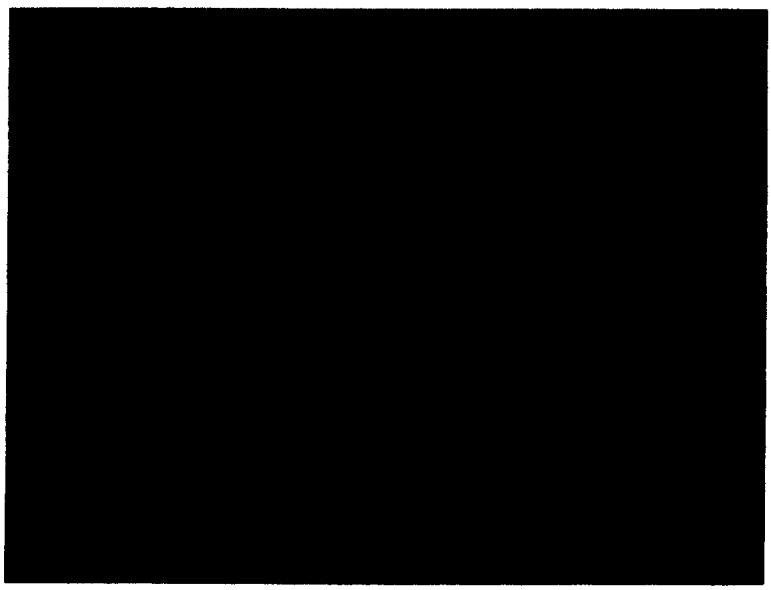
From Forest Nursery Notes, Winter 2010

59. Reforestation: challenges and themes in reforestation research (Chapter 1). Southworth, J. and Nagendra, H. IN: Reforesting landscapes: Linking pattern and process, p. 1-14. Nagendra, H. and Southworth, J., eds. Springer Science. 2010. This book integrates research findings from scientists working in a range of contexts and continents to examine reforestation. It is targeted to research community working on biophysical, geographic, socioeconomic, and institutional processes associated with reforestation.

Chapter 1
Reforestation: Challenges and Themes in Reforestation Research

Jane Southworth and Harini Nagendra



J. Southworth (✉)
Department of Geography and Land Use and Environmental Change Institute (LUECI), University of Florida, FL, USA
e-mail: jsouthwo@geog.ufl.edu

H. Nagendra
Indiana University, Bloomington, IN, USA and
Ashoka Trust for Research in Ecology and the Environment (ATREE), Bangalore, India

H. Nagendra and J. Southworth (eds.), *Reforesting Landscapes: Linking Pattern and Process*, Landscape Series 10,
DOI 10.1007/978-1-4020-9656-3_1.

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).
findings across multiple research loc
processes where they are occurring ir
need to establish broader framewor
associated with reforesting landsca
reforestation, regeneration and regr
thus long overdue within the landsc

1.2 Description of the Bool

The idea for this edited volume er
need for cross-site empirical studie
ing reforestation in a variety of fi
research findings from scientists w
utilizing a variety of integrated, inter-
The cross-site examinations condu
different field settings can help us r
to identify specific factors that are

Reforestation and regrowth is
of ecosystem services, protected
remediation of environmental prob
micro and macro level drivers of
these issues on a global scale, inc
America, Central America, Africa
issues can be addressed, commor
drivers and patterns established.

This book is targeted towards
on issues relevant to the biophysi
processes associated with reforest
processes range from the use o
photography, historical maps an
economic and social datasets, and
data are used in concert, which als
address the issues of scale (spati
functional level of analysis, the
social and biophysical datasets, al

To fully understand both the
cover change, requires both fine
hand, placing specific case studi
multiple case studies is a pre-req
et al. 2005). Thus, critically, su
grated with theoretically motivat
set of potential driving factors an
in different contexts, achieving c

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 multi-scale 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, v
estation studies, which are fu
main themes or challenges wi
linked to relevant chapters in
in greater detail.

These dominant themes an
their importance also deserv
terms of what we mean by ea
to the future research needs v
address these themes.

