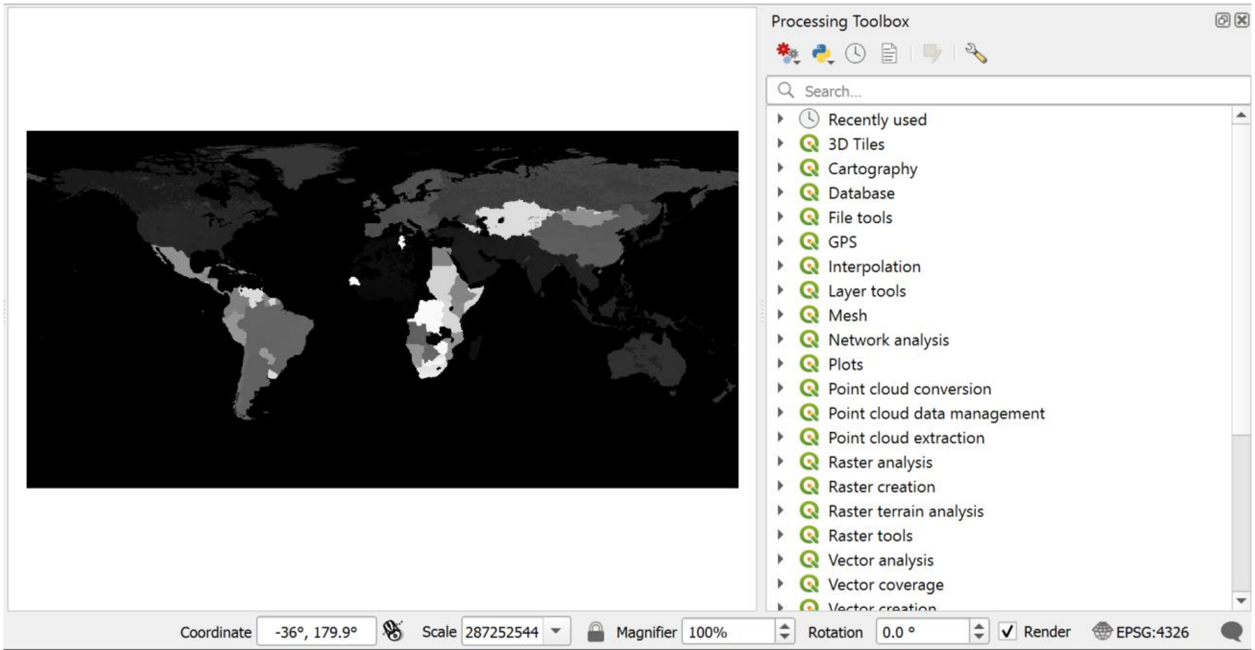
3. Load and Clip the Raster in QGIS

Step 2: Load Raster in QGIS

Extract hwsd_raster.zip

Open QGIS, $Layer \rightarrow Add\ Layer \rightarrow Add\ Raster\ Layer$

Load the raster file



Step 3: Clip Raster to Your Area of Interest (AOI)

Open Processing Toolbox

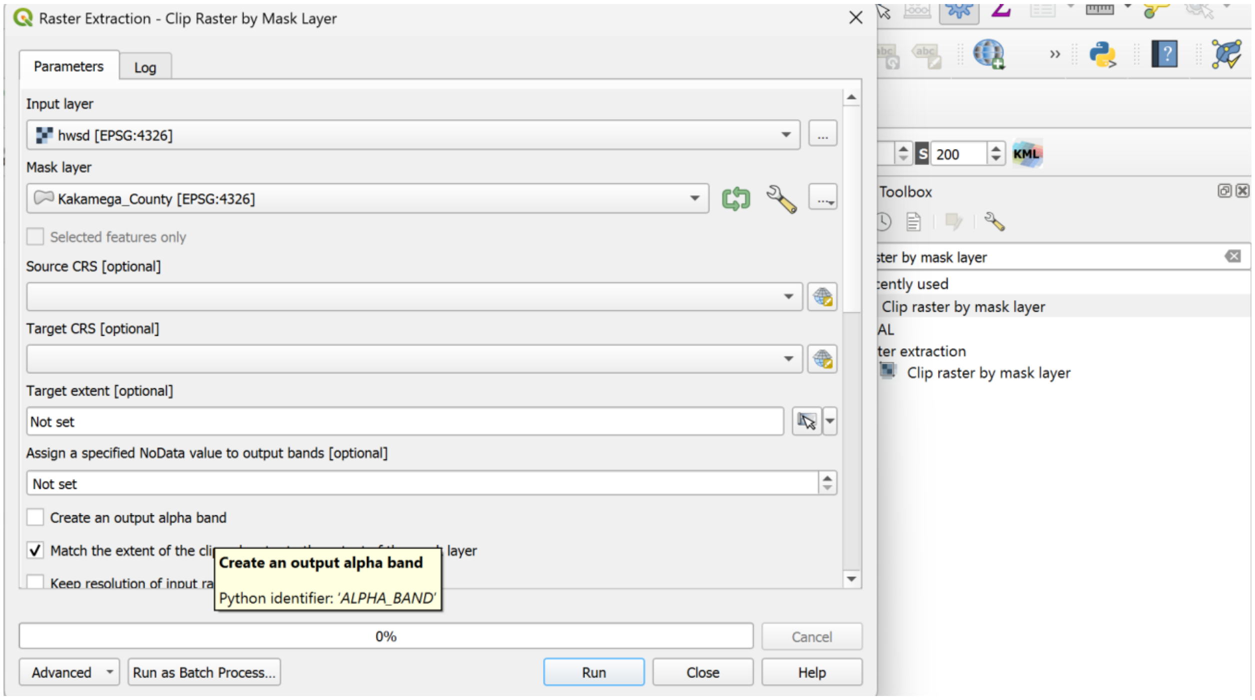
Choose "Clip raster by mask layer"

