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Capturing synergies between rural development and agricultural mitigation in Brazil

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ABSTRACT

This paper presents the results of the EX-Ante Carbon-balance Tool (EX-ACT) application on two rural development projects in Brazil. The analysis provides an estimate of project impact on GHG emissions and C sequestration indicating net mitigation potential: results show that the Santa Catarina Rural Competitiveness Project has the potential to mitigate 12.2 Mt CO_2e and the Rio de Janeiro Sustainable Rural Development Project 0.85 Mt CO_2e. Both projects are successful at promoting activities aimed at reducing rural poverty and also contribute to climate change mitigation, demonstrating the potential importance of sustainable agriculture (improved cropland and grassland management, expansion of agro-forestry systems and protection of forested areas) in delivering environmental services. EX-ACT has also been used as a tool to guide project developers in refining components and activities to increase project environmental benefits. Cost–benefit analysis shows that while both projects generate environmental benefits associated with climate change mitigation, the Santa Catarina Rural Competitiveness Project has significantly higher potential due to the size of the project area and the nature of activities, thus a higher likelihood of potential co-financing from climate finance sources.

Introduction

Agriculture is a major source of greenhouse gas (GHG), directly contributing to 14% of total global emissions (Smith et al., 2007). Concomitantly, the agriculture sector has considerable potential as a mitigation source. For instance, emissions of carbon dioxide (CO_2) could be reduced through the adoption of improved cropland management practices (Bernoux et al., 2001a; UNFCCC, 2008) while emissions of methane (CH_4) and nitrous oxide (N_2O) could be reduced through improved animal production, improved management of livestock waste, more efficient management of irrigation water on rice paddies, and improved nutrient management (Cerri et al., 2010). Furthermore, carbon (C) can be sequestered through the adoption of conservation farming practices, agroforestry, improved grassland management, and restoration of degraded lands (Bernoux et al., 2001a,b, 2006; Cerri et al., 2004, 2007; Corbeels et al., 2006; Horlings and Marsden, 2011; Maquere et al., 2008). Thus, many rural development projects promoting the adoption of sustainable agriculture and land management practices could play an important role in mitigation, either by reducing emissions or by sequestering C, at the same time contributing to increased food security, improved livelihoods and reduced rural poverty (Palmer and Silber, 2012).

Agriculture is a major sector in terms of economy, employment and trade balance for the BRIC (Brazil, Russia, India and China) economies. Brazil is also one of the world's top GHG emitters (Cerri et al., 2009) and Brazilian authorities are targeting the sector for significant reductions in its GHG emissions (McKinsey, 2009). Cerri et al. (2010) considered different agriculture and livestock sector development scenarios that could generate emission reductions in the range of 178.3–445 Mt CO_2 equivalent (CO_2e) by 2020.

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Promoting sustainable agriculture intensification in Brazil therefore has the potential to generate significant mitigation benefits in terms of reduced GHG emissions and increased C sequestration. In fact, in recent decades national agricultural development policies have switched from a focus on productivity increases to increasing sustainable production together with income generation (Sorrensen, 2009). In this regard, participatory programs such as Sustainable Rural Development Programs in Brazil supported by the World Bank and already in place at state level have been successful in driving the transition of degraded rural areas to sustainable productive systems, providing knowledge, technical assistance and incentives to small-scale farmers to plan, implement and monitor sustainable demand-driven interventions. This is in line with national plans that include rural development, such as the proposed Brazil's National Plan on Climate Change which has the objective, among others, of promoting diversity and multifunctionality of rural areas and stimulating technological innovation and sustainability.In this context, models are being developed to estimate the mitigation potential of changes in agricultural production systems and to support project managers in climate change decision making (Bellassen et al., 2010; Easter et al., 2007; Milne et al., 2007). The EX-Ante Carbon-balance Tool (FAO, 2010) is one such model developed by the Food and Agriculture Organization of the United Nations (FAO) to provide an ex-ante evaluation of the impact of rural development projects on GHG emissions and C sequestration, thus estimating the potential contribution of the agriculture sector to climate change mitigation (Bernoux et al., 2010; Cerri et al., 2010). The model can also be used during the project design process, to assist project developers in refining components and activities to increase, whenever possible, the mitigation benefits of rural development projects. Additionally, the analysis can provide a basis for building a C financing framework for agriculture by highlighting the practices with the highest mitigation potential which could be extended either during the project implementation phase or in broader investment programs.

This paper presents the results of the application of the EX-ACT methodology on two rural development projects in Brazil to demonstrate that development projects can also create the necessary mitigation opportunities requested at country level, thus illustrating that the global benefits of carbon mitigation associated with rural development could help leverage needed investments to support small-scale farmers.

Materials and methods

Selected rural development projects as case studies in Brazil

The analysis presented in this paper is developed using two rural development projects as case-studies: the Santa Catarina Rural Competitiveness Project (SC Rural) and the Rio de Janeiro Sustainable Rural Development Project (Rio Rural). These two projects were chosen since they both promote the adoption of sustainable agriculture intensification, increasing farming productivity while improving management and conservation of natural resources. These projects therefore constitute good examples of "climate-smart" agriculture – as they increase food security and farmers' capacities to adapt to climate change while delivering mitigation benefits – and represent suitable cases for applying the EX-ACT methodology. The projects selected as case studies (SC Rural and Rio Rural) have many similarities in that they both: (i) focus on raising small farm competitiveness by introducing best agricultural practices to improve product quality and added value as well as improving market access; (ii) support farmers in complying with federal environmental law; (iii) use the micro-watershed concept as the building block to integrate multisectoral policies and improve governance within local territorial planning units; (iv) have a six-year implementation period; (v) have as an objective the scaling up and fine-tuning with existing state-level rural development programs; and (vi) are financed by World Bank loans with FAO technical assistance.

The Santa Catarina Rural Competitiveness Project (SC Rural)

SC Rural, currently in its second year of implementation, focuses on the competitiveness of Family Agricultural Producer Organizations (FAPOs). FAPOs are defined as producer organizations in which 90% of membership consists of family farmers as defined under Brazil's National Program to Strengthen Family Farming (PRONAF). Both currently existing FAPOs, as well as others to be established during project implementation, are targeted. The objective of SC Rural is to increase FAPOs' competitiveness by: (i) providing finance and related technical assistance to encourage technological innovation and diversification, raise productivity and broaden market access; and (ii) bolstering the provision of needed complementary public goods and services, e.g. infrastructure, certification, and sanitary, legal and environmental regulatory compliance. The total project cost is US$189 million, with US$90 million from a World Bank loan, using a sector-wide approach that includes Government expenditures and activities from various sectors – agriculture, water resources management, environment, infrastructure (rural roads and communication) and rural tourism. The project will cover approximately 3.6 million hectares (ha) (equivalent to 37% of the state's area) characterized by lagging economic performance, potential for improvement and need for technical and financial assistance. It will primarily support rural agricultural and non-agricultural small-scale producers, rural workers and indigenous families, organized in associations, cooperatives, formal (with legal status) and informal networks or alliances. This includes a total of about 936 micro-catchments, e.g. about half of the 1683 micro watersheds into which the State is divided. Productive landscapes directly targeted by the project are estimated at 200,000 ha, but the total area of lands receiving support for improved agricultural systems and natural resources conservation and management totals 661,000 ha (Fig. 1).

