UNIVERSIDAD AUTÓNOMA DE SAN LUIS POTOSÍ
FACULTADES DE CIENCIAS QUÍMICAS, INGENIERÍA Y MEDICINA
PROGRAMAS MULTIDISCIPLINARIOS DE POSGRADO EN CIENCIAS AMBIENTALES
AND
TH KÖLN - UNIVERSITY OF APPLIED SCIENCES
INSTITUTE FOR TECHNOLOGY AND RESOURCES MANAGEMENT IN THE TROPICS AND SUBTROPICS

PAYMENT FOR ECOSYSTEM SERVICES IN DEGRADED LANDSCAPES IN RURAL RIO DE JANEIRO, BRAZIL.

THESIS TO OBTAIN THE DEGREE OF
MAESTRÍA EN CIENCIAS AMBIENTALES
DEGREE AWARDED BY UNIVERSIDAD AUTÓNOMA DE SAN LUIS POTOSÍ
AND
MASTER OF SCIENCE
NATURAL RESOURCES MANAGEMENT AND DEVELOPMENT
DEGREE AWARDED BY TH KÖLN – UNIVERSITY OF APPLIED SCIENCES

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Abstract

Coffee is the second most traded commodity after oil. Since the 18th century, the increasing demand for this product has crated enormous incentives to produce more coffee by intensifying the method of production, or by establishing new farmland. In tropical countries like Brazil, this action often involves the removal of forest vegetation in order for it to be replaced by coffee crops. This study explores the possibility of implementing a PES scheme in the coffee-growing region of Rio de Janeiro in order to push towards a more sustainable method of coffee production. Questionnaires were developed to determine the farmer's ability to participate, the ecosystem service that is more likely to be traded and to determine the target payment for which landowners would adhere to such a scheme. Based on a sample of 26 interviews, it was found that the majority of farmers considered that improving water quality by desisting on the use of chemical fertilizers would be their best option, making the ecosystem service of water quality the most likely to be commercialized. Most of the farmers stated that they would like to participate in a PES scheme, and the ability to participate could be as high as 96.1 %, being land tenure the major limiting factor for participation. Finally, the average remuneration for which they agreed to join a PES scheme was R$ 1,090.91/ha/year. These results suggest that there is a clear positive response to implement a PES scheme in this region. Expert interviews were also conducted, and one carried out with a plausible service buyer showed the differences of appreciation and monetization for conservation activities. This suggests that there is a clear positive response towards implementing a PES scheme in the region.

Resumen

El café es el segundo producto más comercializado después del petróleo. Desde el siglo 18, la creciente demanda de este producto ha proporcionado enormes incentivos para incrementar la producción de café, ya sea intensificando el método de producción con varias entradas, o mediante el establecimiento de nuevas tierras de cultivo, que en los países tropicales como Brasil, a menudo implica la remoción de cobertura forestal para que su lugar sea ocupado por cultivos de café. Este estudio explora la posibilidad de implementar un esquema de PSA en la región cafetalera de Río de Janeiro con el fin de direccionar la producción de café hacia un método más sustentable. Se desarrollaron cuestionarios para determinar la capacidad de participar en un esquema de PSA por parte del agricultor, para determinar el servicio ambiental que es más probable que sea comercializado y para determinar el pago por el cual los productores podrían adherirse a dicho esquema. Después de haber evaluado una muestra de 26 productores, se encontró que la mayoría de los agricultores considera que el servicio ambiental que preferirían comercializar es la mejora de la calidad del agua, y esta será mejorada disminuyendo el uso de fertilizantes químicos en los cafetales. La mayor parte de los agricultores afirmaron que les gustaría participar en un programa de PSA, la capacidad de participación de los productores podría ser tan alta como el 96,1%, siendo el principal factor limitante para la participación la acreditación de propiedad de la tierra. Por último, se encontró que el pago promedio por el cual los productores desean unirse un esquema de PSA es de R$ 1.090,91/ha/año. Una reunión con un posible comprador de servicios ambientales, evidenció las diferencias de apreciación y monetización de las actividades de conservación propuestas. Todo lo anterior, sugiere que hay una clara respuesta positiva hacia la implementación de un esquema de PSA en la región.

Payment for ecosystem services in degraded landscapes in rural Rio de Janeiro, Brazil.

1 Introduction

According to the Millennium Ecosystem Assessment (2005), over the past few decades, humans societies have changed ecosystems more rapidly and extensively than in any comparable period of time in human history, largely to meet rapidly growing demands for food, fresh water, timber, fiber, and fuel. This has resulted in a substantial and largely irreversible loss in the diversity of life on Earth. This can be shown in the fact that more land was converted to cropland in the 30 years after 1950 than in the 150 years between 1700 and 1850.

