Quiz Questions—Week 3

Answer Key (10 pts per question)

1. *Suppose you wished to study the effects of urbanization/ industrialization on stress experienced by a forest ecosystem over the past 100 years. Explain how stable carbon isotope analysis might help you do this. Outline the processes within the plant/atmosphere that permit stable carbon isotope analysis to work and explain what results you would expect during stressed and unstressed times.*

Stable carbon isotope analysis involves the differential uptake of ^{12}C and ^{13}C by plants through the process of photosynthesis. The plants that we would study in a forest are the trees since their tree rings provide a time sequence of carbon fixed throughout the tree's life. Forest trees are C_3 plants and when C_3 plants are not stressed, they preferentially accumulate ^{12}C over ^{13}C. This is due to two processes—the atmospheric process is that $^{13}CO_2$ diffuses more slowly than $^{12}CO_2$, so less $^{13}CO_2$ enters the plant leaves through the stomates. The plant process that discriminates between the two isotopes is RubisCO—the main photosynthetic enzyme—which prefers $^{12}CO_2$. The combination of these two processes results in plant tissue that is depleted in ^{13}C. However, when plants are stressed, they close their stomates and will use a higher percentage of the $^{13}CO_2$ within the leaves. This results in plant biomass that is less depleted in ^{13}C than usual.

So to look at the stress experienced by a forest, I'd select two forest sites—one that is near an urban/industrial site and one that is as similar as possible without the proximity to urban/industrial sites (the control). I'd take wood cores from the trees and look at the ^{13}C concentration in the wood rings. I would expect that in the stressed site, the ^{13}C concentration in the wood would be higher (less depleted) during times of stress and that during unstressed times, the ^{13}C concentration would be the same as the control forest. By comparing this to the non-industrial/urban site, I may be able to discern the impacts of urbanization and industrialization on the forest.

In order to receive full credit, you need to include the two mechanisms that result in depletion of ^{13}C and explain the expected results clearly. It would be possible to do this without a control site, by comparing the annual rings to one another, but then the stress-causing process would not be as clear.

2. *How does an intact forest canopy affect soil moisture content before, during, and after a rain event? Compare/contrast with an area where the forest has been removed (clear cut). What process(es) have been affected? How do they differ between the intact forest and the clear cut.*

Intact forest canopies intercept a great of the precipitation during a rainfall event. This intercepted precipitation can be evaporated back into the atmosphere (10 to 50%), absorbed by the leaves, drip from the leaves (throughfall) or run down the stems to the ground. The canopy decreases the impact of the rain on the soil surface and slows the delivery of rainfall to the surface. This, combined with the greater porosity due to plant roots, results in a higher percentage of water that makes it to the forest floor entering the soil. Stem flow also penetrates the soil profile effectively through root channels. In intact forests, overland flow is very rare.

In a clear cut, there is no canopy to intercept the rain, hence a much higher percentage of the rain reaches the soil surface. Due to this increased rain volume at the surface and possibly a decrease in porosity from the loss of plants, more of the water ends up as overland flow. There could be more, less or the same amount of water entering the soil, depending on soil characteristics. However, without living plants to remove the water through transpiration, the soil can be saturated, which can lead to landslides.

The processes that are missing in the clearcut are: interception, throughfall, stemflow, percolation and transpiration. Comparing soil moisture under an intact canopy, it is likely that it doesn't vary quite as much as in a clearcut. Prior to a rain, the canopy will shade the soil, decreasing evaporation directly from the soil, but transpiration will be pulling water from the soil. During a rain, less of the rain will reach the forest floor, so soil moisture will increase more slowly than in soil in a clearcut. Following the rain, the soil moisture will then slowly decline due to evapotranspiration. In the clearcut, soil moisture will depend a great deal on the characteristics of the soil and how well drained it is. In general, this soil will experience more extreme shifts in soil moisture, being drier before a rain, wetter during and immediately after the rain, and then drier once again. However, it is easy to imagine exceptions to this pattern, with high clay soils, say on the north side of a hill when they don't get direct solar energy, remaining generally moister than soils under a canopy.

Points 5 for identification and explanation of processes, 5 for comparison.