Forests Through Time and Space W05
Workshop: Developing an Outline

One of the biggest challenges in your research project is developing some type of framework or outline to organize all of the information you have collected. For your research project, you have searched through the literature with a specific question in mind. However, it is not unusual to have to slightly modify your research question once you have gathered a number of articles, read all the abstracts, and have started reading the papers and taking notes. Organizing your ideas with an outline can be very helpful to create a logical framework and flow to your paper, as well as sorting the various facts you've uncovered into major points and supporting evidence.

Below is a list of various bits of information about global warming and carbon sequestration in forests. Your task is to organize them into a cohesive outline that has a clear organization. Construct your outline on a separate piece of paper and plug the numbers of the statements below into your outline in the appropriate places. Begin by reading through the various notes and facts and sorting the information into categories. Then construct an outline that follows a logical thought process and plug the information into the outline. There may be some information that you may choose not to include, and you will need to create categories.

Notes and Facts about global warming and carbon sequestration in forests

1. An increase in carbon (C) sequestration by forests due to the fertilization effect is not likely to happen, because of limiting factors, including soil nitrogen and air pollution
2. Ponderosa pine (*Pinus ponderosa*) grown at 700 ppm CO_2 for close to 2.5 years exhibited rates of net photosynthesis in current-year needles that were 49% greater than those of needles exposed to air containing 350 ppm CO_2 (Houpis et al., 1999).
3. Among natural vegetation land-cover types, the growing-season length for forests is strongly correlated with variation in mean annual land surface temperature.
4. Many forests will soon become a source of CO_2 because loss of soil C through temperature stimulation of soil respiration will override any CO_2 or temperature stimulation of plant growth.
5. Carbon dioxide is a potent greenhouse gas.
6. *F. crenata* forest distributions may retreat from some Japanese islands due to an increase in temperature.
7. Recent studies using both field measurements and satellite-derived-vegetation indices have demonstrated that global warming is influencing vegetation growth.
8. Soil respiration rates were not significantly different among six forest sites in Germany (site to site variation) and between the years within the same forest site (interannual variation).
9. Long-term C sequestration in forest soils is dependent on soil type and characteristics, and is therefore unlikely to increase as a result of rising atmospheric CO_2.
10. When broad-leaved trembling aspen (*Populus tremuloides*) were exposed to twice-ambient levels of atmospheric CO_2 for 2.5 years, Pregitzer et al. (2000) reported 17 and 65% increases in fine root biomass at low and high levels of soil nitrogen, respectively; while Zak et al. (2000) observed 16 and 38% CO_2-induced increases in total tree biomass when subjected to the same respective levels of soil nitrogen.
11. The largest carbon fluxes are those that link the atmospheric CO_2 to the land vegetation (primarily forests).
12. There is currently a vigorous debate about whether tropical forest ecosystems might be accelerating or slowing down the rate of atmospheric CO_2 accumulation, and thus global warming.
13. The biosphere (land and ocean) absorbs about half of the roughly 6 petagrams (Pg; 10^{15} grams) of C emitted annually from human activities (Schimel et al. 2001).
14. The release of carbon dioxide from fossil-fuel combustion and land-use changes has caused a significant perturbation in the natural cycling of carbon between land, atmosphere and oceans.
15. Concern exists that soil respiration will increase with global warming, thereby reducing the sink strength of forest ecosystems for carbon or making them sources.
16. Applying a biogeochemical model to forest stands in the western Cascade Mountains of the Pacific Northwest, McKane et al. (1997) suggest that soil N is a primary constraint on the ability of those forests to sequester C.
17. The terrestrial biosphere is currently thought to be a significant sink for atmospheric carbon (C).

