Reforesting Landscapes

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Volume 10

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Reforesting Landscapes

Linking Pattern and Process

Springer

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Foreword by the Series Editors

With the Springer Landscape Series we want to provide a much-needed forum for dealing with the complexity of landscape types that occur, and are studied, globally. It is crucial that the series highlights the richness of global landscape diversity – both in the landscapes themselves and in the approaches used in their study. Moreover, while the multiplicity of relevant academic disciplines and approaches is characteristic of landscape research, we also aim to provide a place where the synthesis and integration of different knowledge cultures is common practice.

This book, Reforesting Landscapes, the tenth in the series, marks a shift in the research perspective from focusing on deforestation to a broader view on regrowth, reforestation, and afforestation. It is particularly timely, as a growing body of literature gives evidence for forest regrowth in developed as well as developing countries. This trend has important implications for biodiversity, carbon sequestration, soil maintenance and reduction of greenhouse gases.

We are proud that this book is part of the Landscape Series, which focuses on integrative aspects in landscape research. The way the authors approach the subject is integrative in a number of ways. Regrowth, reforestation and afforestation are not discussed isolated, but within their biophysical, geographic, ecological, socio-economic, and institutional contexts. The authors have integrated experiences from multiple research locations across the world, thus giving a unique picture of similarities and differences of forestation processes in various physical and social environments. Data gathering reflects an interdisciplinary approach, in which methods and techniques from natural sciences and social sciences complement each other. Field-based examinations ensure practical applicability of the results. Integration was also reached across geographical scales, with some chapters giving a broader international overview and others exemplifying projects on a regional and local scale. Both volume editors are distinguished scholars, with broad experiences in landscape research, landscape ecology, and geography from a variety of different international institutions. The book gives a unique overview for everybody interested in processes of regrowth and reforestation. It will be warmly welcome by professionals as well as researchers and students across the world.

Munich and Toulouse, March 2009

Bärbel Tress
Gunther Tress
Henri Décamps

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Chapter 1
Reforestation: Challenges and Themes in Reforestation Research

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1.1 Introduction

Tropical forest habitat continues to decline globally, with serious negative consequences for environmental sustainability (Rudel 2005). Perhaps as a consequence, studies of land cover change have long been dominated by discussions of deforestation. Most studies on land cover change have been focused on deforestation occurring in different countries, monitored by national level databases such as FAO, regional studies of deforestation in hotspots of deforestation such as the Amazon and Southeast Asia, national level studies and even smaller case studies of specific landscapes (Cropper et al. 2001 ; Seidl et al. 2001; Messina et al. 2006; Kao and Iida 2006). Yet in recent times there has been a growing awareness in the land use/land cover change research community, and amongst landscape ecologists, of the need to move away from the dominant focus on deforestation to examine the patterns and processes associated with reforesting landscapes (Rudel 2005).

There is an increasing body of literature which suggests a recent trend towards forest regrowth in regions across the world. Such forest transitions have been documented in economically developed countries in the temperate world, with the majority of these transitions having occurred towards the last half of the twentieth century. In the past couple of decades, there has been growing evidence of large scale forest regrowth also taking place in tropical and sub-tropical forests, across multiple continents. Even in landscapes which exhibit deforestation, a number of recent studies have increasingly focused on regrowth, reforestation and afforestation, often hand in hand with deforestation and degradation processes (Moon and Park 2004; Munroe et al. 2004; Nagendra et al. 2008; Southworth and Tucker 2001).

The dual and simultaneous focus on regrowth/regeneration and reforestation/afforestation is a welcome change and has serious implications for global biodiversity, carbon sequestration, soil maintenance and reduction of greenhouse gases that contribute to global climate change (Grainger 2008). Reforestation is often patchy, and rates of forest recovery are typically slower than initial rates of clearing. These emerging forests often do not contain the same species or supply the same range of ecosystem goods and services provided by old growth forests (Bentley 1989; Lugo 1992; Rudel et al. 2000). Nevertheless, secondary forests provide important environmental services that assist efforts towards sustainable development, increase carbon sequestration, assist in soil conservation and the stabilization of hydrological cycles, and increase overall biodiversity levels. Developing a more comprehensive understanding of the range of proximate and underlying factors that can help to promote reforestation is therefore critical, if we are to develop useful policy interventions to arrest or reverse deforestation, and encourage forest regrowth (Rudel et al. 2005). Yet it is important to recognize that forests are embedded within larger-level ecological, socio-economic and political settings, which have the capacity to significantly influence outcomes. Thus, discussions of context – biophysical, geographic, ecological, socio-economic and institutional – are essential to the development of our understanding of this area of study.

Despite the increase in case studies examining the patterns and processes of reforestation, though (Moon and Park 2004; Munroe et al. 2004; Nagendra et al.

2008; Southworth and Tucker 2001), there have been few efforts to integrate these findings across multiple research locations. If we are to identify and encourage such processes where they are occurring in different parts of the globe, there is a pressing need to establish broader frameworks to guide our understanding of the drivers associated with reforesting landscapes. A book addressing the issues relating to reforestation, regeneration and regrowth of forest cover from around the world is thus long overdue within the landscape research community.

1.2 Description of the Book

The idea for this edited volume emerged from such an awareness of the critical need for cross-site empirical studies examining the patterns and processes impacting reforestation in a variety of field contexts. In this book, we have integrated research findings from scientists working in a range of contexts and continents and utilizing a variety of integrated, inter-disciplinary approaches to examine reforestation. The cross-site examinations conducted here by scientists working in a variety of different field settings can help us narrow down the larger set of potential variables to identify specific factors that are important in a given context.

Reforestation and regrowth issues are addressed from multiple dimensions of ecosystem services, protected areas, social institutions, economic transitions, remediation of environmental problems, conservation, land abandonment, and both micro and macro level drivers of forest regrowth. This volume sets out to address these issues on a global scale, incorporating research from North America, South America, Central America, Africa, Asia and Europe. Consequently, a diversity of issues can be addressed, common threads discussed and compiled, and different drivers and patterns established.

