Ecosystem Services from Forest Landscapes: Where We Are and Where We Go

Louis R. Iverson, Ajith H. Perera, Guillermo Martínez Pastur, and Urmas Peterson

1 Introduction

In this chapter, we aim for three goals: (1) We summarize some key features from the chapters, as they pertain to the overall themes of the book. The chapters themselves provide great resources to bring awareness to some newer and broader aspects of forest ecosystem services as well as a literature-rich, synthetic approach to understanding these advances and future visions for related research and application. We will highlight some of those points here. (2) We then aim to provide some emerging messages resulting from these newer approaches to understanding the complexities of planning for, evaluating, and accentuating the FES. (3) Finally, we provide some insights on science gaps, research priorities, and potentials for knowledge transfer mainly into practitioners and policy makers.

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2 Complexity of Forest Ecosystem Services

One immediate realization upon opening the book is that the ecosystem services tied to forests require a broad view, and likely a more complex view, than most people realize. We do not dwell on the "usual suspects" in this book (e.g., timber, biodiversity, carbon sequestration) but emphasize some lesser known aspects of ES. Among them are the large, globally significant contributions forests make to regulating chemical composition of the atmosphere, be they trace gases (chapter "Effects of Climate Change on CH_4 and N_2O Fluxes from Temperate and Boreal Forest Soils", Díaz-Pinés et al.) or plant volatiles (chapter "What Are Plant-Released Biogenic Volatiles and How They Participate in Landscape- to Global-Level Processes?", Niinemets). For example, Díaz-Pinés et al. point out the important role that boreal and temperate forest soils play as regulators of atmospheric gases in the framework of a changing global climate. More than half of global carbon is stored in soils, and dynamic changes in environmental conditions underway now and increasing in the future will likely affect the net atmosphere-forest balance of CH_4 and N_2O fluxes at different temporal and spatial scales. These changes, in turn, will feed back on chemical composition of the atmosphere and, thus, on the global climate. However, knowledge is still rather limited with regard to the relationship between forest composition (and associated microbial processes), interactions with changes brought about by climate, and its importance for the function of forests as climate regulators.

Niinemets (chapter "What Are Plant-Released Biogenic Volatiles and How They Participate in Landscape- to Global-Level Processes?") aptly discusses a vastly understudied and underemphasized ecosystem service derived from plants: plant-released volatile organic compounds (at least 30,000 different compounds identified to date), often specialized for a plethora of biological and ecological functions such as the enhancement of plant stress resistance, or communication among plant organs, with other plants, or even with beneficial insects to slow the spread of herbivory. These services are crucial for stability and performance of ecosystems at local scales but collectively can also modify global climate through multiple feedback loops of stress-induced volatile emissions and cloud condensation nuclei interacting with temperature, solar radiation, and plant productivity. As such, the author argues for a much larger consideration of these trace gases in models intending to predict future climate and outcomes.

2.1 Planning for Sustainable Ecosystem Services: Integration Across Borders and Across Land Uses

One of the greatest challenges in the landscape planning is related to maintaining the ES provision in multifunctional managed ecosystems. Research exists in the provision of individual ES; however, only a few studies have considered the

trade-offs and synergies among them, and the literature on the associated landscape planning is scarce. Within the book, we present several examples that lead with this topic, trying to integrate the different proposals across boundaries and land-use types.

Elbakidze et al. (chapter "Towards Functional Green Infrastructure in the Baltic Sea Region: Knowledge Production and Learning Across Borders") focus on sustaining natural capital and enhancing multiple ecosystem services through the use of functional green infrastructure, a network of high-quality natural and seminatural areas intended to deliver ecosystem services and protect biodiversity in both rural and urban areas. These green networks are especially important for smaller countries and jurisdictions, which may not be able to provide sufficiently large green areas on their own, and thus benefit from ecosystem services from forest ecosystems that span international and regional boundaries. This process is challenging in any situation but complicated further when coordinating across multiple country boundaries, as the authors present for the Baltic Sea Region. The authors articulate the challenges but also the opportunities with much to gain from increased multilateral, learning-based collaborations regarding all aspects of sustainable forest landscapes.

LaRosa et al. (chapter "Sustainable Planning for Peri-urban Landscapes") review the special considerations when evaluating ES associated with peri-urban landscapes, those areas located partly outside the more compact part of a city with low density and diverse patterns of development spreading into the surrounding rural areas. These areas provide important functions including enhancing biodiversity of urban areas, enhancing proximal recreation opportunities, and reducing heat island effects, pollution, and noise; thus, they play a fundamental role in health, well-being, and social safety. Many of these services depend on the urban forest; thus appropriate spatial planning may be used to enhance certain ES by modifying the size, composition, and structure of the urban forest. On the other hand, peri-urban landscapes also suffer from increased stresses due to the proximity and accessibility of urban activities, and climate change is likely to impact these regions more than rural areas because of the higher concentration of human activities. Peri-urban landscapes are also understudied and provide another fruitful arena for enhancing ecosystem services via research and spatial planning.

