Plant Ecology, Final Exam
Due: December 16, 2011 (before 12:30 PM)

Name ________________________________
Student ID ____________________________

Answer all questions fully and directly, but please restrict your responses to the spaces provided. Point totals for each question are given in parentheses.

Please do not consult with other students regarding the content of this examination.

Please submit this examination in electronic form (PDF or WORD document) as an e-mail attachment to Mark (mark.blonquist@utah.edu) or Suzy (suzy.khachaturyan@gmail.com).

For each question true/false question below, answer true or false, and if false, change the statement so that it is true.

(2) _F__ 1a. Soils represent the largest global carbon pool in terms of magnitude.
Sediments and rocks represent the largest global carbon pool in terms of magnitude.

(2) _F__ 1b. In C_4 plants, concentrating CO_2 at the site of PEPC minimizes photorespiration.
Concentrating CO_2 at the site of Rubisco minimizes photorespiration.

(2) _F__ 1c. Increased Net Ecosystem Production (NEP), observed at sites in the eastern U.S., is consistent with shorter growing seasons and increasing Total Ecosystem Respiration (TER).
Longer growing seasons and decreasing TER would be observed with increasing NEP.

(2) _F__ 1d. Fossil fuel emissions are higher in magnitude than gross uptake by oceans and land ecosystems.
Fossil fuel emissions are lower in magnitude, by approximately 20 times.
Fossil fuel emissions are higher in magnitude than net uptake by oceans and land.

(2) _F__ 1e. On average, glaciers around the world have remained at a relatively constant mass over the past 40 years.
Glaciers in most places around the world are losing mass.
The exceptions are glaciers in Europe and the Andes.

(2) _F__ 1f. Cheatgrass, Tamarisk, Cottonwood, and Russian olive are all examples of invasive riparian plant species.
Cheatgrass is not a riparian species. Cottonwood is not invasive in Utah.

For the next section of the test (questions 2a-2m), please restrict your answer to no more than 3-5 lines of text per question (we will not read beyond the 5th line of your answer). You should be able to convince us of your answer within 3-5 lines of text.

Certain plant and environmental characteristics fit together while some combinations are never observed in nature. Below, there are multiple sets of plant and/or environmental characteristics.

For each set of characteristics, decide whether or not they would be expected to be found together. Answer **yes** or **no**.

If **no**, explain why not.

If **yes**, list a plant type and/or ecosystem/biome that the characteristics may represent.

Each question is worth **four** points: **one** point for yes or no and **three** points for the remainder of the answer.

(4) 2a. Epiphyte
CAM photosynthesis
Low water use efficiency
NO. Epiphytes often have the CAM photosynthetic pathway, but CAM plants have a high water use efficiency because stomata are opened at night, to minimize water loss during CO_2 uptake.

(4) 2b. High leaf nitrogen content
High photosynthetic capacity
Annual plant
YES. Desert species that have short lifespans, those that sprout and complete their life cycle in a few weeks/months when water is available in the desert. Most crop species.

(4) 2c. Leaf temperature less than air temperature
Low leaf stomatal conductance to water vapor
Low leaf water potential
NO. Low leaf water potential is indicative of water stress, and would likely lead to stomatal closure and low stomatal conductance. However, leaf temperature would likely be greater than air temperature under this condition, because evaporative cooling of leaves is reduced.

(4) 2d. Blacktop surfaces
Latent heat flux from urban forest
Increased urban heat island effect
NO. Blacktop surfaces are consistent with an increased urban heat island effect, but latent heat flux from an urban forest is a cooling process and would decrease the urban heat island effect.

(4) 2e. P > PET
Phanerophyte life form
Evergreen leaves
YES. Temperature evergreen forest/boreal forest, or any evergreen forest species.

(4) 2f. Enzymatic oxygenase activity
Enzymatic carboxylase activity
PEP carboxylase
NO. Enzymatic carboxylase and oxygenase activity are associated with Rubisco, not PEP carboxylase. PEP carboxylase does not have oxygenase activity.