This book is targeted towards an interdisciplinary research community working on issues relevant to the biophysical, geographic, socioeconomic and institutional processes associated with reforestation. Methods used to study these patterns and processes range from the use of techniques of satellite remote sensing, aerial photography, historical maps and GIS, to the collection of intensive field data, economic and social datasets, and the study of political and social institutions. These data are used in concert, which also leads the often interdisciplinary teams to directly address the issues of scale (spatial, spectral and temporal), the organizational and functional level of analysis, the timing of data acquisition and the linkage of the social and biophysical datasets, all necessary to answer their research questions.

To fully understand both the social and ecological dimensions of regional land cover change, requires both fine scale data and in depth field studies. On the other hand, placing specific case studies within the larger body of literature and linking multiple case studies is a pre-requisite to synthesis and theoretical progress (Rudel et al. 2005). Thus, critically, such field based examinations are also closely integrated with theoretically motivated examinations of literature, to distil the complex set of potential driving factors and narrow in on variables that are the most important in different contexts, achieving clarity without sacrificing relevant detail.

The book is organized in a hierarchical fashion, beginning with chapters that lay out broader frameworks for the study of reforesting landscapes, then moving to regional studies of reforestation, and from there, finally, to case studies of reforestation in specific landscapes. The geographic scope is vast and varied, covering countries as diverse as Bhutan, Madagascar, Peru, Poland, USA and Vietnam. While all authors address issues of specific importance to their landscapes of focus, there are some common themes that link these discussions.

We begin with a set of three chapters which discuss issues relevant to reforestation research across all landscapes. In Chapter 2, Grainger discusses the challenges of monitoring long term forest change. When deforestation and reforestation simultaneously take place in an area, problems of aggregation ensue, leading to substantial uncertainties about the nature and extent of forest change. Chapter 3 (Rudel) then uses a comparative historical approach to outline the human drivers of forest expansion, describing three pathways that give rise to reforestation under different social circumstances, and describing policy initiatives that would help encourage such change. Chapter 4 (Perz and Almeyda) presents an alternate tri-partite framework, drawing on concepts of hierarchy, heterarchy and panarchy to develop multiscale perspectives of reforestation that reconcile short term, medium term and long term forest dynamics, and explore drivers of forest change at scales ranging from the local to the global.

Latin America, Eastern Europe and South Asia form three major regions of the world that have experienced large scale reforestation in recent times, and Chapters 5–7 discuss reforestation in these different regional contexts. Chapter 5 (Bray) focuses on the dynamics of forest transition in Mexico and Central America, while Chapter 6 (Taff et al.) examines reforestation in Central and Eastern Europe, and Chapter 7 (Nagendra) looks at the drivers of reforestation in South Asia.

Chapters 8–15 develop themes relevant to reforestation research in specific landscapes located in a variety of social, institutional, biophysical, economic and historical settings. These landscapes range from the Midwestern USA (Chapter 8, Evans et al.) to the Peruvian Amazon (Chapter 9, Crews and Moffett), northwestern Costa Rica (Chapter 10, Daniels), the Polish Carpathian mountains (Chapter 11, Kozak), Kibale National Park in Uganda (Chapter 12, Hartter et al.), southern Madagascar (Chapter 13, Elmqvist el al), Vietnam and Bhutan (Chapter 14, Meyfroidt and Lambin) and China (Chapter 15, Song and Zhang). A diversity of issues critical to understanding the social and ecological aspects of reforestation are addressed in this range of landscapes and socio-ecological contexts.

1.3 Challenges for Reforestation Research

Through this book, our endeavor is to map our current state of knowledge on reforestation, to outline the gaps in our understanding, and to identify the major challenges for reforestation research. Based on discussions with all authors contributing to this volume, we have identified major challenges critical to reforestation studies, which are further addressed in the chapters in this volume. These main themes or challenges within this field of study are discussed in Table 1.1, and linked to relevant chapters in the book which address these challenges or themes in greater detail.

These dominant themes and challenges will be addressed within this volume but their importance also deserves some brief attention here in the introduction, in terms of what we mean by each of these themes and how these are also challenges to the future research needs within these fields. The following section will briefly address these themes.

1.3.1 Definitions of Reforestation

Definitions for the terms of reforestation, afforestation, regeneration, etc. are used differently in different disciplines and areas of research. This range of terms reflects the range of contexts and meanings that these terms represent, and as such, this diversity mirrors the interdisciplinarity of thought represented in reforestation research. This volume consequently reflects the same diversity of meaning. All authors clearly describe the terms they use and their meaning in each chapter, providing clarity. In a broader sense though, the use of different terms interchangeably, across different disciplines and methodologies, is a major problem not just within this arena, but also within many fields of research that similarly cross disciplinary and methodological boundaries. Unfortunately, however, the field of reforestation research is a nascent one and does not appear ready as yet for the emergence of standardized terminologies that researchers from different disciplines will be willing to adopt. The most we can do at this point is to clearly define each author's use of such terminology and to take care that the uses of such terms are appropriate for the specific subject matter under discussion.

1.3.2 Interdisciplinarity

Human–Environment interactions and their study, especially under changing conditions, pose challenges to research requiring not only a *multidisciplinary approach*, with contributions from several social and biophysical science disciplines, but also an *interdisciplinary conceptual framework* that integrates social and ecological changes and their iterative feedbacks. Due to the complexity of social, economic, institutional, biophysical, ecological and policy drivers, reforestation requires an inherently interdisciplinary approach to a much greater degree than many other land use conversions. While reforestation may be a biophysical process and as such much in the realm of ecologists and other physical scientists, in order to understand the drivers of these processes and to better explain these systems we

Table 1.1 Dominant themes within the study of reforestation and regeneration – compiled by Southworth and Nagendra with inputs from all authors of this volume

