

# Contents

List of Maps vii

List of Figures ix

List of Tables xiii

Introduction: Land Use and Deforestation in the Amazon 1

*Charles H. Wood*

## Part I. National Policies and Regional Patterns

1. Spatial Regression Analysis of Deforestation in Santa Cruz, Bolivia 41

*David Kaimowitz, Patricia Mendez, Atie Puntodewo, and Jerry Vanclay*

2. Deforestation and Forest Degradation in Lowland Bolivia 66  
*Pablo Pacheco*

3. An Analysis of the Geographical Patterns of Deforestation in the Brazilian Amazon in the Period 1991–1996 95

*Diógenes S. Alves*

4. Population Growth and Net Migration in the Brazilian Legal Amazon, 1970–1996 107

*Stephen G. Perz*

## Part II. Land Use Decisions and Deforestation

5. The Colonist Footprint: Toward a Conceptual Framework of Land Use and Deforestation Trajectories among Small Farmers in the Amazonian Frontier 133

*Eduardo S. Brondízio, Stephen D. McCracken, Emilio F. Moran, Andrea D. Siqueira, Donald R. Nelson, and Carlos Rodriguez-Pedraza*

6. Land Use Patterns on an Agricultural Frontier in Brazil: Insights and Examples from a Demographic Perspective 162

*Stephen D. McCracken, Andrea D. Siqueira, Emilio F. Moran, and Eduardo S. Brondízio*

7. Trajectories of Land Use: Soils, Succession, and Crop Choice 193  
*Emilio F. Moran, Eduardo S. Brondízio, and Stephen D. McCracken*
8. Reading Colonist Landscapes: Social Factors Influencing Land Use Decisions by Small Farmers in the Brazilian Amazon 218  
*John O. Browder*
9. Endogenous Patterns and Processes of Settler Land Use and Forest Change in the Ecuadorian Amazon 241  
*Francisco Pichón, Catherine Marquette, Laura Murphy, and Richard Bilsborrow*

### **Part III. Fires, Pastures, and Deforestation**

10. Investigating Positive Feedbacks in the Fire Dynamic of Closed Canopy Tropical Forests 285  
*Mark A. Cochrane, Ane Alencar, Mark D. Schulze, Carlos M. Souza, Jr., Paul Lefebvre, and Daniel C. Nepstad*
11. Can Pasture Intensification Discourage Deforestation in the Amazon and Pantanal Regions of Brazil? 299  
*Philip M. Fearnside*
12. Land Use, Cattle Ranching, and the Concentration of Landownership in Maranhão, Brazil 315  
*Roberto Porro*

### **Part IV. Community Participation and Resource Management**

13. Lessons Learned from Participatory Land Use Planning in the Brazilian Amazon 341  
*Virgílio M. Viana and Renata Freire*
14. An Experiment in Participatory Mapping in Brazil's Jaú National Park 352  
*Muriel Saragoussi, Marcos Roberto Pinheiro, Maria do Perpétuo Socorro R. Chaves, Andrew William Murchie, and Sérgio Henrique Borges*

Contributors 365

Index 369

## Maps

1. Spatial representation of deforestation in the Brazilian Amazon 5
- 1.1. Deforestation map of department of Santa Cruz, Bolivia 49
- 1.2. Land utilization map of department of Santa Cruz, Bolivia 50
- 1.3. Precipitation map of department of Santa Cruz, Bolivia 51
- 1.4. Soil map of department of Santa Cruz, Bolivia 52
- 2.1. Lowland Bolivia 68
- 3.1. Distribution of deforestation in the 1991–96 period showing the 25% minimal subset (MSS), the 50% MSS, the 75% MSS, and the 95% MSS 99
- 3.2. Distribution of the 25%, 50%, and 75% MSS and 50-kilometer buffers around the western, eastern, and central road networks 103
- 4.1. States and frontier study sites of the Legal Amazon and Brazil 109
- 4.2. Net migration rates: municipalities, Brazilian Legal Amazon, 1980–91 120
- 7.1. Study areas 196
- 9.1. Ecuador and study area (Amazon settlement frontier) 248
- 10.1. Study regions 286
- 11.1. Brazilian Legal Amazon and Pantanal regions 301
- 12.1. Meso- and micro-regions in the state of Maranhão 317
- 12.2. Cattle density and babassu density by municipalities in the state of Maranhão, 1998 333
- 14.1. Location of the Jaú National Park 353
- 14.2. Zoning of the Jaú National Park according to residents' perspective 361
- 14.3. Zoning of the Jaú National Park according to researchers' perspective 361
- 14.4. Zoning of the Jaú National Park integrating residents' and researchers' perspectives 362