1.3.1 Definitions of R

Definitions for the terms of
differently in different discipl
the range of contexts and m
diversity mirrors the interd
research. This volume cons
authors clearly describe the te
clarity. In a broader sense th
different disciplines and me
arena, but also within many
methodological boundaries.
research is a nascent one ar
standardized terminologies
willing to adopt. The most v
use of such terminology and
for the specific subject matt

1.3.2 Interdisciplinar

Human–Environment intera
tions, pose challenges to res
with contributions from sev
an *interdisciplinary concep*
changes and their iterative
institutional, biophysical, e
inherently interdisciplinary
land use conversions. Whi
such much in the realm o
understand the drivers of t

. beginning with chapters that lay
ting landscapes, then moving to
nally, to case studies of reforesta-
pe is vast and varied, covering
ru, Poland, USA and Vietnam.
ance to their landscapes of focus,
scussions.
scuss issues relevant to reforesta-
Grainger discusses the challenges
restation and reforestation simul-
gation ensue, leading to substan-
orest change. Chapter 3 (Rudel)
tline the human drivers of forest
e to reforestation under different
tives that would help encourage
nts an alternate tri-partite frame-
y and panarchy to develop multi-
nort term, medium term and long
st change at scales ranging from

sia form three major regions of
orestation in recent times, and
ent regional contexts. Chapter 5
nsition in Mexico and Central
es reforestation in Central and
at the drivers of reforestation in

estation research in specific land-
physical, economic and historical
ern USA (Chapter 8, Evans et al.)
offett), northwestern Costa Rica
ountains (Chapter 11, Kozak),
tter et al.), southern Madagascar
an (Chapter 14, Meyfroidt and
g). A diversity of issues critical
of reforestation are addressed in
exts.

arch

current state of knowledge on
ding, and to identify the major
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	Current socio-cultural and ecological understanding of reforestation is limited and	Chapters 6, 8, 10, 11, 14, 15

	analyses of land cover change, land cover modeling and historical comparative research are essential for a more complete understanding of landscape processes.	
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 d
However, our understanding of
interactions is limited (Moody
is critical to our ability to b
dynamics of reforestation, and
and temporal heterogeneity and
(Qi and Wu 1996).

1.3.4 *New Methodologi*

While remote sensing has help
their drivers, the techniques cu
in their approaches. The most
change is that of discrete land
changes in land cover, and do
within a land cover category. T
to understand the extent of ref
a forest category), but not en
within a forest category, which
sequestration, soil conservatio
more import to forest manage
develop and test the use of n
more on the creation of contin
modeling. We also need robust
by remote sensing from local
entiate degraded forests from
and separate out processes of r
for any understanding of the c
to incorporate multiple data so
radiometric resolutions, to en
Less reliance on Landsat will
dictated due to the failure of t
readiness. Such a data gap will
community and hence the ev
technologies is now essential.

In addition, an added probl
estation is a much easier proc
this is itself a quick process w
it takes for trees to grow and
forest expansion is visible to t
sensing seems too 'young' a
landscapes for a tree to grow

onent. People are an integral part
lonment which has left an area to
or a human led replanting effort.
ısequences of these systems and
ıodel both the social and physical
l and economic determinants of
uch better understanding of the
olicies, and bottom-up responses
es. People play a key role which
acknowledge that most of these
y and ecologically. Thus, there is
s and frameworks that integrate
ological approaches for the study

oral Scales

occurring and interacting simul-
ly et al. 2008; Lettenmaier et al.
ales and characteristic response
the atmosphere, and the surface
nental processes. Up-scaling and
lem (Bloschl and Sivapalan 1995).
rmation into land-cover change
ion available to modeling studies
and Strahler (1994) found that
ıcs across the landscape and its
d longer lasting and longer-term
and within class changes are
xample, inter-annual variability

processes interact in reforesting
s to create characteristic patterns
temporally and spatially varying
ıse of the lack of spatio-temporal
etches of time (Southworth et al.
land-surface processes occur in
tand and manage the causes and
g landscapes, it is imperative that
temporal variation, the processes
ways in which pattern-process
ıas 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
systems. It is the consolidatio
allows for land abandonment a
estation however takes place i
urbanization need to be viewe
comes of reforestation. Give
anticipated globally, we mu
urbanization and reforestatio
land abandonment and consec
understand the limits to this r
such processes may not result
and extent of reforestation in
countries is significant, this
expected to continuously proc

1.3.8 Forest Transition

Forest Transition Theory has b
in a range of countries, particu
popularity of this theory, one
return to deforestation in the
deforestation to reforestation (
rent studies are located are of
years, and tightly linked to th
However, we may simply be i
than this being an end point.
study, and we may start to see
trajectories which may lead th
forest transition theory really
developing countries that have
tion to follow the same traje
What relevance does reforest
potential in developing countr

