# Homework 3

**(1)** The mass of humanity. Estimate the mass of the current human population in metric tons, then express your answer as a fraction of the total mass of all living organisms worldwide (use units of parts per million, as is often done with trace contaminants!)

**(2)** Leaves and trees. Here's a question you might ask a small child, or vice versa: Are there more trees in the world, or leaves on a big tree? Now try to answer it! Hint: Read the problem, take a walk through some Monterey woods, and then make your estimates.

**(a)** About how many trees are there in the world, counting as a tree anything bigger than a seedling? Hint: Start with the area covered by forest (from lecture or the COW Appendix) and go on from there. (Why is forested area, rather than forest biomass, likely a better approach?)

**(b)** Go find a very big Monterey Pine tree (Pinus radiata, the common, beautiful deep green pine tree of the Monterey peninsula, with clusters of 3 long needles) and estimate the number of needles. Alternatively, you can find a large Eucalyptus tree (many to be found in the little parks in Pacific Grove, where Monarch butterflies come to visit).

**(3)** Land use change, ecosystem services, and biodiversity. Indonesia is the world's 4th most populous country ($230 \times 10^6$ people). It is comprised of 17,500 islands with a total land area of $1.92 \times 10^6$ km$^2$. In 1990, Indonesia's land area was 61% covered by primary forest, but by 2010 that figure had decreased to 49%.

**(a)** Approximately how much carbon has been lost from Indonesia's cleared forests since 1990? Use values from Cow Appendix XII-2, assuming a conversion from tropical forest to grassland.

**(b)** Much of Indonesia's forest that has been cleared has been converted into oil palm plantations. (Palm oil can be used for prepared foods in the place of partial hydrogenated vegetable oils that have trans fats.) These require 5 years to establish (assume no cost and no revenue) and then produce oil for 25 years with a net annual return of $800/ha. To discourage the clearing of forests that absorb climate-changing carbon dioxide, there is an international system of carbon credits and carbon markets. A carbon credit is a generic term for any tradable certificate or permit representing the right to emit one metric ton of carbon dioxide or the mass of another greenhouse gas with a carbon dioxide equivalent ($tCO_2e$) equivalent to one metric ton of carbon dioxide. Carbon trading is an application of an emissions trading approach. The goal is to allow market mechanisms to drive industrial and commercial processes in the direction of low emissions or less carbon intensive approaches than those used when there is no cost to emitting carbon dioxide and other GHGs into the atmosphere. One site on the Net was selling carbon credits for $13.12 per t (C) on 10/1/12. What would be the minimum price per metric ton of carbon that makes forest conservation more valuable than oil production? (Assume carbon payments are given annually over the same 30-year time frame; ignore interest rates.)

**(c)** Besides carbon storage, what other ecosystem services might have been provided more effectively by the primary forest than by palm plantations or grassland? Name two.

**(d)** Indonesia has extremely high levels of endemism (species that exist only there and nowhere else). About 40% of its 120,000 forest species are endemic. The number of species, S, can be calculated using the species-area relationship of $S = cA^z$, where c is a constant for the region, A is the habitat area, and z is the slope of the species area on a graph of log S vs. log A. For Indonesian forests, z = 0.33, c = 1333, and A = the current forest area in $km^2$, calculate the following:

(i) the number of species in Indonesia lost due to deforestation from 1990 to 2010;

(ii) how many of those species were endemic (and thus are now globally extinct);

(iii) the additional number of endemic species that will go extinct by 2030, assuming a continuation of Indonesia's current deforestation rate of 2.6% per year. (Note that this is an exponential decay.)

**(e)** Name two assumptions that were necessary for your calculations in part (d) that may not be true in real life.

**(4)** Solar energy, biomass energy, and land use. U.S. electricity production is currently about four trillion kWh per year. Estimate what percentage of U.S. land area would be required to supply this electricity if it came entirely from:

**(a)** Photovoltaic panels, which convert incoming solar radiation to electricity with an efficiency of ~10%. (You can use 250 $W/m^2$ for the average solar irradiance reaching the Earth.)

**(b)** Biomass in the form of sustainably harvested trees, converted to electricity in conventional steam power plants at an efficiency of 30%. "Sustainably harvested" means that only the annual increment of new tree biomass can be used, not liquidating the stock by cutting down forests and burning them. (You can use the NPP estimate of 0.56 $kg(C)/m^2y$ for temperate forests and the energy value for biomass of 16 MJ/kg(biomass) given in COW.)

**(5)** **Fossil fuels and $CO_2$ emissions.** Fossil fuels are hydrocarbons, meaning they contain primarily hydrogen and carbon in different ratios: $C_XH_Y$. The following is a typical reaction that takes place in the internal combustion engine.

$$2C_8H_{18}(g) + 25O_2(g) \rightarrow 16O_2(g) + 18H_2O(g)$$

**(a)** Super-simplified chemical formulae for coal, petroleum, and natural gas respectively are CH, $CH_2$, and $CH_4$. Write a balanced equation without physical states for the combustion of each fuel.

**(b)** Currently the world consumes roughly 4 billion metric tons of oil, 6 billion metric tons of coal, and 3 trillion $m^3$ of natural gas per year. Assume that 20% of the oil and 10% of the natural gas is used for purposes other than combustion (such as making plastic, fertilizer, etc.), and that 40% of the mass of the coal is inert ingredients (i.e. water, ash, and other stuff besides CH). Calculate the $CO_2$ emissions from the combustion of each fuel, and the total.

**(c)** At what rate does humanity consume fossil fuels each year, in Btu/y and TW? Assume the following energy contents:

oil = 40 MBtu/t

coal = 20 MBtu/t

natural gas = 35 MBtu/1000 $m^3$