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Communication

Adaptation of Forests and Forest Management to Climate Change: An Editorial

Rodney J. Keenan

Melbourne School of Land and Environment, The University of Melbourne, 221 Bouverie St., Carlton, VIC 3010, Australia; E-Mail: rkeenan@unimelb.edu.au; Tel.: +61-3-9035-8227

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Abstract: Climate change presents potential risks to forests and challenges for forest managers. Adaptation to climate change involves monitoring and anticipating change and undertaking actions to avoid the negative consequences and take advantage of potential benefits of those changes. Forest managers are accustomed to considering the long-term implications of their decisions. However, many are now responding to much shorter term economic or political imperatives. Climate change potentially increases the consequences of many existing challenges associated with environmental, social or economic change. Some current management measures may continue to be suitable in responding to increasing pressures under climate change, while for other situations new measures will be required. This special issue presents papers from Africa, Europe, and North America that provide examples of the type of analysis being implemented to support forest management in a changing climate. The implications in the context of uncertainty in climate projections and ecosystem responses are discussed.

Keywords: risk management; disturbance; silviculture; monitoring

1. Introduction

Forests are significant global ecosystems, dominating over 30 percent of the terrestrial landscape and providing habitat for many species of plant, animals, invertebrates and micro-organisms and numerous goods, services and benefits to people [1]. Forests are also a major part of the global carbon cycle [2], containing significant stocks of carbon and emitting carbon to the atmosphere during and following disturbances such as fire, storms or landslides or human disturbances such as timber harvesting or clearing for agriculture. Forests remove carbon from the atmosphere in periods of growth and recovery following these disturbances.

For some time, forests have been identified as a potential mechanism to human-induced climate change [3]. Carbon dioxide emissions can be lowered by reducing emissions from clearing for agriculture or urbanisation, and offset by afforestation and forest landscape restoration or changing forest management to increase carbon stocks. These solutions have been incorporated into international agreements and national policies to address climate change [4].

Climate change also presents potential risks to forests and challenges for forest managers. Forest ecosystems are resilient and many species and ecosystems will adapt to changing conditions. Some aspects of climate change may be positive for forests (for example, tree growth may increase under longer growing seasons and increased levels of CO_2), many projected future changes in climate and their indirect effects are likely to have negative consequences for forests and those people and organisms that depend on them. These changes are potentially of such magnitudes or will occur at rates that are beyond the natural adaptive capacity of forest species or ecosystems, leading to local extinctions and the loss of important functions and services [5].

Adaptation to climate change involves monitoring and anticipating change and undertaking actions to avoid the negative consequences and take advantage of potential benefits of those changes [6]. It is an emerging issue for society. Forest managers are accustomed to thinking in long time scales and considering the long-term implications of their decisions and factoring in uncertainty and unknowns into management. Climate change introduces new uncertainties and new unknowns. How do managers incorporate these into their management decisions? What types of tools are needed to improve decision making capacity? This special issue presents papers from Africa, Europe, and North America that provide examples of the type of analysis being implemented to support forest management in a changing climate.

While there is certainly great awareness of climate change impacts in parts of the tropics such as low-lying islands and delta cities, people in Europe and North America have, perhaps, become more acutely aware of the implications of climate change for societies and ecosystems. Climatic conditions in these regions are generally less variable and more reliable than other parts of the world and the climate signals, together with the implications of higher temperatures, increased precipitation, storm frequency, warmer winters and longer growing seasons are being felt more rapidly in higher northern latitudes than other parts of the globe [7,8]. Adaptation can be considered from a number of perspectives [9]: reducing the impact of climate disasters, reducing vulnerability to climate impacts, managing a broader suite of climate ‘risks’ or increasing resilience in forest ecological and production systems to recover from climate ‘shocks’. Climate change potentially increases the consequences of many existing challenges associated with environmental, social or economic change. Some current management approaches may continue to be suitable in responding to increasing pressures under climate change, while for other situations new measures will be required.

2. Forests and the Carbon Cycle

Hoover [10] in this issue demonstrated the importance of forest dynamics and disturbance history in determining forest composition and carbon uptake in an analysis of long-term carbon accumulation in two hardwood forest types in northeastern USA. Average annual increase in carbon stock was 0.53 t/ha/yr between 1932–2001 in a New Hampshire forest and 0.89 t/ha/yr over a similar period in an experimental forest in northwestern Pennsylvania. This corresponded to a 55% and 140% increases in carbon stored per unit area, respectively. There were significant differences in carbon accrual rates between age classes (38% for old unmanaged stands and 78% for younger unmanaged stands) and climate and succession-induced changes in species composition. Primary forests continued to take up carbon over the measurement period. These results parallel those reported at regional and national scales in the USA with estimates of carbon uptake in the coterminous US states of 191.8 MtC/yr [11] as forests regrow on previously cleared land and those subject to past disturbances mature.