The Rio de Janeiro Sustainable Rural Development Project (Rio Rural)

Rio Rural has the objective of increasing small-scale farming productivity and competitiveness through the adoption of integrated and sustainable farming system approaches. Project activities are structured into three components: Support to Small Farmer Production and Competitiveness; Institutional Frameworks; and Project Coordination and Information Management.

Most of the technical activities are found under the first component aimed at supporting changes in sustainable rural production processes within a framework of market-driven improvements in productivity and competitiveness of smallholders. The Project will target approximately 37,000 small-farming families (some 150,000 people), which corresponds to roughly 30% of the total rural population of the state. The target population resides primarily in three main regions including the North, the Northwest (also known as the "North and Northwestern Fluminense"), and Serrana administrative regions, representing an area of about 23,000 square kilometers (53% of the total area of the state). An estimated 227,811 ha of agricultural lands would receive support to implement improved production systems while the total project area has been estimated at 800,000 ha (productive and non-productive lands, equivalent to a total area of about 270 micro-catchments) (Fig. 2).

Total project cost is US$79.0 million, with a World Bank Loan of US$39.5 million. Counterpart financing from the State of Rio de Janeiro through the Rio de Janeiro State Secretariat of Agriculture, Livestock and Rural Development (SEAPEC) totals US$21.4 million,

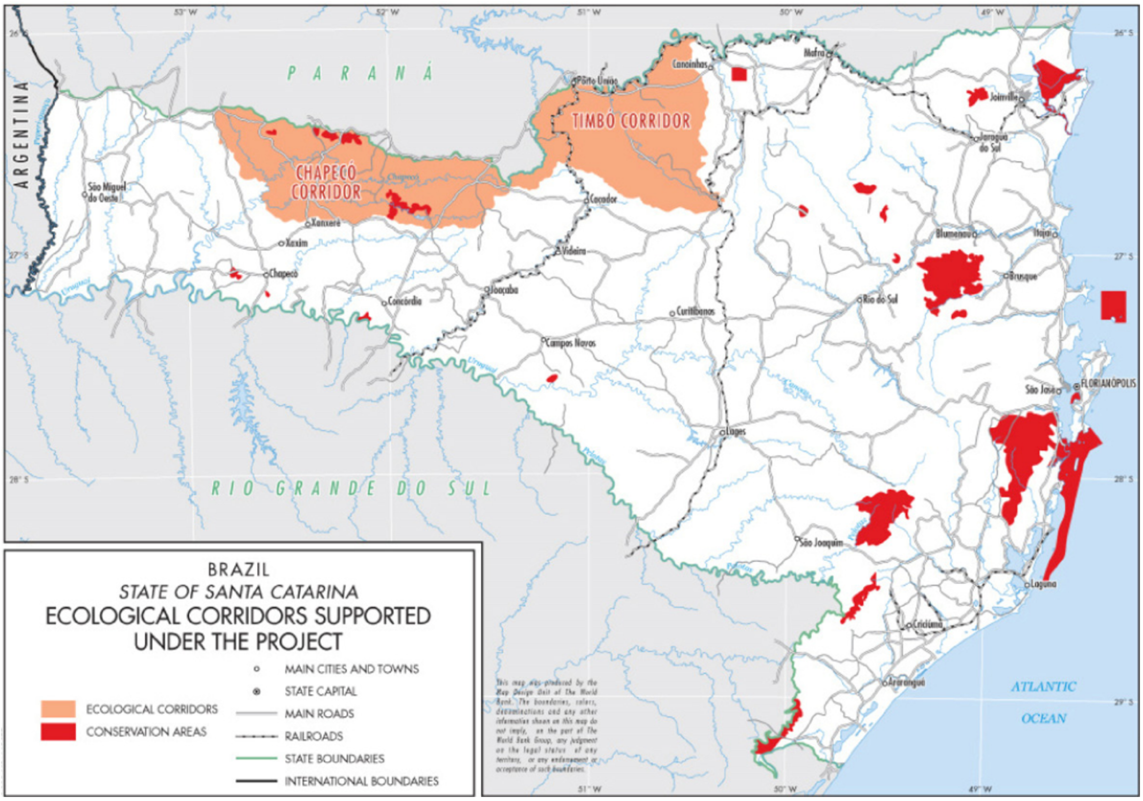

Fig. 1. Map of the SC Rural project area.

Source: World Bank, 2010, The Santa Catarina Rural Competitiveness Project, Project Appraisal Document.

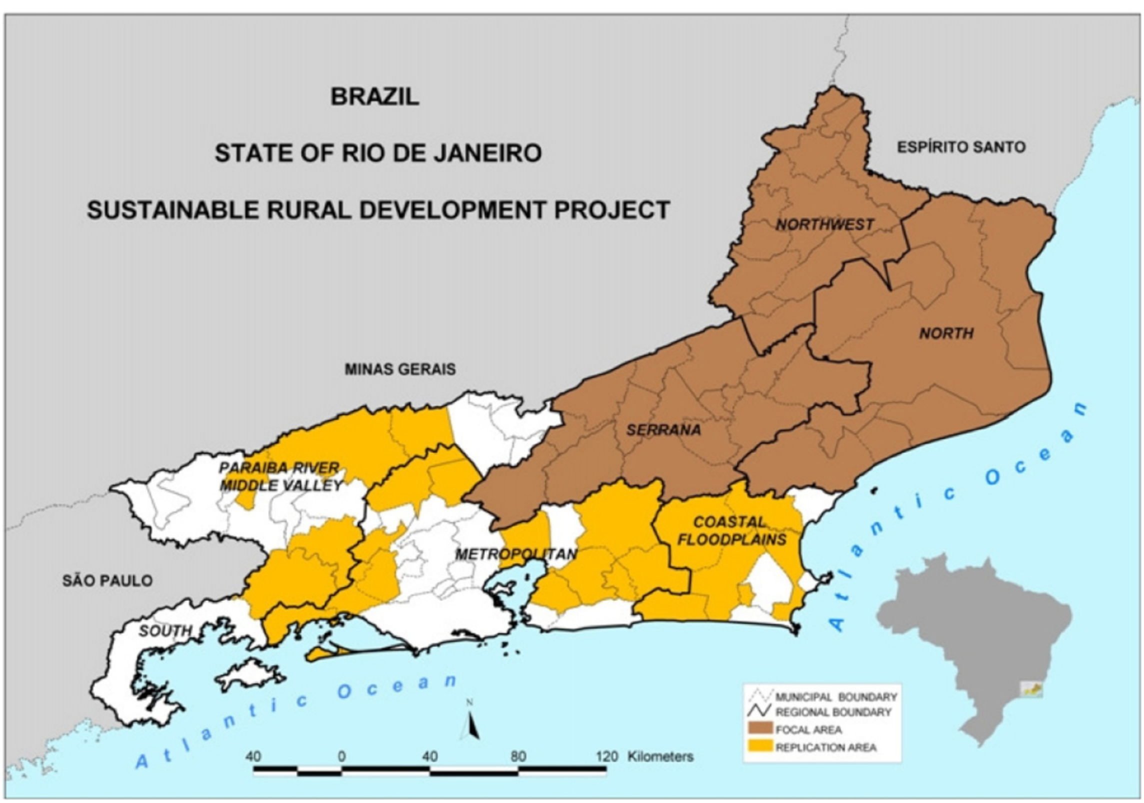

Fig. 2. Map of the Rio Rural project area.