Theme/challenge	Description	Chapters in this volume which address this topic
1. Definitions of reforestation	The multitude of co-existing definitions of reforestation is a major issue.	All chapters address this issue, with many of the chapters using their own definitions
2. Interdiscplinarity	Reforesting landscapes are linked social-ecological systems, and to understand the process of reforestation an interdisciplinary approach is required which links both social and ecological research. In addition, we need multiscalar studies, over varying temporal and spatial scales.	Chapters 2–8, 10–15
3. Multiplicity of spatial and temporal scales	Reforestation occurs over a range of time periods and spatial scales – thus, drivers of reforestation need to be studied using an approach that incorporates an awareness of spatial and temporal scale.	Chapters 2–8, 10, 11, 14, 15
4. New methodological approaches	Better methodological approaches are required in addition to traditional classification analyses, to get at intermediate steps of change and to evaluate modification processes that occur within forest classes in addition to conversion from forest to non-forest areas or vice versa. Further, satellite remote sensing is a relatively young area of research, and approaches such as aerial photography, continuous analyses of land cover change, land cover modeling and historical comparative research are essential for a more complete understanding of landscape processes.	Chapters 2, 3, 8, 9, 11, 12, 14
5. Reforestation as a Process	The drivers of reforestation are not simply the inverse of drivers of deforestation, and are often distinct. In addition to processes which lead to reforestation we also need to understand processes by which forest has been maintained on the landscape, focusing less on the deforestation process and more on reforestation or forest maintenance.	All chapters
6. Global focus	We need to move away from an exclusive focus on hotspots of deforestation and on tropical forests, towards more diverse studies of a range of ecosystems, including wetlands, coniferous forests, dry tropical forests and woodland savanna. We must also acknowledge and attempt to understand the global differences in the processes of reforestation.	Chapters 2–4, 6, 10, 11, 13–15

7. Urbanization	This is becoming a dominant process in many regions around the globe. While urbanization appears to be linked to reforestation in surrounding rural areas, the long term consequences of urbanization on reforestation are unclear. We need to have stronger linkages with forest transition theory and urban growth, and to also study this process over time and see if there are trends which can be discerned over time.	Chapters 3, 5, 6, 8, 11, 14
8. Forest transition theory	Can FTT ever relate to a global process of reforestation, and if not what are the implications of this? How useful is FTT for developing versus developed and what is the role of protected areas or parks within this work?	Chapters 2–8, 10, 12–14
9. Cultural and ecosystem processes and services	Current socio-cultural and ecological understanding of reforestation is limited and we need much more research in this area, including an understanding of the ecological processes associated with, and the cultural and ecosystem services offered by reforestation.	Chapters 6, 8, 10, 11, 14, 15
10. Future expansion of plantations	Where do plantations fit within a reforestation dialogue and what is their future role?	Chapters 2, 3, 7, 10, 14, 15

must look much more closely at the social component. People are an integral part of the dynamic, be it in the form of a land abandonment which has left an area to regenerate and ultimately return to forest cover, or a human led replanting effort. Thus, in order to understand the causes and consequences of these systems and their implications for reforestation, we need to model both the social and physical components, and to better understand the social and economic determinants of different management strategies. We need a much better understanding of the interplay between top-down processes such as policies, and bottom-up responses of the local land managers and local communities. People play a key role which is currently not well understood, and we must acknowledge that most of these landscapes are 'working' landscapes, both socially and ecologically. Thus, there is a need for the development of new approaches and frameworks that integrate across disciplines, and integrate different methodological approaches for the study of reforestation.

1.3.3 Multiplicity of Spatial and Temporal Scales

Changes in climate, population and land use are occurring and interacting simultaneously at different time and space scales (Milly et al. 2008; Lettenmaier et al. 2008). Nonlinearities and differences in timescales and characteristic response times across key interfaces between land cover, the atmosphere, and the surface complicate efforts to monitor and model environmental processes. Up-scaling and down-scaling in space and time is a challenging problem (Bloschl and Sivapalan 1995). Incorporation of both spatial and spectral information into land-cover change analyses greatly improves the amount of information available to modeling studies (Southworth et al. 2006). For example, Lambin and Strahler (1994) found that changes in the spatial extent of land cover patches across the landscape and its arrangement or pattern were more likely to reveal longer lasting and longer-term land-cover changes, while spectral differences and within class changes are more sensitive to shorter-term fluctuations, for example, inter-annual variability in climatic conditions.

Anthropogenic, ecological and land-surface processes interact in reforesting landscapes at multiple spatial and temporal scales to create characteristic patterns (O'Neill et al. 1996). The relationships between temporally and spatially varying processes and patterns are poorly understood because of the lack of spatio-temporal observations of real landscapes over significant stretches of time (Southworth et al. 2004). Interacting anthropogenic, ecological and land-surface processes occur in landscapes at multiple scales. If we are to understand and manage the causes and consequences of anthropogenic effects on reforesting landscapes, it is imperative that we develop approaches to understanding spatial and temporal variation, the processes that produce the patterns that we observe, and the ways in which pattern-process relationships change with scale. Remote sensing has traditionally been considered an ideal tool for providing data to describe landscape patterns and dynamics. However, our understanding of the scale dependency of landscape pattern-process interactions is limited (Moody and Woodcock 1995). Understanding scaling effects is critical to our ability to better understand, model and/or predict landscape dynamics of reforestation, and specifically for understanding the roles of spatial and temporal heterogeneity and the hierarchical arrangement of landscape elements (Qi and Wu 1996).

1.3.4 New Methodological Approaches

While remote sensing has helped to advance our studies of land cover change and their drivers, the techniques currently utilized are often quite limited and very static in their approaches. The most commonly used technique for studying land cover change is that of discrete land cover classification. This only enables the study of changes in land cover, and does not allow us to view the extent of modification within a land cover category. Thus, for instance, such an approach would enable us to understand the extent of reforestation (conversion from a non-forest category to a forest category), but not enable us to study increases or decreases in density within a forest category, which are also critical for issues such as biodiversity, carbon sequestration, soil conservation and water management, and hence may be of much more import to forest managers, planners and policy makers. As such, we need to develop and test the use of more advanced remote sensing techniques, focusing more on the creation of continuous datasets, and different approaches to land cover modeling. We also need robust and detailed strategies to monitor and map reforestation by remote sensing from local to regional, and up to global scales where we differentiate degraded forests from secondary growth, plantations from natural forest, and separate out processes of regeneration and degradation, as this is a precondition for any understanding of the causes and effects. Tied in with this goal, is the need to incorporate multiple data sources, across different spatial, spectral, temporal and radiometric resolutions, to enable a more complete answering of our questions. Less reliance on Landsat will be beneficial in the long run, and is currently being dictated due to the failure of the Landsat 7 ETM sensor, and the lack of Landsat 8 readiness. Such a data gap will have massive repercussions on the land change science community and hence the evaluation of the integration of different sensors and technologies is now essential.

