Chapter 28
Promoting Sustainable Agriculture, Boosting Productivity, and Enhancing Climate Mitigation and Adaptation Through the RIO RURAL Program, Brazil

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Abstract The Brazilian agricultural sector is a major source of greenhouse gas emissions, but climate-smart practices combined with degraded land restoration can result in a more resilient landscape contributing to integrated climate change mitigation and adaptation efforts. The Sustainable Rural Development Program of Rio de Janeiro (RIO RURAL) has been supporting the transition of degraded rural areas to sustainable productive systems by providing technical assistance and incentives to small-scale family farmers. RIO RURAL promotes reforestation and sustainable agriculture practices, which can boost productivity as well as carbon stocks in the agricultural landscape. Using estimates of carbon mitigation potential for such practices, we identified methodologies eligible for certification in the voluntary markets. We estimated transaction, implementation, and certification

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costs and calculated potential revenues associated with RIO RURAL's activities. This did not only allow us to discuss the constraints and identify opportunities and co-benefits from RIO RURAL's contribution to climate mitigation, adaptation, and environmental integrity but also to food security as it targets family farms. We propose a bundling approach to carbon, where multiple benefits are measured and certified including water, food systems, as well as social and cultural benefits. This would allow accessing resources from both mitigation and adaptation programs in addition to markets that value ecosystem integrity as well as water and food security.

Keywords Family farming · Cost-effectiveness · Sustainable agriculture · Low-emission agriculture · Rio de Janeiro · Co-benefits

28.1 Introduction

Land use change and agriculture are the major sources of greenhouse gas (GHG) emissions in Brazil (Escobar 2015). In the state of Rio de Janeiro (RJ), agriculture plays a key role in supplying products to nearly 16 million inhabitants (IBGE 2010), mostly concentrated in the metropolitan region. Furthermore, 80% of the food production in RJ originates from small-scale agriculture (RIO RURAL 2014, Fig. 28.1), which accounts for ~90% of all rural properties (INEA 2013).

RIO RURAL[1] supports the transition of degraded rural areas to sustainable productive systems by providing technical assistance and economic incentives to small-scale family farmers. Practices promoted by RIO RURAL include the protection of springs and streams, establishment of agroforestry systems, and sustainable agriculture practices (see Hissa et al. 2018 in this volume).

Low emissions agriculture combined with the restoration of degraded land can result in a more resilient landscape that contributes to climate change mitigation and adaptation efforts. The objective of this chapter is to assess RIO RURAL's potential to generate climatic solutions as well as other co-benefits. We first present the main linkages between agriculture, climate change, and the concept of low-emission agricultural systems (Sect. 28.2). Section 28.3 gives an overview of RIO RURAL's program and their promoted activities; Sect. 28.4 summarizes legal frameworks and mitigation policies relevant to the agriculture, land use change, and forestry sectors. Section 28.5 introduces emission trading in the compliance and voluntary markets, and Sect. 28.6 presents the processes required to assess the mitigation potential of agricultural projects eligible for certification. Based on the identification of RIO RURAL's activities with mitigation potential, we have assessed the feasibility of carbon finance to provide incentives for the program's promoted practices (Sect. 28.7). We discuss constraints and identify opportunities associated with RIO RURAL's contribution to climate mitigation, adaptation, and environ-

[1] The Sustainable Rural Development Program in Micro-Watersheds of the State of Rio de Janeiro.

Fig. 28.1 Small-scale agricultural systems in Rio de Janeiro

mental integrity (e.g., recovery of degraded pastures by enriching soil carbon stocks) as well as to food security as it targets family-oriented rural properties in agricultural landscapes across the state of RJ (Sects. 28.7 and 28.8).

We found that carbon finance can be an important complementary source of funds but that it cannot support changes in agricultural practice alone. To this end, a change in the consumption patterns to value local food production, equitable distribution of returns related to such production, and ecocertification with differential pricing for reduced external costs to the society is required (Komives and Jackson 2014). Carbon financing may be significant for large-scale integrated crop/livestock production systems. Small-scale diversified systems often do not generate sufficient additional carbon mitigation to justify the effort. However, the assessment and inclusion of other co-benefits (e.g., the promotion of water conservation and quality, productivity improvements, moderation of extreme events, and biodiversity conservation) can make RIO RURAL's contribution more feasible, financially. Additional benefits of the program include enhancing ecosystem integrity and fostering water and food security.

28.2 Agriculture, Climate Change, and Low-Emission Agricultural Systems

Three major links exist between climate change (CC) and agriculture. First, the agricultural sector is highly affected by the impacts of CC, especially in relation to increased mean temperature, higher variability in temperature and rainfall patterns, changes in water availability, as well as more intense and frequent extreme events. These changes affect crop production, food distribution, and supply (FAO 2013) but also generate significant social and economic costs (Young et al. 2015).

