Exercise Erosion and Sediment

Exercise 1

Task:

Use the map and tables (U.S. Customary Units) to select appropriate numerical data to use for each of the variables. How many metric tons per hectare will be lost per year in the following three locations ?

a. Whitman County(Washington state)
   - Walla walla silt loam (Mollisol), 2% organic matter
   - 16% slope, 100m slope lenght
   - Clean-tilled, dry-farmed wheat, poorly maintained contours that are probably no more effective than having no conservation measures (P=1)

b. La Crosse (Southwestern Wisconsin)
   - Seaton silt loam (Alfisol), 4% organic
   - 5% slope, 75m slope length (interpolate value)
   - Straight rows of a corn and a cover crop oats

c. Southern Piedmont (Georgia)
   - Cecil sandy loam (Ultisol), less than 1% organic matter
   - 7% slope, 150m slope length
   - Terraced cotton crop

Given:

Empirical calculation of soil loss (Wischmeier & Smith, 1978, SI Units)

$$A = R \cdot K \cdot L \cdot S \cdot C \cdot P \quad \left[t \cdot ha^{-1} \cdot a^{-1} \right]$$

A: Average annual erosion rate (sheet and rill erosion only)

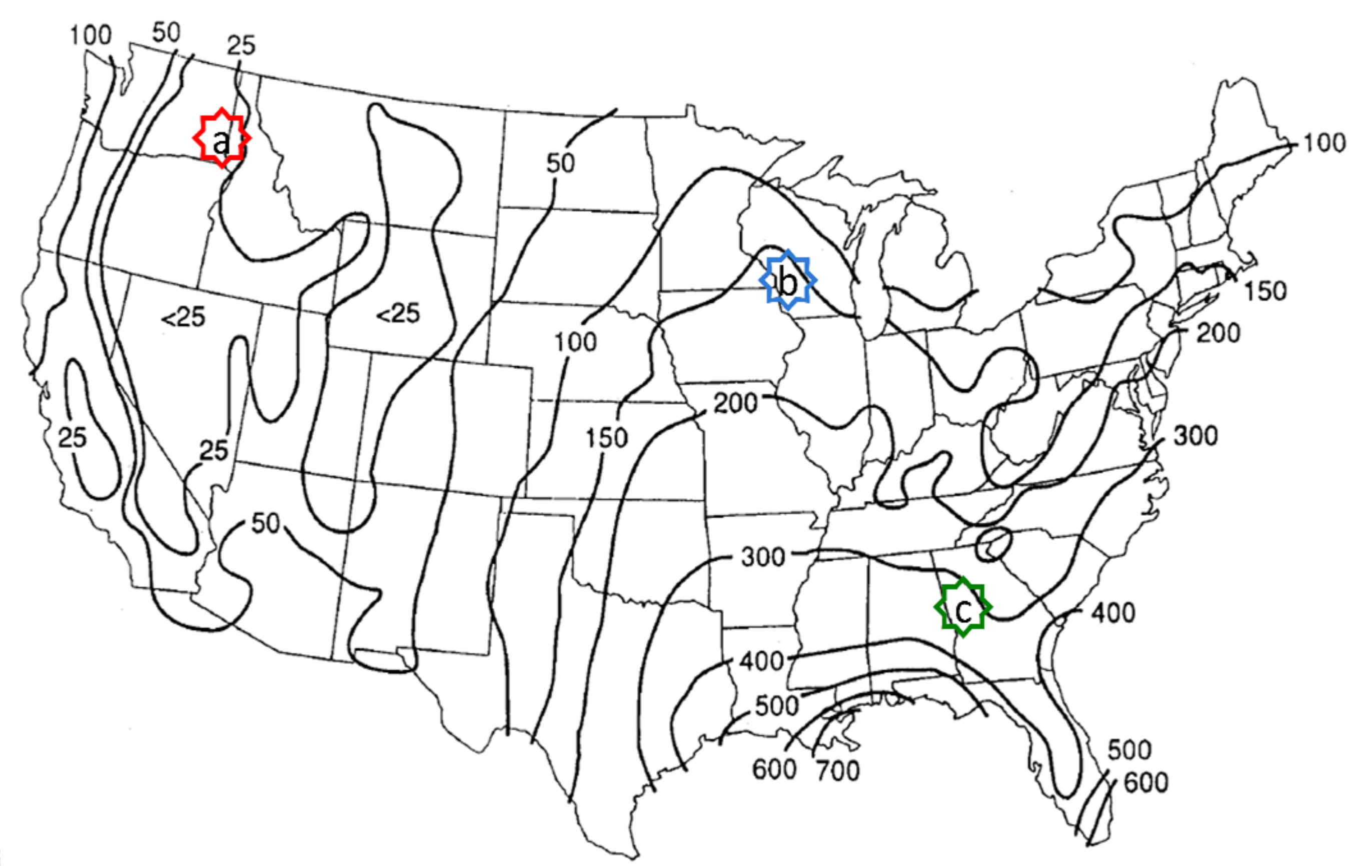
R: Rainfall factor (runoff erosivity index) [MJ mm/ ha h yr]