Input layer: HWSD raster

Mask layer: e.g., your County or Study Area shapefile

Set output file path

Run

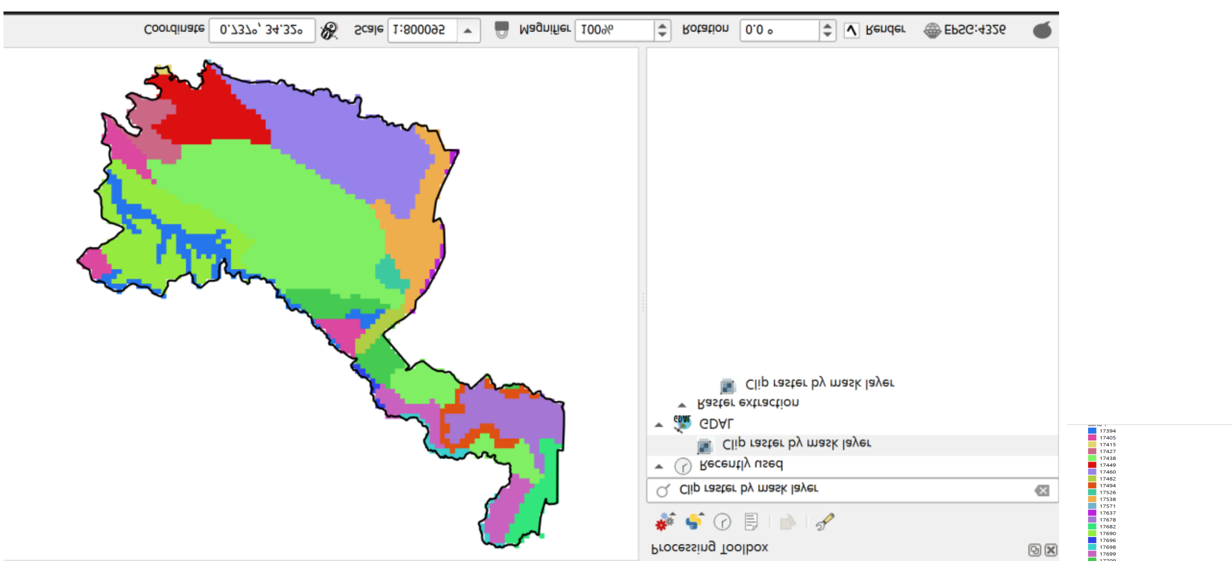


Step 4: Visualize Unique Soil Units

$$Right - click\ clipped\ raster\ \rightarrow\ Properties\ \rightarrow\ Symbology$$

