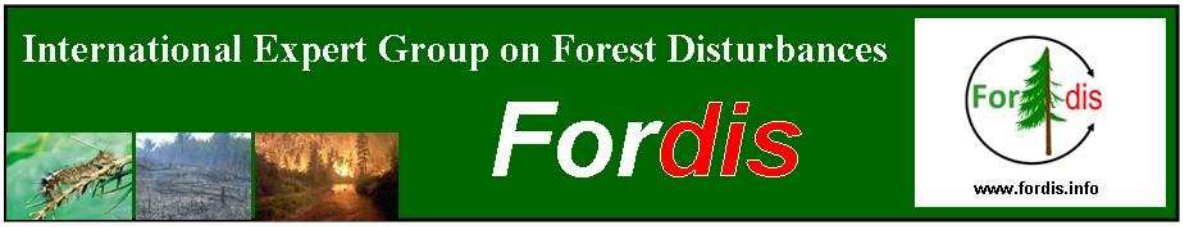

Insect Mass Outbreaks – An Increasing Risk Of Losing Biodiversity and Carbon in Forests?

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Abstract

Outbreaks of insects causing a moderate disturbance level are known to serve as important drivers of forest dynamics (at the biogeochemical as well as the organism scale); disturbances such as defoliation events enhance the amount of light and heat reaching the forest floor, subsequently triggering nutrient availability and boosting species richness in forest ecosystems. Nevertheless, exceeding this outbreak level in terms of frequency, severity, and spatial magnitude, insect mass outbreaks can cause considerable damage and lead not only to high economic losses (productivity sector) but also to a reduction of wildlife habitat quality and species richness if adequate, effective measures are not taken in time. Considering pest-antagonist relationships, high insect abundance will enhance the abundance of predators and parasitoids as well, followed by an increase of multitrophic interactions in above- and below-ground systems, where plants and deep tree roots in particular, play an important role. However, when looking at the organism scale, these rather short-term effects are outweighed by more serious effects in the long run: Climate change-induced alterations in precipitation and temperature patterns will affect occurrence patterns of xylophagous and phytophagous insects by changing the natural cycles of mass outbreaks associated with the frequency, intensity and duration of the reproduction characteristics of insects. It can be foreseen that limitations of water availability during growing season will not only affect the metabolism of plants by lowering the photosynthetic activity and thus biomass ecosystem productivity, but will also increase the susceptibility of trees to insect attacks. Thus, insects will attack trees that are weakened due to unfavourable environmental conditions. Trees serve as habitats for many animals and plants - however, - mass outbreaks of insects can within only a few months lead to a high percentage of damaged forest area, followed by the dieback of the insect-attacked hosts. Hence, habitat utilized by many animals associated with this specific tree species is lost. Moreover, in some cases, after heavy outbreak events, the natural regeneration of the forests is heavily impeded by competition between young trees and other forest

floor vegetation such as grass. Naturally-occurring disturbance, such as insect mass outbreak events, which are often accompanied by drought and other disturbances (e.g. forest fire and overgrazing), commonly result in the transition of forested areas into grassland (Radeloff et al., 2000).

In such cases, not only has tree species composition changed but also the character of the entire landscape, resulting in an increased deterioration of forests and their associated fauna and flora. This phenomenon is known to occur in managed forest systems as well as in their unmanaged counterparts.
At the biogeochemical scale, forest insects also have the potential to greatly affect nutrient cycles in terms of quantity and quality, with substantial consequences for C and N storage capabilities in above- and below-ground systems. For example, our studies have shown that during mass outbreaks (defoliation), insect-mediated organic matter fluxes from canopy to soil foster soil decomposition activity of microorganisms and subsequently elevate CO_2 and N_2O production significantly (le Mellec et al., in prep.). In forest ecosystems, insect mass outbreaks following severe or repeated periods of drought might therefore serve as a trigger for converting carbon sinks turn into carbon sources due to limited C sequestration in woody material and enhanced soil-induced respiration. Due to an insect induced limited above and below ground C sequestration ability and an enhanced production of CO_2 and N_2O forest stands with an enhanced susceptibility to mass outbreaks are likely to occur with an increased global warming potential (GWP). If climate change does enhance the frequency, magnitude and interannual activity of forest disturbances such as forest fires and insect outbreaks, forest ecosystems will lose their ability to sequester C (Lyassert et al., 2008) and more frequent disturbances might not allow full recovery of C (**Figure 1**).
It remains uncertain how forest ecosystems will respond to the changing environmental conditions in the long run. It can be assumed that in some regions forests will not offer sufficient resilience to adapt to these rapidly changing climatic conditions and the associated increased occurrence of forest disturbances such as fires and mass outbreaks of insects. Thus, it is of utter importance **to preserve our existing forests** to maintain a high diversity of ecosystem functions and services such as the ability to sequester carbon and provide habitat for a large variety of species.

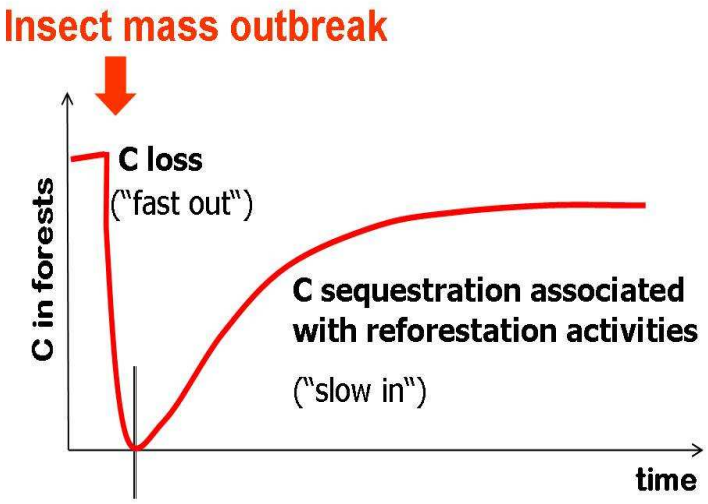

Figure 1: Insect mass outbreaks and ecosystem feedbacks: Considering the fact that carbon sequestration related to reforestation activities takes much more time ("slow in") than the loss of carbon during mass outbreaks of insects ("fast out"), it is of utter importance to safeguard our existing forests and provide protective strategies for managed as well as for unmanaged forest ecosystems. Additionally, more frequent disturbances do not allow full recovery of C. In this context it is indispensable to take preventive measures such as identifying issues that make forests more predisposed to the predicted potential impacts (adapted from Körner, 2003 and slightly modified).