BIOL 5490, Ecosystem Ecology, Fall 2017, Exam 1

NAME _____

This exam has 5 pages, consisting of 16 questions. Make sure you have all the pages.

Answer all questions. Be concise – the right answer is what's important, not a lot of words. This is a closed-book exam to be worked individually, and no cell phones or calculators are permitted.

1) List two aspects of climate that are important controls on plant productivity. (4 pts)

precipitation, temperature, and radiation (sunshine) are the most important - others could be related to microclimate (the above as modified by aspect or slope angle or shading), or ocean surface currents (e.g., the UK is warmer due to Gulf Stream), or many other possibilities

2) Suppose the midday balance of shortwave and longwave radiative fluxes in a wetland is positive, meaning that wetland is gaining electromagnetic energy. What are the possible fates for that energy? (5 pts)

This is simply the energy balance equation. Net radiation (R_{net}) is positive, and that must be balanced by some combination of the fluxes of sensible (H) and latent heat (LE), conductive heat to ground (G), storage (ΔS), and photosynthesis (P, which is trivial compared to the others but very important for living things).

$R_{net} = H + LE + G + \Delta S + P$

3) What key soil physical property influences plant water potential and thus water availability to plants (3 pts), and <u>why</u>? (3 pts)

Soil texture (the combination of mineral-derived particles of different size classes, sand/silt/clay), because it influences the size and surface area of soil particles, the matric potential of water adhered to those surfaces, and thus the plant water potential required to pull water from the soil.

4) What is the Bowen ratio and how might it differ between a semiarid shrubland near Moab and the aspen forests of the Uinta mountains? (4 pts)

The Bowen is the ratio of sensible to latent heat flux. A semiarid shrubland will have a much higher Bowen ratio than an aspen forest because the aspen forest has much higher transpiration rate.

5) Define the following terms. (12 pts)

net radiation the balance between inputs and outputs of shortwave and longwave radiation

potential evapotranspiration the amount of ET that would occur if water given unlimited water (depends on net radiation, air temperature, and humidity)

permanent wilting point the threshold water potential at which the water adhered to soil particles (matric surfaces) can no longer be removed by root uptake

stomatal conductance the size of the pores in the leaves at a given time that allow water to exit the leaves (formally this is quantified as the ratio of the water vapor flux to the water potential gradient from leaf to atmosphere)

longwave radiation radiation associated with emission at temperature in the range of Earth's surface (L_{out} in our surface energy balance diagram) or atmosphere (L_{in}) - formally, this is electromagnetic radiation with wavelengths in the range 4-30 microns, although we did not focus on the particular wavelengths

parent material rocks that undergo weathering that are the starting point for soil development (local bedrock at a site)

6) For each of the state factors, provide an example of how each could affect transpiration of shrubs in the intermountain west. (12 pts)

The state factors are fixed, but the examples could vary widely. Here are a few:

climate – amount of water available in soil
topography – more soil water available on north facing slopes (in N hemisphere)
time – forest structure changes during succession
parent material – available nutrients to support plant activity
potential biota – do competing species alter the light environment?
humans – bulldozers and chainsaws definitely alter tree transpiration

7) What fundamental physical principle (law) is described by the ecosystem energy balance equation? (3 pts)

conservation of energy

8) List five independent lines of evidence that Earth's climate is changing. (10 pts)

air temperature increase
sea temperature increase
change in frequency of extreme events such as heat waves
glacier retreat
sea level rise
sea ice loss
ocean acidification
habitat shifts of marine and terrestrial species
etc.

9) How does an ecosystem pool differ from an ecosystem flux? (4 pts)

A pool (or stock) is the amount of energy or matter contained in an ecosystem compartment (e.g., amount of carbon in soil organic matter of a forest). A flux is the transfer of energy or materials from one pool to another (e.g., amount of carbon fixed by photosynthesis, which transfers it from the atmospheric CO_2 pool to the organic plant sugar pool).

10) In the context of the global carbon cycle, provide one example for each: ecosystem pool and ecosystem flux. (4 pts)

ecosystem pool:

CO_2 in atmosphere, dissolved inorganic C (DIC) in ocean, C in plants or soils

ecosystem flux:

fluxes: gross (or net) photosynthesis, respiration, fossil fuel combustion, ocean-atmosphere exchange

11) Explain in detail how the greenhouse effect influences the surface temperature of Earth, including how this natural process is changing. (10 pts)

Shortwave radiation penetrates the atmosphere and is absorbed by Earth's surface. This leads to energy storage in Earth's crust. Electromagnetic radiation from Earth's surface is a function of the surface temperature, and is primarily longwave radiation. Longwave radiation is absorbed by greenhouse gases (GG) in the atmosphere, and also radiated by those molecules back to Earth's surface. This allows the surface temperature of the planet to be much higher than it would be without those gases in the atmosphere. This is changing because additional GG in the atmosphere produced by human activities have increased the longwave radiation back to the surface.

12) What is meant by the term leaf area index, and how might it differ between a Sonoran desert shrubland and a redwood forest on the California coast? (3 pts)

Leaf area index (LAI) is simply total leaf area per unit ground area, and a redwood forest has much higher LAI than a desert shrubland.

13) Methane and carbon dioxide are both greenhouse gases that are produced by metabolism of living things. What physical property makes them greenhouse gases? (5 pts)

A greenhouse gas is defined by strong absorption of infrared (longwave) radiation.

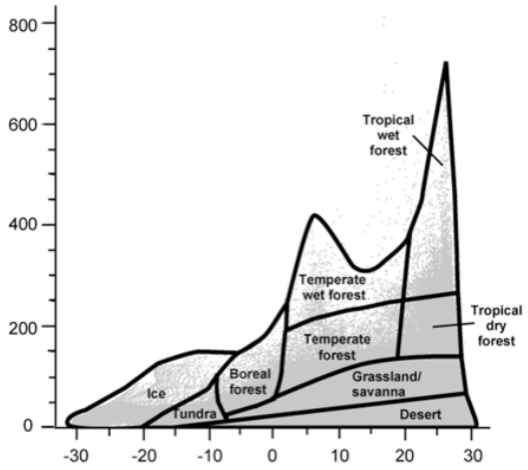
14) How much metabolic energy is required for plants to move water from the soil to the leaves (3 pts), and explain why. (4 pts)

The answer is very little energy, although none is acceptable based on what we discussed in class. Transpiration is not dependent on metabolic energy, rather the gradient of water potential from the soil to the atmosphere. The "dryness" of the air provides the energy for evaporation at the leaf intercellular surfaces. In reality, some metabolic energy is required to provide osmotic potential to open the stomata, and for regulation of hydraulic conductance in the xylem, but these are very small amounts of C-derived energy.

15) Explain why we have seasons (summer, fall, etc.). (5 pts)

The Earth rotates on a tilted axis, and that rotating sphere orbits the sun. The combination means that a particular hemisphere is tilted toward the sun during its summer, and away from the sun during its winter. The vernal and autumnal equinoxes (equal length of day and night) occur at the midpoints of these transitions.

16) The plot below shows how climate affects biome type. What variables are depicted on the axes? (6 pts) Extra credit - what are the units for those variables? (2 pts).



x = annual mean air temperature (°C), y = total annual precipitation (cm yr^{-1})

full credit given for just "temperature" and "precipitation" as long as you get the correct axis