Climate Change Management

Walter Leal Filho
Leonardo Esteves de Freitas *Editors*

Climate Change Adaptation in Latin America

Managing Vulnerability, Fostering Resilience

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Preface

Similar to what is seen in other parts of the world, there are clear signs of the impacts of climate change to Latin American countries. The region, where a substantial portion of the world's biological diversity can be found, hosts a wide range of ecosystems including rainforests (especially, but not only in the Amazon region) and semi-arid zones. The disruption of natural ecosystems is one of the main causes of biodiversity and ecosystem losses in Latin America, a proportion of which is due to human-induced climate change.

According to the Fifth Assessment Report (AR5) produced by the Intergovernmental Panel on Climate Change (IPCC), climate change in Latin America is likely to contribute towards altering coastal and marine ecosystems, with mangrove degradation being observed on the north coast of South America, for instance.

In addition, AR5 mentions the fact that significant trends in precipitation and temperature have been observed in Central America (CA) and South America (SA) and that changes in climate variability and in extreme events have severely affected the region.

The above state of affairs illustrates the need for a better understanding of how climate change affects the Latin American region, and for the identification of processes, methods and tools which may help the countries in the region to adapt. There is also a perceived need to showcase successful examples of how to cope with the social, economic and political problems posed by climate change in Latin America.

This book, which contains a set of papers presented at the Symposium on Climate Change Adaptation in Latin America, held in Rio der Janeiro, Brazil, in November 2016, plus some additional ones, serves the purpose of showcasing experiences from research, field projects and best practice in climate change adaptation in Latin American countries—with examples from Bolivia, Brazil, Colombia, Guatemala, Mexico and Uruguay—which may be useful or implemented in other countries and regions. A further aim of this book is to document and disseminate the wealth of experiences available today.

This book is structured in two main parts. Part I addresses the connections and impacts of climate change to ecosystems. It entails a set of papers which describe current and future impacts of climate change to fauna, flora and landscapes.

Part II is concerned with the socio-economic aspects of climate change adaptation. As one of the most vulnerable regions in the world, Latin America is especially affected by a variety of social problems, as a result of climate change. Part II describes some of these issues and examines some ways they may be overcome.

A short, final chapter presents some perspectives on climate change in Latin America and outlines some of the research needs seen in the region.

We thank the authors for their willingness to share their knowledge, know-how and experiences, as well as the many peer reviewers, which have helped us to ensure the quality of the manuscripts.

Enjoy your reading!

Hamburg, Germany
Rio de Janeiro, Brazil
Winter 2017–2018

Walter Leal Filho
Leonardo Esteves de Freitas

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Dietmar Sattler, Roman Seliger, Udo Nehren, Friederike Naegeli de Torres, Antonio Soares da Silva, Claudia Raedig, Helga Restum Hissa and Jürgen Heinrich

Introduction

Land degradation is a global phenomenon, which is defined by the FAO as "··· the persistent decline or reduction in the capacity of the land to provide ecosystem goods and services and assure its functions over a period of time for the beneficiaries of these". Mostly addressed with regard to soil degradation in drylands, several estimates of the global extend of land degradation, based on varying approaches, indicate that 20–25% (Clausing 2011) up to 35% (Bai et al. 2008; Nachtergale et al. 2011) of all used land can be considered as degraded, at least to some extent. Bai et al. (2008) assessed land degradation using long-term (1981–2003), remotely sensed Normalized Difference Vegetation Index (NDVI) data at country level. Following this analysis, 1.882 million km^2 or 22.11% of Brazil's

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territory are subject to degradation. Before the background of Brazil's outstanding natural heritage, the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) established a more focused definition, where land degradation "…occurs when native vegetation and fauna has been destroyed, removed or displaced, the fertile soil is lost, removed or eroded and the hydric system has been altered. Land degradation takes place when the capacity for natural physical, biological and chemical adaption is lost and makes socio-economic development unfeasible" (IBAMA 1990). Pasture farming is among the most habitat consuming land uses in Brazil, making up almost half of all agricultural activities (Dias Filho 2014). Being a human-modified landscape, pastures exhibit degradation as a combination of unsuitable land use (use of land for purposes for which it is environmentally unsuited) and inappropriate land management practices (use of land in ways which could be sustainable if properly managed, but necessary practices are not adopted). Additionally, pasture farming systems in SE Brazil are exposed to some natural degradation hazards which limit the inherent capacity of the ecosystems for the provision of adequate geo-ecological services, such as water retention, nutrient availability and recycling and habitat for biodiversity. In this paper, we briefly analyse the drivers and status of pasture degradation in SE Brazil and assess the possibilities for bringing together both sustainable pasture rehabilitation and management and transformation potentials of this widespread land use towards climate change mitigation.

