Appendix 2: Risk-Based Framework and Risk Case Studies

Risk-Based Framework for Evaluating Changes in Response Thresholds and Vulnerabilities

Dennis S. Ojima, Louis R. Iverson, and Brent L. Sohngen[1]

What is "risk," and how can a "risk-based framework" help plan for climate change? Risk is described by the likelihood of an impact occurring and the magnitude of the consequences of the impact (Yohe 2010) (fig. A2-1). High-magnitude impacts are always risky, even if their probability of occurring is low; low-magnitude impacts are not very risky, even if their probability of occurring is high. Applying this approach to forest management is difficult because both the likelihood of occurrence and the magnitude of the effects may be difficult to estimate (especially at local scales) and often depend on past and current land use, and the timing, frequency, duration, and intensity of multiple chronic and acute climatic disturbances.

Despite these challenges, there is much that we do know and it is possible to begin thinking about approaches for developing a risk-based framework for forests in the context of climate change. A risk management framework simply means that risks are identified and estimates are made for their probability of occurrence and their impact. Where we have sufficient knowledge, this framework provides a means to quantify what is known, identify where uncertainties exist, and help managers and decisionmakers develop strategies with better knowledge of risks.

Climate change is likely to affect forest ecosystems, and the risk of negative consequences to forests and associated socioecological systems will probably increase (Ryan and Archer 2008). However, predicting these risks is difficult because of uncertainty in almost all aspects of the problem.

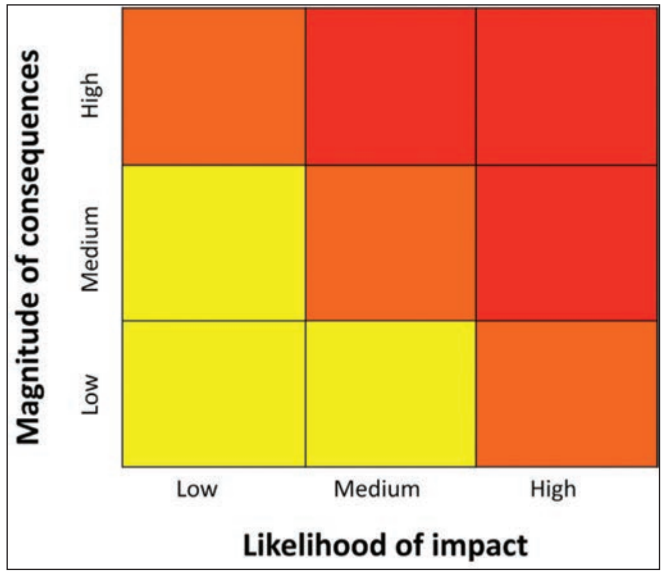

Figure A2-1—A conceptual risk framework used to help identify risks associated with climate change and prioritize management decisions (Yohe and Leichenko 2010). Colors represent varying degrees of risk (red = highest; yellow = lowest). In a qualitative definition of consequence, low = climate change is unlikely to have a measurable effect on structure, function, or processes within a specified timeframe (e.g., 2030s, 2050s, 2090s); medium = climate change will cause at least one measurable effect on structure, function, or processes within a specified timeframe; and high = climate change will cause multiple or irreversible effects on structure, function, or processes within a specified timeframe. In a qualitative definition of likelihood, low = climate change impacts are unlikely to be measurable within the specified timeframe, medium = climate change impacts are likely to be measurable within the specified timeframe, and high = climate change impacts are very likely (or have already been observed) within or before the specified timeframe.

How can we incorporate uncertainty into an analysis of risks and subsequent management decisions?

Regional and local projections of climate change are uncertain (Baron et al. 2008, Fagre et al. 2009, Joyce et al. 2008). Despite these uncertainties, climate science has advanced to provide a set of robust climate change projections: the climate is warming, the probability of large precipitation events is increasing, seasonal patterns will be altered, and

[1] **Dennis S. Ojima** is a senior research scientist, Colorado State University, NESB B231, Natural Resource Ecology Laboratory, Campus Mail 1499, Fort Collins, CO 80523; **Louis R. Iverson** is a research landscape ecologist, U.S. Department of Agriculture, Northern Research Station, 359 Main Road, Delaware, OH 43015; **Brent L. Sohngen** is a professor, Ohio State University, Department of Agricultural, Environmental, and Development Economics, 103 Ag Administration, 2120 Fyffe Road, Columbus, OH 43210.

extreme events are more likely (Solomon et al. 2007). These tendencies are becoming more apparent in observations across the United States and will affect forest resources nationwide (Karl et al. 2009). A key challenge is to determine how climate change may alter local socioecological systems, trigger threshold-dependent events, and create nonlinear interactions across interconnected stressors on forest resources (Allen et al. 2010, Fagre et al. 2009), and further, how climate change effects can be addressed by local management actions. Forest managers have extensive experience adapting forest management practices to climate variability and a wide range of disturbance regimes. For example, conifer plantations are often managed in short rotations, which limits exposure to risks from insects, wildfires, and windstorms. In mixed-age hardwood forests where management is often less intensive (e.g., where partial harvests are the norm), managers simultaneously choose trees to remove and trees in the understory to release for the next generation of growth. Hence, by using silvicultural techniques to select the species, density, and age class distribution of the next generation of forest, managers can influence susceptibility to a range of future threats.

Given what we do know about climate change, a robust decisionmaking approach is needed that acknowledges sources of uncertainty, incorporates what is known of system vulnerabilities, and evaluates assets critical for making sound forest management decisions (Australian Government 2005, Baron et al. 2008, Fagre et al. 2009, Joyce et al. 2008, Ranger and Garbett-Shiels 2011). A risk management approach provides a robust framework for planning management options for climate change, where uncertainties are recognized and key elements relative to various management objectives and priorities are explicitly addressed (Dessai and Wilby 2011, McInerney and Keller 2008, Ranger and Garbett-Shiels, 2011, Yohe and Leichenko 2010). This approach incorporates aspects of vulnerability assessments, identifies priority actions relative to multiple management goals, identifies critical information needs, and provides a vision of short- and long-term strategies to enhance the flexibility of management decisions and reduce the probability of poor decisions (Australian Government 2005, Peterson et al. 2011). This approach also promotes a shift from reactive adaptation to proactive adaptation and coping management (Ranger and Garbett-Shiels 2011), including the following general strategy:

- Identify actions to avoid, that is, avoid choices that lead to less flexibility to adjust to changing conditions in the future.
- Implement "no regrets" management to cope with stresses now and increase resilience to anticipated climate-related stresses.
- Make decisions that integrate across landscapes and governance and that include all concerned and affected stakeholders.
- Develop activities that have strong links among observations, research, and management to understand how ecosystems and social systems are changing, help make decisions, understand thresholds, and help adjust future management and research.

The risk framework must consider the socioecological context of the system being evaluated, reflecting the contribution of forest ecosystem services to different communities and the capability of forest systems to withstand different climate effects. Providing a more thorough consideration of sources of uncertainty allows for improved development of management strategies, which include key socioeconomic properties. This integrated and multisectoral approach will incorporate an improved assessment of risk and current management capacity, and will identify critical uncertainties that may exist under future scenarios if novel consequences emerge.

Case studies using a risk-based framework and concepts are discussed in the following sections on carbon, fire, forests, and birds. They are intended as examples, using different approaches to convey risk assessment, and will hopefully create interest by scientists and land managers in refining risk assessments for the effects of climate change on a wide range of forest resources.

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