We need to separate out dr
spatial differentiation. Much
from the late nineteenth centu
are different from current dri
developing economies, in diff
ries, for example, Eastern Eur
community institutions and pl

s such as historical comparative

r one is that we need to focus less
hange science overall. Within the
one-way process, it is not simply
te process, usually with separate
se issues in order to fully under-
e occurrence of reforestation over
to do this until we have actually
ese occurrences, from individual
ted to do for deforestation. Our
ed and we have a lot of catching
t factors determine where (at what
lizes or plateaus? How does this
, regional, national and interna-
rs of reforestation we know even
to begin with, that is, drivers that
edged, for example, coffee agro-
ieed more landscape or regional
ion.

s and ecosystems, beyond the
ation, specifically extending into
cosystems such as wetlands, dry
avanna is essential, as in these
ifferent. More of a focus is also
d fragmented land cover types,
sions with trees – that is to say,
We must also acknowledge and
the processes of reforestation.
) are being encroached upon by
(e.g., much of Eastern Europe),
roplands, many of which then
tion on abandoned agricultural
ks, with the associated loss of

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 rela
need of resolution.

1.3.10 *Future Expansio*

We need a better understanding
and trade policies regarding nat
plantations worldwide alleviate
lead to further deforestation by
timber trade and policies lead t
tree growth, or at the contrary to
This also links in with the issue
stand the carbon sequestration p
and plantations. Further researc
or failure of many programs c
tions for facilitating reforestati
purchase of carbon credits.

1.4 Concluding Remar

In conclusion, this book repres
interdisciplinary, cross-country,
an integration of theoretical per
the world. In this introductory c
that are particularly relevant for
to address these and other issue
a range of diverse methodologi
arching, innovative, interdiscipl
(or the "whats", "hows" and "
chapter, we will return to the th
of thesis findings, and to highli
in this field. This volume, as pr
assessments of reforestation pr
the future of forests and biodiv

Acknowledgments The idea of this
of Institutions, Population and Envir
like to thank our colleagues at CIPE
ing to reforestation research. We are
thank Romer Kohlhaas and Parker Kr
Suri and Dhwani Suri for their patien
gratefully acknowledges financial su

g like a 'spatial diffusion' of forest
nerica, to some developing and tran-
Asia, and Latin America. If forest
area globally will increase, but this
e the question that forest transition
d, perhaps only some regions may
e clearing forests. As such is forest
ently believed?

ses and Services

and the processes associated with
ugo 1992) in terms of their ecology,
o the social, economic and institu-
ecological understanding in some
if we observe an increased species
ea, this does not necessarily have
ease in the number of species can
/stem function, if the landscape is
knowledge on restoring important
of importance for the production
ncreased field research on restora-
ion plots and transects to increase
cesses associated with reforestation
species assemblages.
oretical constructs such as system
the importance of reforestation in
he fact that multiple directions of
ape, often reversibly, needs more
f ecosystem services provided by
on on soil fertility, carbon seques-
les, is also essential for managers.
ce, while in many parts of South
n is a desirable process, reforesta-
wed as undesirable, leading to the
cape that culturally defined large

endencies in reforestating land-
our data affect, or even define,
al pace of forest expansion? How
rest"? What stem density, succes-
"forest" for different regions?
re 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.

Acknowledgments The idea of this book grew out of many discussions at the Center for the Study of Institutions, Population and Environmental Change (CIPEC), at Indiana University, and we would like to thank our colleagues at CIPEC for the many helpful exchanges we have had with them relating to reforestation research. We are also indebted to our families - Jane Southworth would like to thank Romer Kohlhaas and Parker Kohlhaas, and Harini Nagendra would like to thank Venkatachalam Suri and Dhwani Suri for their patience with us as we worked our way through this book. Harini also gratefully acknowledges financial support from the Branco Weiss Society in Science fellowship.

