

# Ecological Studies, Vol. 221

---

Analysis and Synthesis

Edited by

M.M. Caldwell, Washington, USA

G. Heldmaier, Marburg, Germany

R.B. Jackson, Durham, USA

O.L. Lange, Würzburg, Germany

H.A. Mooney, Stanford, USA

E.-D. Schulze, Jena, Germany

U. Sommer, Kiel, Germany

For further volumes see list at the end of the book and:  
<http://www.springer.com/series/86>



Jörg Bendix • Erwin Beck • Achim Bräuning •  
Franz Makeschin • Reinhard Mosandl •  
Stefan Scheu • Wolfgang Wilcke  
Editors

# Ecosystem Services, Biodiversity and Environmental Change in a Tropical Mountain Ecosystem of South Ecuador

 Springer

*Editors*

Jörg Bendix  
Faculty of Geography  
University of Marburg  
Marburg, Germany

Erwin Beck  
Department of Plant Physiology and Bayreuth  
Centre of Ecology and Environmental Research  
University of Bayreuth  
Bayreuth, Germany

Achim Bräuning  
Institute of Geography  
University of Erlangen-Nuremberg  
Erlangen, Germany

Franz Makeschin  
Institute of Soil Science and Site Ecology  
Dresden University of Technology  
Tharandt, Germany

Reinhard Mosandl  
Institute of Silviculture  
Technische Universität München  
Freising, Germany

Stefan Scheu  
J.F. Blumenbach Institute of Zoology and  
Anthropology  
Georg August University Göttingen  
Göttingen, Germany

Wolfgang Wilcke  
Geographic Institute of the University  
of Bern (GIUB)  
University of Bern  
Bern, Switzerland

ISSN 0070-8356

ISBN 978-3-642-38136-2

ISBN 978-3-642-38137-9 (eBook)

DOI 10.1007/978-3-642-38137-9

Springer Heidelberg New York Dordrecht London

Library of Congress Control Number: 2013943580

© Springer-Verlag Berlin Heidelberg 2013

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed. Exempted from this legal reservation are brief excerpts in connection with reviews or scholarly analysis or material supplied specifically for the purpose of being entered and executed on a computer system, for exclusive use by the purchaser of the work. Duplication of this publication or parts thereof is permitted only under the provisions of the Copyright Law of the Publisher's location, in its current version, and permission for use must always be obtained from Springer. Permissions for use may be obtained through RightsLink at the Copyright Clearance Center. Violations are liable to prosecution under the respective Copyright Law.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

While the advice and information in this book are believed to be true and accurate at the date of publication, neither the authors nor the editors nor the publisher can accept any legal responsibility for any errors or omissions that may be made. The publisher makes no warranty, express or implied, with respect to the material contained herein.

Printed on acid-free paper

Springer is part of Springer Science+Business Media ([www.springer.com](http://www.springer.com))

# Preface

Threat to biodiversity and ecosystem services by global change is meanwhile undisputed. Climate change, expansion of land use, atmospheric fertilization, and invasion by alien species have been identified as the main current and future drivers of ecosystem deterioration (Sala et al. 2000; Pereira et al. 2010). The Millennium Ecosystem Assessment (MEA 2005) connected for the first time the interdependence of ecosystem functioning and human interference with nature in a well-arranged, comprehensive manner by defining specific categories of services which the earth's ecosystems provide for their own stability and in particular for the benefits of their human inhabitants. While acknowledging those services as a major precondition for human well-being, the aim of the report was to assess the consequences of (predominantly) man's impact on ecosystems for human well-being and to provide the scientific basis for a responsible, sustainable use of ecosystems, including conservation. Notwithstanding the appreciation of the impressive conceptual work condensed in that report, its focus on the global dimension of ecosystem services inevitably generates scarcity of regional and local assessments. Thus, e.g. for the biodiversity hotspot of Ecuador information on the current or the predicted states is completely lacking (Fig. 6.1 in MEA 2005). At the same time, the report deplores insufficient knowledge, among others, on (1) long time series of local environmental data, (2) quantitative relationships between biodiversity and ecosystem services, particularly regarding regulative, cultural, and supporting services of specific ecosystems, which would allow predictions, and (3) the incapability to derive regional and local projections of the future development of ecosystem services (MEA 2005).