## Figures

1. Area deforested in the Brazilian Legal Amazon, by year (1988–98) 4
2. Socioeconomic and biophysical drivers of land use and environmental change 9
  - 1.1. Correlation matrix between deforestation and independent variables 58
  - 3.1. Cumulative distribution of the observed deforested areas in 1/4° grid cells 98
  - 3.2. Contribution of the different states to the 25%, 50%, and 75% MSS 99
  - 5.1. Linking a conceptual framework of household stages and land use trajectories to a remotely-sensed-based assessment of farm-level multitemporal analysis of deforestation events 138
  - 5.2. Study area: Transamazon Highway, Altamira, Brasil Novo, Medicilândia, Pará State 140
  - 5.3. The colonization area: deforestation trajectory and cohort arrival 146
  - 5.4. Land cover composition of the 1996 colonization landscape 147
  - 5.5a. Total forest cover (%) in 1996 by farm cohorts 148
  - 5.5b. Total deforestation, secondary succession, and area in production (%) in 1970–96 by farm cohorts 148
  - 5.6a–h. Deforestation trajectories (quartiles) for each cohort 149
  - 5.7. The colonist footprint: Average deforestation trajectories by colonization cohorts 153
  - 5.8a. Deforested areas in 1973 turning into secondary succession in 1996. Farm level (n = 802) 154
  - 5.8b. Deforested areas in 1973 turning into production areas in 1996. Farm level (n = 802) 154
  - 5.9a. Deforested areas in 1985 turning into secondary succession in 1996. Farm level (n = 802) 155

- 5.9b. Deforested areas in 1985 turning into production areas in 1996.  
Farm level (n = 802) 155
- 6.1. Simple comparison of 1985 and 1988 TM land cover change to  
illustrate issue of period vs. cohort/age effects 169
- 6.2. Examples of the use of demographic concepts of cohort, age,  
and period effects to understand the processes of landscape  
transformation 171
- 6.3. Possible scenarios of farm-level and land use trajectories 174
- 6.4. Conceptual framework of household transformations, land use,  
and environmental change 176
- 6.5. Stratified sampling frame: cohorts—timing of initial clearing  
179
- 6.6. Distribution of households by year of arrival on current farm  
180
- 6.7. Persons/year worked by type of labor and period of arrival 181
- 6.8. Age-specific rates of participation in domestic and agricultural  
activities on the farm by gender 182
- 6.9. Age and sex pyramids of current household members, and join-  
ing and leaving members 185
- 6.10. Age and sex pyramids by period of arrival of the households  
187
- 7.1. Soil fertility index 198
- 7.2. Carbon content in successional forests of eastern Pará, Brazil  
199
- 7.3. Soil carbon in Altamira and Bragantina sites 200
- 7.4. Soil texture by depth (Altamira, Marajó, Bragantina, Tomé-Açu,  
Yapú) 202
- 7.5. Levels of pH, aluminum, and calcium and magnesium by soil  
depth at five study regions 203
- 7.6. Height increment in secondary succession 204
- 7.7. Comparison of basal area on soils of different fertilities 205
- 7.8. Deforestation along the Transamazon Highway, Altamira,  
1970–91 206
- 7.9. Altamira: percentage of property planted in cocoa 207
- 7.10. Change in index of household goods/durables: arrival to present  
209
- 9.1. Land use patterns of sample households 259
- 9.2. Settler households by land use pattern and duration of settle-  
ment group 260

- 9.3. Mean percentage plot in different land uses for low-cleared-area-pattern households 261
- 9.4. Mean percentage plot in different land uses for medium-cleared-area-pattern households 264
- 9.5. Mean percentage plot in different land uses for high-cleared-area cattle-pattern households 265
- 9.6. Mean percentage plot in different land uses for high-cleared-area coffee-pattern households 265
- 10.1. Classified imagery of “normal” deforestation and “fire-induced” deforestation 293
- 12.1. Production of babassu kernels, rice, and cattle herd by Maranhão’s meso-regions, 1940–96 321
- 12.2. Areas of landholdings in Maranhão according to land use type, 1950–96 323
- 12.3. Gini coefficient for concentration of landownership in Maranhão’s meso-regions, 1950–96 327
- 12.4. Products from Maranhão’s primary sector, 1960–96 329