Source: World Bank, 2009, The Rio de Janeiro Sustainable Rural Development Project, Project Appraisal Document.

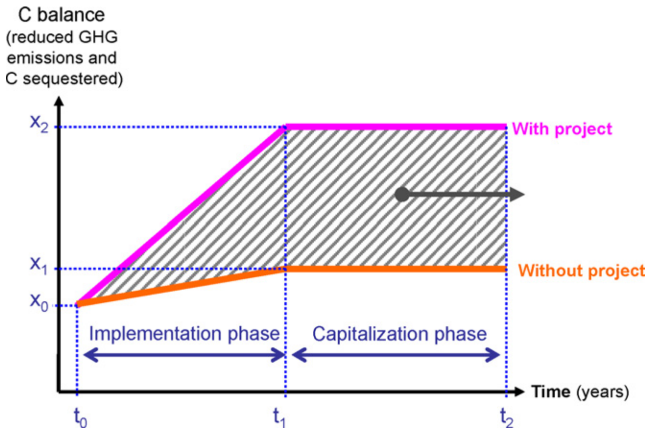

Fig. 3. Schematic representation of how the final C-balance is calculated using EX-ACT.
Source: Bernoux et al. (2010).

in addition to US$18.1 million in private investments. Eighty-four percent of project funds (or US$66.1 million) will be directed to small-scale farmers within the selected communities via participatory planning, capacity building and investment activities.

Estimating the mitigation potential of agricultural projects using the EX-Ante Carbon-balance Tool (EX-ACT)

EX-ACT provides ex-ante estimates of the impact of agricultural development projects on GHG emissions and C sequestration, indicating its effects on the C-balance – expressed in CO_2e based on the global warming potential of each gas – which is selected as an indicator of the mitigation potential of the project (Bernoux et al., 2010; Cerri et al., 2010). A full description of the EX-ACT structure and methodology can be found in Bernoux et al. (2010, 2011). The main output of the tool application is an estimation of the C-balance associated with the adoption of improved land management options ('with project'), as compared with a "business as usual" scenario ('without project') (Fig. 3). EX-ACT has been developed using primarily the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006), complemented by other existing methodologies and reviews of default coefficients. The model takes into account both the implementation phase of the project (i.e. the active phase of the project commonly corresponding to the investment phase), and the so called "capitalization phase" (i.e. the period where project benefits are still occurring as a consequence of the activities performed during the implementation phase). Often, as in the case studies presented here, the sum of the implementation and capitalization phases is set at 20 years.

By default, EX-ACT assumes that changes in land use and management follow a "linear" function over time (see Fig. 3), although the software allows for adopting a different dynamic of change, e.g. "immediate" or "exponential" (Bernoux et al., 2010), depending on the characteristics of the specific project activity and on the information available on the adoption rate of the selected practice among project participants. It is worth highlighting that the "logistic" dynamics, also known as "S-curve" is equivalent to the "linear" default option in terms of results.

Structure and basic assumptions of the analysis

The present analysis takes into account specific environmental features (soil and climate types) of each case study as well as key project activities with higher potential to affect C-balance estimation. Average climates considered in the analysis are: *warm temperate* with a mean annual temperature equal to 18 °C for SC Rural, and *tropical* with a mean annual temperature of 22 °C for Rio Rural. For both case studies, the moisture regime was classified as *moist* while the dominant soil type was considered low activity clay (LAC), i.e. highly weathered soil, dominated by 1:1 clay minerals and amorphous iron and aluminum oxides. Such information is essential, as most coefficients used in the analysis can change drastically according to soil characteristics and climate conditions.

SC Rural activities considered in the analysis as having a potential impact on C-balance are: expansion of training and extension services (pre-investment activities); diversification and enhancement of production systems (expansion of perennial crops, promotion of improved grassland and cropland management, and livestock production); support to the implementation of small-scale agro-industry and to the construction of sanitary installations; rehabilitation of the Areas of Permanent Preservation (APP – *Áreas de Preservação Permanente*) and Legal Reserve (LR – *Reserva Legal*) through the protection of existing forests and the implementation

Without Project			FINAL							
			Forest/ Plantation	Cropland			Grassland	Other Land		
				Annual	Perennial	Rice		Degraded	Other	Total Initial
INITIAL	Forest/Plantation		76316	0	0	0	1810	0	0	78126
	Cropland	Annual	0	285529	0	0	0	0	0	285529
		Perennial	0	0	41629	0	0	210	0	41839
		Rice	0	0	0	51422	0	0	0	51422
	Grassland		0	0	0	0	193955	0	0	193955
	Other Land	Degraded	0	0	0	0	0	10130	0	10130
		Other	0	0	0	0	0	0	0	0
		Total Final	76316	285529	41629	51422	195765	10340	0	661001

With Project			FINAL							
			Forest/ Plantation	Cropland			Grassland	Other Land		
				Annual	Perennial	Rice		Degraded	Other	Total Initial
INITIAL	Forest/Plantation		77193	0	0	0	933	0	0	78126
	Cropland	Annual	1250	281246	3033	0	0	0	0	285529
		Perennial	0	8718	33121	0	0	0	0	41839
		Rice	0	0	0	51422	0	0	0	51422
	Grassland		625	0	55178	0	138152	0	0	193955
	Other Land	Degraded	625	0	9505	0	0	0	0	10130
		Other	0	0	0	0	0	0	0	0
		Total Final	79693	289964	100837	51422	139085	0	0	661001

Fig. 4. Land use matrix of SC Rural (data in ha) (Facsimile of EX-ACT output).

of environmentally sound practices that facilitate forest regeneration or rehabilitation (e.g. fencing of riparian areas, agro-forestry, planting of native species in APPs and LRs for full protection); creation of ecological corridors; and rehabilitation of degraded lands.

Similarly, Rio Rural activities identified as having potential impact on C-balance are: protection of springs and streams (encourage farmers to conserve forested areas around springs and streams by installing fences to protect forest from cattle grazing, and monetary incentives for farmers to cease exploiting these zones and planting native forest in degraded zones); support establishment of LRs (support farmers to comply with current Brazilian Forest Code by undertaking topographic surveys, environmental licensing and notarization of "in-process" LR, provide incentives to farms that have not entered into the process, and fund replantation of native vegetation in degraded zones); expansion of agro-forestry; improvement of annual crop management (crop diversification; integrated pest management and biological control of pests and diseases; bio-fertilization and, in particular, use of 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); improvement of grassland management (restore degraded pastures by improving rotations and support production of sugar-cane forage to feed cattle); improvement of feeding practices for dairy cattle; support small agro-industry and construction of sanitary installations; use of lime to control soil acidification and sustainable use of agro-chemicals. Also, the analysis considers that Rio Rural implementation is expected to intensify technical assistance of 400 project implementers currently operating in the area, resulting in a substantial increase in the annual fuel consumption and, again, an expected increase in GHG emissions.

