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Chapter 16
Reforestation: Conclusions and Implications

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16.1 Major Research Findings from Studies Presented in This Book

This book was written with two major objectives in mind. Our primary goal was to evaluate the drivers and processes associated with reforesting landscapes across a range of contexts and continents, to determine factors which appear to be specific to certain situations, and others which seem to be common across multiple contexts. Since reforestation is an area of study that crosses ecological, biophysical and social boundaries, our second objective was to develop interdisciplinary frameworks that link methods and approaches from different areas of science, to study the patterns and processes associated with reforesting landscapes. We evaluate the major findings of this volume based on these two objectives. First, we compare the research findings from different chapters, to help us discern the common designs and the unique threads that create a variety of reforestation patterns across landscapes (Table 16.1). We then use a combination of FAO data along with the specific case studies presented here for different countries, and develop a typology of forest change (Table 16.2). Finally, the main techniques and approaches used within each research study are presented, and assessed in terms of their effectiveness for reforestation research (Table 16.3). We conclude with an assessment of the implications of these findings, and outline some challenges for future research on reforestation.

16.2 Reforesting Landscapes – Drivers, Processes and Frameworks for Study

16.2.1 Dominant Drivers of Reforestation

For each study the main causes or drivers of reforestation are extracted and illustrated in Table 16.1 in an attempt to determine the common drivers of change. This is one of the major goals of the book and can be related to the numerous research examples where dominant drivers of deforestation (Lambin 1994, 1997; Geist and Lambin 2001) and case studies compiling research results have been undertaken. This is one of the first attempts to undertake such a global compilation on drivers of reforestation, regeneration and regrowth studies (Table 16.1).

In summary, we find that the studies presented in this volume confirm many of the ideas linked to the Forest Transition Theory. The 'economic development' and 'forest scarcity' pathways, as proposed by Rudel et al. (2005), are observed in a number of landscapes, including Mexico and Central America as presented in Chapter 5, Eastern Europe in Chapter 6, as one of a number of drivers in Costa Rica from Chapter 10, Poland in Chapter 11 and for Vietnam in Chapter 14. We also find, however, that FTT is inadequate to explain all the instances of reforestation observed here, as also discussed by Rudel in Chapter 3. Institutions of conservation

Table 16.1 Drivers of reforestation extracted from each case study chapter in the text

Chapter no. and author	Country/study area	Drivers of reforestation
5: Bray	Mexico and Central America (Belize, Guatemala, Honduras, El Salvador, Nicaragua, Costa Rica, and Panama)	Focuses on drivers of forest recovery, maintenance or protection. The four drivers are agricultural abandonment, coffee agroforestry, sustainable forest management and protected areas.
6: Taff et al.	Eastern Europe: with three case studies in Latvia, Romania and Albania	Farm abandonment, population decrease, developing protected areas, sustainable forestry.
7: Nagendra	South Asia: Bangladesh, Bhutan, India, and Nepal	Protection, plantations and agroforestry.
8: Evans and Sweeney	USA – South Central Indiana	Diverse social, economic, institutional and environmental factors.
9: Crews and Moffet	Peruvian Amazon	None. Modeling study.
10: Daniels	Costa Rica	Agriculture intensification in one region facilitated reforestation in less productive lands, protected area establishment, declining beef prices, and revised forest policies.
11: Kozack	Poland	Economic and social transformations leading to declining mountain agriculture, depopulation and land abandonment.
12: Hartter et al.	Uganda	Park establishment and forest protection.
13: Elmqvist et al.	Madagascar	A result of a combination of changes in precipitation, migration and decreased human population and livestock grazing pressure, but only under well defined property rights.
14: Meyfroidt and Lambin	Vietnam and Bhutan	A combination of land scarcity and degradation, agricultural and socio-economic changes and policy in Vietnam. In Bhutan it was a governance and cultural system assigning a high value to nature.
15: Song and Zhang	China	Government sponsored plantation forests.

are a major driver associated with forest preservation, but also forest regrowth. These can be forest institutions such as government protected national parks (as one of the drivers in Costa Rica from Chapter 10 and in Uganda as illustrated in Chapter 13), but there are also several instances of forests protected by local communities (such

Table 16.2 Countries studies in chapters in text and their current FAO information with references to change in forest area and forest stocking density, across the two time periods 1990–2000 and 2000–2005