(4) 2g. High N allocation to plant defense
High photosynthesis rate
Long life span of leaves
NO. Leaves with a long life span require high nitrogen allocation to defenses, but this means there is less nitrogen that can be allocated to the photosynthetic machinery (particularly Rubisco) required to support high photosynthesis rates.

(4) 2h. Seasonal CO_2 patterns
Plant photosynthetic activity
Terrestrial ecosystems are wintertime carbon sinks
NO. Plant photosynthetic activity is one of the factors contributing to seasonal CO_2 patterns. However, terrestrial ecosystems are typically wintertime carbon sources, another factor contributing to seasonal CO_2 patterns.

(4) 2i. Atmospheric CO_2 increasing
Diminished Greenhouse Effect
Earth's current energy balance: energy in > energy out
NO. Currently, increasing atmospheric CO_2 is enhancing, not diminishing, the Greenhouse Effect, thereby causing an energy imbalance (energy in > energy out) for Earth.

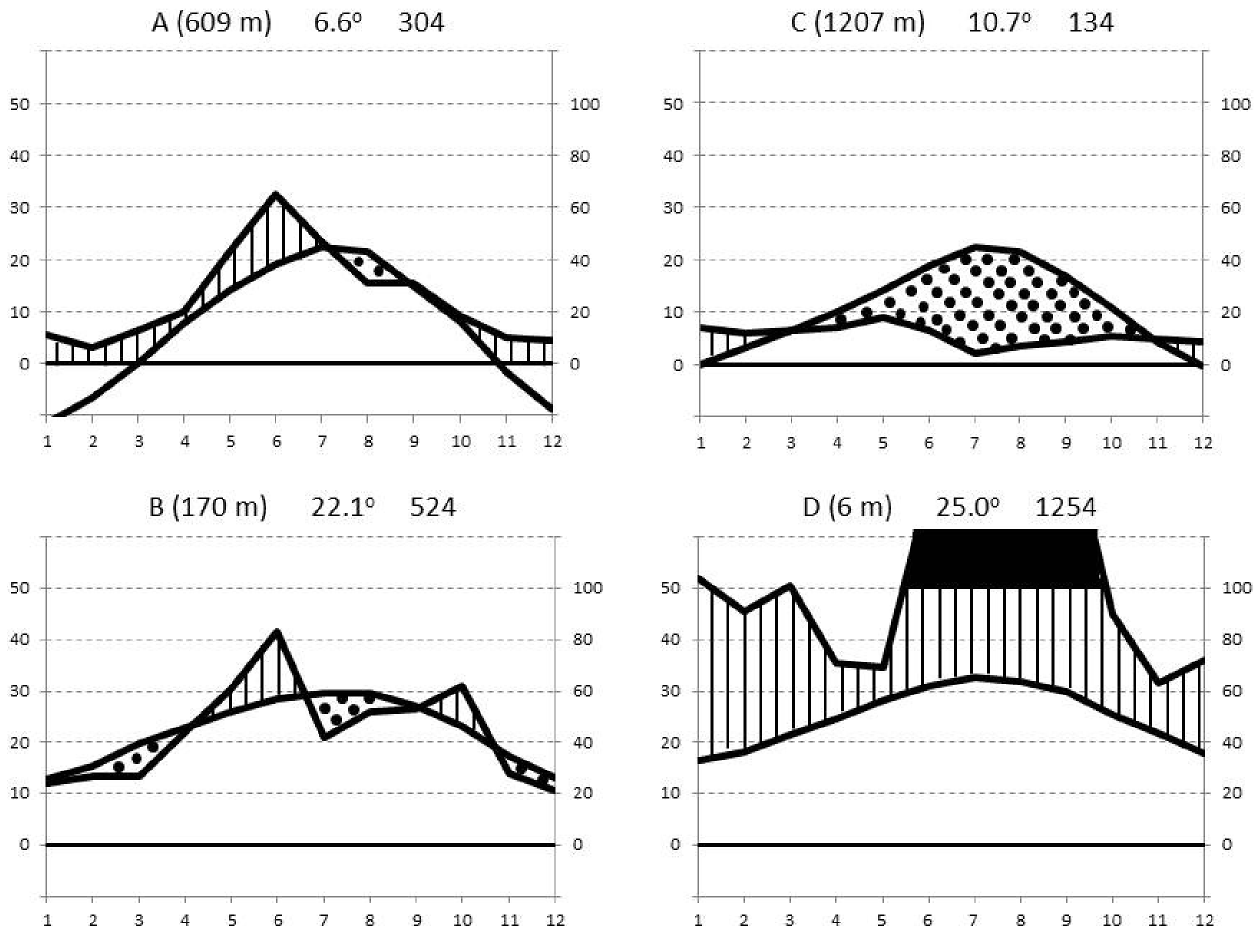
(4) 2j. Diaheliotropic leaf orientation
Maximum photosynthesis rate
Low soil water content
NO. Maximum photosynthesis rates are usually associated with diaheliotropic leaf orientations because leaf area is positioned perpendicular to direct rays from the sun, allowing maximal capture of photons. However, this usually occurs when water is readily available, when soil water content is high.