Angelstam et al. (chapter "Barriers and Bridges for Landscape Stewardship and Knowledge Production to Sustain Functional Green Infrastructures") use six long-term, place-based case studies throughout Europe to explore their social-ecological systems and the various approaches to enhancing green infrastructure and sustainable forest management. Across the region, landscape histories and governance contexts are very diverse, so that experiences of human and natural scientists, practitioners, and stakeholders from each study were crucial for knowledge production and learning to understand the full process toward functional green infrastructure. They point out the important role that expert knowledge can play to supplement or complement empirical knowledge at least in the short term. The authors provide seven key actions to promote multilevel learning toward enhancing sustainable landscapes and their respective ES.

3 Challenges and Opportunities in Managing for ES in Forested Landscapes

Another great challenge is the balance of ES provision in managed landscapes. In the past, research was focused on maximizing the provisioning ES, despite the other services. However, within the new management paradigm, we must consider the maintenance of other ES inside the areas under intensive management. Several studies have focused on the theoretical framework, but implementation in the field still needs research. In this framework and within the book, the authors present several examples of successful implementation of both theoretical proposals and long-term research of the effects of these new management proposals.

Monkkonen et al. (chapter "Solving Conflicts Among Conservation, Economic and Social Objectives in Boreal Production Forest Landscapes; Fennoscandian Perspectives") focus on preserving certain ecosystem services including biological diversity yet at the same time, maintaining intensive timber extraction in boreal, specifically Fennoscandian, forests. Many ecosystem services and biodiversity are in conflict with intensive timber production in boreal forests; e.g., the proportion of old-growth forests is very small, and natural disturbances such as fires and gap formation are minimized, with negative biodiversity consequences for forest species. The authors present management tools for assessing and finding solutions for conflicts among alternative forest uses, including encouraging more variation in management regimes combined optimally across landscapes, more mixed species stands, more green tree retention, and less thinning. Forest certification, payment schemes, and regional planning differentiating landscapes where environmental and social objectives have priority over timber production landscapes may be policy tools to encourage sustainable landscapes and the broad array of ecosystem services over the long term. This chapter highlights the orthogonality that could occur among ecosystem services (e.g., direct competition between biodiversity conservation and extraction of timber, in this case).

Frelich et al. (chapter "Natural Disturbances and Forest Management: Interacting Patterns on the Landscape") dwell on the question "what is the real level of sustainable harvest" in the context of maximizing ecosystem services and forest health, given the likelihood that natural forests possess some level of redundancy with respect to the amount of dead wood and older trees and stands that are needed to maintain forest health. Though safe levels of harvest are rarely known, practices such as close-to-nature forestry or best management practices with regard to structural features left after harvesting can ensure adequate residuals and help maintain forest resilience to disturbance. However, large infrequent disturbances and novel disturbance regimes in a changing climate may swamp out management practices in shaping the future forest so that additional redundancy, spatially distributed among landscapes, may be needed to sustain ecosystem services across regions. Restoration forestry is also expected to play an increasing role in restoring resilience to forests undergoing increasing natural and human disturbances.