Second, agricultural GHG emissions occur directly (e.g., production and use of synthetic fertilizers and livestock emissions) or indirectly due to deforestation and land use/cover change. The sources of agricultural GHG emissions include carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) resulting from biological decomposition processes in the soils and during digestion by livestock (enteric fermentation). Other processes that generate emissions are rice production, burning of biomass, manure management, feed production, processing and transport, and energy consumption (Gerber et al. 2013; Tubiello et al. 2014).

Third, agricultural practices can influence carbon sequestration processes since carbon can be absorbed from the atmosphere and restored in plant biomass and soils. The soils represent the most important long-term organic carbon reservoir in terrestrial ecosystems (Scharlemann et al. 2014). Sustainable land management practices can thus improve productivity and soil health but also store carbon. Some farming practices foster soil carbon losses, which degrade soil quality and reduce productivity (Lal et al. 2004). On the other side, soil organic carbon losses can be mitigated through management approaches specifically targeting the soil carbon stocks in agricultural systems (Smith and Olensen 2010).

Considering these links, there is a clear need for highly productive but low-emission agricultural systems that use inputs more efficiently (captured in the concept of *climate-smart agriculture*, see WB/CIAT/CATIE 2014). Such systems can lead to more resilient rural landscapes with increased carbon sinks and reduced GHG emissions per agricultural product or/and unit of land, contributing to CC mitigation efforts but also to food security and poverty alleviation (FAO 2013; Wheeler and von Braun 2013). For example, in the livestock sector, practices that reduce emissions depend on the improvements of production efficiency in the animal and herd levels, such as using better feeding practices to reduce enteric and manure emissions and improving husbandry and health management to decrease the unproductive part of the herd and their related emissions (Rojas-Downing et al. 2017). Additional measures include manure management practices that enable recovery and recycling of nutrients as well as a more efficient water and energy use along the supply chains (Brandt et al. 2017).

28.3 The RIO RURAL Program

RIO RURAL supports the transition of degraded rural areas to sustainable productive systems by providing technical assistance and incentives to small-scale farmers based on a micro-watershed level approach in RJ. This program aims at increasing improved agricultural land with more sustainable production systems, reaching 814,000 ha in the period 2010–2018 (RIO RURAL 2014).

The program area embraces 72 municipalities and 366 micro-watersheds across RJ, giving priority to areas with highest poverty incidence. The program area has a

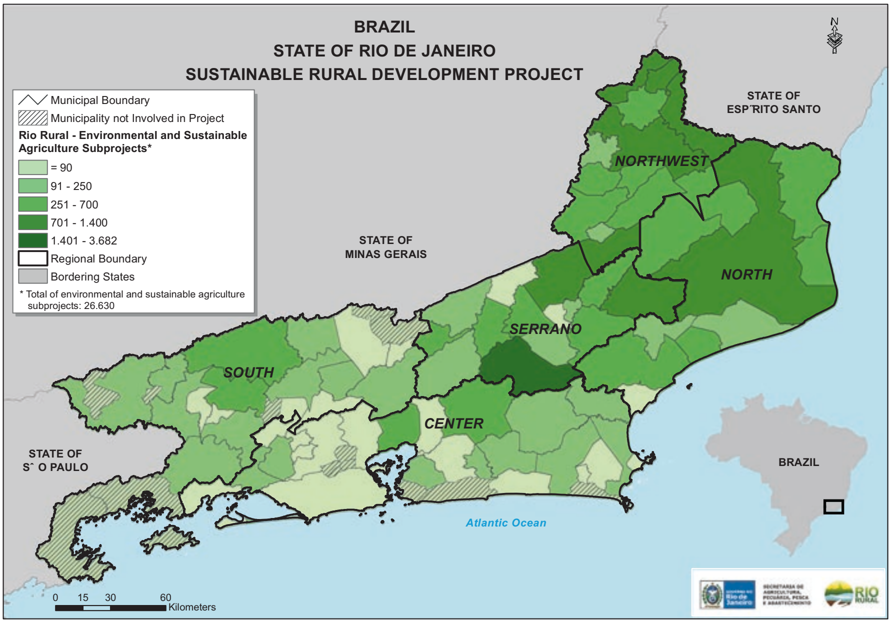

Fig. 28.2 Map of environmental and sustainable subprojects supported by RIO RURAL

high concentration of family-oriented and small-scale agricultural production. RIO RURAL expects to benefit 48,000 rural families, mostly family-oriented and small-scale farmers (RIO RURAL 2014). Figure 28.2 and Table 28.1 illustrate the type, number, and geographic concentration of RIO RIURAL's supported subprojects, including environmental (incentives to conserve forested areas around springs and streams[2]) and sustainable agriculture practices.