Land Use Development and Transformations in the State of Rio de Janeiro

The Southeast Region of Brazil with the states of São Paulo (SP), Minas Gerais (MG), Rio de Janeiro (RJ), and Espirito Santo (ES) is the economic backbone of the country where about 50% of the national GDP is generated (IBGE 2013). About 85 million people live in an area of 924,620 km^2 (IBGE 2014), which corresponds to about 40% of the total Brazilian population, but only to 11% of the country's territory. Such an enormous concentration of both economic power and population results in high pressure on the land and water resources and makes the region particularly vulnerable to extreme climate events and natural hazards such as floods, landslides, mudslides, droughts, and heat waves as well as to long-term effects of land degradation.

RJ is the smallest of the four Southeastern states with an area of 43,910 km^2 and a population of 16.5 million (IBGE 2014). Biogeographically, the state is located within the Atlantic Forest (Mata Atlântica) biome. The Mata Atlântica has been suffering from high historical deforestation rates (Dean 1995). Hence, the formerly forested region turned successively into a highly fragmented landscape which today is widely dominated by livestock farming, agricultural systems, and forest monocultures (mainly *Eucalyptus* species). The coastal zone around the metropolitan area of Rio de Janeiro is densely populated and urbanized, while the mountainous hinterland of the state has a primarily rural character. Due to overexploitation, the rural landscapes show serious soil degradation, such as rill and gully erosion and soil compaction (Nehren et al. 2013). Despite the high degree of fragmentation and land degradation in large parts of the state, the remaining forest patches in the central corridor of the Serra do Mar are highly diverse and are home to numerous endemic species of which many are endangered (Eisenlohr et al. 2015; Raedig and Lautenbach 2009; Galindo-Leal and Gusmão Câmara 2003).

The process of large scale deforestation and land use intensification started already with the arrival of the European colonizers about 450 years ago. Exploitation cycles with the selective extraction of Brazilwood (*Paubrasilia echinata* (Lam.) Gagnon, H.C. Lima & G.P. Lewis), followed by sugar cane plantations, gold mining in Minas Gerais and transportation to the harbors of RJ, as well as coffee plantations are well known and described in the literature (Dantas and Coelho Netto 1995). Several authors also point out the increasingly rapid destruction of the Atlantic Forest that is associated with these exploitation cycles (Dean 1995; Cabral and Fiszon 2004; Nehren et al. 2013). However, while the coastal zone and lower ranges of the Serra do Mar have already been widely deforested and severely degraded in the 17th–18th century (Nehren et al. 2016) the development of the mountainous hinterland of RJ started later and reached a high dynamic within the last 100–150 years. This rapid process of land use intensification was triggered by an active immigration policy in the early 20th century and infrastructural development with railway and road construction. Wide parts of the hilly and mountainous land were used for cattle ranching, while intensive agricultural production was limited to the fertile floodplains and intra montane basins. Moreover, already after the first collapse of the coffee market in RJ in the late 19th century, large former coffee plantations were converted into pasture land. The remaining coffee market in RJ was then affected by the Great Depression of 1929, so that most of the remaining plantations were also transformed into grazing land. Therefore we could consider cattle ranging as the fifth large exploitation cycle.

Status of Pasture Management and Drivers of Pasture Degradation in Rio de Janeiro

Following the last agricultural census of Brazil in 2006, Brazil has 172.3 million ha of pasture land (Dias Filho 2014), making up 48% of all registered agricultural production units. While the pasture area increased on average only by 4% within the period from 1975 to 2006, the herd size increased by 100.8%. Hence, the stocking densities per unit pasture area increased remarkably. Looking at the grand sub-regions of Brazil, this ratio becomes even more pronounced. In the same period of time, the Northern and Central-eastern part of the country showed an increase of stocking density to more than 200%, whereas a respective increase of 62% in SE

Brazil can still be considered as very high (Dias Filho 2014). Taking into account that around half of the pastures in SE Brazil are natural, non-planted and mainly unmanaged (SEA 2011), the grazing pressure on these pastures strongly increased. When compared to the Brazilian federal states of Mato Grosso, Minas Gerais and Goias, which are leading in cattle stock and herd size (IBGE 2013), cattle farming in RJ is mainly made by many small family farmers. Nevertheless, 55% of RJ's area is used as pasture land, especially in the Northern and North-western parts of the state (SEA 2011). Only 3% of these pastures are situated in alluvial plains, which are mainly used for crop production, due to the fertile soils, suitable relief and stable water supply. Hence, the vast majority of the state's pastures are on more or less steeply sloped hills. Pasture farming sloping hills carries a high risk for degradation, mainly due to the predominance of weathered tropical soils (Acrisols according FAO-WRB, or Ultisols according to USDA soil classification, respectively). Even though not taking into account possible inadequate or lacking management, natural forces of water erosion combined with soil compaction due to cattle stock activity and the related formation of initial erosion forms (e.g. slope parallel cattle tracks and trails along vertical fences) are exacerbating degradation risk (Galdino et al. 2015; Silva and Botelho 2014). When combined with excessive cattle stock density, lacking pasture grass management and lacking vegetation recovery periods, these drivers lead to rapid and severe pasture degradation (Fig. 1.1).