4 Emergent Messages

- *Complexity associated with the knowledge of forest ecosystem services is high.*
  In addition to the vast array of services provided by forest ecosystems, interactions (both positive and negative) among those as well as their numerous feedback loops to influencing composition and function of forest ecosystem themselves render information, knowledge, and investigations of forest ecosystem services highly complex.
- *Forest ecosystem services are not limited to localities and fine scales.*
  Services offered by forest ecosystems are broad. Their influence extends beyond local benefits (e.g., atmosphere and hydrosphere) and cross ecological, geographic, and jurisdictional scales.
- *Much uncertainty exists in scientific/empirical knowledge about services from forest ecosystems at broad scales.*
  With regard to atmospheric gas regulation, for example: how do the composition and spatial configuration of forest ecosystems affect the services they provide? How will these services continue as the climate changes and alter the atmosphere and ecosystems themselves? These are complex research questions, but their answers may divulge vital information about crucial services provided by forest ecosystems.
- *Planning for forest ecosystem service provision needs a broad-scale perspective.*
  In many regions where forest cover dwindles due to urbanization or other land use, continuation of a sustained provision of ecosystem services is a challenge. Spatial configuration of the remaining forest cover, especially their connectivity as networks, becomes an important element in planning that requires cross-national and regional boundaries. Policy makers and land-use planners must broaden their planning horizons and collaborate with neighboring countries and regions.
- *Education and awareness of forest ecosystem services is essential.*
  Consideration of forest ecosystem services is limited to rhetoric in land-use planning exercises in most countries and regions. In part this is due to a lack of awareness and knowledge. Educating and making policy makers and land-use planners aware of the range of services that forest ecosystems provide, necessity to sustain these services, and how best to design land use for sustained provision of the ecosystem services, even with the limited knowledge, are crucial.
- *New approaches and shifts in present management paradigms are necessary.*
  It may be necessary to adopt new approaches (e.g., use of expert knowledge and adaptive management in the case of limited knowledge) and tools (e.g., different simulation models for designing and assessing land-use plans). This includes changing the culture in land management agencies to embrace new approaches in policy development, strategic land-use planning, and optimizing land management goals.

5 Applying the Messages

Here we explore the applications of the messages in this book from two viewpoints: their use in land management approaches and decisions and how they can guide future research activities. While these points are not independent, we treat them separately to address the interests of both land managers and researchers.

5.1 Implementation Approaches to Optimize Forest Ecosystem Services

The chapters within the book emphasize the complexity and breadth of forest ecosystem services, particularly at broad scales. The many steps involved in the provisioning of ecosystem services involve ascertaining the full suite of ecosystem services desired by the local communities as well as the regional and global community, quantifying and analyzing the capacity of extant forest ecosystems to provide those services, designing an optimal extent and spatial configuration of supplementary forest ecosystems, formulating management plans that both ensure a sustained supply of ecosystem services and minimize conflicts, institutionalizing these plans in land management authorities that may need cultural shifts, educating and transferring knowledge to land management professionals to ensure continuation of these plans, and self-governance. The complexities associated with provisioning ecosystem services are enormous. Their relative magnitude and importance will vary and depend on specific cultural, social, and economic milieus (Fig. 1). Only through innovative and adaptive management approaches can these obstacles may be overcome, and therefore benefits may be achieved.

As such, the approaches to provide a full suite of ecosystem services may be complex as well. First principles of landscape ecology, the study of patterns and processes, e.g., patches, matrix, connectivity, heterogeneity, will be quite useful in designing strategies for sustaining the supply of cross-scale forest ecosystem services. Several general landscape ecology principles can be set forward that are likely valid for many services. First, land planners and managers need to think broadly and spatially as to how various land cover/land-use patches influence each other and how the whole region's ecosystem services can be affected by their decisions. In particular, the concepts of patterns, especially spatial configuration and connectivity of forest ecosystems, matter! An additional challenge for planners and decision-makers is that the ecosystem services that transcend local scales are generally less recognized, especially the regulatory services – they are generally indirect, intangible, and beyond the scale of human perception. Thus, the services that extend beyond individual forest patches, e.g., those which rely on the connected networks of forests, may not be on the radar screen of local agencies responsible for managing forest ecosystem services. This points to the need for (i) education of the local agencies on the regional and global values of the forest patches they manage and (ii) the need for vertical