Country	Percent change in forest areas 1990–2000	Percent change in forest area 2000–2005	Dominant process DEF = deforestation REF= Reforestation	Annual change rate in growing stock in 1,000 m³/year 1990–2000	Annual change rate in growing stock in 1,000 m³/year 2000–2005	Dominant process DEG = degradation REG = regeneration
China	1.2	2.2	REF	186,560	181,400	REG
Costa Rica	−0.8	0.1	DEF to recent REF	−1,940	200	Recent REG
Guatemala	−1.2	−1.3	DEF	−8,806	−8,806	DEG
Honduras	−3.0	−3.1	DEF	−16,800	−12,800	DEG
India	0.6	0.0	REF to stable	29,900	7,200	REG
Latvia	0.4	0.4	REF	9,500	10,600	REG
Madagascar	−0.5	−0.3	DEF	−11,400	−6400	DEG
Mexico	−0.5	−0.4	DEF	NA	NA	NA
Nepal	−2.1	−1.4	DEF	23,000	−9,400	Recent DEG
Nicaragua	−1.6	−1.3	DEF	−11,400	−8,000	DEG
Peru	−0.1	−0.1	DEF	NA	NA	NA
Poland	0.2	0.3	REF	25,120	25,660	REG
Turkey	0.4	0.2	REF	9,890	5,679	REG
Uganda	−1.9	−2.2	DEF	−3,730	−3,800	DEG
USA	0.1	0.1	REF	189,600	210,000	REG
Vietnam	2.3	2.0	REF	13,570	11,183	REG

Table 16.3 Tools and techniques used to analyze and detect the process of reforestation or forest regrowth

Chapter no. and author	Remote sensing	GIS	Spatial statistics	Modeling	Forest plots	Household or community surveys	Meta-analysis of published case studies	National and global datasets e.g. FAO
2: Grainger								X
3: Rudel							X	X
5: Bray							X	X
6: Taff et al.	X		X					X
7: Nagendra	X	X	X			X	X	X
8: Evans et al.	X	X		X		X		X (FIA)
9: Crews and Moffet	X	X	X	X				
10: Daniels	X	X	X	X		X		
11: Kozak	X						X	X
12: Hartter et al.	X	X	X			X		
13: Elmqvist et al.	X	X	X		X	X		
14: Meyfroidt and Lambin	X	X	X					X
15: Song and Zhang	X	X	X					X

as in Nepal, Chapter 7 or Madagascar, Chapter 13, or even as in Chapter 14, Bhutan, where it was a governance and cultural system assigning a high value to nature). The discussions in these chapters clearly indicate that people do not only protect forests from a utilitarian perspective, driven by perceived scarcity of forest products, as proposed by Rudel et al. (2005) – but in addition, there is a basic human tendency towards conservation that makes itself powerfully shown even in cases where extreme poverty and forest dependence coexist with high population densities. Rudel also raises some of these issue is Chapter 3 of this volume.

Plantations and Agroforestry systems are also increasingly common pathways to reforestation and dominate in some cases, such as in China (Chapter 15), where government replanting schemes have created widespread reforestation in the form of plantations. Agroforestry generally occurs on a much smaller scale than government led plantation programs, but can also be a significant reforestation process, as illustrated in Central America and Mexico (Chapter 5 – both coffee agroforestry and sustainable forestry programs) and in South Asia (Chapter 8). With increasing concern about environmental services and the development of payment for environmental services provided, we may well see an increase in these smaller scale reforestation and agroforestry systems and so a better understanding of these systems is warranted. Ultimately, as stated Section 10.6, this volume: in

> context-specific case studies must be linked to broader global forest cover trends and the supply/demand of forest goods in order to appropriately contextualize regional or national-level forest recovery, its driving forces, and its degree of permanence. ....As of now, the issues of land development pressure, the timber trade and deforestation displacement are not explicitly addressed in the forest transition literature for developing countries. (Daniels, page 249)

This is an important addition to this body of literature and these forces of plantation forests, forestry and agroforestry will lead an increasingly important role if payment for environmental services programs continue (see Chapter 10 for more discussion) and also larger programs such as REDD (Reducing emissions from deforestation and degradation) which are policy programs linked to the post-Kyoto climate change agreements (see later for more discussion) which may link payments to reforestation.

16.2.2 *Typologies of Forest Change*

Before 1990 there was much debate on the quality of the FAO database. However, for the 1990–2000, and 2005 datasets recalculations were undertaken, in which a single forest definition was used (10% canopy closure), and along with the advent of the use of coarse scale remote sensing as a means of collecting the data to supplement expert opinion for each country, these data are now more useable and more accurate (Grainger 2008; FAO 2006; Rudel et al. 2005). By using FAO databases some basic national-level information on the various countries can be discerned for the same time period (FAO 2006).

