Land Degradation (GEO3-4304)

Second Exam

5 November 2014
09.00 – 12.00 h

Answers

1a. What are the three main types of soil conservation measures? (2 pts)
1b. Describe briefly each of those three main types of measures, including how they influence soil erosion by wind or water? (6 pts)
1c. Which of the three main types of measures is generally preferred and why? (2 pts)

1a.
Agronomic measures,
Soil management,
Mechanical measures

1b.
Agronomic measures:
Optimize vegetative cover of the soil and reduce raindrop impact, surface runoff and wind speed

Soil management:
Tillage techniques that improve soil fertility, soil structure and soil resistance against shear forces caused by wind, surface runoff and raindrop impacts

Mechanical measures:
Engineering structures (terraces, wind breaks, etc); reduce the impact of strong wind on the soil surface or break a slope in sections in such a way that surface runoff amounts and velocities are reduced

1c.
Agronomic measures are preferred because these are the cheapest and usually the least complicated to implement

2a. What is agroforestry? (2 pts)
2b. Mention at least three beneficial effects of agroforestry practices for crop production. (4 pts)
2c. Why can agroforestry reduce soil erosion problems? (4 pts)

2a. Agroforestry is an agricultural practice that integrates the growing of trees with crop production or animal husbandry.

2b.

1. Micro-climate improvement
2. Nutrient availability (N-fixation, recycling)
3. Improved soil physical properties (higher OM)
4. Useful products (timber, fruits, firewood, medicines, ..)

2c.

1. Tree/shrub canopies reduce raindrop impact and wind speed
2. Litter from trees/shrubs on the surface protect the soil against splash erosion
3. Hedgerows along the contour increase infiltration
4. Shrub-type vegetation can trap sediments

3. Landslide classification and hazard

3.a In addition to translational and rotational slides, Varnes distinguished 3 other main types of movements and 3 types of material. List these types. (4 pts)

3.b Varnes' original classification showed shape and rate of movement for the different landslide types. Explain how these two aspects are related to landslide hazard. (3 pts)

3.c One aspect of landslide hazard is missing. Which is this and explain whether this is covered by the classification proposed by Sidle and Ochiai (2002) or not? (3 pts)

3.a Falls / Topples / Flows / Lateral spreads / Complex types
Bedrock / Debris / Earth
(One point deducted for any missing)

3.b Shape is linked to magnitude and onsite damage, rate of movement to runout and the offsite damage. (1 points for identifying the components of hazard, 1 for on- and offsite effect)

3.c Missing from the above is information about the frequency. The classification of Djakal and Siddle (2002, Table 2.2 in Sidle and Ochiai) covers this by relating this to the type of rainfall and hydrological conditions leading to failure. (2 points for explanation on frequency, 1 for a clear relation to triggering hydrological conditions / rainfall or climate)

4. Natural factors influencing slope stability

As you know, rainfall often leads to landsliding.

4.a Name at least three rainfall attributes and explain how they are linked to landslide initiation. (3 pts)

4.b Name another important natural factor that leads to the widespread initiation of landslides. (1 pts)

Vegetation influences slope stability through both hydrological and mechanical effects (Greenway, 1987).

4.c Give two ways by which vegetation interacts with the hydrology of a slope and explain whether this influence is predominantly beneficial (i.e., stabilizing), adverse (i.e., destabilizing) or alternately both dependent on the conditions. (3 pts)

The dominant mechanical effect of vegetation is root reinforcement, which is beneficial to slope stability.

4.d Mention two conditions that may be reduce the effectiveness of roots to stabilize slopes. Briefly explain your answer. (3 pts)

4.a (1) total rainfall, (2) short-term intensity, (3) antecedent storm precipitation, (4) storm duration (Sidle and Ochiai, page 69). Also spatial distribution, dry spell length and the fraction of precipitation falling as snow can be mentioned and are considered correct. Explanations can be found in Table 2.2 and can include:

- Antecedent rainfall determines how much water is needed to reach a critical rainfall threshold;
- Total rainfall determines the maximum groundwater tables that are attained;
- Short term intensity determines the possible build-up of perched water tables in the (top)soil as the infiltration exceeds the rate by which water can percolate into the deeper soil;
- Storm duration influences the time (perched) water tables exist and the downward transport of water along the slope can persist, thus negatively influencing the stability of footslopes.