Between 1960 and 2000, the demand for ecosystem services grew significantly as world population doubled to 6 billion people and the global economy increased more than six fold. To meet this demand, food production increased by roughly two-and-a half times, water use doubled, wood harvests for pulp and paper production tripled, installed hydropower capacity doubled, and timber production increased by more than half. The changes that have been made to ecosystems have contributed to substantial net gains in human well-being and economic development, but these gains have been achieved at growing costs in the form of the degradation of many ecosystem services, increased risks of nonlinear changes, and the exacerbation of poverty for some groups of people. These problems, unless addressed, will substantially diminish the benefits that future generations obtain from ecosystems (Millennium Ecosystem Assessment, 2005).

Latin America has the planet's largest land portions destined reserves for agriculture and had the most rapid agricultural expansion during the twenty-first century, and a large portion of the expansion has replaced forests (Graesser, Mitchell, Grau, & Ramankutty, 2015). This cropland expansion could have resulted from intensified use of land previously cleared for cattle ranching or new deforestation, the latter has major implications for future biodiversity, carbon fluxes, forest fragmentation, and other associated ecosystem services (Morton, et al., 2006).

Thus, while Latin America can play a key role in future global and regional food security (Zeigler & Truitt, 2014), further agricultural expansion could have substantial environmental impacts, particularly on biodiversity (Wright, 2010) and carbon emissions.

In Latin America, at the national level, the greatest increases (as a percentage) in harvested area during the 2001–2011 period occurred in Argentina, Bolivia, Brazil, Guatemala, Paraguay, and Uruguay, and the greatest decreases in Colombia, Cuba, and Mexico (FAOSTAT, 2015).

Coffee is the most valuable and widely traded tropical agricultural product (FAIRTRADE, 2012) According to the International Coffee Organization (ICO), the size of the retail market for coffee was over $70 billion in sales per year. An estimated 17 to 20 million families in more than 50 developing countries produced and sold coffee. Global consumption has almost doubled in the last 40 years and is forecast to reach 9.09 million tons by 2019 (FAIRTRADE, 2012).

Brazil is by far the world's largest coffee producer, followed by Vietnam, Colombia, Indonesia, Ethiopia, India, Mexico, Guatemala, Honduras, Peru, and Uganda (ICO, 2014).

2 Ecosystem services and coffee

2.1 Ecosystem services

Mankind depends completely on Earth's ecosystems and the services they provide. To fully comprehend the concept of ecosystem services, it is necessary to take the concept apart and understand individually each of its components, so: an ecosystem as defined by Odum (1972) is a unit including all the organisms (community) in a given area, acting in reciprocity with the physical environment so that a flow of energy leads to trophic structure, biotic diversity and biogeochemical cycles. A service is defined as "the action of helping or doing work for someone"; so, by joining this two concepts together it can be stated that ecosystems provide humans by supplying and maintaining a system that would be unobtainable or very hard to do so in any other way.

Merely from the perspective of human life, ecosystems provide a continuous flow of goods and services necessaries for to maintain life, economic resources and other aspects of human welfare. In a broad sense, ecosystem services refer to the set of conditions and processes through which natural ecosystems and the species they harbor contribute to sustain human existence (Penna & Cristeche, 2008). In addition to providing tangible or intangible benefits for human societies, the majority of environmental services share another characteristic: they are positive externalities, providing a net benefit to society whose value is not reflected in the cost of the direct products and services affected (Polasky, 2012).

The Millennium Ecosystem Assessment (2005), classifies ecosystem services in four different categories:

- Provisioning services: These refer to the products that are obtained directly from ecosystems like: food, fiber, medicinal plants, fuel, fresh water and ornaments.

- Regulatory services: These are the benefits obtained from the regulation of ecosystem processes including: air quality regulation, climate regulation, erosion regulation, water regulation and purification, disease regulation, pest regulation and pollination.

- Cultural services: These are the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences.

- Supporting services: Those that are necessary for the production of all other ecosystem services. They differ from provisioning, regulating, and cultural services in that their impacts on people are often indirect or occur over a very long time. Examples of such services are: soil formation, photosynthesis, nutrient and water cycling.

The intervention in ecosystems by human societies to meet their needs, however, has modified the composition, structure and functions of them and has caused detrimental changes that threaten the long-term sustainability of societies around the world. The demand for ecosystem services is now so great that tradeoffs among services have become the rule. A country can increase food supply by converting a forest to agriculture, for example, but in so doing it decreases the supply of services that may be of equal or greater importance, such as clean water, timber, landscape beauty, or flood regulation and drought control. The problem posed by the growing demand for ecosystem services is compounded by increasingly serious degradation in the capability of ecosystems to provide these services (Millennium Ecosystem Assessment, 2005; Joly, 2014).

2.1.1 Payment for ecosystem services

Economic and financial interventions provide powerful instruments to regulate the use of ecosystem goods and services. Because many ecosystem services are not traded in markets, markets fail to provide appropriate signals that might otherwise contribute to the efficient allocation and sustainable use of the services. A wide range of opportunities exists to influence human behavior to address this challenge in the form of economic and financial instruments. However, market mechanisms and most economic instruments can only work effectively if supporting institutions are in place, and thus there is a need to build institutional capacity to enable more widespread use of these mechanisms (Millennium Ecosystem Assessment, 2005).