The attempt to intensify cattle ranging productivity in smallholder farming systems is mainly made by enhancing cattle stock density. Taking into account the geo-ecological conditions in rural RJ and lacking adequate and sustainable pasture management, the opposite effect occurs. Mainly due to soil compaction and subsequent erosion the overgrazed pastures become increasingly degraded, resulting in production losses (Junior et al. 2013). Due to the pressure of an increased number of trampling cattle per unit area, the bulk density of the mainly fine textured, clay rich Acrisols increases, while soil porosity and water infiltration decreases. Such

Fig. 1.1 Sloped pasture showing multiple erosion forms such as gullies, rills, cattle tracks and bare soils. Municipality of Porciuncula, RJ © D. Sattler 2014

compacted top soils impede plant root penetration and hinder soil aeration and drainage (Araujo et al. 2004). Hence, a vicious cycle of soil and vegetation impoverishment and laminar erosion is initiated. Soil bulk density data from RJ (Sattler et al. 2014, own unpubl. data) reveal significant differences for soils under forest (0.6–1.2 g cm^{-3}) when compared with pasture soils (up to 1.6 g cm^{-3}). Soil erosion especially starts in areas that combine soil compaction and the steepness of slopes, ranging between 8 and 20%. As shown in Fig. 1.1, soil compaction and the loss of a well-drained humus-rich topsoil may lead to scattered vegetation cover and progressive erosion forms (e.g. deep gullies). Additionally, the surface runoff caused by heavy rains that occur during the austral summer aggravate the erosion of initial forms (e.g. cattle tracks and small gullies). The thus exposed subsoil with clay contents often exceeding 40 g kg^{-1} and apparent soil bulk density above 1.6 g cm^{-3}, generate even higher surface runoff that accelerates further erosion (Silva and Botelho 2014).

Another driver of soil erosion at pastures is the widespread practice of tillage for seedbed preparation for pasture renewal. While the adoption of no-tillage management in annual crops production, in Brazil mainly soybean and corn, has gained raising attention, the tillage of pastures is still a common management practice. Sparovek et al. (2007) estimate an area of 10 million ha $year^{-1}$ of pasture renewal by tilling at a large spatial dispersion over Brazil, especially in the Central-Western and South-eastern parts of the country. This area can easily compete with the magnitude of non-protective annual crop production. The mainly sloped pastures in RJ are particularly prone to soil erosion caused by top-down hill tillage, as mechanized tillage following slope parallel contours is mostly not possible due to steep slope angles. On the other hand, the traditional, low impact and slope parallel ox-ploughing is a fading out management practice due to understaffed rural labour. Even though the local effects of top soil erosion by pasture tillage are often compensated with soil liming and fertilizing, the off-site effects of such management are tremendous. In SE Brazil, pasture tilling is applied at the beginning of the rainy austral summer to ensure the growth of the sawn, mainly African *Brachiaria* pasture grasses. The soil washed away by strong summer rains causes a multitude of negative environmental effects such as silting and sedimentation of rivers and water reservoirs, contribution to river floods, degradation of riparian areas and decrease of water quality due to sediment load and related decline of dissolved oxygen (Niyogi et al. 2007; Sparovek et al. 2007).

Besides the strong degradation hazards caused by overgrazing, soil compaction and lacking or inadequate pasture management, projected environmental conditions driven by climate change will exacerbate land degradation. Regional climate models suggest that in the future droughts might affect SE Brazil in higher frequency and intensity, while at the same time heavy rainfall events will also increase (Dereczynski et al. 2013; Salazar et al. 2015). Especially when combined with unsustainable or inappropriate land use, both will trigger further degradation of rural areas, and in the worst case lead to badlands, which cannot be used for pasture farming and agriculture anymore in an economically feasible way. This will have implications not only on the geo-ecological stability and resilience of the natural landscape, but can lead to the loss of a family agriculture-dominated rural cultural landscape in RJ, and in the long run to accelerated rural exodus.

Options for Sustainable Pasture Farming and Mitigation of Degradation

Since 2013, the Brazilian–German research and development Project INTECRAL ("Integrated eco technologies and services for a sustainable rural Rio de Janeiro") has been developed as a cooperation of the German research institutions TH Köln University of Applied Sciences, the University of Leipzig, the Friedrich-Schiller-University of Jena and several small and medium sized German enterprises, all funded by the German Federal Ministry of Education and Research (BMBF), and the Rio de Janeiro State Secretariat of Agriculture and Livestock (SEAPEC). SEAPEC coordinates a large scale development project for rural areas of RJ, the "Rio de Janeiro sustainable rural development project" (Projeto Rio Rural, PRR), funded by the World Bank and supported by the United Nations Food and Agriculture Organization (FAO). Following a pilot phase, the actual phase of PRR project from 2011 to 2018 invests about USD 233 million in the family farming and environmental sector. In this phase, the programme strengthens organization and community mobilization in 366 watersheds of 71 municipalities in all regions of RJ, developing skills and encouraging the adoption of best practices. By 2018, the program will benefit 48,000 farmers, rural women and young people, encouraging them to become key players in developing their watersheds. More than food producer, the farmer is considered the main ally in the sustainable management of natural resources indispensable to the survival and well-being of the entire population. The PRR farm level activities are mainly implemented as community-based investments in water and sanitation infrastructure, sustainable agricultural management, land restoration and preservation activities, and in related capacity building. Most of those activities are supported by the INTECRAL project by providing scientific, technical and operational assistance necessary for the development and adaptation of technologies. Together with the Rio de Janeiro state Enterprise of Technical Assistance and Rural Extension (EMATER-RIO) and the Agricultural Research Corporation of Rio de Janeiro State (PESAGRO-RIO), the INTECRAL project develops and implements several research based pilot measures, e.g. for water quality monitoring, sustainable small scale sugarcane farming, silvo-pastural farming and pasture rehabilitation for degradation mitigation.

