

# Restoring Tropical Forests

A Practical Guide

---

This book is dedicated to the memory of Surat Plukam. A talented artist and illustrator, his clear and simple artwork has made forest restoration more accessible to both children and adults, from villagers to government officers, throughout SE Asia.

This publication has been made possible with funding from the Darwin Initiative, supported by the RBG Kew Programme in Restoration Ecology, John Ellerman Foundation, Man Group plc, and Kew's Millennium Seed Bank Partnership.

For bibliographic purposes, this book should be referred to as:

**ELLIOTT, S. D., D. BLAKESLEY AND K. HARDWICK, 2013. Restoring Tropical Forests: a practical guide. Royal Botanic Gardens, Kew; 344 pp.**

# **RESTORING TROPICAL FORESTS**

## **A PRACTICAL GUIDE**

**BY STEPHEN D. ELLIOTT,  
DAVID BLAKESLEY AND KATE HARDWICK**

**ARTWORK BY SURAT PLUKHAM AND DAMRONGCHAI SAENGKAM  
JOSEPH NKONGHO AGBOR**

**SPONSORED BY BRITAIN'S DARWIN INITIATIVE**

**Kew Publishing**  
Royal Botanic Gardens, Kew

© The Board of Trustees of the Royal Botanic Gardens, Kew, 2013

Text © the authors

Illustrations and photographs © the artists and photographers

The authors have asserted their rights to be identified as the authors of this work in accordance with the Copyright, Designs and Patents Act 1988. All reasonable efforts have been made by the authors to trace the copyright owners of all material quoted in this book and any images reproduced in this book.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form, or by any means, electronic, mechanical, photocopying, recording or otherwise, without written permission of the publisher unless in accordance with the provisions of the Copyright Designs and Patents Act 1988.

Great care has been taken to maintain the accuracy of the information contained in this work. However, neither the authors nor the publisher can be held responsible for any consequences arising from use of the information contained herein. The views expressed in this work are those of the individual authors and do not necessarily reflect those of the publisher or of the Board of Trustees of the Royal Botanic Gardens, Kew.

First published in 2013 by  
Royal Botanic Gardens, Kew,  
Richmond, Surrey, TW9 3AB, UK  
[www.kew.org](http://www.kew.org)

Distributed on behalf of the Royal Botanic Gardens, Kew in North America by the University of Chicago Press, 1427 East 60th Street, Chicago, IL 60637, USA

ISBN 978-1-84246-442-7

British Library Cataloguing in Publication Data

A catalogue record for this book is available from the British Library

Production editor: Sharon Whitehead

Design, typesetting and page layout: Margaret Newman

Publishing, Design & Photography, Royal Botanic Gardens, Kew

Cover design: Lyn Davies Design

Printed and bound in Italy by Printer Trento S.r.l.



For information or to purchase additional copies of this book (in English, French or Spanish) and other Kew titles please visit [www.kewbooks.com](http://www.kewbooks.com) or email [publishing@kew.org](mailto:publishing@kew.org)

Kew's mission is to inspire and deliver science-based plant conservation worldwide, enhancing the quality of life.

Kew receives half of its running costs from Government through the Department for Environment, Food and Rural Affairs (Defra). All other funding needed to support Kew's vital work comes from members, foundations, donors and commercial activities including book sales.