K: Soil erodibility factor [(t ha h) / (ha MJ mm)]
-> how easily can soil aggregate be broken by rain drops

L, S: Topographic factors [-]: slope length and slope steepness

C: Crop management factor [-]
-> ratio of soil loss compared to fallow (bare, exposed) soil

P: Erosion control practice factor [-]



R Factors in the United States

Figure 1. Map of R Factors for the USLE (rainfall erosivity) in the United States (generalized for this exercise).

TABLE 1
K Factors (Soil Erodibility)

Soil Texture	**Percent Organic Matter 0**	**2**	**4**	**6**
Sand	.18	.15	.12	.10
Loamy Sand	.23	.20	.17	.12
Sandy Loam	.30	.27	.22	.20
Loam	.38	.35	.30	.27
Silt Loam	.55	.49	.40	.35
Silt	.59	.55	.49	.45
Silty Clay Loam	.40	.37	.32	.28
Clay Loam	.34	.32	.25	.20
Sandy Clay Loam	.27	.24	.19	.17
Sandy Clay	.19	.15	.12	.10
Clay	.27	.25	.20	.15

TABLE 2
Length and Slope Gradient Factors

Slope Angle Percent	Slope Length in Meters 25	50	100	150	200	250	300
2	.20	.23	.28	.32	.34	.37	.40
4	.36	.47	.62	.73	.82	.90	1.01
6	.58	.82	1.17	1.41	1.65	1.90	2.10
8	.86	1.21	1.72	2.10	2.43	2.70	3.14
12	1.56	2.21	3.13	3.83	4.42	4.93	5.71
16	2.46	3.48	4.92	6.01	6.95	7.76	8.98
20	3.53	5.00	7.07	8.64	10.00	11.12	12.90

TABLE 3
Crop and Practice Factors

Crop and Management	**Value**
Bare soil	1.00
Seedling grape vines	.50
Straight row crops (corn, soybeans, cotton)	.40
Straight row crops with a cover crop	.30
Row crops grown on contour	.15
Small grains: oat, wheat, barley (clean till)	.20
Row crop and grain in strips crop on contour	.10
Mature grape vines	.15
Row crops on well-made terraces	.07
Small grains with reduced tillage	.05
Overgrazed pasture	.10
Hay, alfalfa, clover	.04
Grazed forest	.03
Meadow or grass sod	.02
Undisturbed forest	.001 - .0001

To Convert From:	U.S. Customary Units	Multiply By:	To Obtain:	SI Units
Rainfall intensity, i or I	inch / hour	25.4	millimeter / hour	mm* / h
Rainfall energy per unit of rainfall, e	foot-tonf / acre-inch	2.638×10^{-4}	megajoule / hectare•millimeter	MJ† / ha•mm
Storm energy, E	foot-tonf / acre	0.006701	megajoule / hectare	MJ‡ / ha
Storm erosivity, EI	foot-tonf•inch / acre•hour	0.1702	megajoule•millimeter / hectare•hour	MJ•mm / ha•h
Storm erosivity, EI	hundreds of foot-tonf•inch§ / acre•hour	17.02	megajoule•millimeter / hectare•hour	MJ•mm / ha•h
Annual erosivity, R‖	hundreds of foot-tonf•inch / acre•hour•year	17.02	megajoule•millimeter / hectare•hour•year	MJ•mm / ha•h•y
Soil erodibility, K#	ton•acre•hour / hundreds of acre•foot-tonf•inch	0.1317	metric ton•hectare•hour / hectare•megajoule•millimeter	t•ha•h / ha•MJ•mm
Soil loss, A	ton / acre	2.242	metric ton / hectare	t / ha
Soil loss, A	ton / acre	0.2242	kilogram / meter²	kg / m²

*Hour and year are written in U.S. customary units as hr and yr and in SI units as h and y. The difference is helpful for distinguishing between U.S. customary and SI units.

†The prefix mega (M) has a multiplication factor of 1×10^6.

‡To convert ft-tonf to megajoule, multiply by 2.712×10^{-3}. To convert acre to hectare, multiply by 0.4071.