28.4 Legal Frameworks and Policies Related to Climate Change Mitigation and the Agriculture and Forestry Sectors

In terms of legislation, both the "*Forest Code*" (Law 12.651/2012) and the Atlantic Forest Law impose certain limitations on agricultural production. The latter prohibits the conversion of secondary forest to other land uses and the Forest Code establishes that 20% of rural properties' area need to be maintained under permanent forest cover as a "*legal reserve* (LR)," in the Atlantic Forest biome (INEA 2013).

Additionally, this legislation also established the *Areas of Permanent Preservation* (APPs), which determine a minimum vegetation area to protect riverbanks and springs to conserve water resources and prevent soil erosion. APPs embrace both

[2] For further details on economic incentives, see May et al. (2018).

Table 28.1 Activities with potential impact on the GHG balance for RIO RURAL program over a period of 6 years

(a) *Protection of springs and streams*. This activity includes (i) installation of fences to protect forest from cattle grazing and monetary incentives for farmers to cease exploiting these zones and (ii) reforestation with native species on degraded zones
(b) *Support to the establishment of legal reserves*. The RIO RURAL program intends to support the legal compliance of rural properties by (i) undertaking topographic surveys, environmental licensing, and notarization of "in-process" legal reserve areas, (ii) providing incentives to properties that have not entered into this process, and (iii) reforestation of native vegetation on degraded zones
(c) *Expansion of agroforestry*. RIO RURAL especially encourages its development in areas of permanent protection, such as those around springs and streams or legal reserves as established by the Brazilian Forest Code
(d) *Improved annual crop management*. RIO RURAL promotes the adoption of several sustainable agricultural practices including crop diversification; integrated pest management and biological control of pest and diseases; bio-fertilization (in particular the use of compost, organic fertilizer and green manure); soil analysis, and rational use of fertilizers; zero or minimum tillage, planting contour, intercropping, and mulching; and irrigation management
(e) *Improved grassland management*. RIO RURAL aims to restore degraded pastures by improving crop rotations and supporting the production of sugarcane forage to feed cattle
(f) *Improved feeding practices of dairy cattle*. This is by the development of improved feeding practices for dairy cattle, which are already adopted for 12% of the 421,000 dairy cattle heads counts in the Rio de Janeiro state
(g) *Use of lime to fight soil acidification and sustainable use of agrochemicals*. The project supports the use of lime to combat soil acidification and a more sustainable use of agrochemicals in cropland and grassland management

Modified from Branca and Medeiros (2010)

riparian preservation areas (RPAs) and *hilltop preservation areas* (HPAs) on hilltops, steep slopes, and elevations >1,800 m (Soares-Filho et al. 2014).

Small-scale properties, ranging from 20 to 140 ha in RJ, are not obliged to restore 20% of LR in their properties if the deforestation occurred before 2008, and RPAs can also be included in their calculation of the LR area. In this way, the restoration requirement is reduced. The restoration of APPs in rural properties is mandatory and differs according to the property size, where smaller properties have lower requirements[3] (INEA 2013).

The Brazilian INDCs[4] at Paris included efforts toward zero illegal deforestation by 2030, compensation for the GHG emission from legal suppression of vegetation, restoration, and reforestation of 12 M ha of forests and the enhancement of forest management systems (Federative Republic of Brazil 2016). Brazil also committed

[3] 10% of property area for rural properties <2 fiscal modules and 20% for those with an area > 2 and 4 fiscal module (INEA 2013).

[4] Intended Nationally Determined Contributions (INDC) are public disclosures of countries' intended post-2020 climate action, which were adopted at the UN Framework Convention on Climate Change (UNFCCC) Conference of the Parties in Paris.

to strengthen the Low Carbon Emission Agriculture program (known as the ABC) as the core strategy for sustainable agriculture development, including the restoration of additional 15 M ha of degraded pasturelands by 2030 and the establishment of 5 M ha of integrated cropland-livestock-forestry systems, by 2030 (Federative Republic of Brazil 2016). The ABC program seeks to reduce emissions by promoting the best practices in agriculture, targeting medium to big farmers. For small-scale farmers and/or family farmers, Brazil's Federal Government has established the national agroecology policy and its corresponding "PRONAF agroecology" credit program (MDA 2016a).

28.5 Emission Trading: Compliance and Voluntary Markets

There are two types of markets for the GHG emission reductions transactions. On one hand, the *compliance markets* are ruled by the UNFCCC framework, where private and public institutions of industrialized countries are encouraged to promote reduction emission projects in developing countries, through the Clean Development Mechanism (CDM).

