Risk Case Study: A Framework for Assessing Climate Change Risks to Forest Carbon Stocks

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Forest ecosystems have the ability to reduce the effects of climate change through the sequestration of carbon (C) (Pan et al. 2011) as well as contribute to net emissions through disturbance events such as wildfires and widespread tree mortality (Kurz et al. 2008). A conceptual framework for assessing climate-change risks to forest ecosystem C stocks facilitates efficient allocation of efforts to monitor and mitigate climate-change effects, and the U.S. National Greenhouse Gas Inventory (NGHGI) of forest C stocks (Heath et al. 2011) may be used as a basis for development of a climate-change risk framework for forest C stocks.[2]

A forest C stock risk framework incorporates two components of risk: consequence and likelihood (fig. A2-2). One of the most critical future consequences of climate change on forest C stocks is the shift from C sink (net annual sequestration) to C source (net annual emission). Although global forests currently sequester more carbon than they emit on an annual basis (Pan et al. 2011), the ability of forests to continue this trend in the future has been questioned (Birdsey et al. 2006, Reich 2011). If the strength of the C sink decreases and forests became net emitters of C and other greenhouse gasses (GHG) (e.g., methane) a positive feedback loop may be created whereby negative climate change effects may further exacerbate forest C emissions. Likelihood can be phrased as the probability of a C stock becoming a net emitter of C. For individual C stocks that are least affected over short timespans (e.g., 50 to 100 years), likelihoods would be minimal. Taken together, the C risk framework hinges on the concepts of both a "status change," in which forest C stocks transition between C source or sink, and a "tipping point", when forest systems might collapse with concomitant emission of C and potential positive feedbacks that may exacerbate climate change.

The consequences of a C stock becoming a net emitter of C is postulated as being directly related to its population estimate over a region of interest. In this case study, it is the C stocks of individual forest pools for the entire United States as reported to the Intergovernmental Panel on Climate Change to meet United Nations Framework Convention on Climate Change requirements (USEPA 2011a, 2011b). If a pool is the largest in the United States, then that pool has the largest consequence on global climate change if it is entirely emitted. All current U.S. forest C stocks represent nearly 25 years of U.S. GHG emissions at current emission rates (Woodall et al. 2011). The pools and estimates (Tg of C) of C stocks in 2008 (Heath et al. 2011) are ordered as: soil organic carbon (17,136 Tg of C), aboveground live biomass (16,854 Tg of C), forest floor (4,925 Tg of C), belowground biomass (3,348 Tg of C), and dead wood (3,073 Tg of C).

The likelihood of any individual C stock becoming a net emitter of C is an emerging area of research. For the purposes of this risk framework (fig. A2-2), it is proposed that the likelihood of a C stock becoming a net emitter is related to the empirical variation in the stock across the diverse ecosystems and climates of the United States. If climate change occurs such that a mesic boreal forest ecosystem becomes a xeric mixed-hardwood shrubland, then the contemporary range in variation in C stocks between those systems should indicate likelihood of C emission. For example, if forest floor C stocks change minimally regardless of climate, then in turn climate change should least affect these stocks. As an initial appraisal of empirical variation in C stocks across the United States, the coefficients of variation (percentage) of individual plot-scale measurements of C stocks (Forest Inventory and Analysis; Heath et al. 2011) across the United

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States are ordered as dead wood (126.9 Tg of C), belowground biomass (107.8 Tg of C), aboveground live biomass (104.5 Tg of C), forest floor (73.7 Tg of C), and soil organic carbon (67.6 Tg of C). Although climate change events can alter natural variation in C stocks, when compared to contemporary levels, these estimates of variation can provide a starting point for a risk framework.

When the consequences and likelihoods of forest C stocks becoming net emitters of C are viewed together, a cohesive approach to monitoring and managing risk emerges. Given the magnitude of potential emissions coupled with the natural variability in these stocks at the continental scale, annual monitoring of dead wood and aboveground live biomass C stocks are needed. In addition, strategies to mitigate negative climate change events (e.g., droughts) can be undertaken. The major research gap in such an approach is how far a pool would move within the risk framework after a climate change event (the length and direction of the negative/positive arrows [fig. A2-2]). For example, if forest lands convert to grasslands as a result of reduced precipitation and lack of tree regeneration, how would the aboveground biomass pool align itself within the risk framework? Despite the qualitative nature and research gaps within the forest C stock risk framework, this approach provides a conceptual means of identifying priority research needs and a decision system for mitigating climate change events.