Spatial distribution (orographic rainfall) can lead to more instability in steep and rugged terrain, snow melt results in large infiltration amounts and longer dry spell lengths lead to more drainage, thus lowering antecedent conditions. (points dependent on factors and clarity of explanation)

4.b Earthquakes, seismic activity

4.c See Table 3.1 in Sidle and Ochiai (1 point for correct mechanisms, 2 points for explanation)

TABLE 3.1. Relative influences of woody vegetation on slope stability (extensively modified from *Greenway*, 1987). 'A' denotes mechanisms adverse to stability, 'MA' denotes marginally adverse, 'MB' denotes marginally beneficial, and 'B' denotes beneficial mechanisms.

Mechanisms	Influences on types of landslides	
	Shallow, rapid	Deep-seated
Hydrological mechanisms		
1. Interception of rainfall and snow by canopies of vegetation, thus promoting evaporation and reducing water available for infiltration	B	B
2. Root systems extract water from the soil for physiological purposes (via transpiration), leading to lower soil moisture levels	B	B
3. Roots, stems, and organic litter increase ground surface roughness and soil's infiltration capacity	MA	MA
4. Depletion of soil moisture may cause desiccation cracks, resulting in higher infiltration capacity and short-circuiting of infiltrating water to a deeper failure plane	MA	MA

4.d Short-term: water-logging (reduction in shear strength along soil-root interface), loosening of roots due to dynamic wind loading.
Long-term: pests and plagues, logging and root decay.

5. Causes of landslides

5.a Explain the difference between preparatory and triggering factors. (3 pts)

In February 2013, a landslide occurred at the edge of a spoil tip at the Hatfield colliery in South Yorkshire. The landslide blocked major railways in the NE of England for the better half of 2013. The situation and effects of this landslide are shown below.

5.b For the Hatfield landslide give an example of:

1. A factor that could be an external cause for the landslide working in the short-term;
2. A factor that could be an external cause for the landslide working in the long-term;
3. A factor that could be an internal cause for the landslide working in the short-term;
4. A factor that could be an internal cause for the landslide working in the long-term.

Briefly explain your answer. (4 pts)

5.c Discuss the difficulty in distinguishing between preparatory and triggering factors. You can use your answer under (b) to illustrate your motivation. (3 pts)

5.a Preparatory factors are those that gradually lead to a decrease in capacity (resistance) or an increase in demand (loads). Triggering factors are those that almost instantaneously lead to a situation where demand exceeds capacity and slope failure occurs. (see the hand-out, 3 points for a clear definition)

5.b Short-term, external: railway traffic or other dynamic loads;
Long-term, external: undercutting by the stream at the base, continued loading of spoil heap;
Short-term, internal: increased pore pressures, for example as a result of rainfall;
Long-term, internal: weathering, reducing the internal strength. (see Sidle and Ochiai, lecture notes, 1 point per item)

5.c Triggering factors are often superimposed on gradual changes and thus the magnitude of triggers is not constant. Also, changes may work on either side on the stability equation (Safety Factor), so a surcharge may lead to an increase in both loads and resistance. Similarly, rapid loading not only increases demand but also may reduce the capacity (strength) as a result of undrained loading (liquefaction). (3 points for a clear and logical argument)

6. Slope stability analysis

We consider a long, planar slope above a parallel slip surface for which we assume the infinite slope model holds:

$$F = \frac{c' + ((1-m)\gamma_u + m\gamma')z\cos^2\alpha\tan\phi'}{((1-m)\gamma_u + m\gamma_s)z\cos\alpha\sin\alpha}$$

6.a If at its base 40% of the maximum available shear strength is mobilized, what is then the safety factor? And why? (2 pts)

For this slope, the following properties are given:

Variable	Average	Description
γ_s [kN·m^{-3}]	17.5	Saturated bulk unit weight
γ_u [kN·m^{-3}]	17.5	Unsaturated bulk unit weight
γ_w [kN·m^{-3}]	10.0	Bulk unit weight of water
α [°]	30	Topographic slope
m [-]	0	z_w/z
z [m]	2.0	Soil depth
c [kPa]	2.1	Cohesion
ϕ' [°]	37.6	Friction

6.b Compute either the water level or the pore pressure at which the slope will fail. Show how you derived your answer. (3 pts)

Many landslides in cohesive materials show curvilinear slip surfaces that can be approximated by the arc of a circle. In some cases, only the cohesion is considered in the stability calculations and the frictional part of the resistance neglected (c_u or ϕ= 0 analysis).