Render type: Palleted/Unique values

Use a color ramp to display distinct soil units



4. Extract Soil Attribute Data

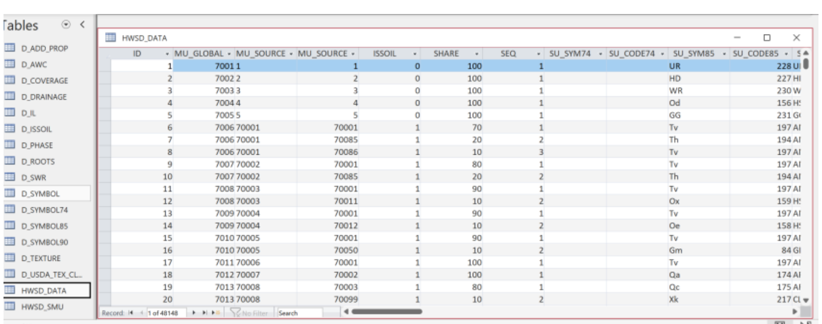
Step 5: Identify Unique Raster Values

Note the unique raster values

Step 6: Get Soil Properties from Metadata

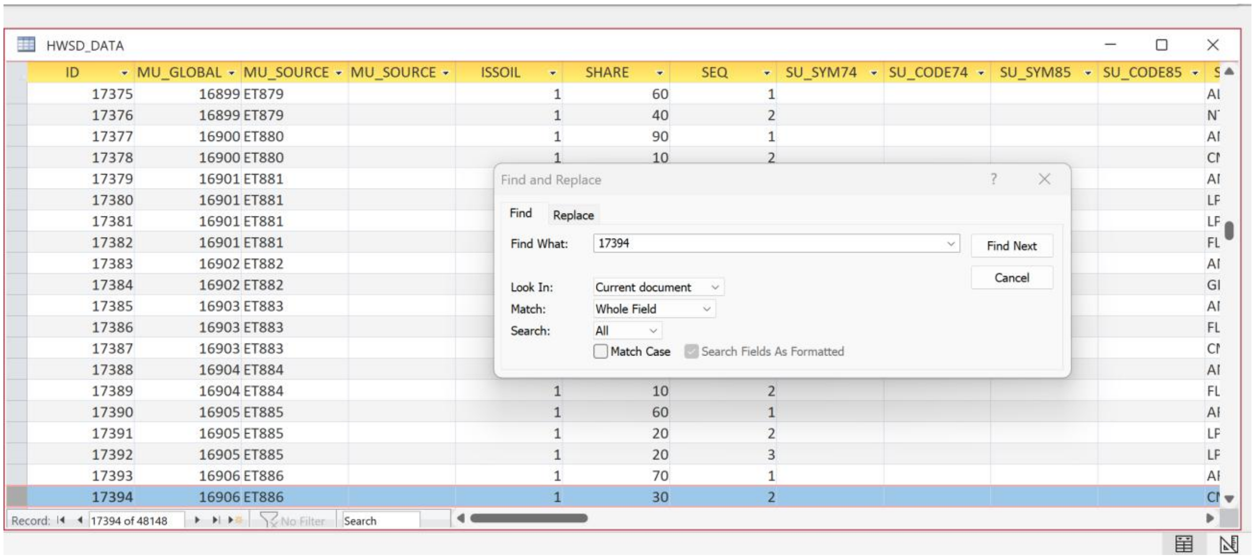
Open hwsd.mdb in Microsoft Access

Go to table: HWSD_DATA



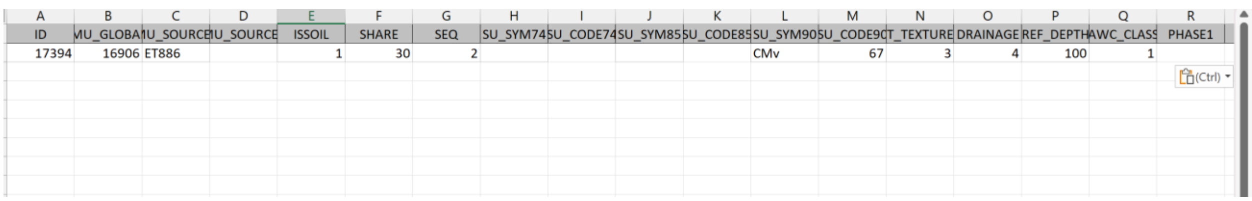
ID	MU_GLOBAL	MU_SOURCE	MU_SOURCE	ISSOIL	SHARE	SEQ	SU_SYM74	SU_CODE74	SU_SYM85	SU_CODE85	S
1	7001	1	1	0	100	1			UR	228	UI
2	7002	2	2	0	100	1			HD	227	HI
3	7003	3	3	0	100	1			WR	230	W
4	7004	4	4	0	100	1			Od	156	H
5	7005	5	5	0	100	1			GG	231	G
6	7006	70001	70001	1	70	1			Tv	197	AI
7	7006	70001	70085	1	20	2			Th	194	AI
8	7006	70001	70086	1	10	3			Tv	197	AI
9	7007	70002	70001	1	80	1			Tv	197	AI
10	7007	70002	70085	1	20	2			Th	194	AI
11	7008	70003	70001	1	90	1			Tv	197	AI
12	7008	70003	70011	1	10	2			Ox	159	H
13	7009	70004	70001	1	90	1			Tv	197	AI
14	7009	70004	70012	1	10	2			Oe	158	H
15	7010	70005	70001	1	90	1			Tv	197	AI
16	7010	70005	70050	1	10	2			Gm	84	GI
17	7011	70006	70001	1	100	1			Tv	197	AI
18	7012	70007	70002	1	100	1			Qa	174	AI
19	7013	70008	70003	1	80	1			Qc	175	AI
20	7013	70008	70099	1	10	2			Xk	217	CL

For every unique raster value, locate and copy the row by searching in the ms access document



ID	MU_GLOBAL	MU_SOURCE	MU_SOURCE	ISSOIL	SHARE	SEQ	SU_SYM74	SU_CODE74	SU_SYM85	SU_CODE85	S
17375	16899	ET879		1	60	1					AI
17376	16899	ET879		1	40	2					N
17377	16900	ET880		1	90	1					AI
17378	16900	ET880		1	10	2					CI
17379	16901	ET881									AI
17380	16901	ET881									LF
17381	16901	ET881									LF
17382	16901	ET881									FL
17383	16902	ET882									AI
17384	16902	ET882									GI
17385	16903	ET883									AI
17386	16903	ET883									FL
17387	16903	ET883									CI
17388	16904	ET884									AI
17389	16904	ET884		1	10	2					FL
17390	16905	ET885		1	60	1					AI
17391	16905	ET885		1	20	2					LF
17392	16905	ET885		1	20	3					LF
17393	16906	ET886		1	70	1					AI
17394	16906	ET886		1	30	2					CI

Paste output into an Excel file



ID	MU_GLOBA	MU_SOURCE	MU_SOURCE	ISSOIL	SHARE	SEQ	SU_SYM74	SU_CODE74	SU_SYM85	SU_CODE85	SU_SYM90	SU_CODE90	T_TEXTURE	DRAINAGE	REF_DEPTH	AWC_CLASS	PHASE1
17394	16906	ET886		1	30	2					CMv	67	3	4	100	1	