§This notation, "hundreds of," means numerical values should be multiplied by 100 to obtain true numerical values in given units. For example, R = 125 (hundreds of ft-ton•in/acre•hr) = 12,500 ft-tonf•in/acre•hr. The converse is true for "hundreds of" in the denominator of a fraction.

‖Erosivity, EI or R, can be converted from a value in U.S. customary units to a value in units of Newton/hour (N/h) by multiplying by 1.702.

#Soil erodibility, K, can be converted from a value in U.S. customary units to a value in units of metric ton•hectare/Newton•hour (t•h/ha•N) by multiplying by 1.317.

Exercise II

Task:

A river bottom ramp with an inclination of 1:10 is to be dimensioned for a discharge of $q = 8.0\ m^3 \cdot s^{-1} \cdot m^{-1}$. Determine the size of the rocks ($\rho_S = 2650\ kg \cdot m^3$) for a stable bottom ramp according to the stability criterion of Whittaker/Jäggi. Calculate the weight for a rounded rock.

Given:

Stability criterion of Whittaker/Jäggi:

$$q_{crit} = 0{,}235 \cdot \sqrt{\frac{\rho_S - \rho_W}{\rho_W}} \cdot \sqrt{g} \cdot I^{-7/6} \cdot d_S^{3/2}$$

q_{crit} : critical discharge per m width ($m^3 \cdot s^{-1} \cdot m^{-1}$)

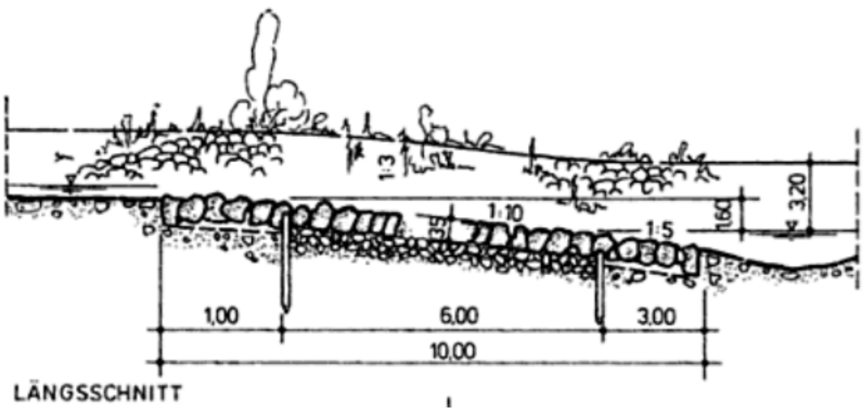
ρ_S : bulk density rocks ($kg \cdot m^{-3}$)

ρ_W : density water($1000\ kg \cdot m^{-3}$)

g : gravity acceleration ($9{,}81\ m \cdot s^{-2}$)

I : inclination of ramp (-)

d_S: rock diameter (m)



Lecher, Lühr, Zanke 2001

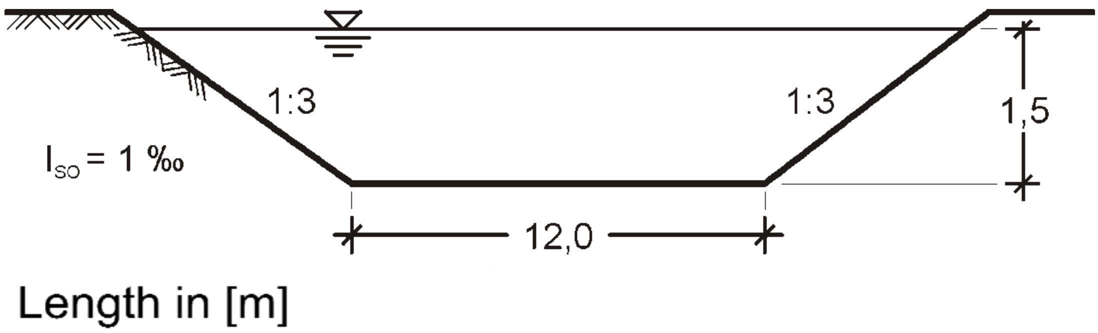
Exercise III

Task:

A seminatural stream (Dimensions of a mean equivalent cross section given in figure below) should be examined for bed and bank stability after the theory of shear stress.

The influence of ground covering is insignificant. The grading curve of the soil (gravel-sand mix) indicates that 25wt% of the soil has a grain diameter bigger than 5 mm. The grain shape is rated as moderately rounded.