The compliance market works under the cap and trade mechanism, where a limit or "cap" is set for the total amount of GHG emissions that can be emitted by companies, power plants, and other installations. Emission trading enables the transaction of allowances and credits[5] in markets and can be considered in national mitigation targets.

On the other hand, *voluntary carbon markets (VCM)* operate outside the compliance market and have more flexible requirements (i.e., they allow for experimentation, new procedures, methodologies, and technological measures). This allows companies, governments, NGOs, and individuals to compensate their emissions through the purchase of offsets generated by this market.[6] VCM participants are enterprises and individuals interested in reducing their carbon footprint, gaining competitive advantage, or anticipating the implementation of compliance markets. In 2015, 84.1 MtCO_2e in VCM emissions credits were transacted from voluntary buyers at the lowest ever recorded average price of US$3.3/t$CO_2$e (Hamrick and Goldstein 2015).

Given the higher applicability of VCM to promote activities for smallholders, the lower transaction costs, and the higher flexibility in requirements when compared to those in the compliance market, we consider VCM to be relevant for RIO RURAL's activities (Phan et al. 2017).

[5] Compliance market credits are known as *certified emission reductions* – CERs.

[6] Voluntary carbon market credits are known as *verified (or voluntary) emission reductions* –VERs.

28.6 Processes and Methods to Assess the Mitigation Potential of Agricultural Projects Eligible for Certification

Methodologies are required to quantify the GHG benefits of a project and guide project developers to determine the project's boundaries, set baselines, assess additionality,[7] and quantify the GHG emission reductions. Baselines express the business-as-usual emission scenario and project emissions methodologies that are used to calculate a project's GHG benefits beyond established baselines.

Thus, as in other carbon markets, a set of project designs, monitoring, and reporting criteria are adopted in the VCM, according to which carbon offsetting activities and/or projects' environmental, social, and other co-benefits are verified. Various standards have evolved, each with its own certification processes and some emission registry services. The project cycle of one of the most commonly adopted certification and registry services, *Voluntary Carbon Standard* (VCS), is shown in Fig. 28.3.

To determine the potential to certify emission reductions from RIO RURAL (Table 28.1), methodologies from both compliance and voluntary markets are identified in Table 28.2. Each methodology has specific eligibility criteria, which needs to be considered when estimating a project's GHG balance.

A methodology, not part of CDM or VCS, considered helpful to assess the mitigation potential of all activities promoted by RIO RURAL, was EX-ACT. This tool, developed by FAO, estimates the net C balance of new investment programs and was developed using recommendations to establish the National GHG Inventories.[8] The main result is an estimate of the CO_2e balance associated with the adoption of land management improvement options when compared to a "business-as-usual" scenario (Bernoux et al. 2010; Cerri et al. 2010). We used the estimations of the mitigation potential of RIO RURAL's activities from Branca and Medeiros (2010), which compared emissions "without project's interventions" to those "with project activities," over 20 years (for more details, see Branca and Medeiros 2010).

We used these estimations, the area size dedicated to RIO RURAL's agricultural and forest restoration activities, and the most conservative price paid by voluntary buyers in 2015 (US$ 3.3 tCO_2e/ha[9]), to estimate the revenues from potential emission reductions. We then estimated the certification, implementation, and maintenance costs based on expert knowledge. With this revenue and cost information, we were able to assess the financial feasibility of carbon finance for RIO RURAL's promoted practices. Finally, we reviewed and analyzed the adaptation and other co-benefits generated from this program's practices.

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[7] Additionality refers to demonstrating that emission reductions are real, permanent, and attributable only to the project and that emission reductions due to the project are additional to the reductions that would have occurred without a project.

[8] Intergovernmental Panel on Climate Change – IPCC (2006) – "2006 IPCC Guidelines for National Greenhouse Gas Inventories" Hayama: Task Force on National Greenhouse Gas Inventories. Intergovernmental Panel on Climate Change.

[9] This payment value refers to the reference average price under the voluntary market in 2015, which is the lowest recorded value and thus considered to follow a conservative valuation approach.

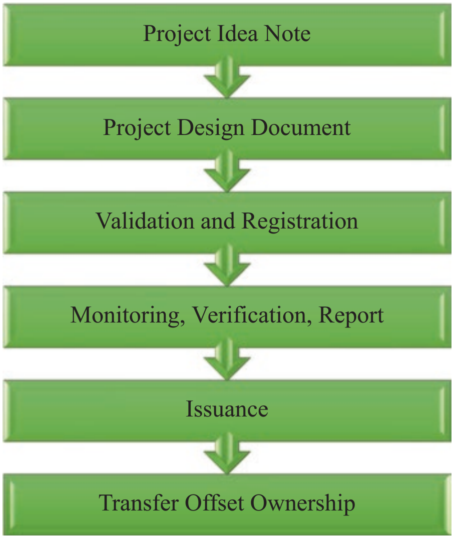

Fig. 28.3 Voluntary Carbon Standard Project Cycle

28.7 Results and Discussion

28.7.1 RIO RURAL's Activities with Mitigation Potential and Methodology Toolkit for Methodologies that Can Be Utilized for Certification