FAO data and location of the research countries within the FAO database and trends of change are given below for the main countries discussed within the text. For each country the dominant processes of reforestation or deforestation at the national level are given based on the change in forest area values, followed by the change in stocking density values, which is used as an indication of within cover processes of forest degradation or regeneration processes. Such processes may also be a precursor to future changes or shifts in forest area, with continued degradation and thinning of forest areas often occurring as a precursor to deforestation, and forest regeneration and increasing biomass within existing stands as a possible precursor to continued forest expansion and reforestation processes. Such an approach allows us to categorize different countries and regions into broad types, and develop a typology of forest change (Table 16.2).

If we review the trends illustrated in Table 16.2 we can see that there are four basic types of groupings occurring here at these national levels. (For a larger discussion of these types see Kauppi et al. (2006), which discusses the top 50 nations in terms of growing stock.) Here we are looking only at the countries highlighted within this volume and placing these countries within this larger discussion. As such we can see the following eight groups are possible outcomes here: (1) reforestation via the addition of new land in forest cover, shown by an increase in the percent area but not in growing stock or density; (2) deforestation via the loss of land in forest cover, but no real change in growing stock on the remaining land; (3) regeneration and increased density of existing forest lands, without additional area in forest cover; (4) degradation and thinning of existing forest areas, without the loss of actual forest cover extent; (5) processes of both reforestation and regeneration occurring together on the landscape; (6) deforestation and degradation occurring on the landscape; (7) reforestation occurring but with degradation within those, shown by decreasing stocking numbers; and (8) deforestation occurring but regeneration on remaining forested areas.

From the table we can see in reality we only have two main groups as the processes of reforestation and regeneration go together and deforestation and degradation. As such, we have China, Costa-Rica from 2000 to 2005, India, Latvia, Poland, Turkey, USA and Vietnam where reforestation is the dominant process occurring on the landscape as evidenced by an increasing area of land in forest cover, but hand in hand is the process of regeneration with increased stocking densities being found on the already forested lands. On the other hand we have Guatemala, Honduras, Madagascar, Nepal, Nicaragua and Uganda where deforestation or loss of land area in forest cover is occurring, and also a decrease in stocking or density on remaining forest lands. The two remaining countries of Peru and Mexico have deforestation as the dominant process, but data on stocking number changes are unavailable and so we do not know if these would also show the degradation trend. It is of interest to note then, that for those countries covered in this book, only half have reforestation and regeneration as the dominant national process occurring on the landscape. The remaining half of the locations has deforestation and most probably degradation occurring nationally, and yet here in this volume, we have highlighted regions or areas where the reverse process is occurring, in terms of reforestation or regeneration.

16.2.3 Tools for Reforestation Studies

The tools used in each of the research sites are highlighted in Table 16.3 and discussed below.

The use of interdisciplinary tools and techniques, as illustrated in Table 16.3, highlights how reforestation crosses social and natural boundaries both in topic and in the range of tools and techniques used in its study. Even with this plethora of information and case studies as illustrated here though, it still seems there are gaps in some areas, as more studies need to directly measure and add an ecological dimension (Chapter 13 provides an example of this integration), and more studies need to add an economic dimension (Chapter 14 provides an example of this). The available case studies in the literature also provide a fruitful base for data mining, and this is growing rapidly with more people waking up to the idea that reforestation is a land cover trend in need of more research. As such this current volume represents timely information and serves to fill a void in the literature.

16.3 Continued and Future 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 not addressed in this volume, but which we feel are critical to address in future research. These are listed and discussed below.

16.3.1 Definitions of Reforestation

A common language needs to be developed and agreed upon across the different scientific communities involved in this work, to consolidate the different terms used within this field. Generally speaking we have found that regeneration implies a natural process often occurring after land abandonment, and if left alone, usually leads to reforestation on the landscape. The point at which a regenerating landscape becomes reforested may be uncertain and is usually a function of the ecosystem in question. This process can be hard to 'see' or 'measure' with many of the interdisciplinary methods currently used (such as remote sensing, see Table 16.3) but links well to the need for more ecological measures and data collection as part of these studies. This implies a natural process and no additional role of humans, beyond the abandonment of the land. Additional forms of reforestation are those which come about as a process of planting trees, such as for agroforestry or plantations,

also termed afforestation within the forestry community. Given the very different processes and pathways which can be followed a consolidation of the terminology currently in use, to create 'set definitions' would help studies crossing such disciplinary boundaries to communicate much more easily, and facilitate data exchange and comparison of studies.