Land-use change promoted by Project activities are shown in the land-use matrices developed for the 'with project' and 'without project' scenarios (Figs. 4 and 5). The matrices show that SC Rural will cause a relevant increase in the size of perennial crops, as a result of the expansion of agro-forestry activities on annual cropland, grassland and degraded land: the initial 41,839 ha of perennial crops will increase to 100,837 ha as a result of conversion from annual crops (3033 ha), grassland (55,178 ha) and degraded land (9505 ha). This will not be the case in the 'without project' scenario, where the initial 41,839 ha of perennial crops will decrease by 210 ha, which will most likely become degraded land (Fig. 4). The matrices also show that the implementation of Rio Rural is expected to determine an increase in forest area (as an effect of the activities aimed at enhancing the areas of permanent protection converting grassland and degraded land to forest/plantation and perennials) and an expansion in agro-forestry systems (Fig. 5). For both projects, the implementation phase is six years (with a linear dynamic of change), followed by a capitalization phase of 14 years.

Results and discussion

Mitigation potential of project activities and land-use implications

The overall C-balance of each project, computed as the difference between C sinks and sources over 20 years, shows that SC Rural activities have the potential to create a sink of 12.2 Mt CO_2e, sequestering 14.3 Mt CO_2e and emitting 2.1 Mt CO_2e (Table 1). These results are much higher than in the case of Rio Rural activities, which show a smaller sink potential equal to 0.85 Mt CO_2e, computed as a difference between 0.86 Mt CO_2e sequestered and 0.01 Mt CO_2e emitted (Table 2). Considering the difference between project area size (661,001 ha for SC Rural and 227,811 ha for Rio Rural), it is expected that each project's average mitigation potential will also differ. In fact, estimated results show that SC Rural activities have a higher average mitigation potential (0.92 t CO_2e ha^{-1} yr^{-1}) when compared to Rio Rural activities (0.2 t CO_2e ha^{-1} yr^{-1}).

Table 1
Mitigation potential (i.e. balance between the project and the baseline) calculated with EX-ACT, in Mt CO_2e, of SC Rural, by project activity (positive values correspond to net emissions, negative values to sinks or avoided emissions).

Project activities	Mt CO_2e	% of total GHG mitigated	% of total GHG emitted
Expansion of training and extension services (pre-investment activities)	0.01	–	0.3
Improved annual crop management	1.7	–	82.8
Improved livestock production	0.3	–	14.0
Support to the implementation of small-scale agro-industry and to the construction of sanitary installation	0.1	–	2.9
Total GHG emitted	2.1	–	100.0
Improved grassland management	−3.8	26.9	–
Expansion of perennial crops	−0.4	3.0	–
Fencing of riparian areas	−0.9	6.3	–
Expanding agro-forestry systems	−8.8	61.7	–
Ecological corridors and land rehabilitation	−0.3	2.1	–
Total GHG mitigated	−14.3	100.0	–
Total C-balance	−12.2	–	–

Impact of the protection of springs and streams and Legal Reserves

Natural resource conservation activities show high mitigation impact. For example, most Rio Rural mitigation potential (more than 60%) is related to protecting springs and streams, and supporting Legal Reserve activities. The project encourages farmers to conserve forested areas around springs and streams (install fences to protect land from cattle grazing and provide monetary incentives for farmers to cease exploiting these zones) which will result in avoided deforestation, natural forest regeneration, and plantation of native forest on most degraded zones, thus protecting 900 ha (720 ha through forest regeneration and 180 ha through avoided deforestation). The Project also supports the establishment of Legal Reserves through several activities which will result in forest

Table 2
Mitigation potential calculated with EX-ACT, in Mt CO_2e, of Rio Rural, by project activity (positive values correspond to net emissions, negative values to sinks or avoided emissions).

Project activities	Mt CO_2	% of total GHG mitigated	% of total GHG emitted
Protection of springs and streams and support to the establishment of the Legal Reserves	−0.52	60.6	–
Expansion of agro-forestry systems	−0.27	31.1	–
Improved annual crop management	−0.02	2.1	–
Improved grassland management	−0.02	2.3	–
Improved feeding practices of dairy cattle	−0.04	4.6	–
Total GHG mitigated	−0.86	100.0	–
Support to small agro-industry	0.010	–	94.7
Technical assistance for project implementation	0.001	–	5.3
Total GHG emitted	0.011	–	100.0
Total C-balance	−0.85	–	–

Without Project

INITIAL		FINAL: Forest/ Plantation	Cropland: Annual	Cropland: Perennial	Cropland: Rice	Grassland	Other Land: Degraded	Other Land: Other	Total Initial
Forest/Plantation		0	0	0	0	6,2	0	0	6
Cropland	Annual	0	225104	0	0	0	0	0	225104
	Perennial	0	0	0	0	0	0	0	0
	Rice	0	0	0	0	0	0	0	0
Grassland		0	0	0	0	691	0	0	691
Other Land	Degraded	0	0	0	0	0	2010	0	2010
	Other	0	0	0	0	0	0	0	0
Total Final		0	225104	0	0	697	2010	0	227811

With Project

INITIAL		FINAL: Forest/ Plantation	Cropland: Annual	Cropland: Perennial	Cropland: Rice	Grassland	Other Land: Degraded	Other Land: Other	Total Initial
Forest/Plantation		6,2	0	0	0	0	0	0	6
Cropland	Annual	0	225104	0	0	0	0	0	225104
	Perennial	0	0	0	0	0	0	0	0
	Rice	0	0	0	0	0	0	0	0
Grassland		0	0	0	0	691	0	0	691
Other Land	Degraded	910	0	1100	0	0	0	0	2010
	Other	0	0	0	0	0	0	0	0
Total Final		916,2	225104	1100	0	691	0	0	227811

Fig. 5. Land use matrix of Rio Rural (data in ha) (Facsimile of EX-ACT output).

regeneration and re-plantation of native vegetations (protecting 400 ha of forests).

EX-ACT results show that this set of activities in Rio Rural will be responsible for sequestering 521,468 t CO_2e, of which 4302 t CO_2e from 'avoided deforestation' of tropical rainforest: it is assumed that the grassland type after deforestation will most likely be *non-degraded* and would remain as such with no fire use. The remaining 517,166 t CO_2e will result from forest regeneration and establishing native forest plantations: it is assumed that forest cover will be regenerated on degraded grassland through naturally re-growing stands with reduced or minimum human intervention (extensively managed forest). Given the climatic conditions of the Rio Rural project area, the vegetation type has been classified as natural tropical rainforest. This affects the growth rate of trees and the process of biomass gains and losses: for natural forests less than 20 years old, it is estimated that above-ground biomass is equal to 11 t of dry matter per ha per year (t dm ha^{-1} yr^{-1}), and below-ground biomass is equal to 4.07 t dm ha^{-1} yr^{-1}. Default value for litter (3.65 t C ha^{-1}) is based on the average between values for broadleaf deciduous and needleleaf deciduous forests, while soil C estimates are based on default references for soil organic C in mineral soils at a 30 cm depth (Bernoux et al., 2011). There are no estimates available for dead wood C stocks; therefore the corresponding value is set equal to 0, while default value for soil C is set equal to 47 t C ha^{-1}.

Impact of agro-forestry activities

As both case studies show, the implementation of agro-forestry activities is also expected to result in high mitigation impact. Most mitigation potential of SC Rural is related to expansion of agro-forestry systems – with different levels of cropping intensity and biological complexity depending on the ecological conditions of the project areas – and to promotion of the integration between woody perennials and crops, shrubs, and/or animals on the same land management unit, with a consequent change in land use (Table 3).