(4) 2k. High incident solar radiation levels
Northern hemisphere
North-facing slopes
NO. High incident solar radiation levels in the Northern hemisphere occur on south-facing slopes. North-facing slopes are directed away from the sun, and are often shaded, with low incident solar radiation.

(4) 2l. $P > PET$
Unpredictable growing season associated with drought
Therophyte life form
NO. Therophyte life forms, or annuals, are very often associated with unpredictable growing season lengths caused by drought, but this occurs in desert ecosystems where $P < PET$.

(4) 2m. Leaf carbon isotope ratio of -14 ‰
Malic acid storage in vacuole
C_4 photosynthesis
NO. C_4 plants usually have a leaf carbon isotope ratio near -14 ‰, but C_4 plants do not store malic acid in vacuoles. This is characteristic of CAM plants.

The following climate diagrams are from four different locations in the United States.



Justify your answers to the following questions (3a-3i) based on the data presented in the climate diagrams and the advantages/disadvantages of the different photosynthetic pathways. Unless stated otherwise, assume atmospheric CO_2 is at the current concentration.

Each question is worth **four** points: **one** point for the correct photosynthetic pathway and **three** points for the remainder of the answer.

(4) 3a. Which photosynthetic pathway most likely dominates the ecosystem found at location A?
At the current atmospheric CO_2 level, approximately 390 ppm (this is the case for questions 3a-3g), C_3 plants likely dominate this ecosystem because monthly mean temperatures during the middle of the growing season are in the low 20s °C, and near 10 °C at the beginning and end of the growing season, likely too cool for C_4 plants to be dominant. Also, precipitation approximately equals potential evapotranspiration (P ≈ PET) year round, thus it is likely wet enough that CAM plants are not dominant.
(4) 3b. Which photosynthetic pathway most likely dominates the ecosystem found at location B?
C_4 plants likely dominate this ecosystem because monthly mean temperatures during the middle of the growing season are in the upper 20s °C, and near 30 °C, in a range that favors C_4 plants over C_3 plants. Also, P ≈ PET year round, thus it is likely wet enough that CAM plants are not dominant.

(4) 3c. Which photosynthetic pathway most likely dominates the ecosystem found at location C?
CAM plants likely dominate this ecosystem because P < PET for most the year, with P well below PET during the middle of the growing season, indicating water may be very limiting and water conserving mechanism of the CAM pathway provides a major advantage.