Branca and Medeiros (2010) identified that the protection of springs and streams and the support to establish LRs (Sect. 28.4) are the RIO RURAL's activities with the highest mitigation potential (Table 28.3). Agricultural activities with mitigation potential included improved annual crop management practices (i.e., crop diversification, integrated pest management, biological control of pest and diseases, agroecological systems), nutrient management (i.e., green manure, organic fertilizer, composting), tillage and residues management (i.e., contour cropping, minimum tillage), and irrigation management.

Independent of the methodology used to estimate the GHG balance of project's activities, a proof of additionality is required (i.e., that the smallholders' restoration efforts are beyond legal requirements, see Sect. 28.4). If the additionality criteria are met, increasing the magnitude of forest restoration activities within the scope of RIO RURAL would result in a higher mitigation potential. Other similar development projects in Santa Catarina, Brazil, showed a higher mitigation potential due to a wider area of forest protection activities, such as expanding agroforestry systems and rehabilitating degraded land (Branca et al. 2013).

Table 28.2 Methodology toolkit for RIO RURAL's program activities with climate change mitigation potential

Activity group	Potential activities to generate emission reductions	Methodology
Protection of springs and streams	Installation of fences to protect forest from cattle grazing and monetary incentives for farmers to cease exploiting these zones Plantation of native forest on degraded zones	VCS VM0015: Methodology for avoided unplanned deforestation AR-AMS0007: Afforestation and reforestation project activities implemented on lands other than wetlands
Support to the establishment of legal reserves	Undertaking topographic survey, environmental licensing and notarization of legal reserve Providing incentives to rural properties to establish legal reserves Reforestation of native vegetation on degraded zones	AR-AM0014: Afforestation and reforestation of degraded mangrove habitats AR-ACM0003: Afforestation and reforestation of lands except wetlands
Improved annual crop management	Foster agricultural practices: Crop diversification; Integrated pest management and biological control of pest and diseases; Bio-fertilization (compost, organic fertilizer and green manure) Soil analysis and rational use of fertilizers Zero and minimum tillage Planting contour, inter/relay cropping and mulching; Irrigation management	AMS-III.BF.: Reduction of N_2O emissions from use of nitrogen use efficient (NUE) seeds that require less fertilizer application AMS-III.A.: Offsetting of synthetic nitrogen fertilizers by inoculant application in legumes-grass rotations on acidic soils on existing cropland AMS-III.BE.: Avoidance of methane and nitrous oxide emissions from sugarcane pre-harvest open burning through mulching VCS VM0017: Adoption of sustainable agricultural land management
Improved grassland management	Restoration of degraded pastures by improving rotations (rotational pastures)	VCS VM0032 methodology for the adoption of sustainable grasslands through adjustment of fire and grazing VCS VM0026 sustainable grassland management
Improved feeding practices of dairy cattle	Supporting the production of sugarcane forage for cattle	Partially included in VCS VM001 methodology

Table 28.3 Estimated annual revenues from emission reduction credits of different RIO RURAL program activities

RIO RURAL program activity	Area size (ha)	Specific measures	Type of mitigation action	Estimated mitigation via EX-ACT (tCO_2e over 20 years)[a]	Annual revenues from emission reduction credits (US$/ tCO_2e)[b]
(a) Protection of springs and streams	900	Forest regeneration and plantation of native forests	GHG removal by sinks	517,166.0	85,332.4
(b) Support to the establishment of legal reserves	110				
(c) Expansion of agroforestry	1,100	Expansion of agroforestry on degraded grassland, resulting in changes in both biomass and soil C stock	GHG removal by sinks	267,257.0	44,097.4
(d) Improved annual crop management	4,110	Improved agricultural practices (higher C biomass and soil C stocks)	GHG emission avoidance	18,334.0	3,025.1
(e) Improved grassland management[c]	691	Improved pasture rotations, supporting the production of sugarcane forage (increase in C stock)	Displacement of a more-GHG-intensive output	19,437.0	3,207.1
(f) Improved feeding practices of dairy cattle: 421,000 herd size, increasing 7% of adoption of practices		Increased productivity (meat and milk), resulting in an overall reduction of CH_4 emissions per unit of product	GHG emission avoidance	39,769.0	6,561.8
					142,223.9