3. Adaptation Measures

Maintaining forest carbon stocks, increasing carbon uptake and continuing the provision of other forest benefits and services will require effective adaption in the face of climate change. In a comprehensive review of adaptation measures in forestry across the 27 member countries that made up the European Union in 2008 and other neighbouring countries, Kolström *et al.* [12] in this special issue identified measures targeted to reduce vulnerability to climate change that aim to reduce forest sensitivity to adverse climate change impacts or increase adaptive capacity to cope with changing environmental conditions.

Actions occurring at stand level in Europe are focusing on the regeneration phase, for example, by increasing the genetic or species diversity in seeded and planted stands. Tree breeding programs are only starting to consider the right suit of attributes of forest tree populations for future climates such as higher temperature and drought tolerance and capacity to take advantage of increased levels of atmospheric CO_2. The point is also raised that selecting new plant material adapted to projected future climatic conditions involves the risk of 'prognostic error' because of the high uncertainties in projections of future climate at local and regional scales. The right forest composition for future conditions is also likely to be sub-optimal for current conditions, meaning there must be trade-offs in suitability for current and future conditions. Other silvicultural measures identified in this study included shifts in planting season, using containerized stock to reduce drought risk and reducing spacing and thinning to increase recovery after dry periods.

Small-scale cutting, continuous cover forestry and variable retention systems have also been proposed as robust strategies under climate change. But Kolström *et al.* argue that these may induce loss of light-demanding, pioneer tree species that are often also more tolerant of water stress and high temperatures. In general, it was concluded the overall benefits of these approaches in increasing resilience remain poorly investigated.

Tiscar and Linares [13] took up this theme in a comparative study of forest structure and regeneration at the southern limit of the range of *Pinus nigra* subsp. *salzmannii* dominated forest in Southeast Spain. While there were high losses of naturally regenerating seedlings due to desiccation across the two sites studied, a more complex forest structure in the stand with minimal human impact provided for facilitation of establishment of tree saplings by the shrub *Juniperus communis*. They considered that stands with intermediate values of canopy cover of either trees or shrubs are likely offer a compromise between light requirements for growth and the soil moisture that *Pinus nigra* seedlings need to establish in the understorey. They preferred natural regeneration because it allows natural selection of genotypes that are well-adapted to the site. Although this may conflict with the suggestion that the introduction of genotypes from other regions may be required to provide the species with the capacity to cope with future conditions [12].

Adaptive actions may also be occurring for other reasons. Thinning is being modified in many European countries to produce species mixtures or uneven-aged and structured stands that are considered more robust to extreme events. Harvesting methods in boreal regions are also changing to accommodate wetter conditions [12].

Adaptation measures in management planning have generally involved modifying the timing of harvest, with rotation lengths reduced due to increased productivity or to provide for more rapid replacement of vulnerable stands [12].

4. Managing Increases in Disturbances

Disturbance agents such as insect pests, diseases and fire are expected to become larger problems for forest managers under climate change. Kolström *et al.* [12] reported an increase in comprehensive planning systems that incorporate pest risk assessment and aim to improve forest health and stability. Mixed species stands that include species that are less susceptible to specific insects or diseases may be more resilient than monocultures, although the selection of tolerant or resistant families and clones may be adequate to reduce the risk of damage by pests and diseases in pure stands.

Also in this issue, Loehman *et al.* [14] suggested that mountainous landscapes are particularly sensitive to climate changes and that the interaction of pest, disease and fire may be important in determining the vulnerability of western white pine (*Pinus monticola*) ecosystems in the United States. Using a mechanistic simulation model to simulate effects of climate change and fire management in Montana, their study indicated that warmer temperatures will favour western white pine over existing climax and shade tolerant species, mainly because warmer conditions will lead to increased frequency and extent of wildfires that facilitates regeneration of this species. These wildfires will be more difficult to suppress under warmer, drier conditions. This increased fire frequency will offset the impact of increased incidence of white pine blister rust.

In general, fire management policies in many parts of the world will need to cope with longer and more severe fire seasons, increasing fire frequency, and larger areas exposed to fire risk. This will especially be the case in the Mediterranean region of Europe [12] and other fire prone parts of the world such as South Eastern Australia [15].

Adaptive measures being undertaken to mitigate the risks of increased fire frequency in Europe included: modification of forest structure to reduce the potential for fire spread, increased fuel management (through prescribed burning, thinning, pruning, understorey biomass removals or grazing, establishing species with the ability to regenerate after fire, creating landscape mosaics that include species with reduced flammability and maintaining or expanding infrastructure for direct attack on fires [12].

5. Adaptation as Risk Management

Adaptation to climate change involves assessing, handling and controlling risks. Kolström *et al.* [12] suggested that models are important for analysing risks, and that improved fire, storm and pest risk simulations are needed to assess the effectiveness of alternative management options in reducing disturbance impacts. Capacity to handle forest management risks can be promoted by education and training focused on risk identification and prevention and mitigation of damage.

Implementing many adaptation options is likely to involve increase costs. Research is required to provide sound frameworks for cost-benefit analysis, particularly in determining the appropriate discount rate for measures with long payoff times. New types of insurance models can also assist with spreading these increased risks and costs among a wider group of forest owners or managers [12].

