16. CLIMATE CHANGE AND CARBON SEQUESTRATION

Increased greenhouse gas (GHG) concentrations in the atmosphere have been linked to the increase in average temperatures observed over the last century. This trend raises the question of what the effects of climate change, particularly global warming, might be on the ecosystem of JDSF. It also raises the question of how mangement of the Forest might contribute to the amelioration of atmospheric carbon through biomass sequestration. These two questions are addressed in this section.

16.1 Climate Change

This historical review draws from Sawyer et al. (2000). Coast redwood is a species that has experienced significant climate change due to global climate changes and tectonic uplift or mountain building in the western United States over the last 3 to 5 million years. More recently (22,000 years ago to present) there have been periods characterized by varying precipitation with cooler and warmer conditions. “Cold temperatures during the late Glacial Maximum probably restricted the distribution of redwood to more southerly coastal regions and small, protected coastal areas within its current range,” (Sawyer et al. 2000, p. 20). Douglas-fir seems to have been more tolerant of a range of climatic conditions and has a much greater geographical range than redwood.

Redwood pollen analysis (Gardener et al. 1988) suggested that redwood responded rapidly to climate change and was more abundant before 5500 B.P. Before this time the interior of California and the Great Basin were warmer causing stronger pressure gradients. This gradient created stronger winds and ocean upwelling which in turn pushed fog more inland. There were wet summer conditions on the west coast up to 2 to 3 million years ago. Afterwards the jet stream moved to the north creating the Mediterranean conditions (hot, dry summers) we have now.

Fog drip is thought to be important to the growth and survival of coast redwood, other tree species and understory plants by providing moisture to their root systems during the summer drought period (Dawson 1996, Dawson 2005). However, at least on JDSF, fog drip does not appear to contribute significantly to stream flow. Keppeler (2004) investigated whether harvesting redwoods reduced water supply by eliminating the interception and delivery of fog water to the forest floor at the Caspar Creek watershed. Measurements of fog drip were made for two summers under mature redwood Douglas-fir forest canopy and in an open clearcut in the late 1990’s. Keppeler (2004) concluded that fog drip makes a highly variable but hydrologically insignificant contribution to groundwater and baseflow processes at Caspar Creek. Following timber harvest, streamflow increases due to reduced interception and transpiration were found to exceed diminishment due to the loss of fog drip.

The increase in global atmospheric carbon dioxide has been hypothesized to produce a “fertilization effect”. These studies were primarily from relatively small trees. A recent study where free air CO_2 was increased in mature deciduous forest trees (Korner et al.

2005) showed no biomass carbon increases after 4 years. At this time it is unknown if there will be a fertilization effect on trees found in North Coast ecosystems.

A case study analysis (Battles, et al. Draft in review) of climate change projection impacts on the Sierra mixed conifer shows a significant reduction in productivity due primarily to increases in projected temperatures. These scenarios would likely cause an increase in inland fog intrusion on the coast and thus create conditions more favorable to redwood and associated species. However, the difficulty in modeling the wind and ocean upwelling effects has prevented an accurate projection of climate for the California North Coast.

16.2 Carbon Sequestration

Increases in atmospheric carbon levels are attributed mainly to the burning of fossil fuels and to land use change (Skog and Nicholson 2000). Forests, wood and paper products currently in use, and wood and paper products in landfills constitute large pools of carbon. Micales and Skog (1997) estimated that no more than 30% of the carbon from paper and 3% of the carbon from wood are emitted from landfills in gaseous form, with the remainder staying in the landfills indefinitely.

Carbon may be stored in the above and below ground biomass of trees and other plants, and may be stored in wood products. Above ground storage may be quantified by bole taper equations and crown allometric functions. Below ground biomass, which is more difficult to measure and hence uncertain to quantify, is primarily from root systems rather than litter inputs.

The California Climate Action Registry was established by California statute as a non-profit voluntary registry for GHG emissions (http://www.climateregistry.org/). The Registry adopted rules to account for carbon emissions and reductions via forest conservation, improved management practices, and reforestation. The Chicago Climate Exchange (CCX) approved the Registry's protocols for tracking forest carbon. Credits certified by the Registry are now freely tradable on the exchange. The value of carbon is estimated to be at most about $2.00 per ton, without a cap and trade program in place. CDF is conducting a demonstration project at LaTour Demonstration State Forest (a predominantly white fir forest located in Shasta County) to evaluate the protocols and develop analysis tools for foresters for use if and when a cap and trade program is in place in the state.

The current protocols require that an organization's (CDF in this case) entire emissions and sequestration be calculated. Given the size of the Department and its heavy equipment and facilities (aircraft, engines, dozers, trucks, stations, camps, etc.), emissions are likely to substantially offset any sequestration credits. Current CDF emissions from equipment operations and facilities management are estimated to be 30,000 tons/year. Also, the amount of carbon that can be registered is a function of the difference between the proposed management and the baseline. According to the protocols, the baseline for timber management is defined by the minimums in the Forest Practice Rules.

By comparison to the California Registry price of about $2/ton, recent carbon prices on the European market have been typically in the range of $14-15 Euros per ton, or about $16-18. Markets for carbon are still in the early stages of development and are likely to change substantially over the next several years. Thus, current market prices may not be a good indicator of even near-term, let alone mid- or long-term prices.[1] Comparing current carbon prices to timber stumpage prices indicates that current markets value timber more as lumber than as sequestered carbon. Using European carbon market prices of $18/ton, a thousand board feet (MBF) of timber would be worth about $10 as sequestered carbon, as compared to current Douglas-fir timber prices of $280-350/MBF or redwood prices of $680-830/MBF in Mendocino County.

