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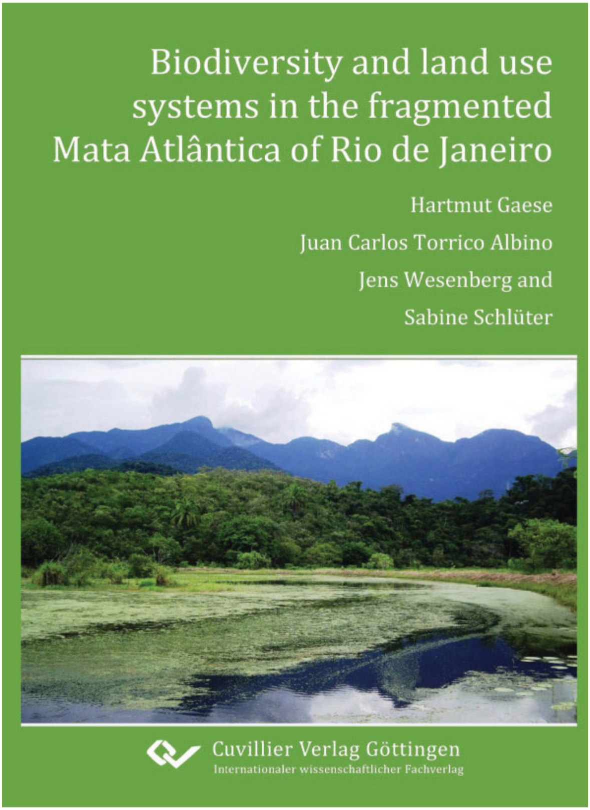
Biodiversity and land use systems in the fragmented Mata Atlanta of Rio de Janeiro



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CHAPTER 1

THE DYNAMIC OF THE MATA ATLÂNTICA

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Abstract: Ongoing deforestation causing fragmentation and habitat loss is a typical phenomenon occurring in all tropical forests around the globe. For the originally contiguously forested Brazilian Atlantic coast, fragmentation and habitat loss are particularly serious due to the long settlement history and to the current high population density. This leads to continuing overexploitation of natural resources, not only in the form of further deforestation, but also erosion of biodiversity, degradation of soil and water quality, water shortage and elevated levels of greenhouse gas emissions. Today, deforestation in the Atlantic forest is mainly caused by the conversion of forest into agricultural land, resulting in further intensification of the already shattered mosaic of forest fragments and matrix areas. Different land use systems in these matrix areas, depending on their sustainability, imply varying potentials to act as benefiting matrix area connecting forest fragments. A concept for biodiversity conservation in such a mosaic landscape cannot solely rely on the protection of single areas of biodiversity, but has to integrate all aspects of the complex human-ecological system, to safeguard biodiversity in accordance with the well-being of local human communities. A

promising approach is the establishment of ecological corridors, which includes matrix areas and forest fragments to improve connectivity of entire regions. For the success of these corridors, the shift towards sustainable land use systems in matrix areas is essential, both for the conservation of biodiversity and for profitable long-term land use. However, implementation of such comprehensive concepts is difficult and necessitates further interdisciplinary and transdisciplinary research combining expertise of all fields related to human-ecological systems.

Introduction

The Atlantic Forest, or Mata Atlântica, is one of the world's most outstanding and most threatened ecosystems (Myers 1990, Myers et al. 2000, Mittermeier et al. 2004, 2005). On the one hand, it hosts an enormous structural, floristic and faunal diversity comprising a high degree of endemism at all levels of organism organisation (e.g. Fonseca 1985, Fonseca et al. 1999, 2004, Kinzey 1981, Morawetz & Krügel 1997, Morawetz & Raedig 2007, Mori et al. 1981, Prance 1987). On the other hand, its destruction since the beginning of the colonisation of South America has led to a dramatic reduction and fragmentation of the ecosystem (e.g. Bertoni et al. 1988, Dean 1996, Leitão Filho 1987). Between the five South American biodiversity hotspots, the Atlantic Forest is the most densely populated one and comprises the one of the smallest portions of protected areas (Mittermeier et al. 2004). Today some of the biggest Brazilian urban agglomerations and agricultural landscapes with different land use types are embedded in the area once almost continuously covered by the Mata Atlântica.