Pilot Pasture Rehabilitation Measure

In the light of frequent and severe pasture degradation in RJ, the INTECRAL research group of the University of Leipzig is developing a pasture degradation assessment system, using remote sensing data, field based indicators and participative monitoring of the awareness of pasture degradation within the farmer communities. Rehabilitation measures to prevent and counteract land degradation in rural RJ will only succeed if based on a wide farmer's acceptance and applicable and pragmatic best practice approaches at low cost. Based on respective assessment data a pilot pasture rehabilitation measure has been planned and implemented on a degraded pasture in the municipality of Itaocara, RJ. The pilot measure was implemented from June to December 2015 by the INTECRAL project with the aim to break the erosive power of surface runoff and interflow at the pasture hill by hedge terraces and subdivide the pasture slope into lots allowing for extensive rotational grazing.

The pilot area is located 6 km southeast of Itaocara city (S21° 41′ 44.10; W42° 02″ 02.51). The pasture has been used for extensive cattle ranching for decades as most of the pastures which cover 70% of the territory within the municipality of Itaocara. Slope degrees of the pilot area mainly range from 8.5° to 24° that represents the two dominant slope classes 'moderately steep' and 'steep' characterizing 50% of municipality territory. Compared to this, plain areas (nearly level and very gently sloping up to 1.1°) with only 3% coverage are strongly underrepresented in this municipality. Sheet erosion, rills and cattle tracks are the major erosion types showing a moderate erosion degree and extent. Moderately degraded areas are preferably recommendable for rehabilitation measures due to an expected high rehabilitation effect at rather low cost. The property size of 22.5 ha corresponds to small to medium farm-size, typically for this region. A good visibility and accessibility of the study area is given due to proximity to the state road RJ 116. This facilitates training activities with farmers and local stakeholders and makes transport and storage of measure-related materials and goods easy. Moreover, the land-owner kindly agreed to cooperate with the project and to hand-over part of his land for temporary research purposes.

The pilot area (3.3 ha) occupies 15% of the whole property area (see Fig. 1.2) This area has been taken off from cattle ranching since end of May 2015 for enabling the measure's implementation. Using a micro-tractor and rotating tiller, three terraces (1 m wide, slightly tilted against the slope) positioned at approximately 20 m altitude difference each have been installed slope-parallel considering the horizontal slope form. Terrace sections crossing erosion areas such as rills and bare soils have been stabilized by 16 palisade constructions using local material such as eucalyptus and bamboo. The terraces subdivide the slope into four parcels (bottom, middle, upper slope and hilltop) and act as breaklines for erosive surface runoff. Each parcel can be accessed through five gates located in different positions of the terraces to better control and vary future cattle movement applying a rotational pasture management concept. Five species of native tree seedlings

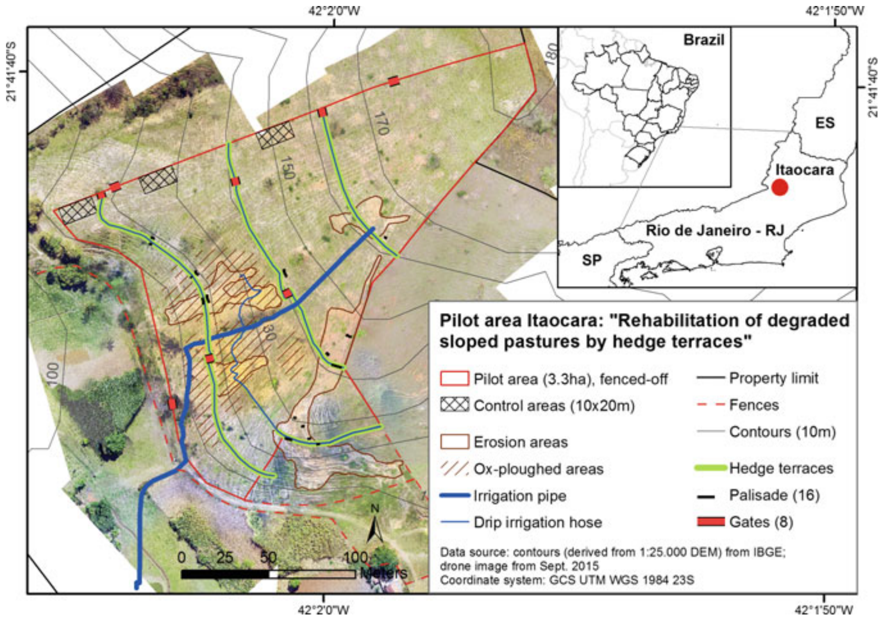

Fig. 1.2 Schematic map of the pilot measure area based on a high resolution DJI Phantom II Drone image © R. Seliger 2016

