Land Degradation (GEO3-4304)

First Exam

10 October 2016
09.00 – 12.00 h

Answers

1a. What is meant with on-site and off-site effects of soil erosion?
1b. Give two on-site and two off-site effects of wind erosion.
1c. Give two on-site and two off-site effects of water erosion.

1a. (2 pts)
On-site: the damage that is caused at the location where the erosion takes place.
Off-site: the damage/effects that occurs at some distance from the erosion sources areas.

1b. (4 pts)
On-site: crop damage, soil loss, loss of soil depth, nutrient loss, soil structure decline.
Off-site: atmospheric pollution, unwanted sedimentation, dune formation.

1c. (4 pts)
On site: soil loss, loss of soil depth, nutrient loss, soil structure decline.
Off-site: sedimentation in reservoirs, surface water pollution, unwanted sedimentation on roads/in houses.

2. The logarithmic velocity profile is defined as:

$$\boxed{U(z) = \frac{u_*}{\kappa} \ln\left(\frac{z}{z_o}\right)}$$

a. Explain the meaning of the variables in the equation.
b. For which part of a boundary layer does the equation apply?
c. Explain in detail how the shear stress at the boundary (τ_o) can be determined using the equation? (what kind of measurement(s) is/are needed and how can this/those be used to determine τ_o ?)

2a. (3 pts)
U = mean velocity (m/s); z = height (m); u_* = friction velocity (m/s);
κ = Von Karman constant (0.4); z_0 = roughness length (m)

2b. (2 pts)
The inner layer of the (turbulent) boundary layer.

2c. (5 pts)
A minimum of two mean velocities (U) at two heights (z_1 and z_2) are needed to determine the shear stress. By plotting the mean velocities versus ln(z) a line can be fitted. The intercept with the ln(z) axis gives the value $\ln(z_0)$. From the slope of the line the value of u_* can be determined. u_* is equal to $\sqrt{\tau_o / \rho_a}$ where ρ_a = the air density (~ 1.3 kg/m^3). Hence from the value of u_* the shear stress τ_o can be determined.

3a. What are the two main driving forces for infiltration of water into a dry soil?

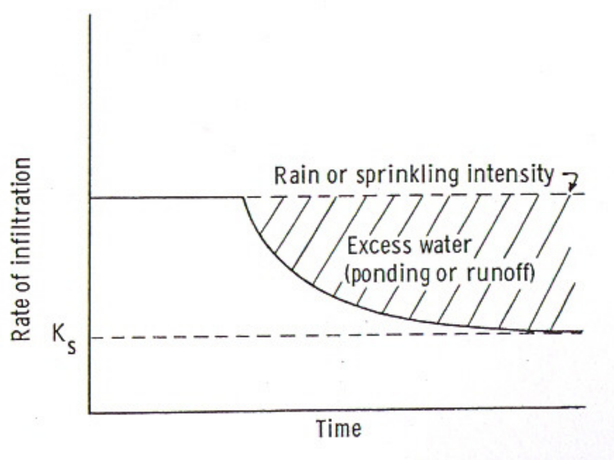
3b. Describe how Hortonian overland flow develops on a hillslope if we start with a relatively dry soil and a constant rain intensity of approximately 50 mm h^{-1}. Draw one or more graphs to illustrate your description.

3c. Surface runoff is flowing on a slope with a steepness of 5%. The depth of the water layer is 0.012 m. Calculate the average velocity of the flow (U), the Reynolds number (Re), and the shear stress (τ_o) at the surface caused by the flow.

Use the Manning's equation: $\boxed{U = \frac{r^{2/3} s^{1/2}}{n}}$ *where r is hydraulic radius (m), s is the slope (m m^{-1}) and n = 0.025 s $m^{-1/3}$. Also given: $\upsilon = 1.14 \cdot 10^{-6}$ m^2 s^{-1} and ρ = 1000 kg m^{-3}.*

3a. (2 pts) The gravity force and the matric suction force.

3b. (4 pts) Initially there is a high infiltration rate meaning that all water falling on the surface can infiltrate. But due to the wetting of the soil the infiltration rate will decrease and at a certain moment it becomes equal to the rain intensity. From this point onward the infiltration rate will become lower than the rain intensity and the surplus rainfall will cause ponding and overland flow generation.