The reduction and fragmentation of natural ecosystems by anthropogenic impacts have elevated the rate of species extinction by thousand times the natural background rate (Pimm et al. 1995). But also physical and chemical qualities of landscapes are affected by the destruction and fragmentation of natural habitats and unsustainable land use practices. Soil erosion and landslides certainly are natural processes, but they are intensified by man-made degradations (e.g. Augustin 2001, Coelho Netto 2003, Figueiredo & Guerra 2001). Other parameters affected by anthropogenic landscape transformations are soil and air quality as well as surface and groundwater availability and quality. In turn, negative effects of man-made habitat destruction impair the productivity of land use systems. In spite of this, the importance of ecosystem services is not sufficiently recognised and appreciated by society (Tonhasca Jr. 2005).

Accelerated anthropogenic climate change will undoubtedly magnify the effects of habitat destruction and fragmentation (Thomas et al. 2004). Its specific effects on biodiversity have yet to be assessed for most of the biodiversity hotspots (Midgley et al. 2002). In general, ongoing climate change affects the vulnerability of ecosystems and land use systems on economic, social and environmental levels (e.g. Felgentreff & Glade 2007, Parmesan & Yohe 2003, Rahmstorf & Schellnhuber 2007). Therefore, the evaluation of related risk and resilience potentials considering climate change scenarios is indispensable for development concepts, strategies and instruments for sustainable natural and agricultural resources management and conservation. One of the most crucial questions in this context is how the vulnerability and resilience of eco- and land use systems vary in response to changes in human-environmental interactions (interactions between ecosystem and economic, political and social factors and processes) caused by climate change.

There is an ongoing public and political debate over climate change. In the context of the intensive public and political attention paid to the climate change problem, it has to be emphasised that a reflection of climate change detached from other social, ecological and economic problems cannot achieve success. Climate mitigation and adaptation measures are not per se socially and/or ecologically suitable. Therefore, these measures and strategies have to meet the demands of the sustainability concept. This implicates the need for interdisciplinary and integrated approaches in assessment, data management, modelling and planning. Additionally, it is necessary to consider spatial and temporal dynamics and interrelationships between the different elements and units of the systems, regions or landscapes to be assessed, modelled and planned. As different elements present different dynamics, individual interrelationships differ in their spatial and temporal dimensions. Thus all approaches have to be multi-scalar and versatile.

The highly fragmented and intensively used landscape of the Mata Atlântica represents an outstanding challenge of modern nature conservation, land and resource use planning and management. The proposed project is designed to face these challenges and to meet the demands for a sustainable, climate efficient rural development in this threatened ecosystem.

Biodiversity and landscape fragmentation

The Brazilian Mata Atlântica is a unique series of South American rainforest ecosystems. The Atlantic Forest has been considered one of the world's biodiversity hotspots ever since Myers (1990) first selected 18 priority regions for the conservation of vascular plants. The ecosystem presents not only a very diverse flora, but also an elevated number of endemic plants. More than 8,000 of an estimated 20,000 species of plants (40%) are thought to be endemic (Brooks et al. 2002, Fonseca et al. 2004, Mittermeier et al. 2004, 2005). Especially tree species show an exceptionally high degree of endemism. The estimates for this ecological group vary from 53% (Mori et al. 1981) to about 70 % (Gentry 1992). However, also other plant groups, such as Bromeliaceae (Smith 1955), ferns (Tryon & Tryon 1982) and bamboos (Soderstrom et al. 1988), present high percentages of species that are restricted to the region. Since Myers' analysis (1990), several databases and estimates about the diversity and endemism rates of different animal groups have been published (e.g. Brown & Freitas 2000, Duellman 1999, Fonseca et al. 1999, Stotz et al. 1996, Sazima 2001, Sazima et al. 2001) and have corroborated the inclusion of the Mata Atlântica in the list of the 34 biodiversity hotspots (Brooks et al. 2002, Myers et al. 2000, Mittermeier et al. 2004, 2005).

The high biodiversity and endemism rates found in the Atlantic Forest can be explained at least partly by historical vegetation dynamics and the related speciation processes as well as by the latitudinal, altitudinal and continentality gradients and the resulting environmental diversity (Almeida 2000, Prance 1989, Thomas et al. 1998, Tonhasca Jr. 2005). On a large scale, different vegetation formations can be recognized and were classified along these gradients (e.g. Joly et al. 1991, Lombardi & Gonçalves 2000, Morellato & Haddad 2000, Oliveira-Filho & Fontes 2000, Rambaldi et al. 2003, Rizzini 1954, Scarano 2002, Veloso et al. 1991, Viana et al. 1997). Several studies from other ecosystems demonstrate that small scale environmental heterogeneity influences the diversity and species composition patterns. This may allow distinguishing different vegetation types within large scale formations (e.g. Dempewolf 2000, Paulsch 2001, Tuomisto et al. 1995, 2002, 2003, Tuomisto & Ruokolainen 2005, Vormisto et al. 2000, Wesenberg et al. 2001). In the Atlantic Forest, small scale floristic differentiation is poorly studied for most of the vegetation formations and was part of the investigations realised in the BLUMEN project (Engelmann 2005, Engelmann et al. 2006, Seele 2005, Seele et al. 2006, Wesenberg et al. in prep.).