The expansion of agro-forestry systems will also have a significant mitigation effect (31.1% of total project mitigation potential) in the case of Rio Rural, which promotes the plantation of native forest on degraded grasslands using a mix of tree species generally composed of two-thirds native (more than 20 types) and one-third exotic commercial species.

Table 3
Expansion of agro-forestry systems in the SC Rural project area.

Previous land use	Area (ha)
Degraded land	533
Degraded grassland	7538
Area under reforestation	8718
Annual cropland	3033
Natural grassland	37,042
Non degraded planted grassland	18,136
Total	75,000

Expanding agro-forestry activities is expected to determine a change in both biomass and soil C stock. It should be specified that currently no default values for agro-forestry systems are available from IPCC. Therefore, the present analysis has adopted default values for perennial crops although, in some cases, a conservative approach is followed by considering a smaller area so as not to overestimate mitigation potential. Although the projects have differences in climate types, the case studies present similar results concerning biomass C stocks: under temperate moist climate in the SC Rural project area, expanding perennial crops on degraded grasslands will cause an increase in biomass C stock from 1.0 to 2.1 t C ha^{-1}, corresponding to 4 t CO_2e mitigated. Biomass will also increase as a consequence of land management: above-ground biomass growth is set using the IPCC default value of 2.1 t C ha^{-1} yr^{-1}, so that total CO_2e mitigated by agro-forestry activities promoted by SC Rural will amount to 127.05 t CO_2e over 20 years.

A similar increase in biomass C stock (from 1.0 to 2.6 t C ha^{-1}) is also expected for Rio Rural as a result of land-use change under tropical moist climate conditions: this corresponds to 6453 t CO_2e mitigated over 20 years. Biomass will also increase as a consequence of the land management: above-ground biomass growth is set using the IPCC default value of 2.1 t C ha^{-1} yr^{-1}, corresponding to 139,755 t CO_2e mitigated from biomass over 20 years.

The EX-ACT module "other land-use change" takes into account the calculations done by IPCC with reference to the changes in land use, while the EX-ACT module "perennials" considers the changes associated with the land management, helping to correct the nominal baseline according to the specific land management. Therefore, the results of the computations from the two modules should be considered as additive in this case.

For example, in SC Rural, the conversion from degraded land to perennials will cause an increase in soil organic C stock from 20.8 to 63.0 t C ha^{-1}, corresponding to 7.7 t CO_2e mitigated. Perennial systems can also store C in soil: default C storage amounts to 0.7 t CO_2e ha^{-1} yr^{-1} for warm moist regions. Similarly, the expansion of agro-forestry on annual cropland (3033 ha) in SC Rural will determine an increase in soil organic C and an increase in biomass C after a limited decrease in the first year as a result of the land-use change. On the contrary, it is assumed that the expansion of agro-forestry on the area under reforestation (8718 ha) in SC Rural will cause a reduction in biomass C as a consequence of decreased tree intensity and a reduction in soil organic C content as a consequence of the land-use change. The effect will be a net source of 2.1 t CO_2e ha^{-1} yr^{-1}. Lastly, the expansion of agro-forestry systems on grassland (37,042 + 18,136 ha) will represent a source of GHG emissions due to a loss in biomass C as a consequence of the land-use change, while it is assumed there will be no change in soil organic C. Nonetheless, as a consequence of land management over the first year, and in subsequent years, of SC Rural implementation, the system will accumulate biomass C so that the net effect will be a sink of 6.4 t CO_2e ha^{-1} yr^{-1}. Overall, this set of activities will create a net C sink of 8,8 Mt CO_2e over 20 years, corresponding to an average net C sequestration capacity of 5.9 t CO_2e ha^{-1} yr^{-1}.

Similar to SC Rural, the conversion from degraded land to perennials will cause the increase in soil organic C stock in the Rio Rural project area (from 15.5 to 47.0 t C ha^{-1}, corresponding to 107,958 t CO_2e mitigated) and perennial systems will store C in soil (0.7 t CO_2e ha^{-1} yr^{-1} for tropical moist regions), so that total mitigation potential is equal to 13,090 t CO_2e. The total amount of CO_2 mitigated from soil organic C as a result of Rio Rural's expansion of agro-forestry systems will therefore amount to 121,048 t CO_2e over 20 years. Total mitigation potential of the expansion of agro-forestry systems under Rio Rural is computed by adding the mitigation potentials from biomass and soil organic C: overall, this activity will create a net C sink of 267,256 t CO_2e over 20 years, i.e. 12.1 t CO_2e ha^{-1} yr^{-1}.

Impact of improved grasslands management

The mitigation potential of improved grassland management is related to the adoption of specific management practices such as pasture rotations and forage production as an alternative to grazing. The Fourth Assessment Report of the IPCC indicates that improved grazing land management has the second highest technical potential for mitigating C emissions from agricultural management changes (Smith et al., 2007). Many of the changes needed to sequester C through improved grassland management are also associated with improved rangeland productivity and rural incomes (Lipper et al., 2010). In the case of degraded grasslands, land rehabilitation might include a combination of cultivation abandonment, controlled grazing, erosion control, soil fertility improvement, plant introduction and seed dispersal, and reforestation, depending on the degree of severity of degradation (Woomer et al., 2004).

Considering the activities of SC Rural, the adoption of improved grassland management practices on the 138,152 ha will create a C sink of 3,797,660 t CO_2e over 20 years. EX-ACT also takes into account the impact on the C-balance of the management of land converted to grassland from other uses (as a result of other project activities), so that total grassland mitigation potential will climb to 3.8 Mt CO_2e over 20 years.

Mitigation potential promoted by improved grasslands under Rio Rural activities is not significant and thus not discussed here.

Table 4
Annual mitigation potential of selected SLM practices used in EX-ACT, considering only CO_2 effect.

Management category	Annual mitigation potential (t CO_2e ha^{-1} yr^{-1})
Improved agronomic practices	0.88
Nutrient management	0.55
Tillage/residue management	0.70
Water management	1.14
Manure application	2.79

Impact of improved cropland management

Both projects will increase the adoption of sustainable land management (SLM) practices such as: improved agronomic practices (improved crop varieties, extended crop rotations, particularly with legumes); integrated nutrient management (improved efficiency of fertilizer applications); improved tillage management (switch from minimum tillage to no-tillage); better water management (enhanced irrigation practices); and manure application and residue management. Many of these practices may increase crop yields and thus generate higher residues with positive effects in terms of mitigation (because of increased C biomass and soil C stocks). For instance, increasing available water in the root zone through water management can enhance biomass production, increase the amount of above-ground and root biomass returned to the soil, and improve soil organic C concentration. Some practices may also lead to a reduction in N_2O and C sources. For example, integrated nutrient management can reduce emissions on-site by reducing leaching and volatile losses, improving N use efficiency through precision farming and improved fertilizer application timing (FAO, 2009).

EX-ACT computes the mitigation potential of this set of activities in terms of soil C change for a 20-year time horizon using only CO_2 emissions factors for the relevant climate (Table 4).