Maintaining and managing infrastructure were identified as important in risk management and adaptation. A dense forest road network is a prerequisite for smaller-scale, structurally diverse thinning and harvesting practices and access is critical for managing disturbance events. Road maintenance will need to consider increasing peak precipitation and runoff effects or changing in freezing and thawing conditions [12].

Successful risk management will require dissemination of knowledge of potential climate impacts and suitable adaptation measures to decision makers at both practice and policy levels. Kolström *et al.* [12] suggested that establishing forest management associations can help to improve management of fragmented forest estates with multiple owners that occur across Europe, as is the case in north eastern USA and parts of Asia.

Uncertainty about the full extent of climate change impacts and the suitability of adaptation measures creates a need for monitoring. A robust monitoring system is important to provide early warning on climate change impacts (including dieback and pest dynamics) and the response of forest ecosystems and people to adaptive management strategies [12].

Research should focus on increasing adaptive capacity and improved regional vulnerability assessments. The call by Kolström *et al.* [12] to resolve uncertainties about the extent of climate change impacts and improve regional climate change projections may be of limited value in the short term. A more 'decision-centred' approach [16] would focus research on improved understanding of tree and ecosystem responses to different climate variables and identifying those aspects of climate to which different forest types are most sensitive. Research can also quantify the adaptive capacity of the forest sector and assess the efficacy of different adaptation measures.

Adaptation is inherently a social process and forests are social-ecological systems that involve both nature and society [17]. Resolving trade-offs between management objectives is important in sustainable forest management. As Kolstrom *et al.* [12] point out, some proposed adaptation measures may change the balance between current objectives and stakeholder interests and it will be important to consider the relative balance of different measures at the stand, management unit and landscape scales.

Broader policy or management decisions being taken in other sectors may affect forestry and forest management. There may be situations where adaptation requires a shift to alternative industries or production systems. Intersectoral coordination will be important to ensure that policy developments in related policy sectors are not contradictory or counterproductive [12]. There is also likely to be a greater need for cross-border implementation of different forest management options, requiring greater coordination between nation states and sub-national governments.

6. Ecosystem-based Adaptation

Strong arguments are being put forward for ecosystem-based approaches to adaptation [18]. As Kalame *et al.* [19] point out in this issue, tree planting has become popular under National Adaptation Plans of Action (NAPAs) but they also suggest that those with tree-dependent livelihoods may remain vulnerable, causing some doubt about the benefit of tree planting to enhance the resilience of livelihoods to climatic shocks. Ideally, effective adaptation projects will reduce both short and long term vulnerabilities without producing negative unintended impacts [20].

In their survey of farmers involved in gum-arabic agroforestry in Sudan Kalame *et al.* in this issue [19] found that maintenance of the producer price, understanding of rainfall patterns, and responding more effectively to pests and diseases such as locust attacks were critical issues in building the adaptive capacity of farmers involved with this production system. Echoing calls in Europe for increased information dissemination and access to different types of financial instruments for risk management, Kalame *et al.* pointed to improved extension services and increased access to micro credit arrangements if tree planting projects are to contribute effectively to building adaptive capacity in this region.

Adaptation is, in essence, about making good decisions for the future, taking into account the implications of climate change. It involves recognising and understanding potential future climate impacts, and planning and managing for their consequences, whilst also considering the broader social, economic or other environmental changes that may impact on us, individually or collectively.

In achieving this, the roles and responsibilities of different levels of government, the private sector and different parts of the community are still being defined. The impacts of changing climate will vary locally and while policy to support climate change mitigation is primarily a task for national governments and international agreements and processes, responsibility for supporting adaptation will fall more to national and local governments.

7. Conclusions

The papers in this special issue have presented some new insights into the role of forests in the carbon cycle and the potential impacts of climate change on forest structure and composition in the USA, the breadth of adaptation options being considered by forest managers in Europe and the ways in which policy and program design can be improved to increase adaptive capacity of small-scale agroforestry producers in Africa.

As Seppala *et al.* [5] point out, most research on adaptation to climate change in forest management is relatively recent. On the other hand, climate change is happening rapidly and forest managers may not have the luxury of delaying decisions until the outcome of longer-term studies are available. Irrespective of the uncertainties, managers will need to make adaptation decisions in the near future if forests and those dependent on them are to adapt effectively in the long-term. However, responses of forest managers to climate change have mostly been reactive and while forest managers often claim to take a long-term view, many are now responding to much shorter term economic or political imperatives.

Uncertainty is often put up as a reason for delaying implementation of more proactive strategies. These papers point to the need for research to improve decision making in a way that addresses the inherent uncertainty in projections of future climate and its impacts. Adaptation decisions will also require difficult social choices about what we value most about forests and what we might be prepared to lose. The diverse values and interests of different stakeholders can impede efforts to reach consensus on longer-term forest management goals under a changing climate [5]. There is a need for better mechanisms to more rapidly consider and integrate these different perspectives in order to rapidly implement proactive management strategies.

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