18. As the CO_2 content of the air continues to rise, nearly all of earth's plants, including various forest ecosystems, will respond by increasing their photosynthetic rates and producing more biomass. These phenomena will allow long-lived perennial species characteristic of forest ecosystems to sequester large amounts of carbon within their wood for extended periods of time (Chambers et al., 1998).
19. A recent (2002) analysis concluded that rates of tropical deforestation and atmospheric carbon emissions during the 1990-1997 interval were lower than previously suggested.
20. As of the early 1990s, the temperate forests of the northern hemisphere have been thought to be a net sink of 0.6 to 0.7 Pg of C per year, based on forest inventories (Goodale et al. 2002).
21. There is general agreement among scientists that the climate system is changing as a result of increasing atmospheric concentrations of CO_2 and other greenhouse gases, the degree to which temperature and precipitation patterns will change is uncertain.
22. Geological tests indicate that for at least the past 300 Myr, there is a remarkably high temporal correlation between peaks of atmospheric CO_2, revealed by study of stomatal indices of fossil leaves of *Ginkgo, Lepidopteris, Tatarina* and *Rhachiphyllum*, and palaeotemperature maxima, revealed by oxygen isotopic composition of marine biogenic carbonate.
23. As a sink, forests are currently increasing through CO_2 fertilization of plant growth but will decline over the next few decades because of CO_2 saturation and soil nutrient constraints.
24. Increasing global temperatures will stress current forests, leading to increased disease and pest outbreaks.
25. Understanding the processes underlying soil N immobilization is essential if we are to predict the future course of the forest carbon sink.
26. While reforestation and afforestation can clearly increase C sequestration (Prentice et al. 2001), it is not certain that rising atmospheric CO_2 will increase sequestration in existing forests.
27. Tree trunks, large branches, and large roots, which remain on the tree for several decades or centuries, are the primary sites of C sequestration. As branches fall and trees die, decomposition releases CO_2 to the atmosphere (Harmon et al. 1990).
28. Burning fossil fuels and other human activities, including deforestation, release 6.9×10^{15} g C/yr into the atmosphere.
29. n a warming experiment in which heaters were suspended over a natural montane meadow for 12 years found that plants in the earlier melting plots generally had the most damage and were attacked by a larger number of species, which is consistent with predictions. However, although the overall trend was an increase in damage with warmer temperatures and earlier snowmelt, some pathogens and herbivores performed better in cooler or later melting plots.
30. Current assessments of climate-change effects on ecosystems use two key approaches: (1) empirical synthesis and modeling of species range shifts and life-cycle processes that coincide with recent evidence of climate warming, from which scenarios of ecosystem change are inferred; and (2) experiments examining plant-soil interactions under simulated climate warming.
31. Capturing CO_2 and storing it in underground geological reservoirs appears as the best environmentally acceptable option. It can be done with existing technology; however, substantial R&D is needed to improve available technology and to lower the cost.
32. Forest insects and pathogens are the most pervasive and important agents of disturbance in North American forests, affecting an area almost 50 times larger than fire and with an economic impact nearly five times as great. Research results indicate that all aspects of insect outbreak behavior will intensify as the climate warms.
33. Theoretically, elevated CO_2 will enhance photosynthesis and decrease the need for plants to open their stomates as widely as they do at lower CO_2 concentrations, allowing them to conserve water (Schäfer et al. 2002).
34. Atmospheric CO_2 concentrations over the past millennium have increased from a pre-industrial level of approximately 280 ppm in the atmosphere, CO_2 concentration to over 370 ppm in the year 2000. By the end of the 21st century – depending on future industrial trends – concentrations are projected to reach 540 to 970 ppm (Prentice et al. 2001).
35. At the ecosystem level, soil N availability can limit the CO_2 fertilization effect and rising atmospheric CO_2 can alter decomposition and N mineralization and fixation, thus changing N availability in the soil (McGuire et al. 1995).
36. Forest products have a carbon- storage half-life ranging from only 4 years for items made of paper to 65 years for building materials and furniture (Pussinen et al. 1997), times similar to those found in leaf litter and branch decomposition.
37. Carbon sequestration will continue to increase over the next century because rising temperature will stimulate the release of plant-available soil nitrogen (N) through increased soil decomposition