Final emission factors reported by Smith et al. (2007) are higher because they also consider non-CO_2 emissions (i.e. emissions from other GHGs). For example, it is estimated that improved agronomic practices are able to store 0.98 t CO_2e ha^{-1} yr^{-1} instead of 0.88 as used in EX-ACT. Nevertheless, a conservative approach is used here: only the mitigation effect related to CO_2 emissions are taken into account. EX-ACT also assumes that when different land management practices are applied simultaneously on the same land, the final effect will be determined by the practice with the highest mitigation potential, i.e. the model will pick the highest coefficient instead of adding up the single coefficients corresponding to each practice (Bernoux et al., 2011). This precautionary option will also prevent the model from overestimating the impact of SLM techniques which require simultaneous adoption of different agricultural practices such as conservation agriculture, which implies minimal soil disturbance, permanent soil cover and crop rotations.

With reference to SC Rural, total mitigation impact of adoption of improved cropland practices will amount to 0.5 Mt CO_2e over 20 years. Concerned crops are: beans, millet, soybeans, tomatoes, onion, rice, potato, and cassava: it is assumed that most farmers are already adopting SLM practices (90% of cropland) and that project implementation will expand the area managed sustainably so that, in the 'with project' scenario, 100% of annual croplands will be managed using SLM practices (Table 5).

Therefore, annual mitigation potential of these activities is equal to 0.1 t CO_2e ha^{-1} on an area of 281,246 ha.

EX-ACT also computes the changes in input (agro-chemicals) use corresponding to the changes in annual crop management. The results for SC Rural show that in the 'with project' scenario there will be an increase in the GHG emissions of 2.2 Mt CO_2e

Table 5
Cropland area under SLM (ha).

Crops	Area (ha)	
	Without project	With project
Beans	32,429	36,032
Millet	21,637	24,041
Soybeans	111,505	123,894
Tomatoes	24,944	27,715
Onion	5856	6507
Rice (rainfed)	46,280	51,422
Potato	2624	2915
Cassava	7848	8720
Total	253,121	281,246

over 20 years. These include: CO_2 emissions from lime and urea application (10% of total), N_2O emissions from N application on managed soils (17%), and CO_2e emissions from production, transportation, and storage of agricultural chemicals which contribute most (73%) to total emissions from agro-chemicals (which should be considered as normal, given the high energy requirements for the production, extraction and transportation process). This is the effect of the increase in input use as a result of the increased cropland area (+8718 ha) foreseen with project activities, although the implementation of SLM practices is expected to increase the efficiency of the input use and cause, on average, a reduction of the use of agro-chemicals on a per ha base.

Improved annual crop management activities foreseen under Rio Rural have a minor mitigation potential or represent a small source of GHG emissions. Thus, while they have been taken into account in the analysis, they are not discussed here.

Impact of improved livestock production

Regarding livestock production, although the implementation of activities in both projects will result in an increase in dairy cattle and sheep population, only results related to SC Rural have shown any significant mitigation potential and thus only these are considered in the following discussion. EX-ACT estimates for CH_4 emissions from enteric fermentation and manure management, as well as nitrous oxide (N_2O) emissions from manure management were produced. CH_4 emissions from manure management are those produced during storage and treatment of manure as well as from manure deposited on pasture, while N_2O emissions are produced, directly or indirectly, during storage and treatment of manure (solid and liquid). Since EX-ACT adopts a Tier 1 approach, only animal population data, together with the mean annual temperature, are needed to estimate the relative emissions. Default values for CH_4 emissions from enteric fermentation and manure management used in EX-ACT computations are shown in Table 6 together with the N excretion rates adopted to compute N_2O emissions from manure management. The mean annual temperature chosen at the beginning of the analysis for SC Rural is a critical parameter here as it affects both enteric fermentation and manure management and relative emissions.

Table 7
Reduction of CH_4 emissions consequent to the adoption of additional technical practices in South America used in EX-ACT.

Livestock category	Feeding practices	Specific dietary agents	Management breeding
	% reduction CH_4 emissions		
Dairy cattle	6.0	3.0	2.0
Other cattle	3.0	2.0	3.0
Sheep	2.0	0.1	0.2

The project is also implementing specific feeding practices for cattle and sheep, together with improved breeding management, which may contribute to reduce GHG emissions. Smith et al. (2007) showed that use of higher level of concentrates may increase CH_4 emissions per animal, but also increase productivity (meat and milk), thus resulting in an overall reduction of CH_4 emissions per unit of product (Table 7).

It is estimated that SC Rural will have an additional technical mitigation potential consequent to the adoption of such practices as shown in Table 8.

Overall, SC Rural activities related to livestock production represents a net C source of 0.28 Mt CO_2e over 20 years.

Impact of technical assistance and training activities

It is interesting to mention that the analysis has also considered the effect on GHG emissions of project activities aimed at providing technical assistance, training and extension services. In the Rio Rural case study, project implementation is expected to intensify the work of the 400 technicians currently operating in the 59 municipalities and 270 micro-watersheds/rural communities which are being targeted by the Project. Therefore, Rio Rural activities are expected to triple total fuel consumption, from 189 m^3 to 630 m^3, resulting in significantly increased GHG emissions. To cope with this expected source of emissions, the Project is expected to increase the use of ethanol as a fuel source, promoting the use of cars equipped with a new technology which uses 100% ethanol as fuel, thus reducing oil consumption and associated emissions: it is estimated that gasoline will emit 2.85 t CO_2e m^{-3} (default value from IPCC) while ethanol will emit only 0.51 t CO_2e m^{-3} (Dias de Oliveira et al., 2005). An alternative and slightly more optimistic value of 0.4265 t CO_2e m^{-3} is used by Macedo et al. (2008): it represents an average of the values found for hydrous and anhydrous production of sugar-cane bio-ethanol in 2005–2006 in Brazil. Nevertheless, the adoption of this alternative coefficient would have not changed significantly the results. Similarly, in the SC Rural study, the expansion of training and extension services is expected to intensify and expand the work of technicians (trainees and extension service staff) currently operating in the area, increasing fuel consumption by 146.16 m^3 yr^{-1}. Current fuel consumption for ongoing extension and training activities in the area amounts to 517 and 172.3 m^3 yr^{-1} of gasoline and ethanol, respectively. By using the same 3:1 ratio of the two fuel types, it is expected that fuel consumption 'with project' will increase slightly to 626.62

Table 6
IPCC default values for methane emissions from enteric fermentation and manure management in S. America used in EX-ACT.

	CH_4 from enteric fermentation	CH_4 from manure management	N excretion rate
	(kg CH_4/head/yr)	(kg CH_4/head/yr)	(kg N/t animal mass/day)
Dairy cattle	63.00	1.00	0.48
Other cattle	56.00	1.00	0.36
Sheep	5.00	0.15	1.17
Swine (market)	1.50	1.00	1.64
Horses	18.00	1.64	0.46
Poultry	0.00	0.02	0.82

Table 8
Adoption of additional technical practices in livestock production in the 'with project' and 'without project' scenarios.

Livestock category	Feeding practices		Management breeding	
	Without project	With project	Without project	With project
	% of population with practices		% of population with practices	
Dairy cattle	30	50	20	40
Other cattle	5	15	20	40
Sheep	5	15	20	40

and 208.84 $m^3\ yr^{-1}$ of gasoline and ethanol, respectively, not significantly increasing the level of GHG emissions. Other projects activities (i.e. support to the implementation of small-scale agro-industry and to the construction of sanitary installation, ecological corridors and land rehabilitation) have minor mitigation potential or represent a small source of GHG emissions. Therefore, although they have been considered in the analysis, they are not discussed here.