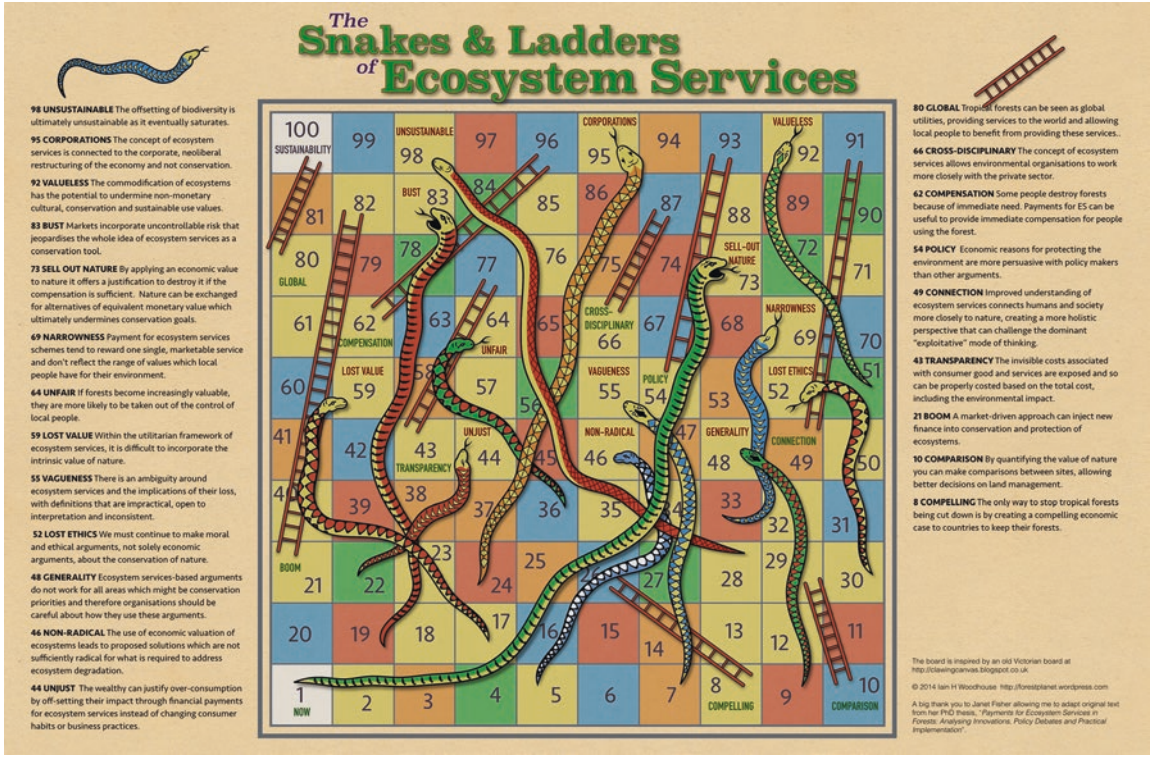

Fig. 1 A graphical depiction of the many benefits and drawbacks associated with provisioning ecosystem services, the array of both benefits and challenges that face land managers in their decision-making. Reproduced with permission from Janet Fisher (Fisher, J. (2011). Payments for Ecosystem Services in Forests: Analysing Innovations, Policy Debates and Practical Implementation. Doctoral Thesis, University of East Anglia.) and Iain Woodhouse (https://forest-planet.wordpress.com/2014/08/18/the-snakes-and-ladders-of-ecosystem-services/)

coordination (hierarchical nesting) among land management agencies across jurisdictions (e.g., towns-cities-townships-counties-states-regions-provinces-countries).

Second, which follows, is that often planning (and incentives and/or regulation) therefore needs to also occur at higher levels, i.e., at broader scales, even if it means crossing many jurisdictional boundaries. Education and communication among policy makers, including across country boundaries, are therefore essential at this level. In addition, because ecosystem services supply often entails a complex mix of ecology, economics, sociology, and politics in the order of decision-making with broadening scales, cross-jurisdictional assessment and planning to supply forest ecosystem services involve complexities not unlike developing and implementing mitigation strategies for climate change, i.e., most action is local, but planning and regulation needs to be at multiple scales, to achieve maximum impact on enhancing or sustaining the ecosystem services.

Third, the transfer of scientific knowledge to decision-makers and land-use planners needs to be readily accomplished via the tools of the landscape ecologist: maps, GIS, animations of model outputs, visual simulations, remote sensing from a host of sensors, on-ground sensing devices, and, of course, field-obtained plot data. Succinct, synthetic, and visual representations of potential future ecosystem services under various land-use decisions would go a long way toward moving to socially responsible optimization of those services. Extracting knowledge from experts would also be important in this effort to evaluate clear representations of alternative management paths forward; the value of expert and traditional knowledge in supplementing empirical (scientific) knowledge should not be underestimated. Some ecosystem services from forests are traditional and even cultural. Ascertaining the value, demand, and supply of these services may depend on traditional and local knowledge that may not be found in scientific knowledge.

6 Research Opportunities

As we conclude this chapter and this book, the editors reflect on lessons learned and provide the following suggestions for ways forward in research needs and implementation avenues toward successful augmentation and sustenance of the ecosystem services from forests. We leave it to the reader to start with these nuggets, listed in no particular order, and generate appropriate research lines to that end.

1. Develop strategies and methods to simply compile all the information available from the “tools of the trade” into meaningful and digestible packets of information for policy makers to make informed decisions.
2. Research methods that can help determine the “real level of sustainable harvest” as put out by Frelich et al. in chapter “Natural Disturbances and Forest Management: Interacting Patterns on the Landscape”.
3. Build up a suite of case studies that cover more and more situations for other jurisdictions to copy. These case studies are often specially funded situations

using a large portion of the landscape ecological toolbox, but the essential tools and methods need to be extracted such that other jurisdictions can replicate the essential elements at low cost. Further, how to best arrive at these essential elements? Included is the need for successful case studies that transcend jurisdictional boundaries with decision-making flowing to and from local, regional, and national levels.