(*Chloroleucon tortum* (Mart.)Pitt., *Machaerium nyctitans* (Vell.)Benth, *Schinus terebinthifolia* Raddi, *Anadenanthera colubrina* (Vell.)Brenan *var. cebil* (Griseb.) Altschul and *Enterolobium contortisiliquum* (Vell.)Morong were horizontally planted each 20 cm along all three terraces (total length: 515 m, n = 2.433). To make the seedlings more resistant against long-lasting dry periods, a hydrogel has been applied on seedling roots during planting process. An installed drip-irrigation system supports the initial growth phase of the tree-seedlings. Bare soil areas were ox-ploughed and seeded with *Brachiaria* grass afterwards. Moreover, areas strongly compacted and/or suffering from rill erosion, have been planted with grass sods. Areas with extreme erosion forms were excluded from the pilot area; here afforestation should be undertaken as most promising and cost-efficient measure. Finally, both a soil (pH) correction with lime and a NPK fertilization have been applied on the pasture, complemented by a novel stonepowder-dung mixture (Silva 2010). During the whole planning and implementation process the land-owner's expertise and advice have always been considered in order to reach maximum acceptance and prospect of success. Continuous scientific monitoring of the pilot measure includes the evaluation of tree-species performance and it's root development along the terraces, impact of pest species, biomass production, effects of erosion control and effects on physical soil features. A more detailed description of the bio-engineered techniques applied by Hebner et al. (2016) is available in this volume.

Potential Carbon Storage Capacity of Afforested Pastures

The rehabilitation and reformation of degraded pastures on slopes for subsequent pasture farming under appropriate and sustainable management is just one option for dealing with degradation phenomena. Taking into account the persisting risk of degradation due to the given combination of unsuitable geo-factors on the one hand (e.g. erodibility and low productivity of predominant Acrisols, steeply sloping relief), and on the other hand the demand for areas to be afforested within the framework of REDD + (Reducing Emissions from Deforestation and Forest Degradation), PES (Payment for Ecosystem Services) and other carbon storage and nature conservation projects, degraded pastures on steep slopes can be perceived as excellent opportunity areas for the enhancement of the landscapes carbon storage capacity by afforestation. Establishing planted or spontaneous vegetation at such areas with marginal agricultural yields which are unsuitable or barely suitable for food or stock production provides multiple positive effects for the re-establishment of ecosystem services and the landscapes resilience to projected climate changes (Dereczynski et al. 2013).

As such action is urgently needed while financial resources for interventions are limited, the prioritization of areas to start with is a crucial issue. Two simple indicators can be used to approach prioritization of areas to be re-vegetated with remote sensing data: a land use land cover (LULC) map for the delineation of pastures and a digital elevation model for the definition of respective slope angle classes. In an exemplary case study we assessed these indicators for two regions, one situated in the mountain foreland of the Serra dos Órgãos Mountain range (Guapi-Macacu Watershed, GMW) and one in the North-western region of RJ (Itaocara municipality, IM). The digital elevation model (DEM) was derived from 10 m equidistant isolines (source: Brazilian Institute of Geography and Statistics, IBGE) as a raster with 20 m resolution. Based on this we calculated the slope angles and subsequently classified them in nine slope classes (0–2°, >2–5°, >5–10°, >10–15°, >15–20°, >20–25°, >25–30°, >30–45° and >45°). As LULC data provided by IBGE are only available from 2007 and at a comparably rough resolution, we produced this information for both municipalities. The land use map for the GMW was derived from a newly developed multisensorial product with 5 m resolution from 2011 (Landsat 5, RapidEye and SPOT 5; unpublished data) and the land use map for IM was developed based on a multi temporal Landsat 8 data product with 15 m resolution. Both land use classifications were then calculated using the Random Forest Classifier (Breimann 2001) with the open-source software R 3.2.2 (R Core Team 2015) and the R Package 'randomForest' (Liaw and Wiener 2015) and obtained excellent overall accuracies of >95%. From both land use maps we extracted the pasture area and calculated the proportions per slope class using the software ArcGIS 10.3. on the 20 × 20 m pixel basis of the slope angle raster (see Table 1.2).

