

Editorial

# Concluding Remarks: Moving Forward on Scientific Knowledge and Management Approaches to Tropical Forests in the Anthropocene Epoch

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**Abstract:** The United States Department of Agriculture Forest Service International Institute of Tropical Forestry (the Institute) celebrates its 75th Anniversary with the publication of this Special Issue of *Forests*. This Issue is based on presentations delivered in a symposium held in San Juan, Puerto Rico in 2014. It augments a quarter century of scientific knowledge and capitalizes on a unique set of synergies chartered by a strategy based on shared stewardship, innovative transdisciplinary collaborations, and breakthroughs in science and technology. The manuscripts contained here present advancements in our approach to the development of policies for effective governance and stewardship, long-term focus for the understanding of ecosystem processes and functions, novelties given attention to cross-boundary collaborative approaches to science, and proposed alternative institutional visions in the Anthropocene. As the Institute continues to collaboratively explore new frontiers in science, we recognize advances in forestry, atmospheric sciences, modeling, hydrology, plant physiology, and microbial ecology as core to the understanding of tropical forests in the Anthropocene.

**Keywords:** conservation; American tropics; long-term ecological research; tropical forest management; Anthropocene; Puerto Rico

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## 1. Scientific Knowledge and Management Approaches to Tropical Forests in the Anthropocene

The United States Department of Agriculture (USDA) Forest Service International Institute of Tropical Forestry (the Institute) has a long history of research. At its inception during the 1930s and 1940s, the Institute completed important silvicultural studies with rigorous controls to provide the basis for tropical forest production. In the 1950s, the ecology of natural, unmanaged forests was added to the research portfolio, while the 1960s marked a period of focus on endangered species being included in the research and development program. Biomass and climate change research began in the 1980s, and watershed and biogeochemical studies were in full swing by 1990. Landscape ecologists using remote sensing techniques and the study of the biology and ecology of soils were added components to the research unit in the 2000s. By the 2010s, the Institute had maintained almost all original lines of research [1], yet had expanded studies to encompass human and ecological systems in an effort of continued application of our research to science, society, and management. In the years ahead, we foresee that the Institute will continue providing society with long-term context, information synthesis, theory development, and deep knowledge of place while we continue working in multidisciplinary and collaborative teams with a focus on the American tropics and Caribbean region, much like the goals established for the United States by the National Science Foundation Long Term Ecological Research Network Program (LTER).

Looking back, one of the main goals of the manuscripts published in the volume that commemorated the 50th anniversary of the Institute [2] was to show the relevance of research to tropical forest management and propose that tropical forests could recover after human intervention, provided they were given the opportunity [3]. In this special issue, we augment a quarter century of scientific knowledge and are poised to capitalize on a unique set of synergies chartered by a strategy based on shared stewardship, innovative transdisciplinary collaborations, and breakthroughs in science and technology [4]. Moreover, the environment under which tropical forests function has dramatically changed over the past 25 years with the advent of the Anthropocene Epoch—the age of significant human impact on Earth’s geology and ecosystems. The manuscripts contained in this special issue present advancements in our approach to the development of policies for effective governance and stewardship [5–8]; long-term focus for the understanding of ecosystem processes and functions [9–13], novelties given attention to cross-boundary collaborative approaches to science [14–17], and proposed alternative institutional visions [18] considering the Anthropocene Epoch.

## 2. Key Considerations Posed for Future Studies as Identified in This Special Issue Are:

- As human activities increasingly influence systems and processes at multiple scales, society may be more likely to see extraordinary and surprising events, making it difficult to predict the future with the level of precision and accuracy needed for broad-scale management prescriptions [5].
- Collaborative relationships with stakeholders, productive ties to the scientific community, and political support for adaptiveness and flexibility are critical elements in managing for the future resilience and sustainability of tropical forests [5].
- Deforestation in the dry tropics, with its artisanal basis for forest utilization, is likely to produce a more fragmented forest than the industrial-scale deforestation in the humid tropics [6].
- Urban knowledge systems can create and help transition to a sustainable and resilient future [7].
- Large-scale conservation partnerships are teams at their core, meaning that relevant land and sea managers are empowered to be part of a team that work toward a shared vision, understand the stressors on the system based on past observations and future projections, and see the opportunities for increased coordination to advance a conservation agenda [8].
- Organisms in the litter and soil of tropical forests in Puerto Rico independently and synergistically influence the rates of decomposition and availability of nutrients to tree roots [9].
- Novel ecosystems are expected to adapt to Anthropocene conditions and continue to function as carbon sinks in a new world order where the speed of ecological processes is accelerated [10].
- The effects from hurricane disturbances maintain Puerto Rico’s forests in a constant state of structural and compositional change in response to the intensity and the cumulative effects of these events [11].
- Conservation efforts of migrant birds are most likely to be effective if based on research that uses a full annual cycle approach for the identification of factors that limit their population growth [12].
- Large-scale manipulative experiments in the Luquillo Experimental Forest have greatly enhanced our understanding of tropical forest function under different disturbance regimes and informed the development of management strategies [13].
- Novel dry forests contribute to the conservation of native plant species on highly degraded lands [14].
- Introduced and native trees can have different resource–investment strategies in tropical novel forests [15].
- Karst vegetation in Puerto Rico appears to be phosphorus limited [16].
- Potential working lands encompass 42% of Puerto Rico, these include lands well suited for mechanized and non-mechanized agriculture as well as for forestry production [17].