(4) 3d. Which photosynthetic pathway most likely dominates the ecosystem found at location D?
C_3 plants likely dominate this ecosystem because C_3 plants typically dominate forest ecosystems, and this ecosystem is very likely a forest, as P > PET year round. Even though temperatures during the middle of the growing season are favorable for C_4 plants, C_3 plants are much better competitors for light in forest ecosystems. CAM is likely not dominant because water is readily available.

(4) 3e. Which photosynthetic pathway is likely least abundant at location C?
C_4 plants are likely least abundant in this ecosystem because monthly mean temperatures during the middle of the growing season are in the lower 20s ^{o}C, and near 10 ^{o}C at the beginning and end of the growing season, below the temperature range where C_4 plants are favored over C_3 plants.

(4) 3f. In addition to the dominant photosynthetic pathway, which other photosynthetic pathway could also likely be found at location D?
CAM plants would likely be found in this ecosystem, in addition to C_3 plants, because many epiphytes are CAM plants. Epiphytes do not have extensive root systems in the soil because they are growing on other plants, often on trunks and branches well above the ground. Even though there is plenty of available water, epiphytes do not have nearly as much direct access to it and often conserve water via the CAM pathway.

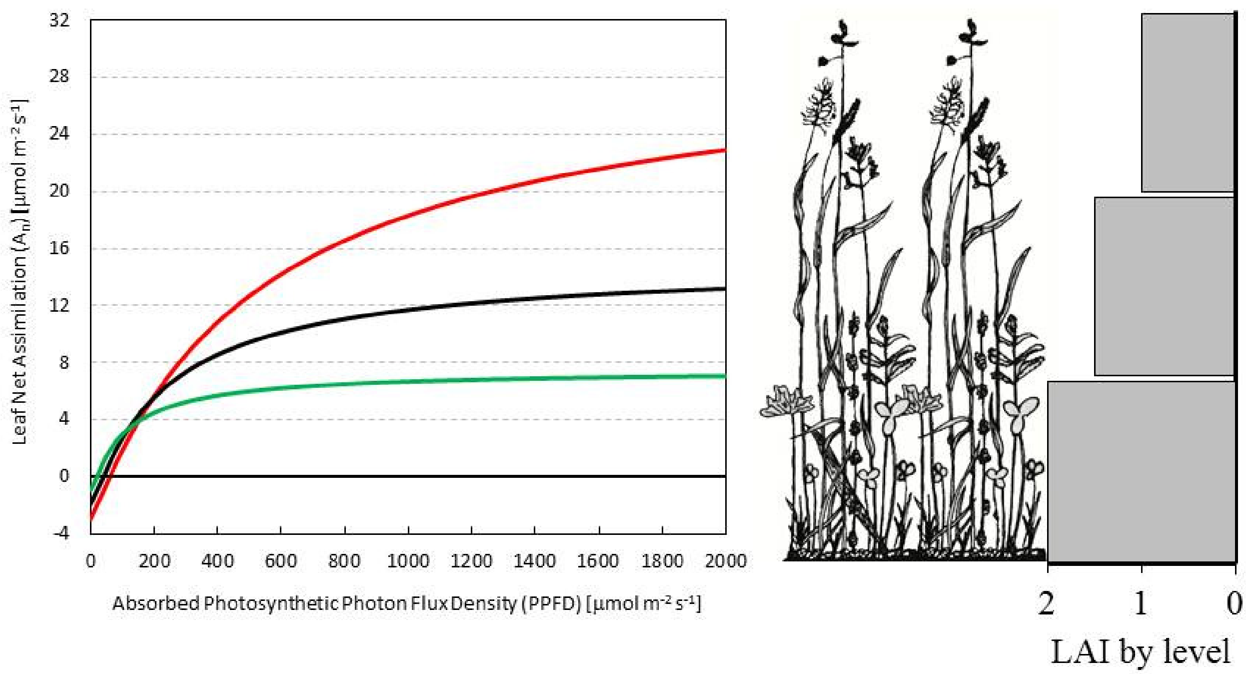
(4) 3g. Which photosynthetic pathway would likely grow best if location D was converted to agricultural land?
C_4 plants would likely grow best at this location if the forest was cleared for agriculture because monthly mean temperatures during the middle of the growing season are in the upper 20s ^{o}C and lower 30s ^{o}C, in a range that favors C_4 plants over C_3 plants. Just by way of information, the major cultivated C_4 plants are maize, millet, sugarcane, and sorghum.