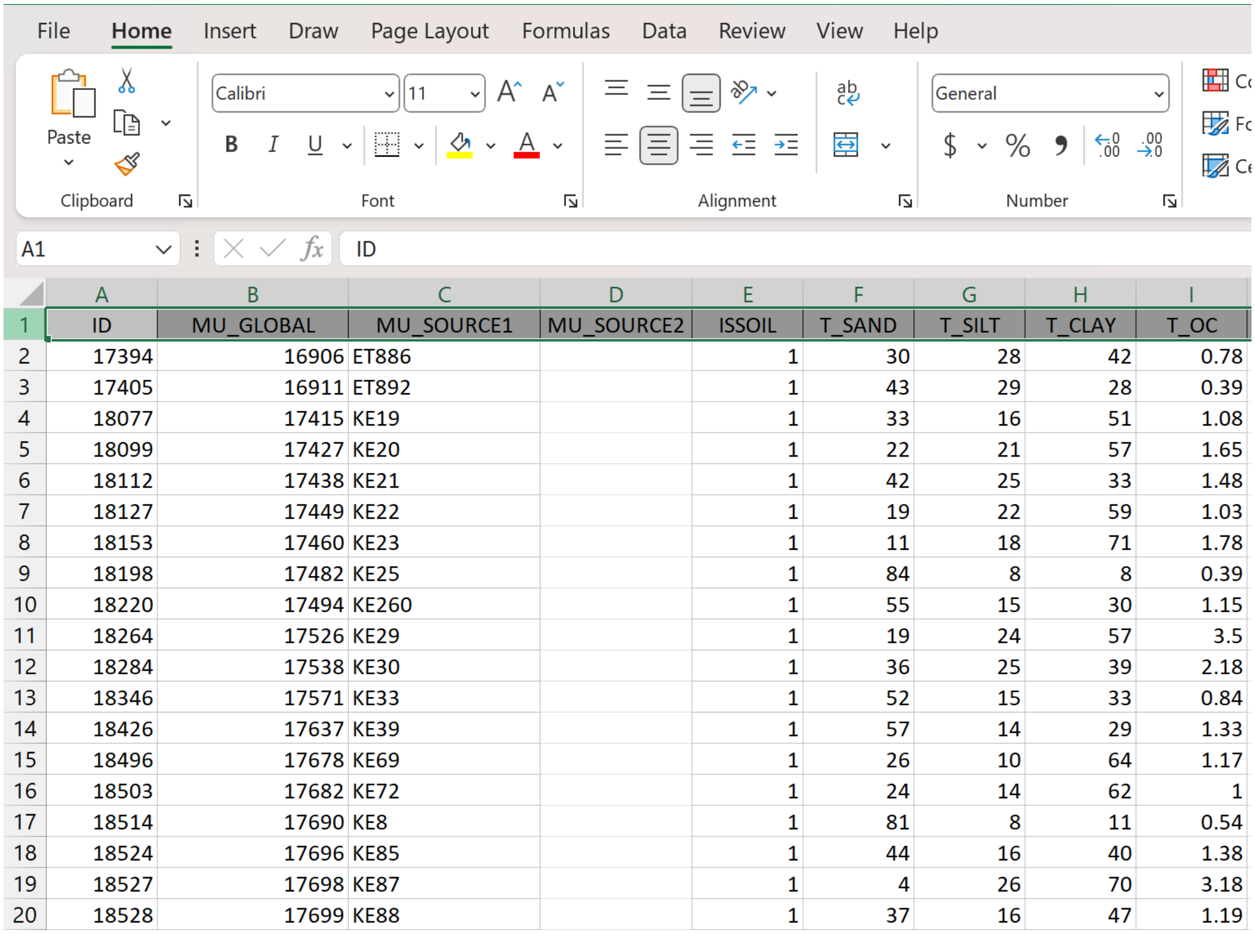
Repeat the process for every unique raster value

5. Prepare Data in Excel

Step 7: Export Significant Columns

Export the following columns:

ID, MU_GLOBAL, T_SAND, T_SILT, T_CLAY, T_OC



	A	B	C	D	E	F	G	H	I
1	ID	MU_GLOBAL	MU_SOURCE1	MU_SOURCE2	ISSOIL	T_SAND	T_SILT	T_CLAY	T_OC
2	17394	16906	ET886		1	30	28	42	0.78
3	17405	16911	ET892		1	43	29	28	0.39
4	18077	17415	KE19		1	33	16	51	1.08
5	18099	17427	KE20		1	22	21	57	1.65
6	18112	17438	KE21		1	42	25	33	1.48
7	18127	17449	KE22		1	19	22	59	1.03
8	18153	17460	KE23		1	11	18	71	1.78
9	18198	17482	KE25		1	84	8	8	0.39
10	18220	17494	KE260		1	55	15	30	1.15
11	18264	17526	KE29		1	19	24	57	3.5
12	18284	17538	KE30		1	36	25	39	2.18
13	18346	17571	KE33		1	52	15	33	0.84
14	18426	17637	KE39		1	57	14	29	1.33
15	18496	17678	KE69		1	26	10	64	1.17
16	18503	17682	KE72		1	24	14	62	1
17	18514	17690	KE8		1	81	8	11	0.54
18	18524	17696	KE85		1	44	16	40	1.38
19	18527	17698	KE87		1	4	26	70	3.18
20	18528	17699	KE88		1	37	16	47	1.19

Step 8: Calculate Organic Matter (OM)

Make a new column in Excel:

Formula: OM = 1.72 × T_OC

J2 | fx =1.72*I2

	A	B	C	D	E	F	G	H	I	J
1	ID	MU_GLOBAL	MU_SOURCE1	MU_SOURCE2	ISSOIL	T_SAND	T_SILT	T_CLAY	T_OC	OM
2	17394	16906	ET886		1	30	28	42	0.78	1.3416
3	17405	16911	ET892		1	43	29	28	0.39	0.6708
4	18077	17415	KE19		1	33	16	51	1.08	1.8576
5	18099	17427	KE20		1	22	21	57	1.65	2.838
6	18112	17438	KE21		1	42	25	33	1.48	2.5456
7	18127	17449	KE22		1	19	22	59	1.03	1.7716
8	18153	17460	KE23		1	11	18	71	1.78	3.0616
9	18198	17482	KE25		1	84	8	8	0.39	0.6708
10	18220	17494	KE260		1	55	15	30	1.15	1.978
11	18264	17526	KE29		1	19	24	57	3.5	6.02
12	18284	17538	KE30		1	36	25	39	2.18	3.7496
13	18346	17571	KE33		1	52	15	33	0.84	1.4448
14	18426	17637	KE39		1	57	14	29	1.33	2.2876
15	18496	17678	KE69		1	26	10	64	1.17	2.0124
16	18503	17682	KE72		1	24	14	62	1	1.72
17	18514	17690	KE8		1	81	8	11	0.54	0.9288
18	18524	17696	KE85		1	44	16	40	1.38	2.3736
19	18527	17698	KE87		1	4	26	70	3.18	5.4696
20	18528	17699	KE88		1	37	16	47	1.19	2.0468

Step 9: Assign Texture Class

Apply T_SAND, T_SILT, T_CLAY, and apply Roose (1996) table to acquire a Textural Class (e.g., sandy clay loam, silty clay, etc.)