This book will contribute to fill such local gaps for one of the "hottest" biodiversity hotspots of the world, the south-eastern Andes of Ecuador. Assessment of the current and future state of biodiversity and ecosystem services in the valley of the Rio San Francisco is based on 15 years of comprehensive interdisciplinary ecosystem research, producing a wealth of data, and profound as well as far-reaching information on ecosystem structure and functioning, covering the biotic, abiotic, and socioeconomic spheres. A basis to this endeavor is the predecessor volume ("Gradients in a Tropical Mountain Ecosystem of Ecuador" in the

same Series, Vol. 198, edited by Beck et al. 2008), which has been published five years ago. A special advantage of the selected study area is the direct spatial vicinity of the protected mountain rain forest as the natural ecosystem of the region on the one side of the valley and an anthropogenic agricultural replacement system on the opposite side. While the natural forest appears to be fairly resilient to climate changes, the agricultural systems, mostly pastures, turned out to be non-sustainable. The unique opportunity to conduct comparative field surveys and ecological experiments in both manifestations of the ecosystem allowed the authors to gather quantitative information on current ecosystem services which are subjected to the impacts of an ongoing climate and land-use change. With regard to ecosystem services, the book is based on an approach adapting the MEA (2005) service categories, as described in detail in Sect. 4.2.

Part II presents the current state of the different service categories. Naturally this part cannot claim to be exhaustive regarding the immense complexity of the tropical ecosystems. Thus, the authors have focused on services which are of major importance for the country, e.g., biodiversity as the main preserving but also cultural service, the regulation of climate, the water, carbon, and nutrient cycles, considering abiotic and biotic elements, the provision of water, the deposition of airborne nutrients, and various options of agricultural provisioning services (forestry and pasture management). The latter have been analyzed in a holistic way, ranging from ecological aspects to socioeconomic issues, in particular the sustainability of indigenous land-use systems.

Regarding prospective approaches, ecological intervention experiments on the one hand and numerical models calibrated and parameterized by a multitude of measured data on the other provide the basis for scenarios for the future development of the investigated ecosystems and ecosystem services. This is the concern of Part III. Special attention is given to derive a sustainable land-use portfolio from an ecologically adapted combination of suitable agricultural strategies and managements.

The main synthesis (Part IV) summarizes the accumulated comprehensive knowledge, culminating in a science-directed recommendation of sustainable land-use system for the hotspot area, which was the overarching aim of the past 6 years of research. Although the book reports projects of basic research, there is one major point which must not be overlooked. In the spirit of the Access and Benefit Sharing (ABS) principle publicized by the CBD (Convention on Biological Diversity), research in a developing country should address the needs of the local communities and should be conducted together with the local people, scientists, and stakeholders for the sake of building capacity. After 15 years of joint German–Ecuadorian research, a multitude of benefits have been achieved and are communicated in Part IV. This holds in particular for the academic scene of southern Ecuador. Furthermore, the compiled results and developed technologies of several projects are now ready for transfer into application to serve the local society. Consequently, the potential of the research results for knowledge transfer has been assessed here, too.

At this point, it should be stressed that the results of this book not only hold for the ecosystem of the Rio San Francisco Valley but *mutatis mutandis* show transferability to other forested tropical mountain areas of the Andes (and beyond), if located in a comparable altitudinal range of approximately 1,000–3,500 m a.s.l. The environmental background conditions of the study area are comparable to many other sites at the tropical eastern Andean ranges. The altitudinal level of the study area is subjected to the influence of a belt of high cloudiness and precipitation, the so-called Andes-Occurring System (AOS), ranging from Columbia to Peru (Bendix et al. 2006). As in the study area, the population pressure in the biodiversity hotspot of the entire tropical Andes is one of the highest in the world. This causes ongoing land-use changes, i.e., clearing of the natural forest to increase livelihood by exploiting provisioning services as revenues from agriculture. However, the needed conversion of natural forest into arable land at the same time deteriorates ecosystem services at other levels. As in the study area, the removal of forest for pastures is the current land-use practice everywhere in the tropical Andes (Mulligan et al. 2009). This type of land-use change is generally suspected to threaten cultural, supporting, regulating and provision services, and also knowledge which is associated with functional biodiversity.

However, many uncertainties of ecological, economic, and social nature remain with respect to the bouquet of ecosystem services from the natural and the man-made ecosystems in the research areas and beyond. The book takes up all these uncertainties and attempts to provide exemplarily transferable comments on the state of current ecosystem services and their management.

