Observations and assessment of forest carbon dynamics following disturbance in North America

S.J. Goetz, *et al*, *Journal of Geophysical Research*, Vol. 117, GO2022, DOI:10.1029/2011JG001733, 2012

Objectives:

- This paper reviews a recent North American Carbon Program disturbance synthesis, capitalizing on that work to discuss techniques and future work needed to understand carbon dynamics after forest disturbance.
- A series of questions about the carbon dynamics and regrowth inspired this paper. These questions include the magnitude of source vs. sink, the interaction of rate of disturbance with forest age structure, the drivers of post-disturbance carbon uptake, the interaction of the extent and spatial distribution of disturbance on successional trajectories, and the roles of management or climate in modulating forest response to disturbance.
- In addition, the synthesis identified three primary topics: The history, spatial distribution and characteristics of different types of disturbance; the integrated measurements and experimental designs required to quantify forest carbon dynamics after disturbance; and identification of the greatest uncertainties in the studies, as well as assess the utility of multiple types of observations as used in the case studies.

New Science:

- Case studies are used to present the integrated measurements and experimental designs required to quantify forest carbon dynamics in years and decades after disturbance in different geographic regions of North America, including the southeast US, central boreal Canada, U.S. Rocky Mountains, and Pacific Northwest.

- It was found that the metrics of the classic “Odum curve”, including the size of the pulse, the time of zero crossing, the peak uptake and its timing, and the time a new equilibrium is reached, vary considerably for forest types, based on ecosystem and disturbance characteristics.
- It was found that our current models are not always able to capture the full range of this variability.
- Two key areas where broad uncertainties exist were identified: 1) in understanding the implications of disturbance severity, which carries potentially nonlinear effects and 2) in understanding of large-scale and long-term disturbance dynamics, including factors which affect the dynamics, such as drought, climatic changes, insect outbreaks, and numerous other factors.
- After considering the broader uncertainties, the most useful measurements to capture regrowth dynamics and their carbon implications change with the type of disturbance.
- To improve understanding in particular ecosystems, further research in specific areas would carry high benefit. These areas include heterotrophic respiration, insect outbreak dynamics, and life-cycle analyses.

Significance:

- Forest disturbances modify ecosystem properties and processes, and can initiate a range of feedbacks between terrestrial system and climate.
- Paleo and modern records show that disturbances, which have had a significant impact on the carbon cycle throughout the Holocene, continue in modern times. The distribution of the dominant types of disturbance in North America varies, due to many factors.
- Post disturbance carbon balance can be highly variable across space, time and disturbance type, but the ecophysiologic models to date fail to reproduce the full range of this variability.
- Our understanding of the many pathways of post-disturbance carbon fluxes is particularly limited by our understanding of 1) disturbance severity 2) Longer and large-scale disturbance dynamics and how they may interact.
- Only by use of multiple techniques and integrative science can we quantify, constrain uncertainties and accurately predict the dynamics of forest carbon regrowth following equally dynamic disturbance regimes.

Fire in a boreal forest

The distribution of the dominant types of disturbance in North America varies. Fire dominates much of the western boreal ecosystems of Canada , storms impact the Gulf Coast of the US, insect damage is widespread but currently concentrated in the western regions, and harvest prevails in the southeastern United States.

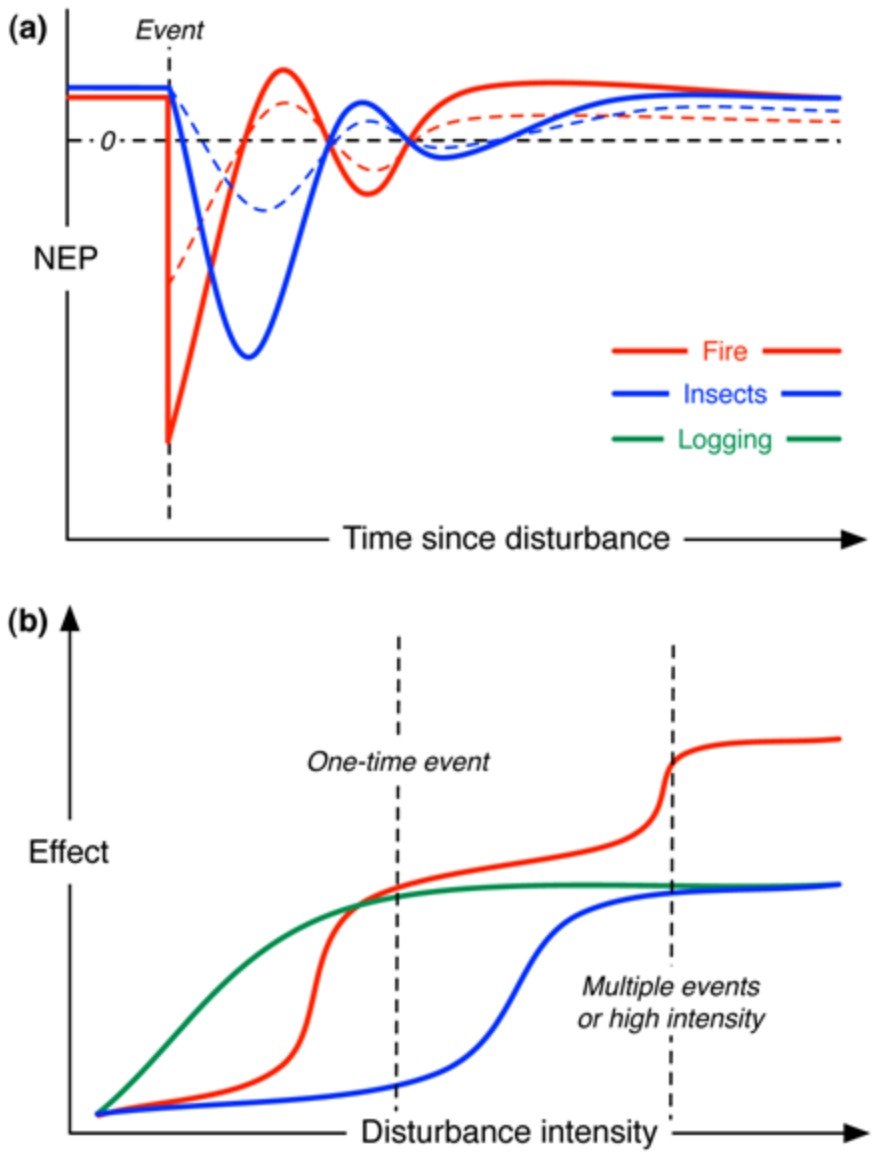

Figure 8. Conceptual figures, by disturbance type.
(a) How net ecosystem production (NEP) can change over time due to the initial disturbance and secondary decadal effects such as dead wood decay and disturbance interaction.
(b) How increasing disturbance intensity can exert nonlinear effects. Jumps in lines occur when the entire stand is killed and, for fire, when system reorganization occurs into a new successional trajectory.