Calculate the actual shear stresses and compare them with the maximum permissible values! How do you rate the river profile stability?



Shear stress at river bed [N·m^{-2}]:

$$\tau_{So} = \frac{F}{L \cdot B} = \rho_W \cdot h \cdot g \cdot I_{So} \quad (5)$$

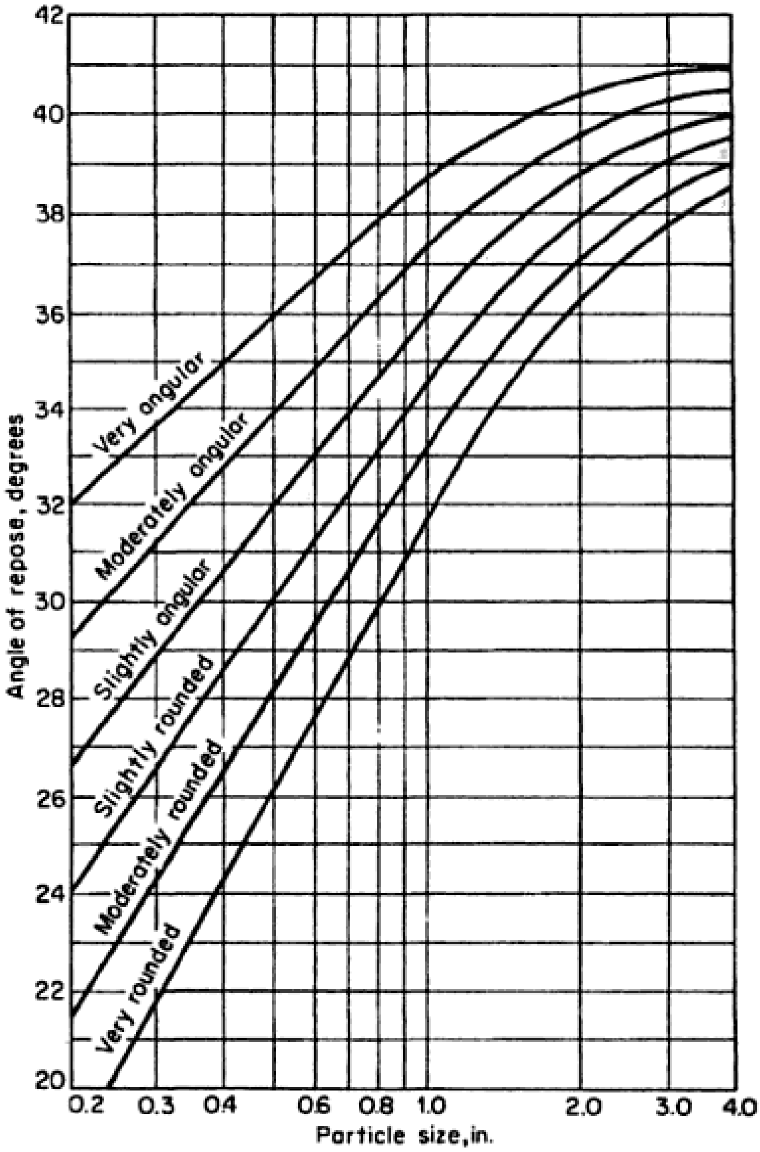
Average shear stress for profile:

$$\tau_{m,w} = \rho_W \cdot r_{hy} \cdot g \cdot I_{E,w} \quad (6)$$

Shear stress at bank:

$$\tau_{Bo,w} = \tau_{So,w} \cdot \sqrt{1 - \frac{\sin^2 \alpha}{\sin^2 \varphi}} \quad (7)$$

α	Angle of slope
φ	Angle of repose
τ_{So}, τ_{Bo}	actual (w) and maximum permissible (crit) shear stress at bed and at bank (critical shear stress)



Angle of repose according to grain size (d_{25}) and grain shape
d_{25}: grain size with 25 wt%

Bed texture		Grain size in [mm]	Critical shear stress [N*m^{-2}]
Single grain structure	Fine sand	0.063-0.2	1
	Medium sand	0.2-0.63	2
	Coarse sand	0.63-1	3
	Coarse sand	1-2	4
	Coarse sand	0.63-2	6
	Gravel-sand-mix ,close-grained, continuously overflowed	0.63-6.3	9
	Gravel-sand-mix ,close-grained ,short-term overflowed	0.63-6.3	12
	Medium gravel	6.3-20	15
	Coarse gravel	20-63	45
	Boulders bedload		50

Critical shear stress according to bed texture (DIN 19661-2, 2000)