Based on Branca and Medeiros (2010)
[a]Branca and Medeiros (2010)
[b]Based on an estimated payment of US$ 3.3/ tCO_2e. RIO RURAL's activities (a) and (b) were calculated using the "forest regeneration EX-ACT module," (c) "other land use change and perennials modules," (d) "annuals module," (e) "grassland module," and (f) "livestock module"
[c]The use of lime against soil acidification and the sustainable use of agrochemicals are included in the module "inputs" for improved annual crop management practices

28.7.2 Estimated Costs and Revenues Associated to Obtaining Carbon Credits for RIO RURAL's Agricultural and Forest Restoration Activities

Considering the mitigation potential presented in the previous subsection and the average value paid by voluntary buyers in 2015, the estimated annual revenue that can be obtained by RIO RURAL's activities is US$ 142,223.9 (Table 28.3). The average costs for obtaining *Verified Emission Reductions* are estimated in Table 28.4, considering that these vary according to the methodology used (the required human resources matter more than the project size). The annual certification costs (Table 28.4) are estimated at US$ 29,644 for project development and validation, in addition to US$ 12,704 for annual verification, monitoring, and reporting (over 10 years). Certain activities (such as agroforestry) yield minimal or zero reductions and then achieve an increase in sequestration at a certain vegetation age, after which they stabilize. This means that most projects will not provide any payment until a certain duration after its implementation. In addition, implementation and maintenance costs are taken into account. In the current carbon projects in the Atlantic Forest, such costs (mean value per hectare) represent US$ 1,222 and US$ 348, respectively (Table 28.5).

28.7.3 Financial Analysis of the Mitigation Potential from RIO RURAL's Promoted Practices and Adaptation Benefits

Certification costs in the voluntary market are estimated at US$ 156,691 (Table 28.4). Variations will depend on the project's selected activities and corresponding methodologies. Furthermore, the annual implementation and maintenance costs also need to be added.

Table 28.4 Estimated costs related to certification schemes in the voluntary market

Estimated costs of certification schemes	US $a
Internal costs (including project development, feasibility study, data inquiry)	5,293.6
Carbon consultant for developing the project as a carbon project (i.e., writing a project design document (PDD), financial analysis, baseline determination)	10,587.2
Validation body	12,704.6
Administration costs and fees	1,058.7
Costs for development and validation of the project activity	29,644.1
Verification body for periodic verification (each year)	8,469.8
Carbon consultant for preparing the monitoring report (annually)	4,234.9
Total costs for annual verification of the GHG emission reductions over a verification period (10 years)	127,047.0

[a]Costs converted to USD using the exchange rate of 1EUR = 1.05872 US$

Table 28.5 Implementation and maintenance costs in carbon-related projects of the Atlantic Forest region

Project	Implementation costs (R$/ha)	Annual maintenance costs (R$/ha)
Banco de Carbono (Brasil)	7,000	1,000 (3 years)
Mapa dos Sonhos do Pontal do Paranapanema (SP)	5,000	1,800 (3 years)
Plantando Água (SP)	5,000	1,800 (3 years)
Neutralização de Emissões de Carbono (SP, MG)	7,000–9,000	1,800–2,500 (3 years)
Com Café (CE)-SAF	4,100 (coffee plantation + forest shading)	300
EcoCitrus (RS)-SAF	2,175 (enrichment of citrus trees with native forest)	n.d
Carbono, Biodiversidade e Comunidade (BA)	15,000	6,000 (3 years) + 1,500 (monitoring −30 years)
Projeto Floresta Viva (BA)	12,000	n.d.
Brazil Mata Viva (GO)	1,043	n.d.
Carbono, Biodiversidad e Renda (SP)	5,000	1,800 (3 years)
Carbono Seguro (SP)	n.d.	256 (30 years)
Projeto Ação contra o Aquecimento Global em Guaraqueçaba (PR)	US$ 230	US$ 45
Projeto de Restauração da Floresta Atlântica (PR)	US$ 350	US$ 65
Projeto Piloto de Reflorestamento em Antonina (PR)	US$ 300	US$ 60
Reflorestamento das Bordas dos Reservatórios da AES Tietê (SP)	11,000	Included in implementation value
Programa Desmatamento Evitado (PR/SC)	n.a.	500
Recomposição da Paisagem e SAFs (Café com Floresta, SP)	920	n.d.
Mean values	4,750 R$[a] (1,222 US$)	1,354 R$ (348 US$)

Modified from May (2011)
[a]Considering an exchange rate of 1 US$ = 3.88 R$

RIO RURAL's activities were found to have a positive but low annual average mitigation potential of 0.2 tCO_2e/ha (Branca et al. 2013), which valued at US$ 3.3/tCO_2e implied a return of only US$ 0.6/ha/yr. Even with the cost advantage for the registry and the certification of RIO RURAL's projects given their large area for operation, these returns are not sufficient to counteract other land use options.