About 40% of the Guapi-Macacu Watershed and 60% of the Itaocara municipality are pastures. In GMW, 24% of them are situated at slopes steeper than 15°, in IM 43%, respectively. This fraction of pastures represents priority areas to be suggested for abandonment of pasture farming an for the implementation of planted or spontanuously regenerating forest. Taking into account the potential carbon storage capacity of afforestation and varying successional stages of Atlantic forest, based on above- and below ground biomass estimates (Table 1.1), approximately 80,000 MgC could be stored at these steeply sloped pastures of the two example areas just by anbandonment and spontaneous growth of shrubby vegetation. A (potentially supported) forest succession could even sequester up to 3.4 million MgC (Table 1.2) at steeply sloped pastures of the two example areas. The critical point of this calculation is the uncertainty regarding the time needed to reach the respective successional stages.

The time scale of Atlantic Forest succession within human-modified landscapes is difficult to predict because initial site conditions, proximity to other forest fragments and local climate may result in alternative regeneration pathways, most of them resulting in more or less species poor, edge affected secondary forests (Joly et al. 2014). Hence, this time scale uncertainty is a major constraint and limits the validity of the calculation presented above. Nevertheless, secondary Atlantic Forest can reach structural convergence to the canopy structure of an old-growth forest in as little as 12 years (Nascimento et al. 2014), which is important in terms of carbon storage capacity and landscape resilience. Supporting natural regeneration by enrichment planting or protecting spontaneously grown tree seedlings from remaining pasture grass are easy and cheap alternatives to comparably expensive forest plantations (De Moraes et al. 2013; Parotta et al. 1997). However, the carbon storage capacity of marginal, low yield and high environmental risk pastures is enormous and should be taken into account first when designing incentive payment for ecosystem services strategies.

Potential Contribution of Degraded Pastures to Biodiversity Conservation

One option for the use of degraded pastures in the state of regeneration is the integration into conservation activities. The awareness for the need of biodiversity conservation in Brazil is increasing. An indicator for this development is the growing number of established private protected areas, the so-called Natural Heritage Private Reserves (Reservas Particulares do Patrimônio Natural, RPPNs). However, the conversion of regenerating pastures into an RPPN is only possible, if 70% of the entire area planned as an RPPN consists of natural forest, and only 30% of the area is degraded (INEA 2015). Nonetheless, such areas could be included into corridor strategies: in order to re-establish linkages between forest remnants, they can serve as connectors between isolated forest stands in the long run. Corridor

Table 1.1 Biomass and carbon content of varying vegetation formations of Southeastern Atlantic Forests and afforestations

Source	Location	Vegetation type	DBH range (cm)	AGB (Mg/ha)	BGB (Mg/ha)	MgC/ha (0.47 × AGB + BGB)
Robinson et al. (2015)	Itatiaia, RJ	Seasonally dry semi-deciduous AF fragment	>3	158.90 (±42.10)	39.72 (±10.52)	93.35 (±24.73) C
		Trees (initial succession) at abandoned pasture (30 year ago)		10.90 (±6.30)	2.72 (±1.57)	6.40 (±3.70)
		Trees + shrubs (Capoeira) at abandoned pasture (30 year ago)		5.90 (±3.50)	1.47 (±0.87)	3.46 (±2.06)
Alves et al. (2010)	Serra do Mar State Park, SP	Submontane tropical moist evergreen forest	5–156	247.70 (±14.70)	61.92 (±3.67)	145.52 (±8.64)
Barbosa et al. (2014)	Vale do Ribeira, SP	Ombrophilous tropical forests, initial succession	1.6–47.8	54.00 (±68.00)	13.5 (±17.00)	31.72 (±39.95)
		Ombrophilous tropical forests, advanced succession		128.00 (±190.00)	32 (±47.50)	75.20 (±111.62)
Sattler et al. (2014)	REGUA, Guapiaçu, RJ	4 year old afforestation, plane	4–116	81.00 (±15.00)	20.25 (±3.75)	47.59 (±8.81)
		4 year old afforestation, slope		37.20 (±12.60)	9.3 (±3.15)	21.85 (±7.40)
Lindner and Sattler (2012)		Submontane dense ombrophilous secondary forest	10–70	250.40 (±77.90)	62.6 (±19.47)	147.11 (±45.77)
Tiepolo et al. (2002)	Serra do Itaqui, Guaraqueçaba, PR	tropical moist forest, young secondary	4–116	45.10	11.275	26.50
		Tropical moist forest, medium secondary		150.60	37.65	88.48
Diniz et al. (2015)	Pinheiral, Vale do Paraiba do Sul, RJ	Seasonally dry semi-deciduous AF, 25 year medium succession	N/A	34.30	8.575	20.15
		Seasonally dry semi-deciduous AF, 65 year advanced succession		115.60	28.9	67.91

AGB Above ground biomass, *BGB* below ground biomass (root/shoot ratio 0.25 according to Nogueira Junior et al. 2014), *DBH* diameter at breast hight (1.30 m), *RJ* Rio de Janeiro state, *SP* São Paulo state strategies support biodiversity conservation, since they facilitate the exchange of propagules (including individuals, seeds and genes of species) between isolated forest stands.