In addition, an added problem or current limitation relates to the fact that deforestation is a much easier process to “see” in terms of remotely sensed analyses, as this is itself a quick process when compared to that of reforestation due to the time it takes for trees to grow and to be of a size where the process of regeneration and forest expansion is visible to the satellite. To study forest expansion, satellite remote sensing seems too ‘young’ a discipline as compared to the time needed in many landscapes for a tree to grow to maturity (i.e. over thirty years in some landscapes).

The use of aerial photography, and approaches such as historical comparative analysis become critical in this regard.

1.3.5 Reforestation as a Process

Within this theme are a number of issues. A major one is that we need to focus less on unidirectional change within the field of land change science overall. Within the arena of reforestation we need to look at it not as a one-way process, it is not simply the reverse of deforestation. Rather it is a separate process, usually with separate and different drivers and we must understand these issues in order to fully understand the process, and to therefore help increase the occurrence of reforestation over deforestation (Rudel et al. 2005). We cannot start to do this until we have actually understood, monitored, mapped and modeled these occurrences, from individual case studies to global analyses, as we have started to do for deforestation. Our understanding of reforestation is much more limited and we have a lot of catching up to do within this area. For example, in FTT what factors determine where (at what percent forest cover) the reforestation phase stabilizes or plateaus? How does this pattern and trend vary across the local landscape, regional, national and international? Secondly, just as we know little on the drivers of reforestation we know even less about those that actually maintain forest cover to begin with, that is, drivers that are maintaining existing forests are little acknowledged, for example, coffee agroforestry and sustainable forest management. We need more landscape or regional scale studies of the ecological effects of reforestation.

1.3.6 Global Focus

A broader focus on understudied areas, latitudes and ecosystems, beyond the traditionally popular ‘tropical hotspots’ of deforestation, specifically extending into regions of less studied but critical and endangered ecosystems such as wetlands, dry tropical forest, coniferous forest and woodland/savanna is essential, as in these locations the dynamics of reforestation are very different. More of a focus is also required on the intermediate, human dominated and fragmented land cover types, for example, pastures with trees, suburban subdivisions with trees – that is to say, those landscapes within which many of us reside. We must also acknowledge and attempt to understand the global differences in the processes of reforestation. Currently while some forests (e.g., in the Amazon) are being encroached upon by migrating populations, in some parts of the world (e.g., much of Eastern Europe), populations are migrating to cities, abandoning croplands, many of which then undergo reforestation. Interestingly, such reforestation on abandoned agricultural lands has its own set of concerns or perceived risks, with the associated loss of some cultural landscapes in those regions.

1.3.7 Urbanization

The processes of urbanization and reforestation are tightly coupled within many systems. It is the consolidation of people within such concentrated regions that allows for land abandonment and hence, often, reforestation to occur. Such reforestation however takes place in areas away from the city, and thus, the impacts of urbanization need to be viewed at a landscape scale in order to perceive these outcomes of reforestation. Given the projected trends of increasing urbanization anticipated globally, we must better understand this relationship between urbanization and reforestation, and take advantage of possible opportunities for land abandonment and consequent natural reforestation. We also need to better understand the limits to this relationship and to predict under which conditions such processes may not result in increased forest cover. At a time when the pace and extent of reforestation in near-urban areas of both developed and developing countries is significant, this leads us to question whether reforestation can be expected to continuously proceed alongside the process of urban sprawl.

1.3.8 Forest Transition Theory

Forest Transition Theory has been successfully applied to understand reforestation in a range of countries, particularly in North America and Europe. Yet, despite the popularity of this theory, one issue that often arises is whether we can expect a return to deforestation in the future in places that have thus far transitioned from deforestation to reforestation (Rudel 2005). The time frame within which our current studies are located are often limited to the last 100 years, if not the last 35 years, and tightly linked to the advent of satellite remote sensing technologies. However, we may simply be in a transition phase when reforestation occurs, rather than this being an end point. Our time frame may not be the appropriate one for study, and we may start to see these areas of reforestation once again follow new trajectories which may lead them back to deforested landscapes. As such, is this forest transition theory really useful? Along these same lines, can we expect developing countries that have not yet transitioned from deforestation to reforestation to follow the same trajectory of developed countries that created the FTT? What relevance does reforestation in developed countries have for reforestation potential in developing countries?

We need to separate out drivers of reforestation in terms of their temporal and spatial differentiation. Much of what seemed to be critical drivers of reforestation from the late nineteenth century to before World War two (economic growth etc.) are different from current drivers of reforestation; and reforestation in different developing economies, in different parts of the world takes very different trajectories, for example, Eastern Europe with land abandonment versus South Asia with community institutions and plantation forestry.

It currently appears that there is something like a ‘spatial diffusion’ of forest transitions from Western Europe and North America, to some developing and transition economies including Eastern Europe, Asia, and Latin America. If forest transition becomes a global process then forest area globally will increase, but this is not really feasible to expect. Rather, we raise the question that forest transition can possibly never be global in scope. Instead, perhaps only some regions may experience it, while other countries may again be clearing forests. As such is forest transitions theory much more cyclical than currently believed?

1.3.9 Cultural and Ecosystem Processes and Services

While ecologists are coming to better understand the processes associated with reforestation across landscapes (Bentley 1989; Lugo 1992) in terms of their ecology, we are still quite limited in our studies related to the social, economic and institutional roles in such conversions. In addition, the ecological understanding in some instances is also still limited. For instance, even if we observe an increased species richness in a regenerated or replanted forest area, this does not necessarily have positive implications for the landscape. An increase in the number of species can come at the cost of ecological integrity or ecosystem function, if the landscape is invaded by exotic species. Thus, we still lack knowledge on restoring important ecological functions and ecosystem services of importance for the production landscape. This can only be achieved through increased field research on restoration ecology, with field measurements in vegetation plots and transects to increase our knowledge of the ecosystem functions and processes associated with reforestation in different landscapes, associated with different species assemblages.