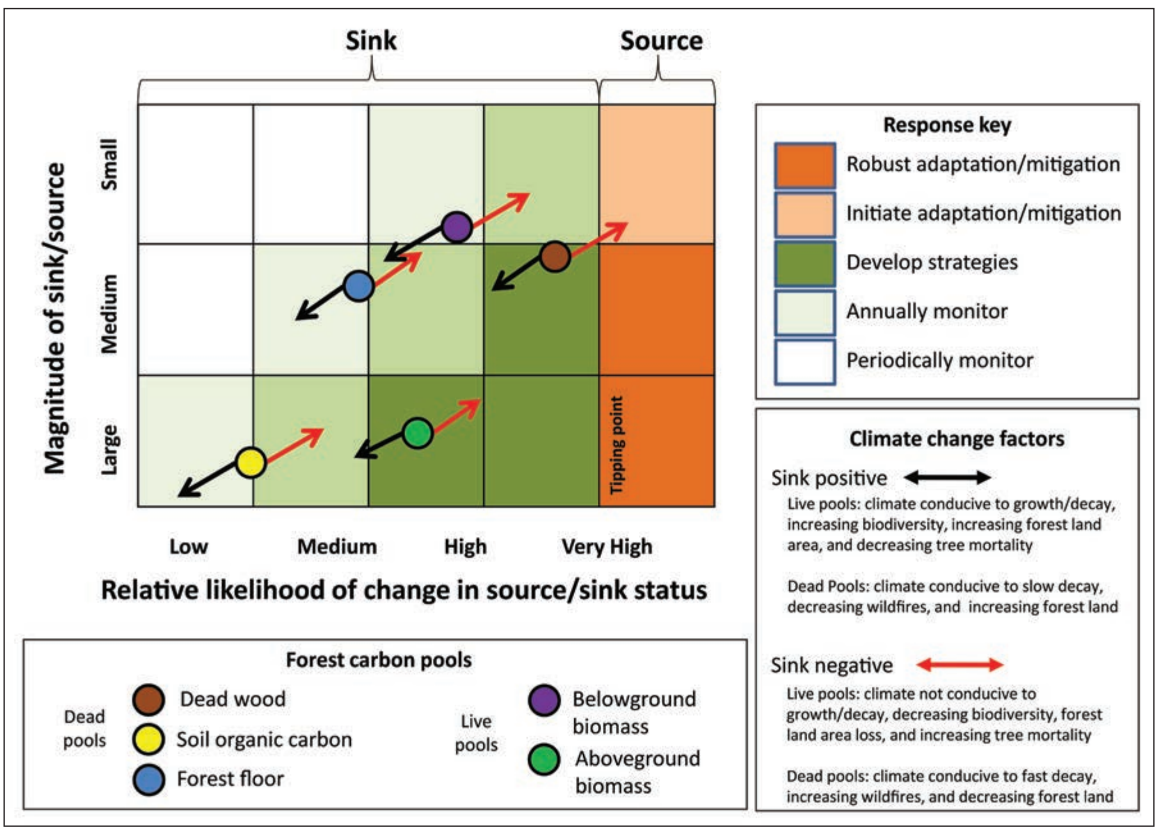

Figure A2-2—Climate change risk matrix for forest ecosystem carbon (C) pools in the United States, in which climate change may cause C pools to move in a positive (sink = net annual sequestration) or negative (source = net annual emission) direction. Likelihood of change in C stocks is based on the coefficient of variation across the national Forest Inventory and Analysis plot network (x-axis). Size of C stocks is based on the U.S. National Greenhouse Gas Inventory (y-axis). Societal response (e.g., immediate adaptive response or periodic monitoring) to climate change events depends on the size and relative likelihood of change in stocks. The dead wood pool, a relatively small stock, exhibits increasingly high variability across the landscape and therefore may be affected by climate change and disturbance events such as wildfire. In contrast, the forest floor is also a relatively small C stock, but has low variability. Potential future climate-change effects are not incorporated in the matrix, because they represent many complex feedbacks both between C stocks (e.g., live aboveground biomass transitioning to the dead wood pool) and the atmosphere (e.g., forest floor decay).

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