WP 7.01.07 Multiple Stressors on Ecosystems

State of the Knowledge

The importance of studying the effect of concurrent, multiple environmental stressors (elevated ozone, excess nitrogen deposition, drought, increased temperature) or enhancers (elevated CO_2 or nitrogen deposition) on forest ecosystems is increasingly highlighted (Bytnerowicz et al., 2007; Paoletti et al., 2007). Anthropogenically driven gradients in pollution exposure and deposition have been used historically to elucidate long term effects of concurrent stressors on forest ecosystems (overview in Arbaugh et al., 2003). Long term, chronic to acute (in the mid 1970s and 1980s) O_3 exposure increased mortality of sensitive species and altered forest stand composition (Miller et al., 1989). Recent studies of this pollution gradient demonstrated a link between high air pollution exposure, tree susceptibility to bark beetle, and higher tree mortality (Grulke et al., 2008).

Multi-factorial experiments (Karnosky and Pregitzer 2006) have produced novel results. For example, plant species, genotype, and specific growth conditions yielded conflicting responses to combined elevated CO_2 and O_3. Continued studies of the effects of singular stressors are still important in order to place older studies into the context of current studies. Carrying these multi-factorial studies out over time can yield additional insights. For example, under warm, dry conditions, bole growth of aspen was greater in elevated CO_2 treatments, but in cool, moist years, it was depressed (less radiation). In cool, moist conditions, bole growth was enhanced in elevated O_3 treatments, probably due to better antioxidant defense and less drought-induced oxidative stress (Fig. 2; Kubiske et al., 2007). These complex responses will likely have long term effects on the gene pool of tree populations, altered species composition, and consequences for food webs. Because of the focus of current modelling efforts on elevated CO_2 effects on