(4) 3h. Which photosynthetic pathway would likely dominate location A if atmospheric CO_2 was at the CO_2 concentration experienced 350,000 years ago (assume temperature and precip do not change)?
C_4 plants would likely dominate this ecosystem because the atmospheric CO_2 level 350,000 years ago was approximately 200 ppm. Thus, monthly mean temperatures during the middle of the growing season, in the upper 20s ^{o}C, are now in a range that favors C_4 plants over C_3 plants. Also, P ≈ PET year round, indicating it is likely wet enough that CAM plants would not be dominant.

(4) 3i. Which photosynthetic pathway would likely dominate location B if future atmospheric CO_2 increases to 1.5 times the current CO_2 concentration (assume temperature and precip do not change)?
C_3 plants would likely dominate this ecosystem because the atmospheric CO_2 level at 1.5 times the current level is approximately 600 ppm. Thus, monthly mean temperatures during the middle of the growing season, in the upper 20s ^{o}C and near 30 ^{o}C, are now in a range that favors C_3 plants over C_4 plants. Also, P ≈ PET year round, indicating it is likely wet enough that CAM plants would not be dominant.

Optional Bonus Questions

The following light response curves are for leaves in a grass canopy. The leaf area distribution shows the approximate leaf area index (LAI) for three leaf layers, where the distinction between layers was based on the average photosynthetic photon flux density (PPFD) incident on the leaves in each layer.



(6) 4a. Calculate canopy net assimilation (A_n) from the leaf net assimilation responses to light. Assume PPFD at each level in the canopy is calculated as $I = I_0e^{-KF}$, where F is LAI, the extinction coefficient K = 0.5, PPFD absorptivity for leaves = 0.85, and PPFD incident at the top of the canopy = 2000 $\mu mol\ m^{-2}\ s^{-1}$. Show your calculations.

Top layer: Absorbed PPFD = 0.85 * (2000 $\mu mol\ m^{-2}\ s^{-1}$ * $e^{-0.5 * 0.5}$) = 1324 $\mu mol\ m^{-2}\ s^{-1}$.
From the graph, leaf A_n at 1324 $\mu mol\ m^{-2}\ s^{-1}$ = 20 $\mu mol\ m^{-2}\ s^{-1}$ (approximately).
A_n for layer = layer LAI * leaf A_n = 1 $m^2\ m^{-2}$ * 20 $\mu mol\ m^{-2}\ s^{-1}$ = 20 $\mu mol\ m^{-2}\ s^{-1}$.