16.3.2 Need Long-Term Assessments of Change

Just like the long term ecological research sites (LTER) and other long term assessments, we also need these longer term research sites to study the issues of land cover change, including those related to reforestation. These studies should link the social and ecological processes together, and be at multiple temporal and spatial scales. They should incorporate a multitude of available methodologies (Table 16.3) and also emphasize repeat measures and the potential role of remote sensing, not just in terms of land cover classifications and conversions but also to emphasize the 'within-class' changes and modifications which are so key for us to evaluate and understand (Southworth et al. 2004). Such studies could be tied in with some major, key issues which we will be addressing in the coming years, specifically those of Carbon/REDD and Climate Change. This is important as issues of reforestation are long term processes that may be difficult to study in single date snapshots or shorter duration field studies (unlike the abrupt changes brought about immediately upon deforestation) and so to gain spotlight or the attention deserved we should link the issues associated with reforestation and the research needs, to those larger and more critical topics such as 'Carbon' and 'Climate Change'.

16.3.3 Drivers of Future Change

There are a few drivers which we pick up as currently only influencing a small part of our study landscapes, but which are likely to play an increasingly significant role in the future. These drivers link to future research directions, and specifically are linkages between the environment and our existing social, political, and economic systems. As such we will mention these areas briefly in this section as these may well provide future mechanisms by which reforestation will occur. These areas are: climate change; carbon sequestration and REDD; and payment for environmental services.

Climate change has the potential to drive land cover change as people seek to sequester more carbon in our ecosystems (such as via reforesting landscapes) and so decrease the atmospheric carbon dioxide concentrations. While there is still much current debate on the role of forests and potential gains of reforestation schemes (Clark 2004; IPCC 2007), this debate seems likely to continue and the potential for reforestation schemes to increase globally (though there are projected

regional differences in the potential impacts of reforestation). This also links into the topic of carbon sequestration and REDD (reducing emissions from deforestation and degradation). This program was created by the United Nations as collaboration between FAO, UNDP and UNEP and is a financial pooling of resources to provide funding of activities which will lead to a reduction in deforestation and forest degradation in developing countries. This program came about as a direct result of the intergovernment panel on climate change (IPCC 2007) report which estimated that deforestation was contributing over 20% of the overall greenhouse gas emissions and that forest degradation added even more to this. As such they stated:

> there is an immediate need to make significant progress in reducing deforestation, forest degradation, and associated emission of greenhouse gases. The UN-REDD Programme is aimed at tipping the economic balance in favour of sustainable management of forests so that their formidable economic, environmental and social goods and services benefit countries, communities and forest users while also contributing to important reductions in greenhouse gas emissions. The aim is to generate the requisite transfer flow of resources to significantly reduce global emissions from deforestation and forest degradation. The immediate goal is to assess whether carefully structured payment structures and capacity support can create the incentives to ensure actual, lasting, achievable, reliable and measurable emission reductions while maintaining and improving the other ecosystem services forests provide (from the UN-REDD Program website http://www.undp.org/mdtf/un-redd/overview.shtml, accessed Feb 2009).

If indeed such an influx of resources, aimed specifically at forest recovery and reforestation in developing countries comes to fruition, then new pathways of reforestation seem likely, driven by this global policy and effort.

While the REDD program has very specific goals there are more general types of trading and payment programs for environmental service, such as the carbon market, and individual country programs (see Chapter 10, Costa Rica for an example). These also seem likely to not only continue but also to expand in the future, as more developing countries realize the financial gain possibilities related to their forests or the processes of reforestation. While not all such ecosystem services may result in reforestation of landscapes, it seems likely that linked in to the carbon markets, some reforestation will occur, although the longevity of these programs and their sustainability over time may lead to future challenges.

Overall though, through all three of the topics discussed here, it seems future trajectories of land cover change may increasingly relate to reforestation and our understanding of these pathways and their associated processes is therefore of paramount importance.

16.4 Final Thoughts

To this point there has been a lot less emphasis on reforestation, both in the scientific literature and also within the general public arena (Table 16.4). This book was developed as an attempt to address some of these limitations and also to provide a single summary of a suite of theoretical, methodological and substantive examples

Table 16.4 The numbers of web based search results of the terminology used in this book, highlighting the dominance of deforestation over reforestation as a subject of study

Search term	Google	Scholar Google	Web of science
Deforestation	3,710,000	107,000	5,653
Reforestation	2,690,000	52,800	1,853
Forest degradation	400,000	195,000	2,678
Forest regeneration	462,000	153,000	5,707
Forest regrowth	517,000	32,700	742

of reforestation research underway across the globe. It was our hope to attempt to provide researchers with an ability to determine common drivers of reforestation processes (Table 16.1), to illustrate the commonly used tools and techniques (Table 16.2) and also to highlight the gaps in the current research where future work must be directed (this chapter). We hope to have satisfied these criteria and that this volume both initiates new discussions and serves as a basis for continued future research on the development of improved understanding of reforestation pathways, processes and drivers.

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