Roose (1996)

Estimating soil erodibility (K) based on soil texture and organic material content.

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

Note that the table in the guide accounts for % organic matter (OM), not just organic carbon (OC). If we do not know the conversion value for the area, the value OC is multiplied by 1.72 to get OM.

OM=1.72*OC

The references for conversion factors are given in IPCC-AFOLU report 2006.

Insert this as a new column: TEXTURE_CLASS

K1 | TEXTURE_CLASS

	A	B	C	D	E	F	G	H	I	J	K
1	ID	MU_GLOBAL	MU_SOURCE1	MU_SOURCE2	ISSOIL	T_SAND	T_SILT	T_CLAY	T_OC	OM	TEXTURE_CLASS
2	17394	16906	ET886		1	30	28	42	0.78	1.3416	Clay
3	17405	16911	ET892		1	43	29	28	0.39	0.6708	Clay Loam
4	18077	17415	KE19		1	33	16	51	1.08	1.8576	Clay
5	18099	17427	KE20		1	22	21	57	1.65	2.838	Clay
6	18112	17438	KE21		1	42	25	33	1.48	2.5456	Clay Loam
7	18127	17449	KE22		1	19	22	59	1.03	1.7716	Clay
8	18153	17460	KE23		1	11	18	71	1.78	3.0616	Clay
9	18198	17482	KE25		1	84	8	8	0.39	0.6708	Loamy Sand
10	18220	17494	KE260		1	55	15	30	1.15	1.978	Sandy Clay Loam
11	18264	17526	KE29		1	19	24	57	3.5	6.02	Clay
12	18284	17538	KE30		1	36	25	39	2.18	3.7496	Clay Loam
13	18346	17571	KE33		1	52	15	33	0.84	1.4448	Sandy Clay Loam
14	18426	17637	KE39		1	57	14	29	1.33	2.2876	Sandy Clay Loam
15	18496	17678	KE69		1	26	10	64	1.17	2.0124	Clay
16	18503	17682	KE72		1	24	14	62	1	1.72	Clay
17	18514	17690	KE8		1	81	8	11	0.54	0.9288	Loamy Sand
18	18524	17696	KE85		1	44	16	40	1.38	2.3736	Clay Loam
19	18527	17698	KE87		1	4	26	70	3.18	5.4696	Clay
20	18528	17699	KE88		1	37	16	47	1.19	2.0468	Clay

Sheet1

Step 10: Assign Mean K Value

Apply the Roose (1996) table to acquire a mean K value on:

Texture class

OM content

Insert a new column in Excel: K_VALUE

A	B	C	D	E	F	G	H	I	J	K	L
ID	MU_GLOBAL	MU_SOURCE1	MU_SOURCE2	ISSOIL	T_SAND	T_SILT	T_CLAY	T_OC	OM	TEXTURE_CLASS	K_VALUE
17394	16906	ET886		1	30	28	42	0.78	1.3416	Clay	0.24
17405	16911	ET892		1	43	29	28	0.39	0.6708	Clay Loam	0.33
18077	17415	KE19		1	33	16	51	1.08	1.8576	Clay	0.24
18099	17427	KE20		1	22	21	57	1.65	2.838	Clay	0.21
18112	17438	KE21		1	42	25	33	1.48	2.5456	Clay Loam	0.28
18127	17449	KE22		1	19	22	59	1.03	1.7716	Clay	0.24
18153	17460	KE23		1	11	18	71	1.78	3.0616	Clay	0.21
18198	17482	KE25		1	84	8	8	0.39	0.6708	Loamy Sand	0.05
18220	17494	KE260		1	55	15	30	1.15	1.978	Sandy Clay Loam	0.2
18264	17526	KE29		1	19	24	57	3.5	6.02	Clay	0.21
18284	17538	KE30		1	36	25	39	2.18	3.7496	Clay Loam	0.28
18346	17571	KE33		1	52	15	33	0.84	1.4448	Sandy Clay Loam	0.2
18426	17637	KE39		1	57	14	29	1.33	2.2876	Sandy Clay Loam	0.2
18496	17678	KE69		1	26	10	64	1.17	2.0124	Clay	0.21
18503	17682	KE72		1	24	14	62	1	1.72	Clay	0.24
18514	17690	KE8		1	81	8	11	0.54	0.9288	Loamy Sand	0.05
18524	17696	KE85		1	44	16	40	1.38	2.3736	Clay Loam	0.28
18527	17698	KE87		1	4	26	70	3.18	5.4696	Clay	0.21
18528	17699	KE88		1	37	16	47	1.19	2.0468	Clay	0.21