## Tables

1. Total area of deforestation, 1988–98, by state 6
- 1.1. Conclusions from previous spatial regression models about the effects of different variables on deforestation 44
- 1.2. Proportion of forested area in 1989 in Santa Cruz cleared between 1989 and 1994 by zoning category 59
- 1.3. Proportion of forested area in 1989 in Santa Cruz cleared between 1989 and 1994 by USDA land use potential class 59
- 1.4. Proportion of forested area in 1989 in Santa Cruz cleared between 1989 and 1994 by distance to Santa Cruz and distance to the nearest classified road 59
- 1.5. Proportion of forested area in 1989 in Santa Cruz cleared between 1989 and 1994 by precipitation level 61
- 1.6. Regression results for the probability of a forested area in Santa Cruz in 1989 remaining forested in 1994 61
- 1.7. The expected percentage of forest clearing between 1989 and 1994 for different values of the independent variables in an otherwise typical case 61
- 2.1. Land tenure and other use rights 69
- 2.2. Available estimates of deforestation in Bolivia 72
- 2.3. Actors that influence land and forest use in Lowland Bolivia 74
- 2.4. Effects of new natural resource policies on forest use 86
- 3.1. Municipalities in the 25% and 50% minimal subsets 100
- 3.2. Deforestation within 25 and 50 km from the western, eastern, and central road networks 103
- 4.1. Population growth in states of the Brazilian Legal Amazon, 1970–96 113
- 4.2. Rural and urban population growth and urbanization in states of the Brazilian Legal Amazon, 1970–96 115
- 4.3. Estimates of net migration in states of the Brazilian Legal Amazon, 1970–80 118
- 4.4. Estimates of net migration in states of the Brazilian Legal Amazon, 1980–91 119

4.5. Estimates of net migration in states of the Brazilian Legal Amazon, 1991–96	121
4.6. Estimates of annual net migration in states of the Brazilian Legal Amazon, 1970–96	122
5.1. Distribution of farm lots into cohort groups and definition of cohort groups	145
6.1. Conceptual and methodological issues in linking demographic and remote sensing analysis	164
7.1. Percentage choosing <i>terra roxa</i> by cohort	207
7.2. Crops and <i>terra roxa</i>	210
7.3. Crops and credit	211
7.4. Use of credit	211
8.1. Factors affecting deforestation and land use	221
8.2. Land use patterns (hectares)	226
8.3. Gross income for marketed output (1991 U.S.\$)	227
8.4. Capital investment and assets	227
8.5. Rural job creation	228
8.6. Natural forest resource use and tree planting	229
8.7. Percentage of total farm labor input and farm income by activity and daily return to labor (1980 Cr\$)	232
9.1. General characteristics of settler households in the northeastern Ecuadorian Amazon, 1990	249
9.2. Share of gross cropped area (GCA)	253
9.3. Crops grown by settlers and pasture and cattle-owning by duration of settlement	254
9.4. Comparison of crops grown before and after settlement among settler households who owned land in area of origin	256
9.5. Land use patterns among settler households in northeastern Ecuadorian Amazon based on cluster analysis	257
9.6. Characteristics of settler land use patterns identified through cluster analysis	262
9.7. Distribution of settler households by previous economic status and frontier economic bracket, Ecuadorian Amazon, 1990	269
9.8. Distribution of settler households by income level and proportion of plot in pasture, Ecuadorian Amazon, 1990	271
10.1. Deforestation and forest burning in several study regions	289
10.2. Forest, fuel, and fire characteristics for four different forest types within the Tailândia study region	291
11.1. Phosphate requirements for maintaining pasture in the Brazilian Amazon	308



- 12.1. Major social processes associated with land use/land cover change in Maranhão, 1750–2000 319
- 12.2. Distribution of number and area of landholdings in Maranhão, 1985 and 1996 326
- 12.3. Gini coefficient for concentration of landownership in Maranhão's meso- and micro-regions, 1940–96 328
- 12.4. Total and percentages of 1996 cattle herd in states of the Brazilian Amazon by groups of landholdings according to their size 331
- 12.5. Landholdings engaged in cattle ranching: total and average cattle herd by groups of landholdings according to their size 332