Additional questions, linked more tightly to theoretical constructs such as system resilience, are also critical to understand. What is the importance of reforestation in building resilience to large-scale disturbances? The fact that multiple directions of forest increase and decrease coexist in a landscape, often reversibly, needs more consideration in forestry studies. Quantification of ecosystem services provided by regrowing forests, such as the impact of reforestation on soil fertility, carbon sequestration, biodiversity protection, or hydrological cycles, is also essential for managers. Cultural services also play a key role. For instance, while in many parts of South Asia, forests are viewed as sacred and reforestation is a desirable process, reforestation in large parts of Eastern Europe is socially viewed as undesirable, leading to the disappearance of the traditional agricultural landscape that culturally defined large parts of the region.

Understanding spatial and temporal scale dependencies in reforestating landscapes is critical here. How does resolution of our data affect, or even define, our understanding of the spatial patterns and temporal pace of forest expansion? How big must a patch of forest have to be to count as “forest”? What stem density, successional stage, canopy closure should characterize “forest” for different regions? This will be context and site-dependent – thus, are there empirical scaling relationships that can be used to develop relationships across sites? These are key questions in need of resolution.

1.3.10 Future Expansion of Plantations

We need a better understanding of the role of plantations, as well as timber trades and trade policies regarding natural forest preservation. Do the increases in area for plantations worldwide alleviate the pressure on natural forests, or at the contrary lead to further deforestation by reducing incentives to manage natural forests? Do timber trade and policies lead to an adjustment to the optimal natural conditions of tree growth, or at the contrary to leakage and a "moving wall" of forest exploitation? This also links in with the issue of carbon sequestration, as we need to better understand the carbon sequestration potential of planned reforestation, natural reforestation and plantations. Further research also needs to be conducted into the effectiveness or failure of many programs currently widespread, that compensate local populations for facilitating reforestation on their lands, through approaches such as the purchase of carbon credits.

1.4 Concluding Remarks

In conclusion, this book represents one of the first large scale efforts to provide an interdisciplinary, cross-country, multi-scalar perspective on reforestation that includes an integration of theoretical perspectives with empirical analyses from many parts of the world. In this introductory chapter, we outline a number of themes and challenges that are particularly relevant for reforestation research. The rest of the chapters go on to address these and other issues relevant to reforestation at a variety of scales, using a range of diverse methodological and theoretical perspectives that provide an overarching, innovative, interdisciplinary approach to studying the patterns and processes (or the "whats", "hows" and "whys") of reforesting landscapes. In the concluding chapter, we will return to the themes outlaid here, use these to provide an assessment of thesis findings, and to highlight some of the major challenges for future research in this field. This volume, as presented here, will thus provide one of the first global assessments of reforestation process, a knowledge which is critical to understanding the future of forests and biodiversity in an increasingly human impacted world.

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Chapter 2
The Bigger Picture – Tropical Forest Change in Context, Concept and Practice

Alan Grainger

2.1 Introduction

The trajectory of the long-term trend in global forest area is still very uncertain (Mather 2005). This is also apparent in inconsistencies between tropical area trends published by the UN Food and Agriculture Organization (FAO) (Fig. 2.1). Moreover, evidence for deforestation in the humid tropics based on FAO statistics or sampling by independent analysis of satellite images cannot be substantiated by evidence for a long-term decline in forest area obtained from independent surveys (Fig. 2.2) (Grainger 2008).

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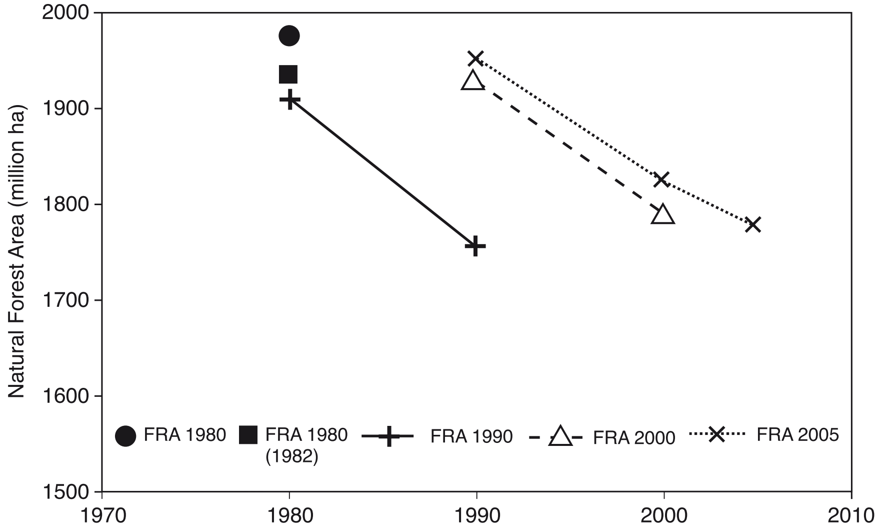

Fig. 2.1 Trends in Natural Forest area in 90 tropical countries, 1980–2005, from data in FAO Forest Resources Assessments (FRAs) 1980, 1990, 2000, and 2005 (million hectares) (Grainger 2008)

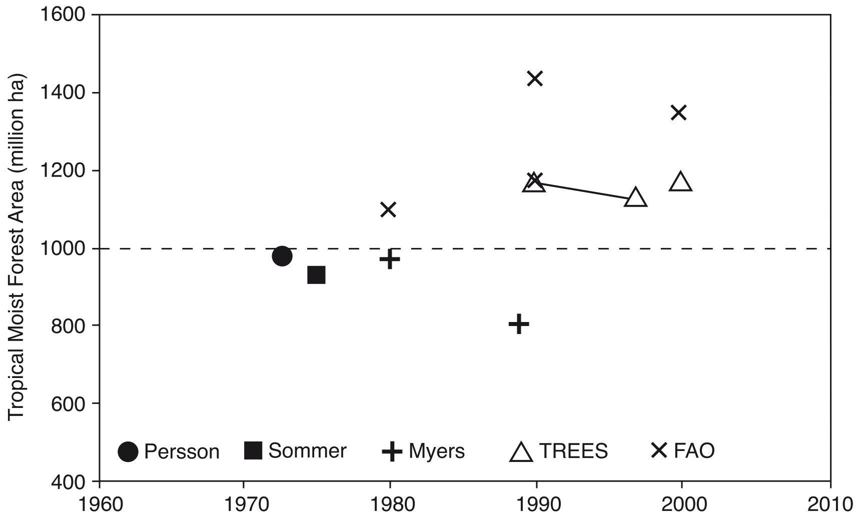

Fig. 2.2 Estimates of tropical moist forest area 1970–2000 (million hectares) (Grainger 2008), based on data in Lanly (1981); FAO (1993, 2001); Persson (1974); Myers (1980, 1989); with TREES data from Achard et al. (2002); Eva et al. (2002a, b), Mayaux et al. (2003); Stibig et al. 2003, 2004) Sommer (1976)