4. Investigate ways to improve understanding of the political dimension to forest ecosystem services/governance that plays, a huge role. Studies like those in chapters "Towards Functional Green Infrastructure in the Baltic Sea Region: Knowledge Production and Learning Across Borders" and "Barriers and Bridges for Landscape Stewardship and Knowledge Production to Sustain Functional Green Infrastructures" can elicit cross-country comparisons such that the best components for optimizing forest ecosystem services can be gleaned among multiple country-level approaches.
5. Investigate ways to better understand the influence of land-use legacies as to what constraints and opportunities exist for forest ecosystem services. Remote sensing from satellites, now with over 40 years of history, can be valuable to trace back at least the short-term legacies. Digitization and analysis of historic maps and aerial photos can extend the information base farther into the past. Learning from the past can help in managing for the future.
6. Investigate further the role of scaling in the fluctuation and provision of ecosystem services. For example, how much does a local land-use decision affect the whole? Or for a more specific example, how much do regional components of trace gases and plant volatiles affect the local conditions for humans and other organisms?
7. Research the specific and general roles of plant-emitted volatile organic compounds in modifying specific ecosystem services. We hope this book has opened the eyes of many readers as to the vast ecological influence of volatiles and the large amount of research still needed to further uncover both the local (e.g., insect resistance or pollinator attraction) and regional/global (e.g., climate regulation or cloud condensation nuclei) impacts across landscapes. Plenty of research questions here!
8. Investigate ways to uncover the net atmosphere-forest balance of CH_4 and N_2O fluxes at different temporal and spatial scales and to evaluate the feedbacks to the global climate system. Again, this is a vastly understudied aspect of forests and their ecosystem services.
9. Investigate the ways in which resilience of a landscape may vary over time, under a changing climate, and the ways in which management actions can enhance resilience. How do we even determine how resilient landscapes are, and which ecosystem services are included when we examine resilience?
10. Develop procedures to evaluate conflicts and trade-offs when opposing ecosystem services need to be optimized across landscapes (e.g., optimal arrangements of land uses within the peri-urban landscape or timber vs. biodiversity emphasis).

11. Develop methods to evaluate, especially within urbanizing landscapes (i.e., peri-urban landscapes), critical limits to the amount and juxtaposition of forested parcels which enable the sustenance of key ecosystem services. For example, how might forest parcel arrangement affect the provision of habitat for various species of birds, pollinating insects, and a biodiverse flora? How do we factor in many of the human influences on these critical limits (e.g., population density, housing/income, traffic patterns/density, gentrification, attitudes toward green space)?
12. Develop new management alternatives for land management which replace traditional (and often one-dimensional) management, and which enhance the provision of ecosystem services, especially nonmonetary services, while also decreasing the conflicts of use among the different social groups that use the ecosystem.
13. Create more studies which analyze synergies and trade-offs with implementation of different management and conservation strategies, especially in the peri-urban regions, the fringes between the urban and natural landscapes.

7 Conclusion

In this book, the authors emphasize, again, that the study of ecosystem services is a very broad and complex topic, which lies within the confluence of environmental, political, and personal values, across scales from very local to global scale. Many variables and strategies come into play, several of which may not have been generally recognized before but are elevated in this book, from the relatively less known molecular-level plant processes (chapters "Effects of Climate Change on CH_4 and N_2O Fluxes from Temperate and Boreal Forest Soils" and "What Are Plant-Released Biogenic Volatiles and How They Participate in Landscape- to Global-Level Processes?") to the widely known forest stand-level processes (chapters "Solving Conflicts Among Conservation, Economic and Social Objectives in Boreal Production Forest Landscapes: Fennoscandian Perspectives" and "Natural Disturbances and Forest Management: Interacting Patterns on the Landscape"), and ecosystem service provisioning strategies that transcend from the local jurisdictional level (chapter "Sustainable Planning for Peri-urban Landscapes") to the international level (chapters "Towards Functional Green Infrastructure in the Baltic Sea Region: Knowledge Production and Learning Across Borders" and "Barriers and Bridges for Landscape Stewardship and Knowledge Production to Sustain Functional Green Infrastructures").This book is not a definitive road map for provisioning ecosystem services from forested landscapes but is a starting point of discussion for future research and applications in a world that must improve their management and conservation strategies, to ensure the sustenance and enhancement of ecosystem services now and into the future.

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Broadscale Considerations

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