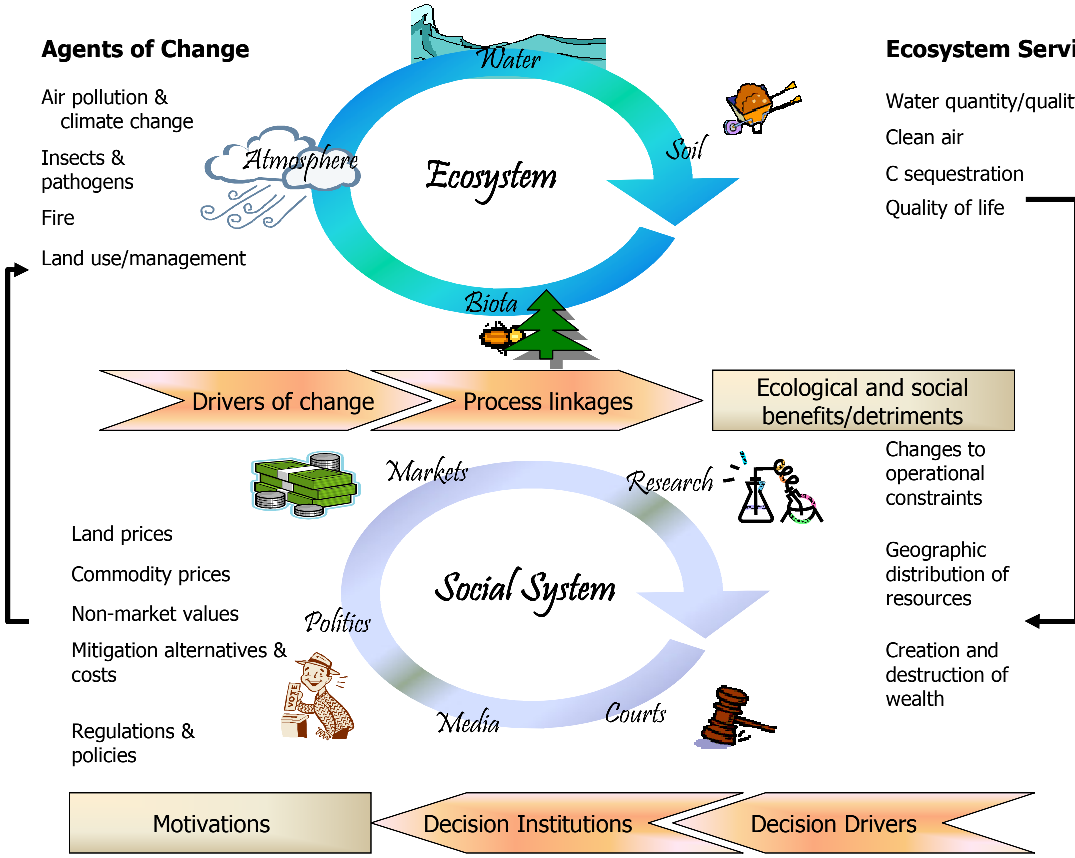

Figure 1. Multiple, interactive effects of different drivers, in particular air pollution (ozone, nitrogen oxides, excess nitrogen deposition) and climate change (increase in CO_2, temperature, extreme climatic events), on forest ecosystems and the services they provide.

forest carbon sequestration, the trade-offs between enhanced forest ecosystem carbon sequestration with elevated CO_2 and reduced water availability in elevated O_3 has been largely ignored (see empirical study McLaughlin et al., 2007). Forest ecosystem response to environmental stressors and enhancers will likely continue to be poorly predicted until mechanistic explanations underlying key components and processes are developed.

The gradual rise in temperature associated with greenhouse gas accumulation in the atmosphere will likely increase the sensitivity of trees to air pollutants via several mechanisms. Increased frequency and intensity of dry-season droughts are likely outcomes of greenhouse gas-forced temperature increases in mid-latitude temperate forests. While water stress may limit pollutant uptake, ozone can impair plant water control, and both excessive nitrogen and ozone pollution reduce the ratio of below- to above-ground biomass. This unbalanced ratio may increase forest vulnerability to water deficit and storms. Wind storms are likely to be larger and more frequent in central Europe. Excessive nitrogen loads could enhance fuel buildup for fires, which are in turn expected to increase under prospective climate change scenarios. The degree to which the effects of global climate change on forests will be masked or enhanced by regional variability is not known. Although we know little about the multiplicative effects of climate change and air pollution on forest ecosystems, we know less about how forest management and fire frequency will influence forest ecosystem processes, functions, and ultimately, integrity (Fig. 3). Human attitudes (personal vs. public responsibility for fire safety), behaviors (location of houses in the wildland/urban interface, lack of clearance around structures), and governing decisions (land use decisions, policies and regulations surrounding fire buffer zones) significantly affect how land is managed and how wildfire is controlled (or controllable), with profound effects on forest carbon and water balance. We hope to improve visibility of emerging threats to forest health, and to entice new scientists (social scientists, urban planners, policy makers) to contribute to our understanding of forest ecosystems. Having a better understanding of the interactive effects of air pollution and climate change on forests is of paramount importance in order to maximize forest research, monitoring and management and environmental policies efficiency.