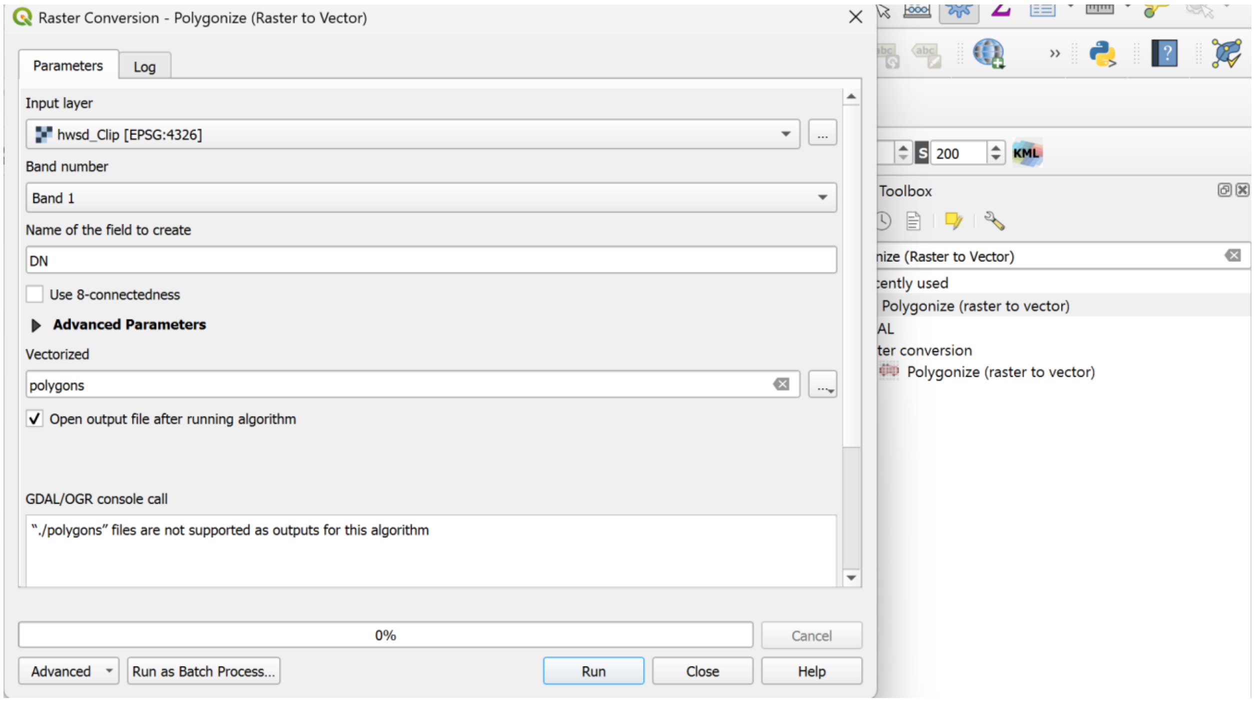
6. Combine K Values to QGIS Layer

Step 11: Raster to Polygon

$$Raster \rightarrow Conversion \rightarrow Polygonize\ (Raster\ to\ Vector)$$

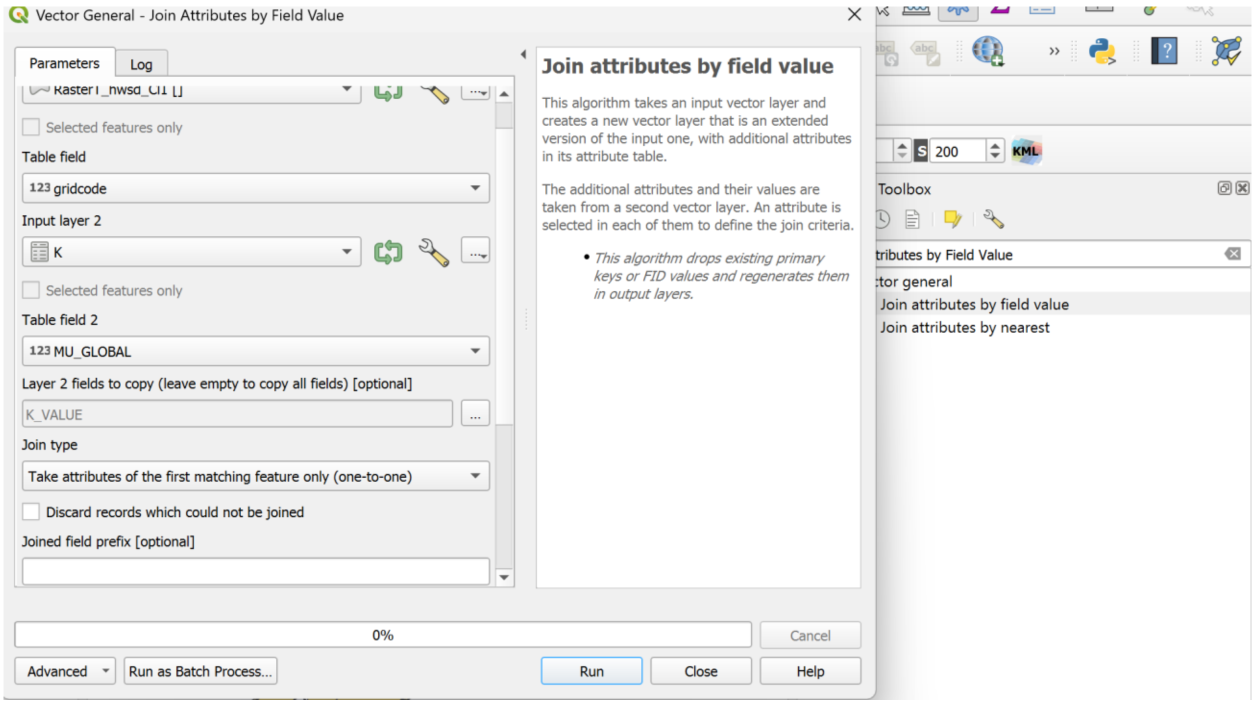
Input: Clipped raster layer

Output: A vector polygon shapefile in MU_GLOBAL units



Step 12: Join Excel Data to Polygon Layer in QGIS

- ✓ Convert the Excel file to CSV format.
- ✓ Load the polygon layer and the CSV file into QGIS.
- ✓ Ensure both layers contain a common field (used as a common key).
- ✓ Open the polygon layer's attribute table and confirm the existence of the K_VALUE field.
- ✓ Use the "Join Attributes by Field Value" tool:
  - Input Layer: polygon layer
  - Table Field: Unique Field
  - Input Layer2: CSV file
  - Table Field2: Unique Field
  - Layer2 fields to copy: K_VALUE
  - Join Type: Take attributes of the first matching feature only