Scenario analysis

An analysis of alternative scenarios has been carried out to deal with the uncertainty of data used. Two different scenarios are built, one more "pessimistic" and one more "optimistic" with respect to the main scenario outlined above, considering a change in the rate of adoption of practices promoted by the projects.

With respect to SC Rural's main scenario, the "pessimistic" scenario considered: a 30% decrease of the cropland area which will be managed with SLM practices; a 50% reduction of the grassland area by introduction of improved grassland management options; a reduction in the percentage of livestock population by additional technical practices (i.e. feeding and management-breeding). Also, a 20% increase in fuel consumption (both diesel and gasoline) and a 30% increase in electricity consumption is hypothesized. The results show that the mitigation potential of SC Rural in the "pessimistic scenario" will be equal to 10.0 Mt CO_2e, corresponding to a 17% reduction with respect to the main scenario.

The "pessimistic" scenario built for Rio Rural considered that the rate of adoption of the agricultural practices proposed by project activities among farmers could be lower than 100% (as implicitly assumed in the main scenario), mainly because of the extra investment needed in terms of capital and labor, as well as a certain farmer's resistance to change current practices (a cultural factor). However, previous experiences in south Brazil have shown that spontaneous adoption of improved practices may occur in non-project targeted areas (World Bank, 2000). Therefore, in the "pessimistic" scenario, it is assumed that the adoption rate of some of the practices with more capital and labor requirements is 50%. Results show that Rio Rural mitigation potential in the "pessimistic scenario" will be equal to 0.52 Mt CO_2e, corresponding to a 39% reduction with respect to the main scenario.

The "optimistic" scenario for SC Rural is built by assuming that the adoption rate of the activities promoted by farmers will be faster than expected. While in the main scenario it is prudentially assumed that the adoption dynamic will be linear, in the optimistic scenario it is assumed as exponential for most project activities, i.e. management of grasslands and annual crops, expansion of perennial crops, fencing of riparian areas, expansion of agro-forestry systems, creation of ecological corridors and land rehabilitation. In this scenario it is also assumed that the impact on GHG emissions from production, transportation and storage of agricultural chemicals will be lower than in the main scenario. Default values used to estimate this impact are extremely uncertain and correspond to world averages, considering that in most cases the production of agricultural inputs is realized outside the country of the project with high levels of emissions due to transportation. This is certainly true for most developing countries. Nevertheless, in the case of Brazil, it is plausible to assume that project developers could organize the procurement of agro-chemicals on a national basis, thus avoiding the purchase of inputs produced abroad. Therefore, in the "optimistic" scenario, a specific factor corresponding to the lower limit in the range provided by Lal (2004) is used instead of the EX-ACT default that corresponds to the central values of the same range, with a reduction of 61% in GHG emissions from production, transportation and storage of agricultural chemicals. Results show that SC Rural mitigation potential in the "optimistic scenario" will be equal to 14.2 Mt CO_2e, corresponding to a 16% increase with respect to the main scenario.

Lastly, the "optimistic" scenario for Rio Rural was built by taking into account that project activities also include rehabilitating rural roads in many areas. This activity was not considered in the main scenario because of lack of precise data. Otherwise, it is expected that recovering and maintaining 1300 km of rural roads will produce socio-economic benefits in terms of reduced transportation costs and increased people mobility, but it may also have environmental benefits as an overall reduction of GHG emissions in the long run: road rehabilitation will temporarily increase fuel consumption as a result of the construction work, but in the end it will reduce erosion and GHG emissions from soil degradation. Also, roads in better conditions will lower fuel consumption and relative GHG emissions. In the same scenario, it is also assumed that the expansion of improved feeding practices in livestock production will be higher than expected (50% of heads with practices instead of 20% as hypothesized in the main scenario), therefore the additional technical mitigation of this activity will be higher. Results show that Rio Rural mitigation potential in the "optimistic scenario" will be equal to 1.02 Mt CO_2e, corresponding to a 20% increase with respect to the main scenario.

Based on the results for the "pessimistic" and "optimistic" scenarios, the sensitivity analysis is completed with the identification of a "most likely" scenario, computed as the average of the results obtained under the "optimistic" and "pessimistic" scenarios. It is estimated that SC Rural will "most likely" be able to mitigate 12.1 Mt CO_2e (Fig. 6), while Rio Rural will "most likely" be able to mitigate 0.77 Mt CO_2e (Fig. 7).

It is interesting to note that the values in the "most likely" scenarios are similar to what has been estimated in the main scenario,

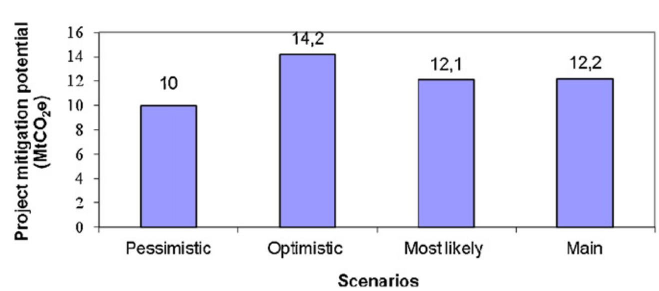

Fig. 6. Sensitivity analysis for SC Rural.

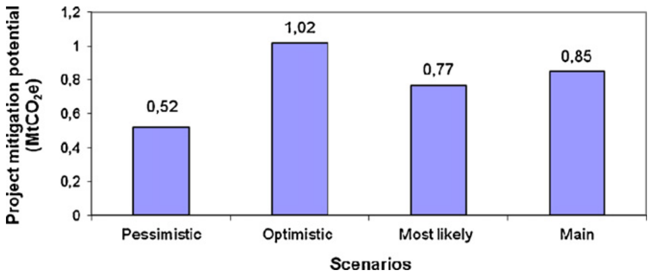

Fig. 7. Sensitivity analysis for Rio Rural.

showing the robustness of the results obtained by applying the EX-ACT methodology to the case studies presented here.

Economic analysis: opportunities for co-financing from the carbon sector

Previous sections have shown that EX-ACT can be used to estimate the mitigation potential of rural development projects. Such estimates would be of great relevance for building approaches to crediting GHG emissions reductions and providing a basis for receiving public or private financing from the C sector. Given the magnitude of investment requirements needed to achieve sustainable agricultural systems in the wake of years of declining investment and neglect, accessing climate finance to support sectoral development is quite important. Mitigation financing for agriculture could potentially be from public or market-based sources and integrated with existing official development assistance (ODA). However, a major barrier to accessing mitigation finance for the sector is related to transaction costs associated with: methodology development, feasibility assessment, legal agreements, and measuring, reporting and verification (MRV). Such costs vary by the type of financing source as well as the institutional capacity already existing in country (FAO, 2009).

It is possible to classify agricultural development projects in terms of their mitigation crediting potential according to the four following types: (i) type 0 – no mitigation potential; (ii) type 1 – low mitigation potential; (iii) type 2 – medium mitigation potential; and (iv) type 3 – high mitigation potential (Branca et al., 2010): type 0 projects have no mitigation potential (e.g. they are a net source of GHG emissions) and they are not taken into consideration here as they cannot benefit from any additional financing from the C sector. On the contrary, type 1 to type 3 projects exhibit positive mitigation potential since the activities implemented result in an increase in biomass above and below ground and/or soil organic C, albeit with varying intensities (Fig. 8).