# CONTENTS

Foreword by HRH Prince of Wales	vii
Preface	viii
Acknowledgements	x
<b>CHAPTER 1 – Tropical deforestation: a threat to life on Earth</b>	<b>1</b>
Section 1.1 – Rate and causes of tropical deforestation	2
Section 1.2 – Consequences of tropical deforestation	5
Section 1.3 – What is forest restoration?	12
Section 1.4 – The benefits of forest restoration	15
Case Study 1 – Cristalino	20
<b>CHAPTER 2 – Understanding tropical forests</b>	<b>23</b>
Section 2.1 – Tropical forest types	24
Section 2.2 – Understanding forest regeneration	45
Section 2.3 – Climate change and restoration	61
<b>CHAPTER 3 – Recognising the problem</b>	<b>65</b>
Section 3.1 – Recognizing levels of degradation	66
Section 3.2 – Rapid site assessment	72
Section 3.3 – Interpreting data from a rapid site assessment	74
Case Study 2 – Littoral forest restoration in south-eastern Madagascar	82
<b>CHAPTER 4 – Planning forest restoration</b>	<b>86</b>
Section 4.1 – Who are the stakeholders?	87
Section 4.2 – Defining the objectives	88
Section 4.3 – Fitting forests into landscapes	90
Section 4.4 – Choosing sites for restoration	95
Section 4.5 – Drafting a project plan	101
Section 4.6 – Fundraising	108
<b>CHAPTER 5 – Tools for restoring tropical forests</b>	<b>110</b>
Section 5.1 – Protection	111
Section 5.2 – ‘Assisted’ or ‘accelerated’ natural regeneration (ANR)	118
Section 5.3 – The framework species method	124
Section 5.4 – Maximum diversity methods	137
Section 5.5 – Site amelioration and nurse plantations	139
Section 5.6 – Costs and benefits	146
Case Study 3 – Area de Conservacion Guanacaste (ACG)	149
<b>CHAPTER 6 – Grow your own trees</b>	<b>152</b>
Section 6.1 – Building a nursery	153
Section 6.2 – Collecting and handling tree seeds	156
Section 6.3 – Germinating seeds	166

Section 6.4 – Potting	171
Section 6.5 – Caring for trees in the nursery	180
Section 6.6 – Research for improving native tree propagation	189
Case Study 4 – Doi Mae Salong: ‘Treasure Tree Clubs’	214
<b>CHAPTER 7 – Tree planting, maintenance and monitoring</b>	<b>216</b>
Section 7.1 – Preparing to plant	217
Section 7.2 – Planting	222
Section 7.3 – Caring for planted trees	229
Section 7.4 – Monitoring progress	231
Section 7.5 – Research for improving tree performance	240
Section 7.6 – Research on biodiversity recovery	251
Case Study 5 – Kaliro District	260
<b>CHAPTER 8 – Setting up a forest restoration research unit (FORRU)</b>	<b>263</b>
Section 8.1 – Organisation	264
Section 8.2 – Working at all levels	267
Section 8.3 – Funding	275
Section 8.4 – Information management	276
Section 8.5 – Selecting suitable tree species	282
Section 8.6 – Reaching out: education and extension services	286
Case Study 6 – Chiang Mai University’s Forest Restoration Research Unit (FORRU)	293
<b>APPENDICES</b>	
A1 – Templates for data collection sheets	296
A2 – Experimental design and statistical tests	307
<b>GLOSSARY</b>	<b>316</b>
<b>REFERENCES</b>	<b>320</b>
<b>INDEX</b>	<b>332</b>



CLARENCE HOUSE

As Patron of the Foundation and Friends of the Royal Botanic Gardens, Kew, I was delighted to have been asked to contribute a foreword to this wonderful book, 'Restoring Tropical Forests: A Practical Guide'. I can only congratulate the authors for their achievement and wish all those who implement its clear practical measures on how to restore tropical forests around the world - in South and Central America, Africa and Asia - every possible success in their vitally important endeavours.

Nature has a remarkable capacity, if given half a chance, to recover and renew herself and it is for this reason, above all, that I believe this book to be so very welcome. I am particularly drawn to its emphasis on the need to restore rich tropical forests, wherever possible with native species; its description of how best to engage local communities in restoration efforts and its focus on the need for landscape and silvopastoral approaches to forest restoration, all of which seem to me absolutely crucial.

I am also intrigued by the book's account of 'rainforestation', the technique pioneered in the Philippines by which indigenous tree species are planted in order to restore ecological integrity and biodiversity, whilst at the same time producing a diverse range of timbers and other forest products for local people.

For many decades, I have been deeply concerned about the plight of the world's tropical forests, inspired both by their timeless grandeur, by the extraordinary biological and cultural diversity to which they are home and by the profound knowledge that neither humanity nor the Earth itself can survive without them, in particular in the face of global climate change. With this in mind, a few years ago I set up my own Rainforests Project, in the hope of drawing attention to the urgent need to establish an international agreement to protect the forests, coupled with a financial mechanism - R.E.D.D.+ - intended to contribute to this protection at the scale required. I have been heartened by progress made in many countries, including Brazil, since then, but note that the global pressures on our remaining forests remain acute. Restoration has a fundamental role in advancing these efforts in the years ahead.