References

Bentley J (1989) Bread forests and new fields: the ecology of reforestation and forest clearing among small woodland owners in Portugal. J For Hist 17:188–195

Bloschl G, Sivapalan M (1995) Scale issues in hydrologic modeling – A review. Hydrol Process 9:251–290

Cropper M, Puri J, Griffiths C (2001) Predicting the location of deforestation: the role of roads and protected areas in North Thailand. Land Econ 77(2):172–186

Food and Agriculture Organization (FAO) (2006) Global Forest Resources Assessment 2005. Food and Agriculture Organization of the United Nations, Rome

Grainger A (2008) Difficulties in tracking the long-term global trend in tropical forest area. Proc Natl Acad Sci U S A 105:818–823

Kao D, Iida S (2006) Structural characteristics of logged evergreen forests in Preah Vihear, Cambodia, 3 years after logging. For Ecol Manag 225:62–73

Lambin EF, Strahler A (1994) Remotely-sensed indicators of land-cover change for multitemporal change-vector analysis. Int J Remote Sens 15:2099–2119

Lettenmaier D, Hayhoe P, Major D, Poff NL, Running S (2008) Water resources, in The effects of climate change on agriculture, land resources, water resources, and biodiversity. Climate Change Science Program Synthesis and Assessment Report 4.3

Lugo A (1992) Comparison of tropical tree plantations with secondary forests of similar age. Ecol Monogr 62:1–41

Messina JP, Walsh SJ, Mena CF, Delamater PL (2006) Land tenure and deforestation patterns in the Ecuadorian Amazon: conflicts in land conservation in frontier settings. Appl Geogr 26:113–128

Milly PCD, Betancourt J, Falkenmark M, Hirsch RM, Kundzewicz ZW, Lettenmaier DP, Stouffer RJ (2008) Stationarity is dead: whither water management? Science 319(5863):573–574

Moody A, Woodcock CE (1995) The influence of scale and the spatial characteristics of landscapes on land-cover mapping using remote sensing. Landscape Ecol 10:363–379

Moon KH, Park D (2004) The role and activities of NGOs in reforestation in the northeast Asian region. For Ecol Manag 201:75–81

Munroe DK, Southworth J, Tucker CM (2004) Modeling spatially and temporally complex land-cover change: the case of western Honduras. Prof Geogr 56(4):544–559

Nagendra H, Pareeth S, Sharma B, Schweik CM, Adhikari KR (2008) Forest fragmentation and regrowth in an institutional mosaic of community, government and private ownership in Nepal. Landscape Ecol 23:41–54

O'Neill RV, Hunsaker CT, Timmins SP, Jackson BL, Jones KB, Riitters KH, Wickham JD (1996) Scale problems in reporting landscape pattern at the regional scale. Landscape Ecol 11:169–180

Qi Y, Wu J (1996) Effects of changing spatial resolution on the results of landscape pattern analysis using spatial autocorrelation indices. Landscape Ecol 11:39–49

Rudel T, Perez-Lugo M, Zichal H (2000) When fields revert to forests: development and spontaneous reforestation in post-war Puerto Rico. Prof Geogr 52:386–397

Rudel T, Coomes O, Moran E, Achard F, Angelsen A, Xu J, Lambin E (2005) Forest transitions: towards a global understanding of land use change. Glob Environ Change 15:23–31

Rudel T (2005) Tropical forests: regional paths of destruction and regeneration in the late twentieth century. Columbia University Press, New York

Seidl AF, dos SV da Silva J (2001) Cattle ranching and deforestation in the Brazilian Pantanal. Ecol Econ 36:413–425

Southworth J, Tucker CM (2001) The influence of accessibility, local institutions, and socio-economic factors on forest cover change in the mountains of western Honduras. Mountain Res Dev 21(3):276–283

Southworth J, Munroe DK, Nagendra H (2004) Land cover change and landscape fragmentation – comparing the utility of continuous and discrete analyses for a Western Honduras region. Agric Ecosyst Environ 101(2–3):185–205

Southworth J, Cumming GS, Marsik M, Binford MW (2006) Linking spatial and temporal variation at multiple scales in a heterogenous landscape. Prof Geog 58(4):406–420

Chapter 2
The Bigger Pictur in Context, Concej

Alan Grainger

2.1 Introduction

The trajectory of the long-term 2005). This is also apparent in by the UN Food and Agricultur deforestation in the humid trop analysis of satellite images can in forest area obtained from in

A. Grainger (✉)
School of Geography, University o
email: a.grainger@leeds.ac.uk

H. Nagendra and J. Southworth (ed
Linking Pattern and Process, Lands
DOI 10.1007/978-1-4020-9656-3_