Uncertainty about the pan-tropical trend undoubtedly reflects the large errors involved in estimating national forest areas in numerous countries (House et al. 2003; Houghton 2005). But it is also possible that deforestation is being offset by various types of forest expansion, or forestation (Wiersum 1984), and the case studies in other chapters in this volume suggest that in parts of some countries the downward trajectory has indeed been reversed. The two explanations could even be linked, since uncertainty could also result from difficulties in making accurate estimates when both deforestation and forestation are occurring simultaneously at significant rates. Aggregating unsynchronized forest trends in many countries, each of which is in a different phase of its land use evolution, is not a trivial matter.

If these assertions are correct then a similar uncertainty might be expected for national trends in countries where there is net forestation in some regions while deforestation continues in others. We test this hypothesis in a non-random sample of eight countries discussed in other chapters: Madagascar in East Africa; India and Nepal in South Asia; Vietnam in Southeast Asia; and Costa Rica, Guatemala, Honduras and Mexico in Central America. Our findings do indeed show uncertainty in some national trends.

Uncertainty is said to be inherent when so-called "post-normal" phenomena are analysed using normal scientific methods (Funtowicz and Ravetz 1993). Global climate change appears to be one of these phenomena (Saloranta 2001), and it seems that global forest change is another. In addition to technical difficulties in making accurate large-area measurements, this chapter provides evidence that social factors contribute to uncertainty too. It identifies concept, context and practice as key elements in this, and shows that how forest change is conceptualized and measured depends on the world views and practices of the groups involved, and the spatial scale at which each group operates.

This chapter has five main sections. Section 2.2 outlines a methodology to frame analyses of disciplinary and scalar differences in knowledge construction. Section 2.3 compares the concepts and practices of two scientific disciplines: forest science and land change science. Section 2.4 examines how conceptualization varies with spatial context. Section 2.5 discusses the role of institutions in forest monitoring. Section 2.6 builds on this foundation to compare different narratives for pan-tropical forest plantation area and natural forest area in the eight case study countries.

2.2 Methodology

2.2.1 Discursive Space

To frame our analysis of the construction of forest trends, we assume that the totality of knowledge of any phenomenon is represented by a two-dimensional *discursive space* (Fig. 2.3).

From a poststructuralist perspective, conceptualization is framed by the world views, or discourses, of the actors involved. A discourse is "a specific ensemble of ideas, concepts, and categorizations that are produced, reproduced and transformed in a particular set of practices and through which meaning is given to physical and social realities" (Hajer 1995). Discourses are an aid to exercising power, as they determine through the use of language what is considered 'normal' in a society.

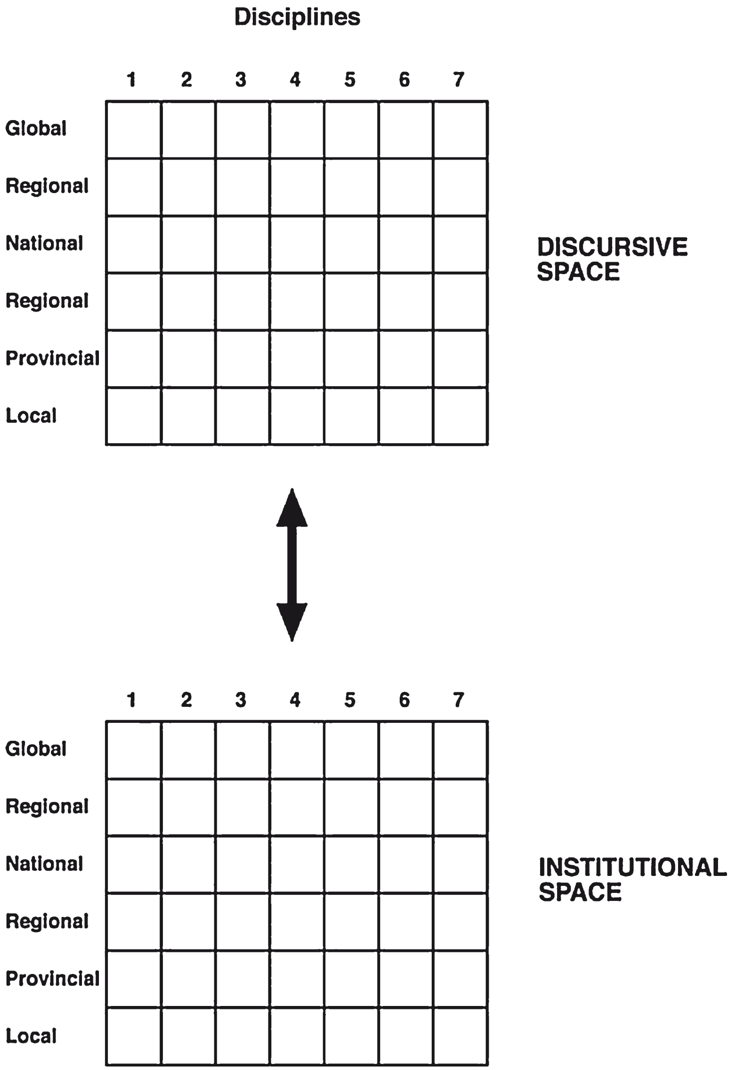

Fig. 2.3 The role of discursive and institutional spaces in knowledge construction by scientists from different disciplines and stakeholders at different spatial scales

One dimension of discursive space, along the horizontal axis, comprises knowledges constructed by different scientific disciplines. Each column represents the terms and relationships used to construct knowledge within the discourse of one discipline. The second dimension, along the vertical axis, comprises contextual knowledges constructed at different spatial scales. Each row includes the terms and relationships in the discourses of actors with expertise derived from living and working at that spatial scale.