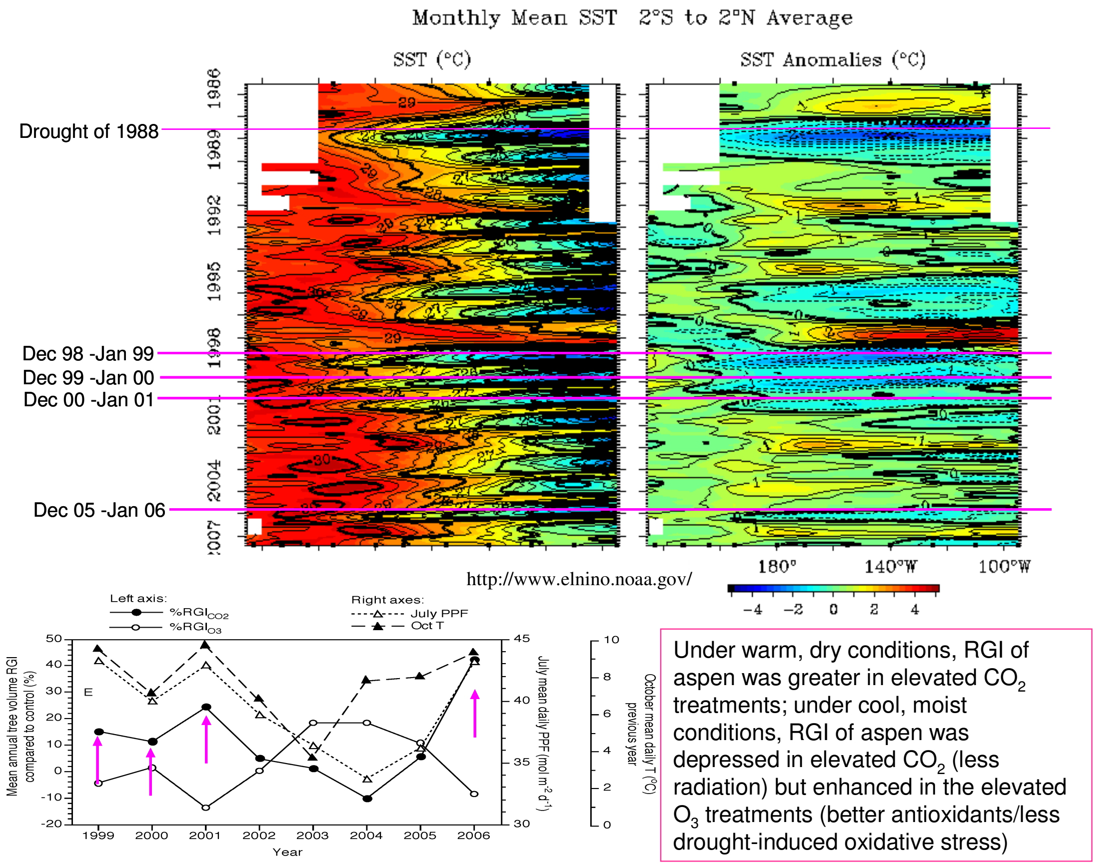

Figure 2. Interactions between climate, CO_2 and ozone on growth of Aspen (Kubiske et al., 2007).

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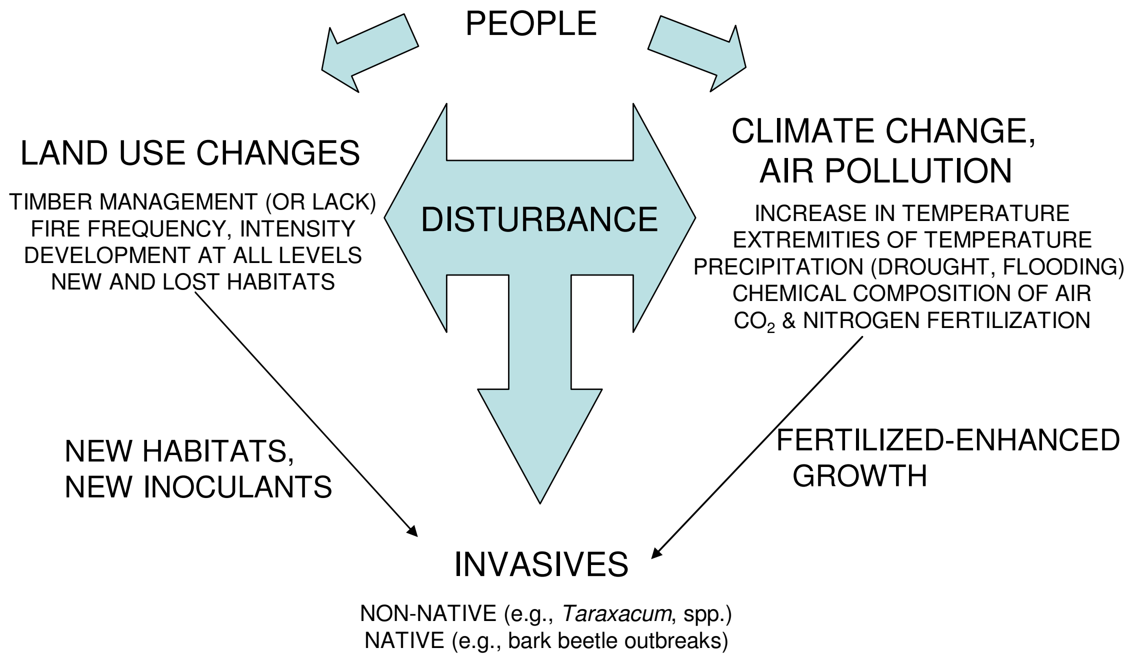

Figure 3. Summary of the emerging threats to forest ecosystem health.

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