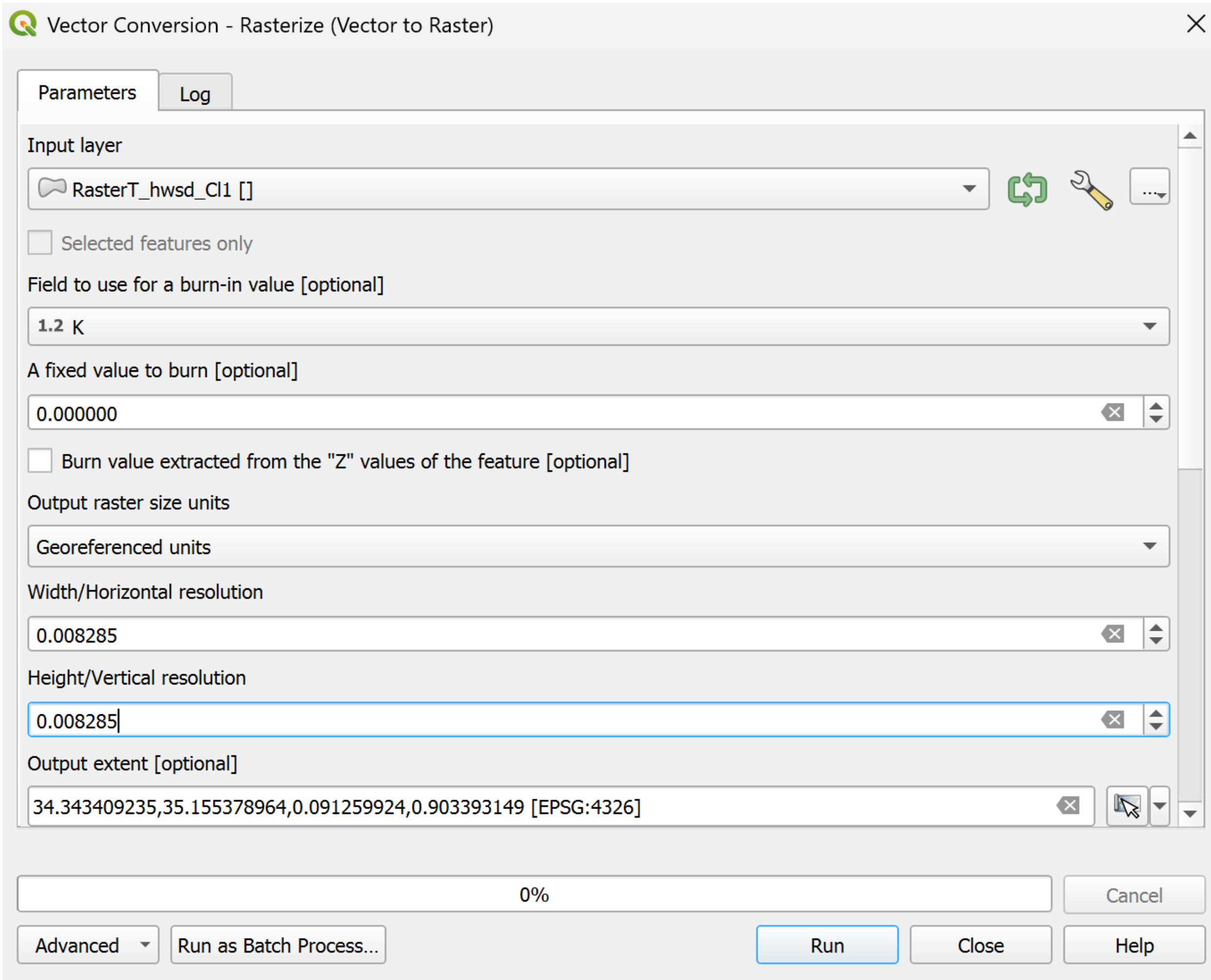


The tool populates the existing K_VALUE field in the polygon layer with matching values from the CSV.

7. Convert the polygons to raster

Step 13: Convert Polygon to Raster (Rasterize K_VALUE Field)

- ✓ In the Processing Toolbox, search for and open "Rasterize (vector to raster)".
- ✓ For the Input layer, select your polygon layer.
- ✓ Set the Field to use for a burn-in value to K_VALUE.
- ✓ Define the Output raster size units (e.g., pixel size in map units per pixel).
    - Common values: 10, 30, or 100 meters, depending on your scale and need.
    - Use the same as the hwsd raster for the vertical and horizontal resolution
    - Specify the extent as your area of intrest
- ✓ Specify the Output file location and give the raster a meaningful name (e.g., K_factor_raster.tif).
- ✓ Click Run.

