GE/BI525 – Final Take Home Exam   Dec., 2008
Hardcopies preferred in my departmental mailbox. Please complete work by Thursday midnight (e.g. late Thursday night deadline). However, you can get the exam to me Friday morning if you wish.
Open Book – but please work alone.

        You have been awarded a NASA grant to design a sustainable human colony on the moon. The project calls for a fully sustainable pod for 100 humans. The key needs for humans are food (reduced carbon), water, and oxygen.

Assume the following:
- Solar energy is saturating for photosynthesis *at the top of the plant canopy* (say, 1200 umol m-2 s-1) and can also be used to create favorable temperatures for plant growth in the pod.
- The pod is a closed system with respect to mass transfers into or out of it.
- Each plant takes up 1 m2 of area and has 3 m2 of leaf area.
- The beer-lambert law is valid for describing light attenuation in the plant canopy, with an extinction coefficient of 0.5. ($I = I_o \exp^{-k\,LAI}$) (look this law up if you are not familiar with it). Assume a nominal light response curve to obtain a vertical profile of photosynthesis, and assume a constant *photosynthetic* WUE throughout the canopy so that you can estimate transpiration as well throughout the canopy.
- Each human requires on average about 10 MJ of carbohydrate energy per day, which must be supplied solely from plants.
- Each human requires 1 kg of oxygen per day to breath. (O_2 = 32 g/mol)
- Each human requires 25 kg of water per day, which must be supplied from plant transpiration that is condensed off the walls of the pod. Assume no soil evaporation, and that humans return all water back to the plants through waste.
- 1% of net plant photosynthesis is converted into glucose that can be eaten by humans, and humans process this glucose to usable metabolic energy with 10% efficiency. Recall from lecture notes (handouts, not on-line) that the free energy of glucose is approximately 3000 kJ/mol.
- Whole plant respiration is a fixed fraction of photosynthesis.
- A nitrogen requirement of 300 kg/ha for plants to supply enough Nitrogen for human nutrition, and that this Nitrogen cycles back to plants through human waste.
- Neglect all other human food needs like proteins, fats, vitamins.
- 1 generic species of plant can meet all of the above requirements.
- Changed gravity on the moon is not a relevant consideration.
- Human and plant respiration allows adequate, sustainable atmospheric CO2 for photosynthesis
- Whatever else you need or want to – but state assumptions clearly.

Use reasonable order of magnitude estimates for photosynthetic, respiration, and transpiration rates to compute the following (show your work, assumptions, back of the envelope calculations): Keep in mind that you should answer the following questions in

the order that makes most logical sense to you – that is, it may or may not be useful to answer the questions in the order given.

1. Draw a whole system box diagram showing flows of energy into, out of, and within this plant-human system, and material flows within the system. Make sure to diagram incoming and outgoing energy fluxes and their type (although you don't need to put numbers on them).
2. How much daily biomass production is needed per plant for food sustainability (kg/plant/day)?
3. How much daily net photosynthesis is needed for meeting human oxygen needs?
4. Assuming a 12 hr daylength (even though its actually more like 14 earth days – but doesn't matter here) what average photosynthetic rate is needed on a per unit leaf area basis? Is this a reasonable value?
5. How much transpiration is needed (kg/plant/day) for sustainability?
6. Assuming a 12 hr daylength, what average transpiration rate per unit leaf area is needed? Is this a reasonable value based on what you know of real plants?
7. If the leaf-to-air vapor pressure *difference* were 1.5 kPa, what would the average leaf conductance be? Does this fall within the range of any value you can find in the text for either total leaf conductance or leaf stomatal conductance?
8. What is the water use efficiency, on a per ground area basis? How does this compare with values given in the text (e.g., p. 55?)
9. How many plants are needed – for (a) food, (b) water, (c) oxygen?
10. How big an area for plants is needed for (a) food, (b) water, (c) oxygen?
11. How much total mass of nitrogen is needed?
12. Given the human water, carbohydrate, and oxygen requirements, which requirement dominates the estimate of how many plants and how big an area is needed? In other words, which requirement that is met will lead to a surplus in the other requirements?