Wangaari Maathai, whose death we all continue to mourn, said, 'We owe it to ourselves and to the next generation to conserve the environment so that we can bequeath our children a sustainable world that benefits all'. What better place to start than with the sound recommendations and practical steps identified in this book?

# PREFACE

*"One touch of nature makes the whole world kin."*  
William Shakespeare, from *Troilus and Cressida*, 1601–1603.

Twenty years ago, when our Forest Restoration Research Unit at Chiang Mai University (FORRU-CMU) was no more than a few wishful bullet points scribbled on the back of an envelope, the decline of the world's tropical forests was seen as an inevitable and irreversible consequence of economic development. The idea that tropical forest ecosystems could actually be restored was viewed by many as naive idealism. Scientists saw tropical forests as being far too complex to be re-constructed, while conservation NGOs regarded the idea as an unnecessary distraction from the vital task of funding the protection of remaining primary forest. Even one of our unit's early funders candidly remarked that he considered the concept to be 'armchair conservation'.

Now, thankfully, attitudes have undergone a paradigm shift. Restoration is seen as complementary to protecting primary forest, especially where protected areas have failed to prevent deforestation. Two decades of research have yielded tried and tested methods that have transformed forest restoration from a romantic 'pipedream' into a readily achievable goal. By combining nature's regenerative capacity with tree planting and other management practices, it is now possible to restore rapidly both the structure and ecological functioning of tropical forests and thus to achieve substantial biodiversity recovery, within 10 years of starting restoration activities. Conservation organisations now recognise restoration as vital to reviving degraded landscapes and improving rural livelihoods, by providing a diverse range of forest products and by developing Payments for Environmental Services (PES) programmes. The inclusion of restoration in the UN's REDD+ scheme<sup>1</sup>, to 'enhance carbon stocks' and mitigate global warming, has resulted in unprecedented demand for restoration knowledge, skills and training. Such knowledge is vital to enable developing tropical countries to cash in on the global trade in carbon credits, while reducing biodiversity losses and meeting the needs of local communities. But very little practical advice has been published to satisfy this demand.

This book seeks to provide such advice. It presents scientifically tested techniques for the restoration of diverse climax tropical forest ecosystems that are resilient to climate change, using indigenous forest tree species, for biodiversity conservation and environmental protection and to support the livelihoods of rural communities. It is based on more than 20 years of research, carried out by FORRU-CMU, as well as on local knowledge and experiences, exchanged over the past 20 years at hundreds of workshops, conferences and project consultations. Plant names in the book generally follow those listed as 'accepted' on Theplantlist.org website, as of June 2013.

Our book presents generic concepts and practices that can be applied to revive forest ecosystems on all tropical continents, in an accessible format and initially in three languages (English, French and Spanish). It includes case studies that illustrate a diversity of successful restoration projects from around the world. It is aimed at the full range of stakeholders, whose collaboration is vital to the success of restoration projects. It provides planners, policy makers and funding agencies with viable and

<sup>1</sup> 'Reducing emissions from deforestation and forest degradation' — a set of policies and incentives being developed under the UN Framework Convention on Climate Change (UNFCCC) to reduce CO<sub>2</sub> emissions derived from clearing and burning tropical forests. [www.scribd.com/doc/23533826/Decoding-REDD-RESTORATION-IN-REDD-Forest-Restoration-for-Enhancing-Carbon-Stocks](http://www.scribd.com/doc/23533826/Decoding-REDD-RESTORATION-IN-REDD-Forest-Restoration-for-Enhancing-Carbon-Stocks)



practicable alternatives to conventional mono-culture plantations that can be used to attain their reforestation goals. For protected area managers, communities, and the NGOs that work with them, the book provides some solid advice on planning restoration projects, as well as scientifically tested instructions for growing, planting and caring for native forest tree species. And for scientists, the book suggests dozens of research project ideas and provides details of standardised research protocols, which can be used to develop new restoration systems that meet local needs. There's even an appendix of proforma for data collection, so that researchers can collect data sets that are comparable with those now being replicated in FORRUs in several countries.