The CORRIM project (Lippke et al. 2004) compared the relative environmental impacts of using wood versus steel and concrete materials for home construction. GHG impacts were estimated to be 26% higher with steel and 31% higher with concrete when compared to wood.

Brown et al. (2004a) estimated the carbon benefits of an unevenaged management, group selection harvest regime as compared to an evenaged mangement, clearcut harvest regime on JDSF. They found that use of group selection (1.5-acre group size) instead of clearcuts (20 acres in size) resulted in an increase in carbon storage of 14-27 tons per hectare (5.7-10.9 tons/acre) over a 90-year rotation. The study did not look at other key timber management systems that are proposed in the DFMP, for example, single tree/cluster selection, variable retention, seed tree, and shelterwood (see Table III.1). The DMFP proposes to use clearcuts only for research purposes or where stands are very difficult to regenerate using unevenaged management silvicultural systems.

Brown et al. (2004b) assessed the relative carbon biomass storage potential of providing wider riparian buffer strips on JDSF. The study compared the effects of adding an additional 100-foot width to the standard Class I watercourse protection requirements of the Forest Practice Rules. The baseline scenario assumed that the additional buffer width would be clearcut harvested; the comparison scenario assumed that there would be no harvest. Starting stand ages of 30, 60, and 90 years were used. Over one 90-year rotation, carbon storage increased from 151 to 208 tons carbon per hectare (61.1 to 84.2 tons per acre) or 921 to 1,269 tons per one kilometer of buffer length (1,482 to 2,042 tons per mile). This clearcut versus no harvest scenario is of limited relevance to the proposed DFMP since the DFMP would severely limit the use of clearcutting.

Table VII.16.1 shows the estimated total net quantity of carbon that would be sequestered at the end of a 100-year period of operating JDSF under the various alternatives. This table is based on a simplified analysis that looks at the current standing timber inventory, the amount of timber harvested over the 100-year period, and

[1] For example, on November 14, 2005, prices surged to 23.45 Euros/ton.

the timber inventory at the end of the planning period. It uses a decay function for harvested timber to account for the fact that a certain amount of the carbon sequestered in timber products is released to the environment over time through burning and decay. Based on Skog and Nicholson (1998), a decay rate equivalent to an 80-year carbon half life is used.

Table VII.16.1 (column 7) shows that Alternative E would sequester the greatest net amount of carbon at the end of 100 years (2,300.5 thousand tons) and Alternative C1 would sequester the least amount (1,648.5 thousand tons).

16.3 Conclusion

Climate change, along with geological processes, has been shaping the range and genetic configuration of redwood and associated species for millions of years. Scientists have modeled what may be near term alterations in climate, but there is a large degree of uncertainty. **There is no significant environmental climate change impact related to management of JDSF that can be predicted given the current state of scientific knowledge.**

Three strategies could be employed, however, to address the uncertainty regarding climate change:

- Keep the Forest healthy to maximize resilience to perturbations in moisture, temperature and storm events.
- Monitor species abundance and health as part of a long-term monitoring strategy.
- Develop partnerships and fund research giving priority to information gaps such as below-ground carbon cycles, fog drip utilization by tree and understory plants, and climatic tolerances of species.

Research efforts at JDSF could build on the information from the LaTour carbon sequestration demonstration project. In particular, there is a need to integrate coastal growth models with carbon budget models and accounting systems. By providing an example and quantifying the costs, this research could facilitate having forest landowners sequester carbon throughout the redwood region if a cap and trade system should develop.

Table VIII.16.1. Comparison of EIR Alternatives for Total Net Carbon Sequestered at End of 100-Year Planning Period.

Alternative	(1) Current Standing Timber Inventory (MMBF)	(2) Above-Ground Carbon Stored in Current Standing Timber (M tons)	(3) Total Harvest Over 100-Yr. Planning Period (MMBF)	(4) Total Estimated Carbon Sequestered in Forest Products at End of 100-Yr. Planning Period (M tons)	(5) Standing Timber Inventory at end of 100-Yr. Planning Period (MMBF)	(6) Above-Ground Carbon Stored in Standing Timber at End of 100-Yr. Planning Period (M tons)	(7) Total Net Carbon Sequestered at End of 100-Yr. Planning Period (M tons) (columns 4+6-2)	(8) Net Carbon Dioxide Equivalent Sequestered at End of 100-Yr. Period (M tons) (column 7 X 3.666)
A	2,093.3	1,099.0	0	0	6,119.8	3,212.9	2,113.9	7,749.7
B	2,093.3	1,099.0	4,258.9	1,536.6	2,374.9	1,246.8	1,684.5	6,175.3
C1	2,093.3	1,099.0	3,789.4	1,369.8	2,624.2	1,377.7	1,648.5	6,043.6
C2	2,093.3	1,099.0	3,721.9	1,342.9	2,701.3	1,418.2	1,662.1	6,093.2
D	2,093.3	1,099.0	2,994.3	1,080.4	3,757.5	1,972.7	1,954.1	7,163.7
E	2,093.3	1,099.0	980.0	354.0	5,800.8	3,045.4	2,300.5	8,433.6
F	2,093.3	1,099.0	2,315.7	835.5	4,145.5	2,176.4	1,912.9	7,012.8