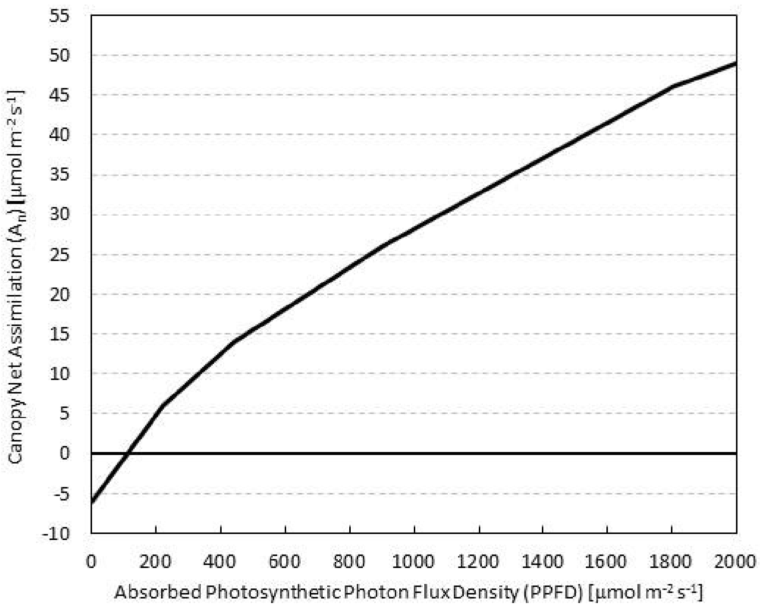
Middle layer: Absorbed PPFD = 0.85 * (2000 $\mu mol\ m^{-2}\ s^{-1}$ * $e^{-0.5 * 1.75}$) = 709 $\mu mol\ m^{-2}\ s^{-1}$.
From the graph, leaf A_n at 709 $\mu mol\ m^{-2}\ s^{-1}$ = 11 $\mu mol\ m^{-2}\ s^{-1}$ (approximately).
A_n for layer = layer LAI * leaf A_n = 1.5 $m^2\ m^{-2}$ * 11 $\mu mol\ m^{-2}\ s^{-1}$ = 16.5 $\mu mol\ m^{-2}\ s^{-1}$.

Bottom layer: Absorbed PPFD = 0.85 * (2000 $\mu mol\ m^{-2}\ s^{-1}$ * $e^{-0.5 * 3.5}$) = 295 $\mu mol\ m^{-2}\ s^{-1}$.
From the graph, leaf A_n at 295 $\mu mol\ m^{-2}\ s^{-1}$ = 5 $\mu mol\ m^{-2}\ s^{-1}$ (approximately).
A_n for layer = layer LAI * leaf A_n = 2 $m^2\ m^{-2}$ * 5 $\mu mol\ m^{-2}\ s^{-1}$ = 10 $\mu mol\ m^{-2}\ s^{-1}$.

Canopy A_n = sum of A_n from each layer = 20 + 16.5 + 10 = 46.5 $\mu mol\ m^{-2}\ s^{-1}$.

Note that the LAI values used in the light attenuation equation for each layer represent an approximation of total leaf area above a point midway through the layer. In other words 0.5 $m^2\ m^{-2}$ is halfway through top layer, 1.75 $m^2\ m^{-2}$ is halfway through the middle layer (total top layer + half of middle layer), and 3.5 $m^2\ m^{-2}$ is halfway through the bottom layer (total top layer + total middle layer + half of bottom layer).

The following light response curve is for the entire grass canopy.



(2) 4b. Calculate canopy net assimilation (A_n) from the canopy net assimilation response to light, and compare this value of canopy A_n to the one calculated in 4a. Assume absorptivity for the canopy = 0.90, and PPFD incident at the top of the canopy = 2000 µmol m^{-2} s^{-1}. Show your calculations.
PPFD absorbed by canopy = absorptivity * incident PPFD = 0.9 * 2000 µmol m^{-2} s^{-1} = 1800 µmol m^{-2} s^{-1}.
Canopy net assimilation (A_n) is read from the graph at an absorbed PPFD of 1800 µmol m^{-2} s^{-1}, thus A_n = 46 µmol m^{-2} s^{-1} (approximately).

From 4a, A_n = 46.5 µmol m^{-2} s^{-1}, thus the bottom-up and top-down calculations of canopy An provide very similar estimates of canopy A_n.

(2) 4c. Based on the answer from part b and the canopy light response curve, what is the approximate light use efficiency of this canopy? Show your calculations.
LUE = carbon fixed / photosynthetically active radiation absorbed (approximation of the slope of the line). Thus, LUE = A_n / absorbed PPFD = 46 µmol m^{-2} s^{-1} / 1800 µmol m^{-2} s^{-1} = 0.026 mol C fixed / mol PPFD absorbed.