Last but not least, the endeavor of compiling an interdisciplinary book of this extent is a major challenge. This had not been possible without the extraordinary commitment of the 103 authors who contributed their excellent knowledge, creativity, and enthusiasm during the compilation of the manuscript. Many thanks go also to our editors for moderating partly controversial but fruitful discussions in order to match the individual chapters and to the publisher for supporting the publication of our results in the Ecological Studies series. Our assistant editor, Dr. Esther Schwarz-Weig (Mistelgau), deserves a special praise for her outstanding perseverance and patience in collecting, editing, and commenting on the chapters. Without her help, this book would certainly never have been realized. The authors would also like to thank the German Research Foundation (Deutsche Forschungsgemeinschaft DFG) for generously funding the research and the external board of advisors/reviewers for their help to refine the research program. For the achievement of the knowledge compiled in this book, the excellent cooperation with Ecuadorian colleagues and local people was instrumental, who became good friends over the time. The foundation Nature and Culture International (NCI) provided the facilities, in particular the very well-equipped research station ECSF (Estación Científica San Francisco) together with the surrounding research area. The effective running of this station by NCI in cooperation with the German scientific coordinators Dr. Felix Matt and Dipl. Geoecologist Jörg Zeilinger must be considered a stroke of luck for the entire enterprise “Ecosystem Studies in South Ecuador.” The support of our counterparts from the Ecuadorian Universities, above

all from the Universidad Técnica Particular de Loja (UTPL), the Universidad Nacional de Loja (UNL), and the University of Cuenca, also deserves special acknowledgment. The authorship and coauthorship of many Ecuadorian collaborators in this book witness the excellent cooperation. Last but not least, we thank the Ecuadorian governmental administration for enabling this exciting research and, on behalf of others, the Ecuadorian Ministry of Environment (MAE) for issuing the research permissions. As the space of this preface is limited, it is not possible to thank all people by names who have contributed to the success of our research and in turn to the realization of this book. Nevertheless, we are very grateful to them and their support of our venture is well appreciated.

Marburg, Germany  
Bayreuth, Germany

Jörg Bendix  
Erwin Beck

## References

- Beck E, Bendix J, Kottke I, Makeschin F, Mosandl R (eds) (2008) Gradients in a tropical mountain ecosystem of Ecuador. *Ecological studies*, vol 198. Springer, Berlin, pp 525
- Bendix J, Rollenbeck R, Göttlicher D, Cermak J (2006) Cloud occurrence and cloud properties in Ecuador. *Clim Res* 30:133–147
- Millennium Ecosystem Assessment (2005) *Ecosystems and human well-being: biodiversity synthesis*. World Resources Institute, Washington, DC
- Mulligan M, Rubiano J, Hyman G, Leon JG, Saravia M, White D, Vargas V, Selvaraj J, Ball C, Farrow A, Marín JA, Pulido OL, Ramírez A, Gutierrez T, Cruz LA, Castro A, Andersson M (2009) The Andes Basin Focal Project. Final report to the CGIAR challenge program on water and food. CPWF Project Report PN63. [http://mahider.ilri.org/bitstream/handle/10568/3872/PN63\\_KCL\\_Project%20Report\\_Dec09\\_final.pdf?sequence=1](http://mahider.ilri.org/bitstream/handle/10568/3872/PN63_KCL_Project%20Report_Dec09_final.pdf?sequence=1). Accessed 15 Sept 2012
- Pereira HM, Leadley PW, Proença V, Alkemade R, Scharlemann JP, Fernandez-Manjarrés JF, Araújo MB, Balvanera P, Biggs R, Cheung WW, Chini L, Cooper HD, Gilman EL, Guénette S, Hurtt GC, Huntington HP, Mace GM, Oberdorff T, Revenga C, Rodrigues P, Scholes RJ, Sumaila UR, Walpole M (2010) Scenarios for global biodiversity in the 21st Century. *Science* 330:1496–1501
- Sala OE, Chapin III FS, Armesto JJ, Berlow E, Bloomfield J, Dirzo R, Huber-Sannwald E, Huenneke LF, Jackson RB, Kinzig A, Leemans R, Lodge DM, Mooney HA, Oesterheld M, Poff NL, Sykes MT, Walker B, Walker M, Wall DH (2000) Global biodiversity scenarios for the year 2100. *Science* 287:1770–1774