The continued destruction of tropical forests is probably the greatest threat to our planet's biodiversity. Although both awareness of the problem and a willingness to solve it have never been higher, they are ineffective without sound, scientifically based practical advice. We therefore hope that this book will not only inspire more people to get involved in saving Earth's tropical forests, but also provide them with effective tools to do so.

Stephen Elliott

Email: [stephen\\_elliott1@yahoo.com](mailto:stephen_elliott1@yahoo.com)

Website: [www.forru.org](http://www.forru.org)

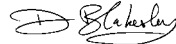
 Facebook Page: Forest Restoration Research Unit



David Blakesley

Email: [David.Blakesley@btinternet.com](mailto:David.Blakesley@btinternet.com)

Website: [www.autismandnature.org.uk](http://www.autismandnature.org.uk)



Kate Hardwick

Email: [k.hardwick@kew.org](mailto:k.hardwick@kew.org)

Website: [www.kew.org](http://www.kew.org)



## ACKNOWLEDGEMENTS

This book is the main output of the project entitled 'Restoring Tropical Forests: a Practical Guide', sponsored by the United Kingdom's Darwin Initiative. We are very grateful for the Darwin Initiative's support of the production costs of this manual, to the Royal Botanic Gardens, Kew, who provided in-house services, to John Ellerman Foundation for funding Kate Hardwick, to Kew Publishing, especially Sharon Whitehead for copyediting and Margaret Newman for layout, and to Kew's Millennium Seed Bank Partnership and Man Group plc, who covered additional costs.

The book is based substantially on the work of the Forest Restoration Research Unit of Chiang Mai University, northern Thailand, and the authors would like to take this opportunity to thank all staff members of the unit, past and present, whose dedicated research has contributed the book's contents, currently Sutthathorn Chairuang Sri, Jatupoom Meesana, Khwankhao Sinhaseni and Suracheat Wongtaewon. Australian Youth Ambassador, Robyn Sakara, funded by Biotropica Australia Plc, and FORRU's research officer Panitnard Tunjai contributed significantly to Chapters 2 and 5, respectively.

The authors also thank all those who contributed text, photos or information: Dominique Andriambahiny, Sutthathorn Chairuang Sri, Hazel Consunji, Elmo Drilling, Patrick Durst, Simon Gardner, Kate Gold, Daniel Janzen, Cherdasak Kuaraksa, Roger Leakey, Paciencia Milan, William Milliken, David Neidel, Peter Nsiimire, Andrew Powling, Johny Rabenantoandro, Tawatchai Ratanasorn, Khwankhao Sinhaseni, Torunn Stangeland, John Tabuti and Manon Vincelette.

Photographs are mostly by Stephen Elliott and FORRU-CMU staff, unless otherwise credited. Line drawings are by Damrongchai Saengkhom and the late Surat Plukam. However, we thank the many others who have provided photographs and illustrations including: Andrew McRobb and other contributors to the Kew photo library, NASA, IUCN for the maps, Tidarach Toktang, Kazue Fujiwara, Cherdasak Kuaraksa and Khwankhao Sinhaseni.

We also thank all reviewers of sections or chapters of the manuscript for their helpful feedback: Peter Ashton, Peter Buckley, Carla Catterall, John Dickie, Mike Dudley, Kazue Fujiwara, Kate Gold, David Lamb, Andrew Lowe, David Neidel, Bruce Pavlik, Andrew Powling, Moctar Sacande, Charlotte Seal, Roger Steinhardt, Nigel Tucker, Prasit Wangpakapatanawong and Oliver Whaley.

We are especially grateful to Val Kapos and Corinna Ravilious (WCMC) for the maps reproduced in Chapter 2.

We thank Joseph Agbor and Claudia Luthi for translating the French and Spanish editions, respectively, and Norbert Sonne and Maite Conde-Prendes for copyediting and proof-reading the translations.

All opinions expressed in this book are those of the authors and not necessarily those of the sponsors or reviewers. The compilers would like to take this opportunity to thank anyone not already mentioned above who has contributed in any way towards the work of FORRU-CMU and the production of this book. Finally, we are grateful to the Biology Department, Science Faculty, Chiang Mai University, for institutional support of FORRU-CMU since its inception, and East Malling Research, Wildlife Landscapes and Royal Botanic Gardens Kew for institutional support of the Darwin Initiative research and the capacity-building programme over a number of years.