Due to the exploration and deforestation of the Atlantic Forest during the last centuries (Almeida 2000, Dean 1996), its forest area is reduced to 5-12% (depending on definition of its inland borders) of its original extent today (Lombardi & Gonçalves 2000, Mittermeier et al. 2004, 2005, Morellato & Haddad 2000, Oliveira-Filho & Fontes 2000, Ranta et al. 1998, Saatchi et al. 2001, Scarano 2002, Viana & Tabanez 1996). The biggest part of this remaining forest consists of comparably small and only partially protected fragments (Lima & Capobianco 1997, Gascon et al. 2000).

The fragmentation of landscapes has severe effects on the function of ecosystems. Habitat reduction, for instance, results in local species loss (Pitman et al. 2002, Silva & Tabarelli 2000, Stratford & Stouffer 1999, Williams-Linera et al. 1998). Furthermore, vegetation structure and dynamics can change due to promotion of invasive species and/or limitation of the regenerative capacity of many species (Benitez-Malvido 1998, Kapos et al. 1997, Laurance 1991, Laurance et al. 1998a, 1998b, 2000, Lovejoy et al. 1986, Tabarelli et al. 1999, Timmins & Williams 1991). The latter is mainly caused by shrinking populations of forest species and splitting of formerly connected populations, respectively. This type of habitat fragmentation also causes interruptions of migration routes for animals. As a consequence, this leads to interruptions of pathways and vectors for pollen and seed dispersal and hence to genetic exchange restrictions (Benitez-Malvido 1998, Hamilton 1999). In addition, former inner forest areas are transformed to more or less exposed forest edges. Consequently, this so-called 'edge effect' is of increasing ecological importance. Several gradients in microclimate, floristic composition or biological interactions can be observed between the edge and interior of the forest fragments (Foggo et al. 2001, Galetti et al. 2003, Kapos 1989, Laurance 1991, Murcia 1995, Stevens & Husband 1998, Young & Mitchell 1994). All these effects of fragmentation lead to a progressive erosion of biological diversity (Pimm et al. 1995, Terborgh & Winter 1980, Tilman et al. 1994, Wilson 1988). Consequently, several Atlantic Forest species from different taxonomic groups are considered to be threatened with extinction nowadays, mainly because of their endemism and habitat degradation (e.g. Bergallo et al. 1999, Brooks & Rylands 2003, Câmara 1983, Fonseca et al. 1994, Ibama 1992, Stattersfield et al. 1998). According to the summarising results of Brooks et al. (2002), the percentage of critically endangered species in different groups vary from at least 1% (plants) up to about 10% (mammals, birds). However, since the current distribution patterns of many species in the Mata Atlânatica are only insufficiently known, these numbers could be much higher.

The destruction and fragmentation of the natural habitats and accelerated species extinction are coupled to several direct and indirect negative consequences for the human population. Flora and fauna provide a great variety of primary resources (e.g. Capobianco 2001, Dean 1996, Tanizaki-Fonseca & Moulton 2000, Jacobs 1988, Kunin & Lawton 1996, Simões & Lino 2002, McNeely et al. 1990, Myers 1988, Prance 1998, Whitmore 1998). The major part of the natural resources that sustained the Brazilian economy during the last 500 years came from the Atlantic Forest (Almeida 2000). However, their overexploitation and habitat destruction do not only affect their actual availability. By destroying this vast genetic storehouse (Myers 1983), we are also eliminating future resource-use options. Furthermore, degradation is prejudicial to the great number of free services provided by ecosystems, such as climate and water regulation, soil formation and protection, nutrient cycling, flood and erosion protection, biological pest and disease control, pollination and recreation. Their intrinsic economic values often exceed the value of the direct use of biological resources many times (e.g. Balmford et al. 2002, Costanza et al. 1997, Ehrlich & Ehrlich 1981, Heal 2000, Ricketts et al. 2004, Tonhasca Jr. 2005). Last, but not least, nature is an integral part of the fabric of all human cultures (Wilson 1984, Wilson & Kellert 1993). Idealistic values can be attributed to nature that represent non-utilitarian reasons for biodiversity and ecosystem conservation (e.g. Dearden 1995, Janzen 1988).