The two dimensions of knowledge must be integrated to describe a phenomenon completely, and any partiality in constructing knowledge within discursive space will lead to uncertainty. So however rigorously scientific knowledge is constructed, each discipline only partially describes a phenomenon and may be more reliable at some scales than others. This explains why disciplinary boundaries must be transcended to understand 'post-normal' phenomena.

2.2.2 Institutional Space

The reproduction of actors' discourses is inseparable from that of their institutions (Hajer 1995). The term institution is often used as a synonym for an organization, but it really refers to a common practice of all members of an organization or any other group. Rationalist theories treat institutions as mainly constraints on human behaviour (e.g. North 1990), but others see them as more multifaceted, in being not so much external impositions on human activity as created and sustained by it. More formally, Crawford and Ostrom (1995) defined institutions generically as "enduring regularities of human action in situations structured by rules, norms and shared strategies, as well as by the physical world", thereby recognizing the importance of context.

So *institutional space* displays the institutions of each of the groups of actors participating in discursive space. Each column represents the institutions of a particular discipline, while the rows comprise the institutions of stakeholders at different scales. At each scale multiple institutions may be present.

2.3 Concepts and Practices of Two Scientific Disciplines

Land change scientists are skilled in analysing changes in trajectory in national forest trends, but have until now often depended on forest scientists for data. So our analysis begins by focusing on the horizontal dimension of discursive space and the concepts and practices of these two disciplines.

2.3.1 Forest Science Concepts and Practices

Cultivating and harvesting trees is for foresters a normative way of using forested land. In their traditional 'productivist' discourse (Dolman 2000), trees are grown to produce timber for conversion into products. This discourse is exclusive, demanding that a certain 'forest space' be totally devoted to material uses, to the exclusion of other uses, such as environmental protection and farming, and actors who might wish to engage in these uses (Mather 2001). Forest scientists are concerned about the erosion of forest space by deforestation, but they do not engage in detailed studies of why it occurs.

The origins of forest science are contextual, and can be traced to Germany in the middle of the sixteenth century. Over the next 300 years a series of abstract geometrical, calculus and economic methods were developed there that created a 'scientific forestry' that could be applied to forest space (Westoby 1987, 1989). The use of a discounting formula to calculate the 'optimal economic rotation' of a plantation, including the costs involved in tending a forest crop over many decades, arguably represented the culmination of this conceptual development (Faustman 1849).

The application of forest science to tropical forests began in the 1850s, soon after its basic set of practices had been assembled. Widespread and prolonged experiments by colonial foresters over the next 100 years were a valuable learning experience (Troup 1952). These showed that various silvicultural systems, in which forestation in natural forests is intentionally manipulated by foresters, could be effective, but were too labour intensive to be economic (Whitmore 1975). This led from 1960 onwards to an increasing professional focus on artificial forest plantations, and to the accumulation of knowledge about this, initially synthesized by Evans (1982).

Knowledge continues to be accumulated within forest science discourse, but is effectively limited to systematizing practices. Wiersum (1984) discussed the general principles of a potential "conceptual framework for a general forestation theory", but this merely comprised sets of strategies, tactics and operations to ensure successful forestation. He edited a collection of studies of forestation experiences, presented to a symposium convened to mark the centenary of forestry education at the University of Wageningen. Another valuable collection was compiled by Mather (1993).

Any group which commissions or engages in a scheme to monitor a phenomenon will design it to maximize the collection of data to provide the information it needs. Forest scientists mainly work at local scale, studying such key issues as the growth of trees and how this affected by different management methods. They use data on trends in national and pan-tropical forest areas to place their studies against a wider background, or measure 'progress' in achieving key policy goals, for example meeting forestation targets or improving the sustainability of forest management by controlling deforestation. So while papers in forestry journals may include tables showing such trends, these data are mainly for background purposes, as the bulk of the analysis depends on empirical data collected in field studies. Forest scientists working for FAO's Forestry Department share the same discourse as their colleagues in government forestry departments, so it is within this framework that they decide how to produce international compilations of national forest statistics supplied by governments.

2.3.2 Land Change Science Concepts and Practices

Land change science recently emerged from efforts by geographers, economists, sociologists and others to explain the social, economic and political reasons for land use and land cover change through empirical study and theoretical development (Rindfuss et al. 2004). Its data needs differ from those of forest science, and ideally comprise annual values of forest area and other attributes for every country.

2.3.2.1 The Forest Transition Model

Particular attention has been paid to studying the reversal in trajectory of the trend in national forest area, from decline to rise. One conceptualization is the *forest transition* model (Fig. 2.4) (Mather 1992). Its popularity stems from the apparent simplicity of the U-shaped curve near the point of transition. Initial studies focused on temperate countries (e.g. Mather et al. 1998; 1999; Mather and Fairbairn 2000; Mather 2004), but evidence for transitions in the tropics is now being reported too (Rudel et al. 2005; Mather 2007). While theorization of the forest transition has not been neglected (Mather and Needle 1998), top priority has been given to empirical studies (Mather 2007)

2.3.2.2 An Alternative Forest Transition Model

The currently dominant land change science discourse assumes that forestation follows shortly after deforestation. If a distinct reversal in trajectory cannot be identified then land change scientists working within this discourse might infer that either data are uncertain, or that the land change pattern is aberrant.

An alternative model, which would not automatically lead to such an inference, was suggested by this author some time ago (Grainger 1995). It divides the forest transition curve into two parts: the decline in forest area, termed the *national land use transition*, and the rise after the forest transition, termed the *forest replenishment period* (Fig. 2.5). The two are separated by an interregnum of variable extent. In certain conditions they combine to give a U-shaped curve, but in the general case they need not do so.