- High unemployment rates, issues of food security, and the rising cost of importing agricultural products are issues that are pressing Puerto Rico toward a revitalization of its working lands sector [17].
- The USDA Forest Service mission has foundational guiding principles that include a science-based, ecological approach to stewardship across all lands along a complex rural to urban land gradient [18].

### 3. Future Research Questions or Directions as Identified in This Special Issue Include:

- How can tropical ecosystems persist in human-modified landscapes, and which management strategies will be most effective at maintaining their structures and functions at different spatial and temporal scales? [5]
- There is an increase in the scientific understanding of tropical forests as complex social-ecological systems; yet variability in the dynamics across systems and related processes are expected to increase in the context of the Anthropocene. Are changes in policy or practice required for dealing with the Anthropocene? [5]
- How can landowners and managers strike the right balance of sustainably managing tropical forests for multiple uses? Furthermore, how do these management considerations, extreme events like fire, drought, or hurricanes interact with climate change and ultimately affect greenhouse gas emissions? [6]
- What are the institutional arrangements and stakeholder engagement processes most useful in the development of knowledge co-production systems to further advance urban sustainability issues? Are there social and institutional conditions that are more conducive to knowledge co-production efforts? [7]
- How can we re-think leadership in collaborative settings and on relational governance, cooperative teamwork procedures, and communications to ensure the long-term success of landscape conservation partnerships? [8]
- How does environmental variation affect the dynamics of different soil microbial and faunal assemblages? How does the variation in the composition of such organismal assemblages control the long-term sustainability and management of ecosystems that are subject to global change? [9]
- How do complexities of land use, cover, and climate change affect the carbon balance of whole tropical landscapes? [10]
- How can the dynamics in forest structure and composition during succession relate to the recovery and resilience of different components of the forest ecosystem after hurricane disturbance? [11]
- How would adaptation to environmental changes, genetic variation, strength, and spatial patterning of selection influence conservation efforts on migrant birds in the Caribbean Basin? [12]
- Will the forests in the Luquillo Experimental Forest continue to persist or will we see a significant shift in its size and composition as the world's climate and disturbance regimes continue to change? What future experiments should be conducted in the Luquillo Experimental Forest if we are to continue providing critical information for the development and refinement of forest management strategies? [13]
- What are the implications of novelty to the ecology, restoration, and conservation efforts of Puerto Rico's dry forests? [14]
- Do introduced and native species in novel forests in Puerto Rico differ in the efficient use of resources? Do they occupy distinct or overlapping positions in the leaf economic spectrum? [15]
- How different are the denitrification rates in karst forests under dry to sub-humid climatic conditions in the Caribbean Basin? [16]

- How can scientific and traditional knowledge, incentive programs, global and local markets, and technology be used to convert planning into productive and sustainable farm and forest activities in Puerto Rico? [17]
- What does the USDA Forest Service need to do during the Anthropocene to be competitive in addressing the contemporary conservation challenges now and ahead? [18]

#### 4. Conclusions

The International Institute of Tropical Forestry exemplifies the United States Department of Agriculture Forest Service's mission of working cross-jurisdictions, building science capacity, and interpretation of the contemporary issues relevant to society and resource conservation. In addition, it has a long track record of doing so in cooperation with partners and stakeholders, while acting as co-conveners and co-facilitators for collaborative learning and decision making. As we continue to collaboratively explore new frontiers in science, we recognize the potential of forestry, atmospheric sciences, modeling, hydrology, plant physiology, and microbial ecology as core to the understanding of tropical forests in the Anthropocene.

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