Central issues to counteract the ongoing isolation of forest remnants are the protection of existing corridors and the preservation of natural connective attributes of the landscape matrix. Instruments to reduce isolation and negative effects of landscape fragmentation are reforestations and the establishment of ecological corridors (e.g. Castro & Fernandez 2004, Hilty et al. 2006, Laurance 2004, Laurance & Laurance 1999). These enlarge forest habitats, increase habitat connectivity and reduce edge effects as well as ameliorate physical characteristics of the landscape such as soil quality and water balance. Furthermore, growing forest being important CO_2 sinks are relevant factors in the context of global climate change. In a biodiversity hotspot such as the Mata Atlântica, it is desirable to promote the use of native species for reforestation and moreover to select adequate species for each specific habitat to be restored (Almeida 2000, Reis et al. 1999). This requires a profound knowledge of the regional habitat variability and the related floristic composition and vegetation dynamics (especially of successional processes) as well as of the autecological characteristics of the species. Yet not only ecological criterions are important. Since most of the land in the Mata Atlântica is private property and the income of the farmers depends on agricultural production, disregarding socio-economical aspects will lead to a failure of all conservation and restoration efforts. Therefore reforestations and the establishment of silvopastoral and agroforestry systems, which open alternative income sources, can be successful concepts to bring together the ecological and socio-economical interest (Almeida 2000, Harvey & Haber 1998, Leakey 1999). In this context, native species with economic value (e.g. medical plants, ornamentals, fruit plants, fibre plants) deserve particular attention in the selection of species to be used in reforestations.

Once chosen as adequate species, the selection of suitable seeds for sapling production is another ecologically and economically important aspect. One of the negative effects of the genetic isolation of fragmentised populations is the possible minor fitness of the propagules (e.g. Koenig & Ashley 2003, Smouse & Sork 2004). Therefore, the origin and characteristics of seed are relevant factors for the success of reproduction and sapling production (e.g. Chacón & Bustamante 2001, Cordazzo 2002, Navarro & Guitián 2003).

Agriculture and biodiversity

Until recently, agricultural land was not regarded as important for biodiversity conservation and conservation activities almost entirely focused on the protection of natural areas. However, an appreciation of the importance of farming activities for biodiversity is emerging (Feehan 2001). Agro-biodiversity or the diversity of cropping systems, crop species and farm management practices has received increasing attention in recent years as a way of spreading risk and supporting food security in resource-poor farming systems (Tengberg et al. 1998). On-farm conservation is a special form of in situ conservation based on the groundwork of traditional farming and gardening methods (Hammer 2004). Management practices that increase the spatial and temporal diversity within fields can enhance production and reduce the environmental impacts of crop production (Bezdicek & Granatsteis 1989, George 1971, Kort 1988, Olson 1995, Pohlan 2002).

The effects of agriculture on biodiversity are of considerable importance because farming is the human activity that occupies the largest share of the total land area in the Mata Atlântica. Even for some regions where the share of agriculture in total land area is smaller, agriculture can contribute to biodiversity conservation by increasing the diversity of habitat types. The expansion of agricultural production and intensive use of inputs over recent decades in the Mata Atlântica Region are considered major contributors to the loss of biodiversity. At the same time, certain agricultural ecosystems create conditions to favour species-rich communities and thus serve to maintain biodiversity. These systems might be endangered if altered to a different land use, such as agroforestry. Agricultural food and fibre production is also dependent on many biological services. These include the provision of genes for development of improved crop varieties and livestock breed, crop pollination and soil fertility provided by micro-organisms (Parris 2001).

First research results in the study area in the municipality of Teresópolis show that favourable economic, geographical and environmental conditions for agriculture increase crop monoculture systems, which dominate the landscape (Torrico 2006). Crop land and cattle range land compete with preservation and reforestation strategies. The degradation of land is a average feature of the municipality. It is evident that in the last 50 years water discharge has decreased to 50 %, due to deforestation and loss of many small springs (1/6 in this survey) (Torrico et al. 2006). Ecological farming systems, such as agroforestry and silvopastoral systems, as well as the cultivation of perennial crops contribute to reduce this pressure on fragments and deforested areas (Torrico 2006). These systems play a key role in linking and buffering fragments and in improving both agro-diversity and biodiversity in the Atlantic rainforest (Torrico et al. 2005). Furthermore, ecological farming systems present the largest value of sustainability in ecological terms and pose the capacity to produce and to save great quantities of biomass in the system. In addition, ecological farming systems need fewer economical resources and more natural renewable resources, which eventually guarantee its sustainability (Torrico 2006).