Factoring these estimates, carbon payments alone are not likely to be a financially feasible option to incentivize emission reductions from RIO RURAL's promoted activities. This analysis assumes limited returns from low carbon payments (average price paid in 2015) but also the constrained area of activities that have high mitigation potential by RIO RURAL (reforestation activities).

Carbon payments per hectare are often rarely higher than what a landowner could gain from an alternative land use (opportunity costs), especially considering cash crops or profitable agricultural activities. This means that carbon finance is not likely to provide incentives to stop land use conversion, if they are based only on economic motivations (Goldstein and Gonzalez 2014). In practice, carbon finance seems to work as an incentive for those already inclined toward forest conservation (May 2011).

The possibility of certifying groups rather than individual farmers can reduce transactions costs and the inclusion of value added to products, such as certified coffee, also helps to make them more viable as financial alternatives. Project preparation expenses assumed by the state through extension or university personnel is another way to make these schemes work (Shames et al. 2012).

Even though we found a low financial mitigation potential for carbon finance alone, sustainable agriculture and productivity enhancement promoted by RIO RURAL has resulted in the gain of ecosystem services and led to effective mitigation actions, increase in landscape resilience, and the adaptive capacity of production systems and people against climate-related hazards.

Significant adaptation benefits result from RIO RURAL's promoted activities that include avoiding or minimizing land degradation, the risk of landslides, and other CC-inducing hazards associated with poor land use management. There have been environmental disasters with considerable economic and social costs stemming from these problems in recent years in Brazil. Economic losses, as a result of the extreme weather events in Brazil (i.e., flooding, flash floods, and landslides) between 2002 and 2012, have led to significant damage valued at between US$ 57.21 and 113.1 billion[10] (Young et al. 2015). The state of Rio de Janeiro reported that 45% of all national number of deaths are associated to such hazards. In times of extreme events, the poor people concentrated mostly in rural areas are more vulnerable to natural disasters and the impacts of CC, which led to rising inequalities (Scarano and Ceotto 2015; Young et al. 2015).

RIO RURAL's promoted activities therefore play an essential role in supporting the CC adaptation by increasing rural landscape resilience. Such efforts are attractive for financial support from international financial mechanisms. For example, the Green Climate Fund (GCF) as the operating entity of the financial mechanism of the UNFCCC has committed among its investment priorities to support activities that encourage low emission and climate resilient agriculture and that scale-up finance for forest and CC.[11]

[10] Using the exchange rate of 1 BR$ = 0.31795 US$ on the original reported data.

[11] Green Climate Fund (GCF) (2014) Funding. Available at: http://www.greenclimate.fund/ventures/funding/#how-it-works

28.7.4 Co-benefits (Water and Food Security, Biodiversity, and Socio-Cultural Contributions)

Water security has become a sensitive challenge that creates conflicts in high deforested areas of the Paraíba do Sul watershed between São Paulo and RJ (Scarano and Ceotto 2015). Therefore, forest restoration activities (particularly on the hilltop and riparian preservation areas) yield hydrological benefits, in terms of water conservation and quality, thus fostering human water security. Moreover, there is a growing market for watershed services in the Atlantic Forest, driven by many initiatives (see May et al. 2018). Some have received support from the private sector (e.g., Oásis Payment for Watershed Services project in São Paulo with funds from the Mitsubishi and Grupo Boticário foundations), which can provide new opportunities in RJ (Veiga and Gavaldão 2011). Additional hydrological regulation services provided by the riparian and hilltop vegetation areas include the moderation of extreme events (e.g., floods and landslides), which have severely hit RJ in the past (Joly et al. 2014).

Despite its outstanding biodiversity and high endemism, the Atlantic Forest is highly fragmented with just 12–16% of the original forest cover left (Ribeiro et al. 2009). The remnant forest is also threatened and has a very low protection level of 2.6%, which is way below the recommended minimum of 17% (Ribeiro et al. 2009; Soares-Filho et al. 2014). Therefore, restoration and reforestation activities are essential to protect native vegetation and biodiversity. Furthermore, landowners that restore forests beyond the requirements set by the Forest Code may be able to generate environmental reserve certificates (CRAs) (See May, Fernandes & Rodríguez Osuna 2018 in this volume), which could be a source of revenue for smallholders. These efforts provide a clear contribution to the costly and high restoration needs in RJ (PACTO 2009).

Family farming is essential for supplying food in RJ, which provides livelihoods, income, and jobs, and is responsible for around 68% of beans, 75% of manioc, 67% of maize, 55% of rice, and 52% of coffee (MDA 2016b). Furthermore, food production from family farming is key to the sustainable development of communities and healthy diets in RJ. To this end, RIO RURAL supports farmers to adopt organic farming practices (>200 families), which makes them eligible to an increased price for their products. This is to incentivize the supply of organic food products aligned with the rules of national programs.