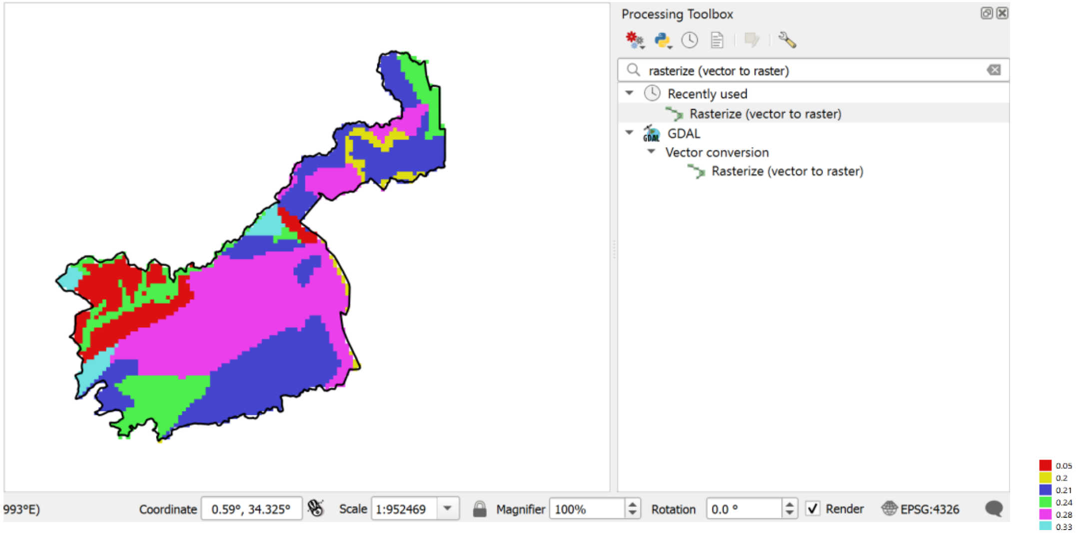


Step 14: Symbolize K Factor

$$Right - click\ polygon\ layer\ \rightarrow\ Properties\ \rightarrow\ Symbology$$

Render type: Categorized or Graduated

Choose a color ramp, e.g., Green-Yellow-Red for increasing erodibility



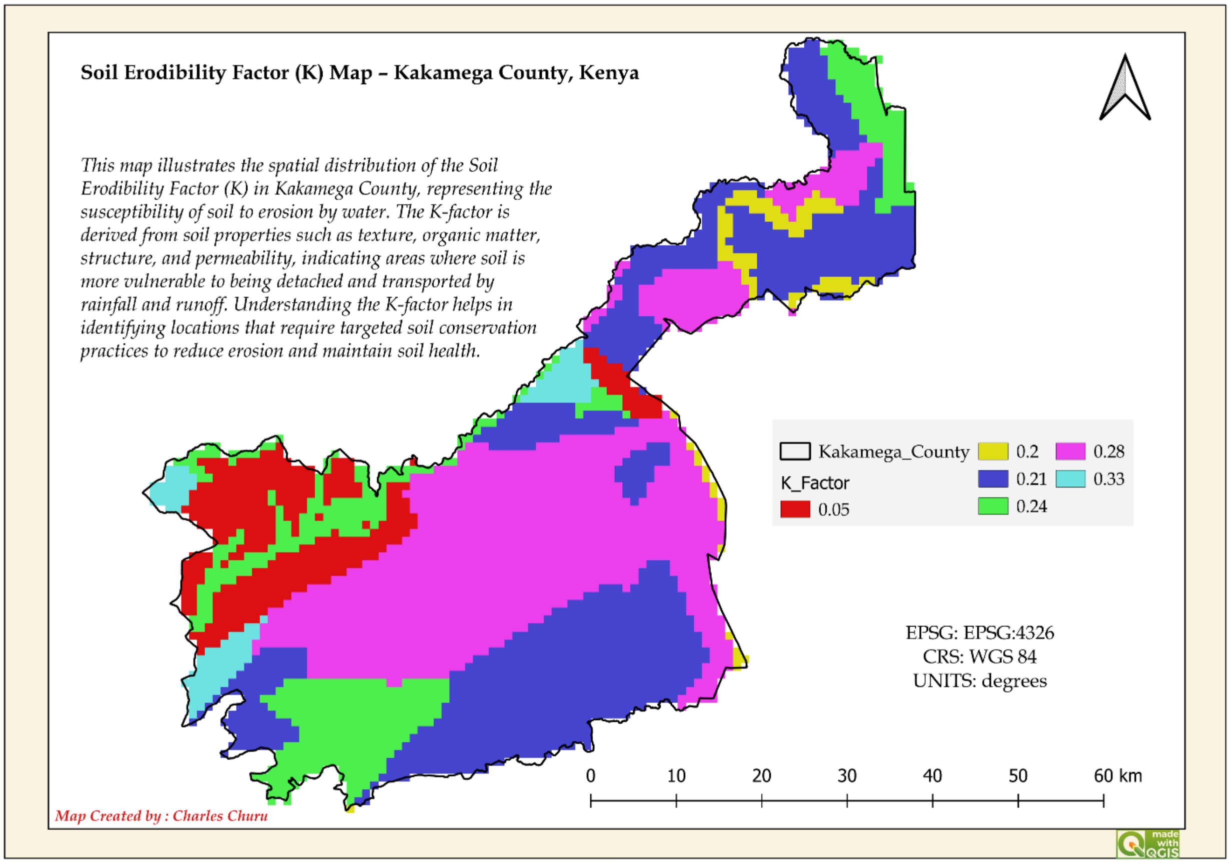
Step 15: Final Map Preparation

$$Go\ to\ Project\ \rightarrow\ New\ Print\ Layout$$

Insert:

- ✓ Title
- ✓ Legend
- ✓ Scale bar
- ✓ North arrow
- ✓ Labels (use on a case-by-case basis)

Export the map as PDF, JPEG, and PNG



Final Output

You now have ready a high-resolution map of the Soil Erodibility (K) Factor to be used in further USLE-based soil erosion modeling in QGIS.

References

QGIS Project. (2024). *QGIS training manual*. QGIS Documentation. https://docs.qgis.org/latest/en/docs/training_manual/

QGIS Development Team. (2024). *QGIS Geographic Information System* (Version 3.x) [Software]. Open Source Geospatial Foundation. https://qgis.org

Roose, E. (1996). *Land husbandry: Components and strategy*. FAO Soils Bulletin No. 70. Food and Agriculture Organization of the United Nations.

United States Department of Agriculture - Natural Resources Conservation Service (USDA-NRCS). (1993). *Soil survey manual*. U.S. Government Printing Office.

Wischmeier, W. H., & Smith, D. D. (1978). *Predicting rainfall erosion losses: A guide to conservation planning* (Agriculture Handbook No. 537). U.S. Department of Agriculture.