# Contents

## Part I Introduction

<b>1 The Study Area . . . . .</b>	<b>3</b>
Michael Richter, Erwin Beck, Rütger Rollenbeck, and Jörg Bendix	
<b>2 Environmental Changes Affecting the Andes of Ecuador . . . . .</b>	<b>19</b>
Thorsten Peters, Thomas Drobnik, Hanna Meyer, Melanie Rankl, Michael Richter, Rütger Rollenbeck, Boris Thies, and Jörg Bendix	
<b>3 The Challenges of Sustainable Development in the Podocarpus-El Cóndor Biosphere Reserve . . . . .</b>	<b>31</b>
Jan Barkmann, Sofia Eichhorn, Byron Maza, Frank v. Walter, and Roland Olschewski	
<b>4 The Research Unit RU 816: Overall Approach in the Light of the Ecosystem Services Concept . . . . .</b>	<b>41</b>
Jan Barkmann, Boris M. Hillmann, and Rainer Marggraf	

## Part II Current Situation of Biodiversity and Ecosystem Services

<b>5 Landscape History, Vegetation History, and Past Human Impacts . . .</b>	<b>53</b>
Fernando Rodriguez, Achim Bräuning, Andrés Gerique, Hermann Behling, and Franziska Volland	
<b>6 Past Dynamics of Speciation in Andean Mountain Rainforests . . . .</b>	<b>67</b>
Konrad Fiedler and Patrick Strutzenberger	
<b>7 Diversity in Soil Fungi, Protists, and Microarthropods . . . . .</b>	<b>81</b>
Matthias C. Rillig, Tessa Camenzind, Julia Gawlik, Ingeborg Haug, Valentina Krashevska, Mark Maraun, Dorothee Sandmann, and Stefan Scheu	

<b>8</b>	<b>Plant Diversity and Its Relevance for the Provision of Ecosystem Services . . . . .</b>	<b>93</b>
	Jürgen Homeier, Florian A. Werner, Julia Gawlik, Thorsten Peters, Karl-Heinz J. Diertl, and Michael Richter	
<b>9</b>	<b>Supporting, Regulating, and Provisioning Hydrological Services . . .</b>	<b>107</b>
	Lutz Breuer, David Windhorst, Andreas Fries, and Wolfgang Wilcke	
<b>10</b>	<b>The Carbon Balance of Tropical Mountain Forests Along an Altitudinal Transect . . . . .</b>	<b>117</b>
	Christoph Leuschner, Alexandra Zach, Gerald Moser, Jürgen Homeier, Sophie Graefe, Dietrich Hertel, Bärbel Wittich, Nathalie Soethe, Susanne Iost, Marina Röderstein, Viviana Horna, and Katrin Wolf	
<b>11</b>	<b>Current Regulating and Supporting Services: Nutrient Cycles . . . .</b>	<b>141</b>
	Wolfgang Wilcke, Jens Boy, Ute Hamer, Karin Potthast, Rütger Rollenbeck, and Carlos Valarezo	
<b>12</b>	<b>Natural Landslides Which Impact Current Regulating Services: Environmental Preconditions and Modeling . . . . .</b>	<b>153</b>
	Jörg Bendix, Claudia Dislich, Andreas Huth, Bernd Huwe, Mareike Ließ, Boris Schröder, Boris Thies, Peter Vorpahl, Julia Wagemann, and Wolfgang Wilcke	
<b>13</b>	<b>Conservation, Management of Natural Forests and Reforestation of Pastures to Retain and Restore Current Provisioning Services . . .</b>	<b>171</b>
	Michael Weber, Bernd Stimm, Maria Fernanda López, Andrés Gerique, Perdita Pohle, Patrick Hildebrandt, Thomas Knoke, Ximena Palomeque, Baltazar Calvas, Sven Günter, Nikolai Aguirre, and Daniel Kübler	
<b>14</b>	<b>Mycorrhiza Networks Promote Biodiversity and Stabilize the Tropical Mountain Rain Forest Ecosystem: Perspectives for Understanding Complex Communities . . . . .</b>	<b>187</b>
	Ingrid Kottke, Sabrina Setaro, Ingeborg Haug, Paulo Herrera, Dario Cruz, Andreas Fries, Julia Gawlik, Jürgen Homeier, Florian A. Werner, Andrés Gerique, and Juan Pablo Suárez	
<b>15</b>	<b>Current Provisioning Services: Pasture Development and Use, Weeds (Bracken) and Management . . . . .</b>	<b>205</b>
	Kristin Roos, Jörg Bendix, Giulia F. Curatola, Julia Gawlik, Andrés Gerique, Ute Hamer, Patrick Hildebrandt, Thomas Knoke, Hanna Meyer, Perdita Pohle, Karin Potthast, Boris Thies, Alexander Tischer, and Erwin Beck	