The social empowerment approach to small-scale rural farmers by the RIO RURAL type of projects can be captured by certifiable social standards, such as the Social Carbon Standard. Others include the Gold Standard, Plan Vivo, which seek to quantify co-benefits from health and gender to the protection of biodiversity. Besides the emission reductions in 2015, global voluntary projects provided several co-benefits such as 8000 jobs, protected habitats for 376 endangered species, support to vulnerable groups, contributions to water security, built resilience to CC impacts, and regularization of land tenure. These beyond-carbon benefits have earned more attractive prices per ton. Nearly half of all forest carbon projects in 2015 engaged in these markets because of such co-benefits (Goldstein and Ruef 2016).

Other potential co-benefits (amenity values) include ecotourism activities associated to an increasing demand of urban settlers that value scenic beauty offered by the rural landscapes in RJ. Ecotourism in private reserves is clearly underdeveloped (de Vasconcellos and Castley 2014) but offers a myriad of opportunities that include income generation for biodiversity protection and benefits such as hiking, bird watching, and outdoor sports, in addition to inspiration for art, music, science, and religion.

Most co-benefits from carbon-related projects in the Atlantic Forest are generated as increased income and often relate to the conservation and restoration of biodiversity and ecosystems, including springs and stream protection. However, grouping diverse ecosystem services requires accounting, monitoring, and verification (May 2011). Consequently, we propose a bundling approach, where multiple benefits are measured and certified (Table 28.6). This would allow accessing resources from both mitigation and adaptation funds, in addition to the markets that value ecosystem integrity as well as water and food security.

28.8 Conclusions

RIO RURAL's forest restoration activities provide small-scale farmers with means to comply with the Forest Code and have the highest mitigation potential. We found that given the low price for conventional emission reduction credits (at the time of this analysis) and the high costs associated with implementation and certification, the estimated carbon revenues potentially generated from RIO RURAL are not financially viable if they are based solely on carbon finance. However, the adaptation benefits from RIO RURAL's actions are remarkable, taking into account how sustainable agriculture and forest restoration practices increase landscape resilience and farmers' adaptive capacity against the impacts of CC.

RIO RURAL's sustainable agriculture practices improve productivity and resource efficiency and contribute positively to food security and rural farming livelihoods. Forest restoration activities promote biodiversity conservation and healthy ecosystem functions and services (especially considering RJ's highly degraded landscape). Some of the most remarkable co-benefits of such promoted activities are watershed protection that foster water security.

The increased incidence of extreme events in RJ has caused significant social and economic costs in recent years. As a result, actions to avoid or mitigate future negative impacts of CC (adaptation benefits), especially on the rural poor, need to be taken seriously. Conflicts related to water insecurity (e.g., access to water between São Paulo and RJ), in addition to the pressures from a growing demand for resources, show the urgency to act now to move from a *shrinking hotspot to a climate hope spot* (Scarano and Ceotto 2015).

Table 28.6 Possible co-benefits associated to activities promoted by RIO RURAL

Activities	Food security (productivity)	Water quality	Water conservation	Soil quality	Air quality	Biodiversity and wildlife habitat	Scenic beauty/ amenity value	Moderation of extreme events
Protection of springs and streams		+	+	+	+	+	+	+
Support to the establishment of legal reserves		+	+	+	+	+	+	+
Expansion of agroforestry	+/–	+/–	+/–	+	+	+	+	+/–
Improved annual crop management	+	+/–	+	+		+		
Improved grassland management	+	+/–		+		+	+	
Improved feeding practices of dairy cattle	+			+				

All these activities are carried out with a social empowerment approach based on participatory management of micro-watersheds (social co-benefits)

We found that a bundling approach to carbon is most appropriate to address RIO RURAL's contribution to CC, which accounts for the various benefits this program provides in both mitigation and adaptation efforts, in addition to the co-benefits associated to increased water and food security. Furthermore, the smallholder social and participative approach of programs such as RIO RURAL add relevant social benefits that improve livelihoods and smallholders' adaptive capacity to cope with the impacts of CC.

Sustainable agriculture activities can also be considered as a contribution to Brazil's national forest restoration and low carbon emission agriculture goals set to be accomplished by 2030. These activities can also contribute to regional land restoration activities launched recently that are supported by public and private funds.

Carbon mitigation is only a small part of the potential social and environmental benefits to be gained from an integrated landscape approach focused on smallholder land use practices allied with the corridors between protected areas and that which take advantage of the Forest Code structures regarding riparian forests and spring protection. These benefits include the protection against the risks associated with CC, and permit better adaptation to these impacts on smallholders, and are not currently supported by any programs other than schemes such as RIO RURAL.

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