Conclusions

Pasture based livestock farming in SE Brazil is a widespread rural land use, mainly situated at marginal land of sloping hills. As economic pressure is becoming stronger, overgrazing and no or minimal investments in sustainable pasture management lead to severe degradation of these areas. Without consolidated intervention towards sustainable management, alternative land use and incentives for abandonment of steeply sloped pastures, an accelerated degradation process will continue. In combination with projected climate change, a system tipping point can be reached where former pastures remain badlands for decades. Our findings indicate that the adoption of bio-engineered pasture rehabilitation measures for erosion control combined with intensification of cattle farming at non-hazardous prime locations (e.g. rotational grazing) can stop or at least considerably reduce pasture degradation. Even though there are many low budget options for pasture rehabilitation, it seems unlikely that these measures are applicable at a large scale, taking into account the economic situation of many developing countries. Furthermore, the acceptance of such measures by a majority of involved farmers and stakeholders needs to be improved. This can only be achieved by better and more widespread education of all actors in the agricultural sector. The respective societal structures and training activities established by the Rio Rural Programme are exemplary in this regard.

Brazil's pasture based livestock production will still grow within the next decades, and ongoing pasture degradation will lead to shortages of suitable pasture land. Nevertheless, extensive expansion of pastureland at the expense of natural habitats is no reasonable option, and intensified pasture farming combined with economic incentives for farmers for the abandonment of hazardous (sloped) pasture areas can lead to sustainable pasture farming (Lataviec et al. 2014). Adopting intelligent and sustainable pasture management, Brazil's productivity of pasture based products can be increased up to more than 50% by 2040 without further conversion of natural habitats (Strassburg et al. 2014). Intensified pasture farming at prime locations and abandonment of critical ones can liberate rural areas for alternative, diversified production with agro-silvopastoral systems that both increase yields and provide a higher productive flexibility (Balbino et al. 2011) when facing future weather extremes. Furthermore, abandoned degraded pastures are excellent opportunity areas for carbon sequestration by afforestation and spontaneous forest re-growth. The implementation of such measures will encompass multiple positive effects (water retention, water quality, erosion control, diminished flood risk, habitat for biodiversity etc.) for both the ecological and economic resilience of RJ's rural landscapes. To meet such complex challenges

Table 1.2 Carbon storage capacity of steep pasture slope classes potentially afforested or spontaneously re-vegetated

Pasture slope class	G-M Watershed (ha)	Itaocara municip. (ha)	Capoeira (30 year) (Robinson et al. 2015) (MgC)	Afforestation 4 year, slope (Sattler et al. 2014) (MgC)	Young sec. forest (Tiepolo et al. 2002) (MgC)	Dense ombroph. forest (Lindner and Sattler 2012) (MgC)
>15°–20°	4125.6	5609.6	33,683.9	212,714.9	257,983.9	1,432,151.2
>20°–25°	3502.4	3695.5	24,904.8	157,274.5	190,744.9	1,058,886.0
>25–30°	2390.2	1475.4	13,375.1	84,464.2	102,439.5	568,674.3
>30°–45°	1447.2	485.04	6685.4	42,218.6	51,203.3	284,245.9
>45°	152.6	0.88	531.0	3353.5	4067.2	22,578.4
Total	11,618.0	11,266.44	79,180.3	500,025.9	606,438.7	3,366,535.9

G-M Watershed = Guapi-Macacu Watershed

evoked by climate change and social transformation in Brazil's and other developing countries rural landscapes, the continuous support of state, federal and international rural development programs such as the Rio Rural Program of the Secretariat of Agriculture and Livestock of the State of Rio de Janeiro will be indispensable.

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Chapter 2
Impacts of Climate Change: A Case in Watersheds in South of Brazil

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Introduction

The 21st century is the century of cities, as people are increasingly living in urban areas and there has been greater impact in the natural resources. However, with increased pressure on the environment, the risks are inevitable, with extreme events causing severe consequences including damage to infrastructure, properties and even loss of life. In this sense, identify risks and vulnerability before the disaster to occur is essential to effective risk reduction in long-term periods (Birkmann 2007). It seems that enhancing the resilience of the urban environment is indispensable for the sustainability of cities.

The increase in population density, traffic, waterproofing of roads and various other needs of modern cities greatly contribute to the risk of natural disasters. These anthropological actions on the environment tend to lead to climate change and stimulate global warming. Despite the availability of water resources being also affected by intense urbanization, land use, occupation and deforestation, climate events certainly emphasize all these problems, causing floods that bring great economic damage and loss of life, and also droughts that damage agriculture, human consumption and the generation of hydroelectric power (Marengo 2006).

In this context, water is an important factor for the development of any community and there is no doubt that climate change threatens the security of this resource. Thus, growth and development resilient to climate change is essential. Strategies, plans and investments that promote good water management are alternatives to promote climate resilience and better management of water resources benefits many sectors (health, energy and agriculture) and also contributes to the goals of sustainable development (AMCOW 2012).