The justification for separating the two parts of the curve is that it combines two functions relating to different market demand curves. The national land use transition curve is merely the inverse of a curve showing how agricultural area expands in response to rising demand for food as a country develops. It tapers off as the limits of land suitability are reached and farming intensifies following investment in

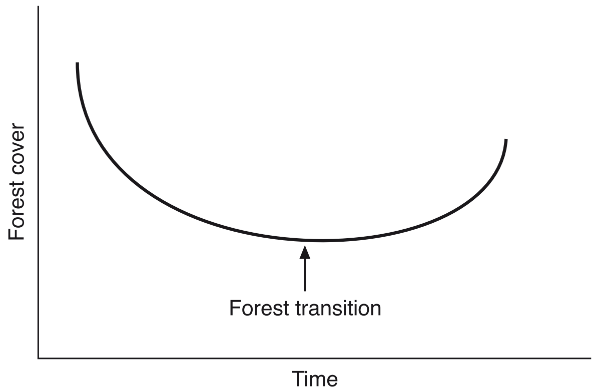

Fig. 2.4 The forest transition model (Mather 1992)

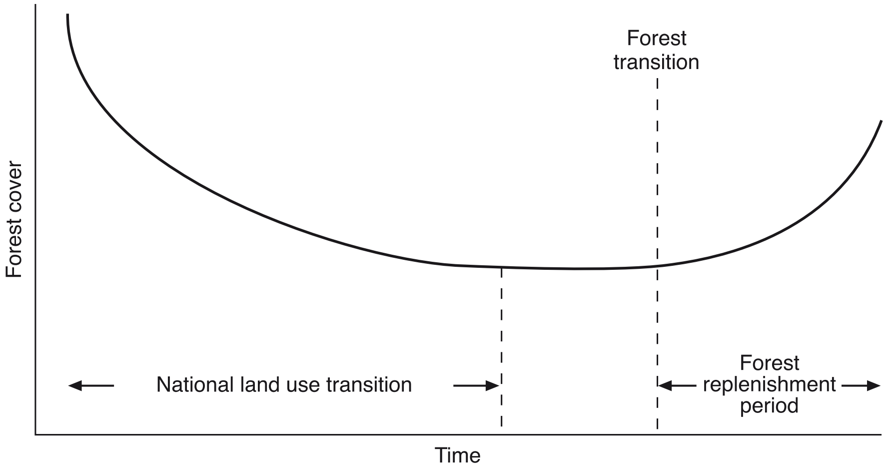

Fig. 2.5 An alternative conceptualization of the forest transition model (Grainger 1995)

improved technologies (Drake 1993). Forest replenishment, on the other hand, is a response to changing demand for wood, and non-market environmental services supplied by forests. Natural reforestation may occur if farmland is abandoned as it becomes unproductive or uneconomic. The forest transition marks a switch from the dominance of agricultural institutions to that of forestry institutions.

A U-shaped curve around the forest transition could be seen if the national land use transition follows what this author has called a 'normative scenario'. Deforestation will end once market mechanisms have allocated all land to its optimum use. A large amount of forest would be left (Fig. 2.6), but as the spatio-temporal land allocation trend is invariably piecemeal, with some marginal farmland cleared before all of the most productive land is identified, the end of deforestation could be followed by natural reforestation on abandoned marginal land. The conditions required for this scenario include the presence of institutions within which: (a) market forces can operate; and (b) the non-market values of environmental services provided by forests affect land allocation decisions.

The U-shaped curve is deformed if these conditions do not apply, and national forest cover falls much lower than in the normative scenario. In what was termed the 'critical scenario' (Fig. 2.6), deforestation does not stop until either (a) environmental services collapse, and floods and other hazards put pressure on governments to intervene: or (b) wood supplies become restricted and a rise in price allows forest protection and forestation to become more profitable. A possible lower limit of 0.1 ha per capita was suggested by Grainger (1993) for this scenario, based on the forest area needed to supply mean internal domestic wood demand. Of the eight case study countries discussed in other chapters, Nepal is close to this limit (Table 2.1). Only India and Vietnam have fallen below it, but seem to have passed through their forest transitions. They also have the highest proportions of plantations in Total Forest area of all eight countries (Table 2.2), and so wood market forces seem to be operating there.

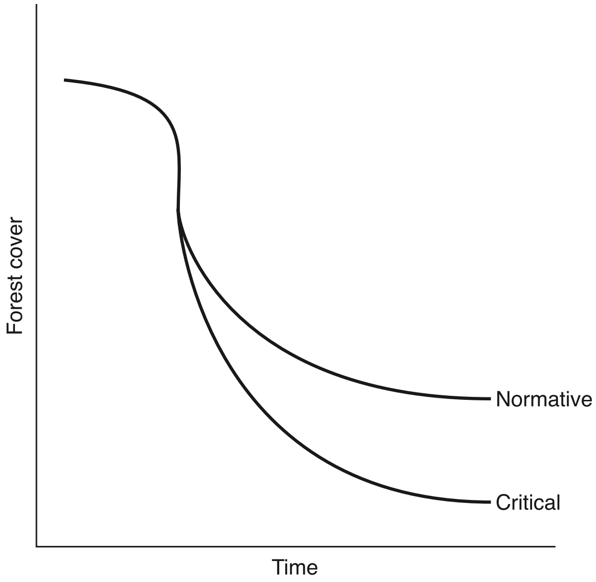

Fig. 2.6 Normative and critical national land use transition scenarios (Grainger 1995)

Table 2.1 Forest area (hectares) per capita and percent forest cover in the eight case study countries, calculated using lowest national forest area in FRAs 2000 and 2005 (million hectares) (FAO 2001, 2006a)

	Lowest forest area	Percent forest cover	Forest area per capita
Madagascar	11.4	19.6	0.74
India	31.5	10.6	0.03
Nepal	3.6	26.3	0.15
Vietnam	6.8	20.9	0.09
Costa Rica	1.8	35.3	0.46
Guatemala	2.7	25.0	0.24
Honduras	4.7	42.0	0.75
Mexico	54.9	28.8	0.56

Table 2.2 The share of forest plantations in total forest area in the eight case study countries 1990 and 2000 (percent) (FAO 1993, 2001)

	1990	2000
Madagascar	2.3	2.6
India	30.1	50.9
Nepal	2.1	2.6
Vietnam	26.9	17.3
Costa Rica	0.0	10.0
Guatemala	2.9	6.9
Honduras	0.0	1.9
Mexico	0.2	0.5

NB. ‘Total forest’ comprises both Natural Forest and Forest Plantations.