3c. (4 pts)
Hydraulic radius (r) for overland flow is equal to the flow depth (h), and slope s is equal to 0.05 m/m. Using Manning's equation the flow velocity is equal to:

$U = (0.012^{0.66} \cdot 0.05^{0.5})/0.025 = 0.469$ m/s

$Re = (U \cdot r)/\upsilon = 0.469 \cdot 0.012)/1.14 \cdot 10^{-6} = 4934.9$

$u_* = (g \cdot r \cdot s)^{0.5} = (9.81 \cdot 0.012 \cdot 0.05)^{0.5} = 0.0767$ m/s

$\tau_{o} = (u_*)^2 \cdot \rho = (0.0767)^2 \cdot 1000 = 5.89$ Pa

4. Fournier (1960) provides the following empirical relationship between mean annual sediment yield (Q_s, $g \cdot m^{-2} \cdot year^{-1}$) where H and S are respectively the mean altitude (m) and slope ($m \cdot m^{-1}$) of the basin:

$$\log Q_s = 2.65 \frac{p^2}{P} + 0.46 \times \log H \times S - 1.56$$

The term p^2/P is called the rainfall aggressiveness and is widely used in generalized hazard assessments. The variable p is the mean monthly precipitation and P the mean annual precipitation. Morgan (1976) based on a regression of p^2/P on drainage texture that it was indicative of the hazard of gully erosion.
Another generalized hazard assessment based on climate data is the erosivity (for example EI_{30}).

4a. Erosivity indices are indicative of the hazard of which erosion process?

Rill erosion (splash erosion and energy input also correct)

4b. Why can climate-based indices be used as an overriding factor in generalized assessments?

Climate always comes into play on a larger, regional scale and its influence is modified only further by local factors. Thus, climate can be seen as the factor defining the potential landslide hazard, all other factors remaining equal.

4c. What is the practical advantage of using climate-based indices for generalized assessments?

Any of the following:
- Data on rainfall depth are widely available
- Data stem from direct observations
- Rainfall data can be extrapolated over larger areas

A limitation of the climate-based indices used for generalized assessment is that they do not take the influence of vegetation cover into account. Therefore, they should be seen as indicative of the potential erosion hazard.

d) Explain how semi-detailed analyses such as land capability classification or land systems classification differ from this. Would you argue that they assess potential or actual erosion hazard?

They explicitly take various aspects of land cover and land cover use/management into account; the semi-detailed classifications look at limitations or resource evaluation in which erosion hazard incorporated. Since the methods look at the interaction between erosivity and erodibility, mitigated by vegetation, they can be seen as indicative of the actual erosion hazard.

Observation (estimation, measurement) of soil erosion only features in detailed surveys. Such observations are costly and often done for a small area with limited support (1 m^2 to 1 ha).

e) Which approach, also used for generalized assessments, could be used to extrapolate locally observed erosion over larger areas? What information would you include and why?

Factorial scores can be used to obtain scores or identify areas of homogenous properties (for this reason also land system classification is taken as correct) to which observed soil erosion can be correlated. Once correlated, the relation between terrain and observed erosion can be used to extrapolate the actual rates over a larger area.

Information should lead to discernible areas and should include:

- Topography: shape, slope and upstream area;
- Vegetation cover
- Soil conditions
- Climate

However, climate is less relevant; microclimate indicators are less easily identified on the regional scale whereas many directly available climate indicators are redundant or closely related to topography etc.

5a. What are the three main modes of transport in wind erosion?
5b. Give the approximate distances that particles can travel by each of these three transport modes.
5c. Explain the difference between 'fluid threshold' and 'impact threshold' in wind erosion.

5a. (3 pts) saltation, creep and suspension

5b. (3 pts)
Creep – few millimeters up to a few meters
Saltation – from less than a meter up to several tens of meters
Suspension – from a few meters to thousands of kilometers

5c. (4 pts)
Fluid threshold – the minimum wind speed or friction velocity required to initiate soil particle movement.
Impact threshold - the minimum wind speed or friction velocity required to maintain sediment transport after it has been initiated already.

6a Much water erosion research has been done under laboratory conditions using rainfall simulators. Describe the main problems with rainfall simulations when compared with natural rainfall.

6b Give one advantage and one disadvantage of measurements with bounded erosion plots on a hillslope. (The advantage and disadvantage should be related to erosion processes!)

6c The Modified Wilson and Cooke sediment catcher has seven traps on a central pole that collect sediment during a wind erosion event. Explain how the mass flux (in kg m^{-1} s^{-1}) can be determined from the measured quantities of trapped sediment at the seven heights. Use equations and graphical illustration in your answer.

6a. (2 pts) Uniform rain drop sizes, low fall velocities of simulated rain, unrealistic kinetic energy.

6b. (4 pts) Advantage: it is exactly known from which area the surface runoff and sediment is collected;
Disadvantage: a bounded erosion plot is not necessarily representative for the hillslope on which it is installed because it does not allow inflow of surface runoff from above.

6c. (4 points) 1) The weights of the trapped sediments at seven heights are converted to mass flux densities; 2) a vertical profile is fitted through the seven mass flux density observations; 3) the vertical profile is integrated over height which results in a mass flux; 4) this mass flux is corrected for the trapping efficiency of the catcher.