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According to the Intergovernmental Panel on Climate Change (IPCC 2007a), the impacts of climate change on water resources will be through changes in the hydrologic cycle, increased extreme events, change in the average flow of the watercourse, longer drought events, rise in sea levels and increased frequency of floods. The increase in the intensity of precipitation will also result in increased erosion and new watershed models. Trenberth (2011) also states that precipitation varies from year to year and over decades, and changes in amount, intensity and frequency affect the environment and society, especially when it potentiates extreme events.

Additionally, limitations on measurements and records of rainfall are difficulties that concern researchers, because the frequency and reliability of the records of regional and global rainfall do not have scales to secure regard to control and record the data. This is because in situ measurements in areas of steep and complex topography does not occur due to numerous limitations (Adam et al. 2006).

The impact scenario on water resources will vary according to the region in Brazil. For example, the tendency is that the precipitation increase in the South and decrease in the North and Northeast (Marengo 2006). This will result in a change in river flows in these regions. The occurrence of floods is due to changes in the watershed and precipitation patterns, and this problem is often seen in urban areas. Therefore, it is necessary to develop new concepts and practices in management and public governance processes to improve coexistence with this phenomenon and minimize the impacts to the affected communities (Kobiyama et al. 2006).

Considering all the impacts to be caused in a watershed, it is impossible to guarantee 100% security and the risk culture is needed. Taking into account, it is particularly important that communities develop the ability to deal with the uncertainties in three main aspects: preparation, response and recovery (Federal Office for Civil Protection 2013). Thus, they are connected to the concept of resilience, that can be understood as “the ability of a country or city to respond to and evade the consequences brought about by global warming and to adapt to them.” The construction of a society based on the principles of resilience requires new commitments and cooperation of all (Mateus 2004).

According to Randhir (2014), it is important to renew the understanding of resiliency, adaptability, and transformability of watersheds through social and ecological research. Its management to climate change requires a thorough understanding of state and dynamics and the result must be information dissemination and decision support systems related to a watershed to enhance resilience to handle adverse impacts of climate change. Urban planning needs to incorporate knowledge of the vulnerability and risk, to propose measures to mitigate potential impacts and to aim the adaptation to increase urban resilience; for that, it is required multidisciplinary approach and integration of researchers from different areas of knowledge (IPCC 2007b; Frank and Sevegnani 2009).

Farwell et al. (2012) point out that quantifying the anticipated changes allows water managers to match adaptive strategies with expected impacts to improve watershed resiliency to potential impacts. Some of the potential impacts include changes in precipitation patterns and temperature changes. In this context, the present study addresses the potential impacts of climate change on patterns of maximum monthly precipitation in Passo Fundo River and Várzea River Watersheds, located in south of Brazil, relating to temperature data. The results can enforce the need of operational management and urban resilience.

Method

Study Area

This research focus on two watersheds and they are show in the Fig. 2.1. The Passo Fundo River and Várzea River Watersheds are located in north region in Rio Grande do Sul State, and belong to the Hydrographic Region of Uruguay.

The climate in the region researched is characteristic of southern of Brazil, the humid Subtropical type. The seasons are well defined, with hot and humid summer and cool winters. The winds affect the climate, and in summer the trade winds blowing, coming from the southeast, causing high temperatures and heavy rains.

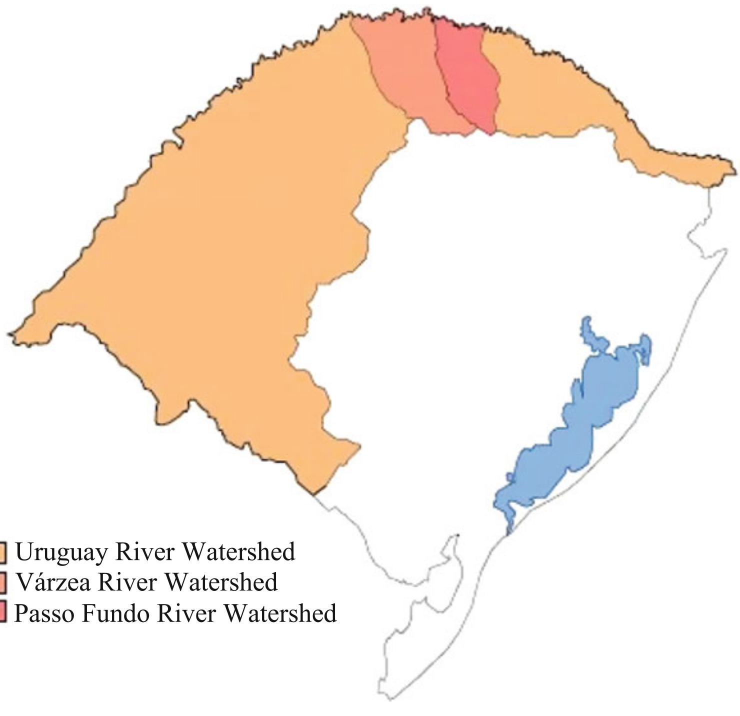

Fig. 2.1 Location of watersheds researched