**16 Current Provisioning Ecosystem Services for the Local Population: Landscape Transformation, Land Use, and Plant Use . . . . . 219**  
 Perdita Pohle, Andrés Gerique, Maria Fernanda López,  
 and Regine Spohner

**17 Sustainable Agriculture and Conservation Payments Are Key Factors in Mitigating Tropical Forest Loss . . . . . 235**  
 Baltazar Calvas, Thomas Knoke, Luz Maria Castro,  
 Patrick Hildebrandt, Michael Weber, Bernd Stimm,  
 Reinhard Mosandl, Sven Günter, and Nikolai Aguirre

**Part III Future Environmental Changes and Their Impacts on Biodiversity and Ecosystem Services**

**18 Climate Change: Effects on Biodiversity and Ecosystem Functioning . . . . . 247**  
 Florian A. Werner, Nele Jantz, Valentyna Krashevska,  
 Thorsten Peters, Hermann Behling, Mark Maraun,  
 Stefan Scheu, and Gunnar Brehm

**19 Global Climate Change Impacts on Local Climate and Hydrology . . . 265**  
 Lutz Breuer, Jean-François Exbrayat, Ina Plesca, Wouter Buytaert,  
 Theresa Ehmann, Thorsten Peters, Edison Timbe, Katja Trachte,  
 and David Windhorst

**20 Impacts of Local Land-Use Change on Climate and Hydrology . . . 275**  
 David Windhorst, Brenner Silva, Thorsten Peters, Hanna Meyer,  
 Boris Thies, Jörg Bendix, Hans-Georg Frede, and Lutz Breuer

**21 Current and Future Variations of Nutrient Depositions and Influences on Tree Growth . . . . . 287**  
 Rütger Rollenbeck, Insa Otte, Peter Fabian, Wolfgang Wilcke,  
 Darwin Pucha Cofrep, Achim Bräuning, and Jörg Bendix

**22 Nutrient Additions Affecting Matter Turnover in Forest and Pasture Ecosystems . . . . . 297**  
 Ute Hamer, Karin Potthast, Wolfgang Wilcke, Hans Wullaert,  
 Carlos Valarezo, Dorothee Sandmann, Mark Maraun, Stefan Scheu,  
 and Jürgen Homeier

**23 Effects of Nutrient Addition on the Productivity of Montane Forests and Implications for the Carbon Cycle . . . . . 315**  
 Jürgen Homeier, Christoph Leuschner, Achim Bräuning,  
 Nixon L. Cumbicus, Dietrich Hertel, Guntars O. Martinson,  
 Susanne Spann, and Edzo Veldkamp

**24 Climate Change and Its Impact on Current and Future Vegetation Dynamics and Carbon Cycling . . . . . 331**  
 Brenner Silva, Claudia Dislich, Ingo Voss, Kristin Roos, Renate Scheibe, Peter Vorpahl, Boris Schröder, Andreas Huth, Erwin Beck, and Jörg Bendix

**25 Sustainable Use of Tropical Forests: A Plea for a Landscape View . . . . . 343**  
 Thomas Knoke, Baltazar Calvas, Patrick Hildebrandt, Michael Weber, Bernd Stimm, Sven Günter, Nikolai Aguirre, and Reinhard Mosandl

**26 Future Provisioning Services: Repasturisation of Abandoned Pastures, Problems, and Pasture Management . . . . . 355**  
 Erwin Beck, Jörg Bendix, Brenner Silva, Rütger Rollenbeck, Lukas Lehnert, Ute Hamer, Karin Potthast, Alexander Tischer, and Kristin Roos

**Part IV Synopsis**

**27 Synopsis: Towards a Sustainable Land Use Portfolio . . . . . 373**  
 Erwin Beck and Jörg Bendix

**28 Knowledge Transfer for Conservation and Sustainable Management of Natural Resources: A Case Study from Southern Ecuador . . . . . 395**  
 Sven Günter, Baltazar Calvas, Thomas Lotz, Jörg Bendix, and Reinhard Mosandl

**29 The Role of Biodiversity Research for the Local Scientific Community . . . . . 411**  
 Perdita Pohle, Maria Fernanda López, Erwin Beck, and Jörg Bendix

**Index . . . . . 429**