6.c Which condition should be met for circular slip surfaces to warrant static equilibrium, other than the force equilibrium used above? (2 pts)

6.d Explain why in the case of an analysis in terms of c_u or $\phi = 0$ for a circular slip plane, the computed safety factor is said to be 'exact'. (1 pts)

6.e Briefly explain under which conditions an analysis in terms of c_u or $\phi = 0$ is appropriate. (2 pts)

6.a The safety factor is based on the principle of limit equilibrium that assesses static equilibrium under the premise that the amount of shear resistance that needs to be mobilized to withstand the downward component of the loads (weight, surcharge, etc.) cannot exceed the maximum strength that is available, so:

$$F = \frac{\tau_{max}}{\tau_{mob}},$$

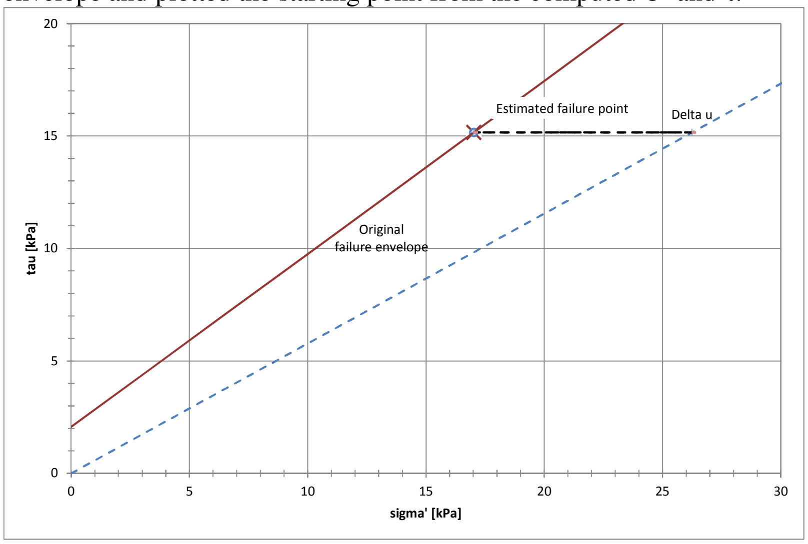
So, in this case, F= 1/0.4= 2.5. Note the safety factor is dimensionless (force over force or stress over stress; lecture notes)

6.b Answers from graphical calculators without a proper answer do not count. There are two solutions. First, one rewrites the above equation. Note that the bulk unit weight under saturated and unsaturated conditions are the same. So, the rewritten equation becomes:

$$m = \frac{\gamma_s}{\gamma_w} + \frac{c}{z\gamma_w \cos^2\beta \tan\phi} - \frac{\gamma_s \tan\beta}{\gamma_w \tan\phi}$$

This allows you to compute m as 0.62. This gives the water depth, 1.24 m, and the corresponding pore pressure, $u = m\gamma_w z\cos^2\alpha$, as 9.23 kPa.

Second, you can follow the graphical procedure using the stress graphs of Sidle and Ochiai, in this case Figure 4.4, and read the change in pore pressure from the graph once you have drawn the failure envelope and plotted the starting point from the computed σ' and τ:



(maximum 3 points, 2 points for a clear explanation and description, 3 points for a correct derivation)

6.c Moment equilibrium. (lecture notes)

6.d In the case the angle of internal friction is zero, there is no longer any frictional strength that is dependent on the normal stress at the base of the landslide as a whole or per slice. This means that the assumptions on the point of application and the direction of the inter-slice forces and the normal force are no longer necessary and the problem is no longer mechanically over-determined. Hence, the safety factors for force equilibrium and moment equilibrium are equal, hence the solution is said to be *exact*. (lecture notes)

6.e The c_u analysis represents the short-term stability, when part of the loads is carried by the pore water and the strength is independent of the normal stress (for example quick loading during construction or earthquakes). (lecture notes)