Chapter 5
Improving Scientific Knowledge

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Scientific literature on the effects of climatic variability and change on forest ecosystems has increased significantly over the past decade, providing a foundation for establishing forest-climate relationships and projecting the effects of continued warming on a wide range of forest resources and ecosystem services. In addition, certainty about the nature of some of these effects and understanding of risk to biosocial values has increased as more evidence has been accrued.

The recent expansion in scientific analysis of the effects of climate on ecological disturbance has provided empirical data on how wildfire and insects respond to warmer climatic periods. However, more information is needed on the interaction of ecological disturbances and other environmental stressors, especially for large spatial and temporal scales. Thresholds for climatic triggers of environmental change are generally poorly understood relative to fire, insects, interactions, and functionality of forest ecosystems. Moreover, simulation modeling can suggest how and when those thresholds might be exceeded, additional empirical data on thresholds will be more definitive, and more process-level research is required to improve current or the next generation of predictive models. In general, our understanding of stress complexes in forest ecosystems needs to be expanded to more ecosystems and transitioned from qualitative to quantitative descriptions.

Despite a century of ecological research on human-altered landscapes, our ability to interpret ecological change in the context of human land use and social values is far from complete. We especially need to improve our ability to quantify climate-ecosystem relationships in the context of land use change at larger spatial and temporal scales. Inferences about climate change effects will be more relevant if various land uses, including evaluation of future alternatives, are considered in a context that incorporates humans, rather than excluding them or considering their actions to be “unnatural” or negative. This leads to the broader need to develop a framework for quantifying ecosystem services that is transportable across different institutions and that will include a wide range of biosocial values.

Some general scientific issues need additional focus. First, the value and interpretation of empirical (statistical) models versus process (mechanistic) models warrants a rich discussion within the scientific community. Conceived from different first principles (e.g., assumed equilibrium [empirical] vs. dynamic [process] climate-species relationships), the output from these models often differs considerably or is difficult to reconcile because of different assumptions, spatial resolution, and hierarchical levels (e.g., species vs. life form) between the models. This disparity needs to be resolved so that resource managers can understand and apply model output appropriately. Second, the direct effects of elevated carbon dioxide (CO_2) on forest ecosystems need to be clarified. Most existing evidence is based on experimental treatments on seedlings and small trees, and on simulation models that assume certain types of growth responses. Assuming CO_2 stimulation (or not) can drive the output of vegetation effects models to such an extent that it greatly modifies simulated response to climate. A unified effort by scientists to resolve the significant challenges in scaling and interpreting data on CO_2 effects is needed to provide accurate projections of vegetation change. Third, effects models that can explore multicentennial patterns of vegetation distribution, disturbance, and biogeochemical cycling dynamics would provide more realistic scenarios for planning and policy decisions. Most projections of climate change effects extend to only 2100, the limit of projections for most global climate models, and a relatively short time for robust evaluations of ecosystem dynamics.

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Some specific research priorities for forest ecosystems include:

- Develop and implement long-term studies on the effects of elevated CO_2 in mature forests. This may involve whole forest stands or physiological measurements of individual trees within stands. Studies in disparate forest ecosystems would provide a broad perspective on this topic.
- Develop a standard approach for tracking carbon dynamics in different forest ecosystems over space and time. This will improve ecological knowledge, as well as input to carbon accounting systems. It will be especially useful if it can be applied in a straightforward manner by resource managers.
- Identify the appropriate uses and limitations of remote sensing imagery for detecting the effects of climatic variability and change in forest ecosystems. A great deal of remote sensing data are available, but they are accessible to only a few specialists. If resource managers were provided tools to access, analyze, and help interpret the most reliable and relevant data, it would provide timely feedback on forest stress and other characteristics on a routine basis.
- Determine which ongoing and long-term forest measurements are useful or could be modified for tracking the effects of climate change. Building on existing infrastructure for monitoring will be efficient and extend time series of measurements taken with established protocols.
- Identify standard approaches for evaluating uncertainty and risk in vulnerability assessments and adaptation planning. Straightforward qualitative and quantitative frameworks will advance the decisionmaking process on both public and private lands.
- Evaluate recently developed processes and tools for vulnerability assessment and adaptation planning to identify which ones are most effective for "climate smart" management on public and private lands. The availability of straightforward social and logistic protocols for eliciting and reviewing scientific information and stakeholder input will make climate change engagement more effective and timely.

It will be especially important to frame the above topics at the appropriate spatial and temporal scales in order to provide relevant input for different climate change issues. In addition, climatic data at different spatial scales needs to be matched with applications at different spatial scales to be relevant for climate smart management. Despite the urgency to provide downscaled climatic and effects data, the appropriate grain and extent of these data differ by resource (hydrology vs. vegetation vs. wildlife) and resource use (timber management vs. water supply vs. access for recreation). Sharing of information and experience within and among organizations involved in climate change will accelerate the incorporation of proven methods and applications across any particular landscape.