Type 1 projects have low mitigation potential and, where mitigation benefits are insufficient to support costs associated with crediting, agricultural development investment funds and ODA are likely to be the most appropriate source of funds. For type 2 projects, the mitigation benefits are higher thus capable of supporting low cost MRV crediting approaches. In these cases, public-sector finance for mitigation – either international or national – could be a possible option which could function as an “add-on” to agricultural investment projects with financing from other sources. It would be the case, for example, of a project aimed at implementing agricultural practices which improve agricultural productivity and resilience, thus contributing to food security in developing countries, but also generating mitigation co-benefits. Type 3 projects have significant mitigation benefits that could support relatively high MRV costs for crediting. In fact, enabling smallholders to access carbon finance requires adoption of MRV standards to demonstrate that carbon credits are real, additional, quantified and monitored, and have been independently verified. In these cases, considering the potential of accessing higher value, private-sector mitigation financing sources may be an option. This type of project may be designed and developed primarily for the mitigation benefit – but with significant agricultural and food security co-benefits.

Methodology development and other transaction costs to access mitigation finance can vary substantially, depending on the level of novelty and complexity of the project. Elements that lower development costs include: existence of validated methodologies that can serve as precedent or template, availability of baseline data, and demonstrated mitigation and sequestration technical packages. The presence of effective institutions among project participants, which can support monitoring activities as well as manage carbon revenues, will further lower transaction costs (Lipper et al., 2011). It is not easy to estimate such transaction costs given the wide variation in circumstances and the general lack of information available. However, for the purpose of this paper, it is assumed that the transaction costs for publically funded mitigation actions are equal to US\$4/t CO_2e ha^{-1} yr^{-1}, which is an arbitrary but plausible value based on some literature available (Cacho et al., 2005; Lipper et al., 2010; Mooney et al., 2004). Transaction costs for selling C credits on the market will obviously be higher, given the number and type of requirements, apart from implementation of project activities, e.g. feasibility assessment and project idea note preparation, project design document development, methodology development and approval, validation and registration, MRV and certification (Cacho and Lipper, 2006; Lipper et al., 2011).

Using this categorization of projects, both SC Rural and Rio Rural can be classified as type 1 projects without any feasible option of being financed on the C sector. SC Rural’s average mitigation potential amounts to 0.92 t CO_2e ha^{-1} yr^{-1}. Using a relatively low price of

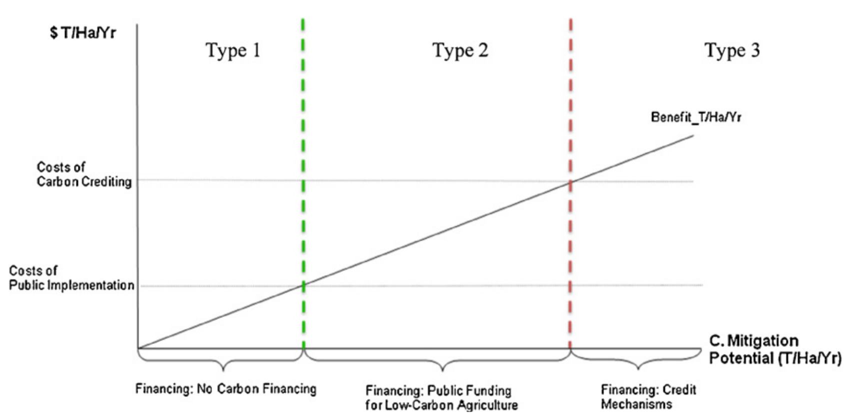

Fig. 8. Financing options for agriculture development and mitigation projects.

Adapted from FAO (2009).

US$3 per t CO_2e, which was the average C price for agricultural soil C at retail level on the voluntary C market in 2008 (Hamilton et al., 2009), the average mitigation value of the project will amount to US$2.76 per t CO_2e (per ha and per year), which is below the level of transaction costs for public implementation (US$4 per t CO_2e). Similarly, Rio Rural's average mitigation potential will be equal to 0.19 t CO_2e ha^{-1} yr^{-1}, i.e. US$0.57 per t CO_2e (per ha and per year), well below the level of transaction costs for public implementation.

However, it is interesting to note that a relatively limited change in the design of SC Rural could slightly increase its mitigation potential and expand C financing opportunities. For example, mitigation potential of the project in the "optimistic scenario" is equal to 1.1 t CO_2e ha^{-1} yr^{-1}. Clearly, if the project is designed with explicit multiple objectives and specific mitigation activities, and if the corresponding mitigation potential value exceeds the level of transaction costs for public implementation, the project could then potentially be considered for public financing for low-carbon agriculture. This being the case, since SC Rural's annual mitigation potential would be equal to 0.6 Mt CO_2e, mitigation benefits would be worth US$1.8 million yr^{-1} at the price of US$3 per t CO_2e. Given that total average project cost is US$31.5 million yr^{-1}, public C finance would therefore potentially cover about 6% of these costs.

Conclusions

The analysis has shown that both SC Rural and Rio Rural will be successful at promoting activities aimed at reducing rural poverty while contributing to climate change mitigation. The two projects entail agricultural intensification and increased productivity, expected to reduce pressure over the native Atlantic Forest. The projects are being implemented in states where past agricultural policies have encouraged agricultural expansion, thus the loss of original vegetation cover, and unmanaged occupation of land has resulted in millions of ha of impoverished soil.

The use of the EX-ACT tool produced estimates indicating that both projects will have positive mitigation benefits: Rio Rural is characterized by an average mitigation potential of 0.19 t CO_2e ha^{-1} yr^{-1} while SC Rural can mitigate 0.92 t CO_2e ha^{-1} yr^{-1}. These results correspond to the type of intervention financed by the projects and the corresponding changes in land use: Rio Rural is concerned more with management of productive systems, while SC Rural has a wider spectrum of actions with relatively greater weight on activities aimed at conserving forest resources and biodiversity, rehabilitating degraded land and expanding agro-forestry systems. Nevertheless, Rio Rural could expand support to enhance landholders' capacity to comply with Brazilian laws governing LRs and APPs – which are among the activities which contribute most to determining SC Rural's mitigation potential. For historical reasons, most agricultural properties in the State of Rio de Janeiro, as in most regions across the country, are currently not complying with the legislation which requires maintaining forest cover in sensitive areas (riversides, high slopes) as well as in a percentage of agricultural properties total area.

The EX-ACT methodology can be effective for providing guidance during project design – to assist project developers in refining project activities so as to increase the environmental benefits of the project itself – and providing a basis for assessing the potential and appropriate approach for possible crediting for mitigation finance. This initial analysis could be extended either during project implementation or through additional financing and future loans. Both projects could benefit from future applications of EX-ACT at local/micro-catchment level, where a more detailed data set will likely be available as a result of the comprehensive diagnostic and planning approach adopted. Also, since EX-ACT is a specific tool aimed at estimating the mitigation potential of project activities, it could be used together with other tools or methodologies adopted to assess a wider range of environmental services linked to agricultural production and farming systems development.

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