One option of a financial incentive for ES maintenance is Payment for Ecosystem Services (PES), which consists on someone's opportunity costs associated with reducing their environmental impacts or with leaving an ecosystem undisturbed, should be compensated through cash transfers or other means provided by someone else, who prefers to improve or maintain the conditions of such area.

The principle carries with it the implicit proposition that the commodification and commercialization of the management of such area is both appropriate and desirable. In the process, the inherently contested nature of the practice of conservation by determining what should be conserved and how, is subsumed within the purportedly value-neutral language of economic transactions (Farrell & Vatn, 2004). The payment must desirably be more than the additional benefit to land users of the alternative land use because it is thought that otherwise, they would not change their current activities, and, at the same time, it should be less than the value of the benefit to downstream populations or else they would not be willing to pay for it (Pagiola, Arcenas, & Platais, 2005).

Payment for ecosystem services is based on the assumption that the ecosystem degradation is a result of the conventional markets failure to internalize the environmental service economic value (Corbera, Soberanis, & Brown, 2009). A PES is defined as [1] a voluntary negotiated agreement, [2] where a well-defined environmental service, [3] is bought by at least one buyer, [4] to at least one environmental service supplier, [5] if, and only if, the provider continues to supply such service (Wunder, 2005).

As mentioned above, participation in PES programs is voluntary, and suppliers of the ecosystem service receive payments for doing so. This implies that suppliers are at least no worse off than they would be without the PES program and, if this was not the case, they could simply decline to participate. Therefore, many have concluded from this that the impact of such schemes can only be positive. Given the environmental and socio-economic benefits that PES provides to local communities it is vital to encourage the adoption of such systems (Pagiola, Arcenas, & Platais, 2005).

Land users can provide a variety of environmental services ranging from the regulation of hydrological flows, and carbon sequestration to spiritual and recreational activities. Nevertheless, land uses that provide such services, such as forests, are being lost at rapid rates (FAO, 2006). An important reason for this loss is that land users typically receive no compensation for the environmental services they generate for others and as a result, they have little incentive to provide these services (Pagiola, Arcenas, & Platais, 2005), so land users must find an alternative source of income, which most of the times involves disturbing the land that provides such services.

However, some case studies in Latin America showed that social values beyond financial payments induced participation in PES (Kosoy, et al., 2007). Therefore, a potential combination of the two concepts of equity and efficiency may be possible (Pascual, et al., 2010). Consequently, there is a clear need to adjust and incorporate the context and perspective of local stakeholders (Adhikari & Boag, 2013; van Noordwijk, et al., 2013); this is particularly true when PES schemes are applied in the context of developing countries with skewed wealth distribution, contested property rights, low law enforcement and weak institutions (Neef & Thomas, 2009). Moreover, in the perspective of developing countries, the inclusion of poverty-alleviation, rural empowerment and social justice might be considered when a PES scheme is designed for areas with historical imbalances in the power, right and wealth status between ES suppliers and beneficiaries (Swallow, et al., 2009).

Currently in Brazil, there is a growing trend of proposing PES schemes to address environmental and social issues. Even though PES schemes are a rather new policy tool in Brazil (the concept was relatively unknown in the country until the early 2000's) since then, the country has been experiencing a "PES boom". A recent report has revealed the existence of more than 70 independent projects using PES schemes as the main instrument of intervention. Most of these schemes are related to the field of water resources protection and carbon-related payments and have been introduced in the center and south areas of the country (Guedes & Seehusen, 2012).

Unlike in Costa Rica or Mexico where PES schemes are driven by federal governments (Le Coq et al., 2012; Corbera et al., 2009), in Brazil PES were initiated by NGOs and local governments, making room for considerable experimentation and leading to a diversity of experiences across the country (Pagiola et al., 2012; Guedes & Seehusen, 2011 cited by Coudel, et al., 2015).

In Brazil, specifically in Rio de Janeiro, in recent years, after some discussions between government and key actors, the necessity for the creation of the State Policy of Environmental Services and the State Program of Payment for Environmental Services became clear. This resulted in established forms of control and funding of ES activities, as well as the Green Economy Plan of the State of Rio de Janeiro and the Pact of the Atlantic Forest Restoration. With such actions, it is expected that the farmers will increasingly adopt practices such as reforestation, spring protection, recovery of riparian vegetation and protection of water recharge areas, sanitation, road rehabilitation, green and organic manure, among other actions with direct impact on natural resources (FAO, 2013).

2.2 Coffee

The coffee tree belongs to the Rubiaceae family, genus *Coffea* is widespread throughout the tropics with more than 120 species (The Plant List, 2013). All cultivated species originated in Africa. Today, only two of them possess an economic importance, *Coffea arabica*, also known as Arabica coffee, is responsible for approximately 64 % of the world production, and *C. canephora* (*C. robusta*), also known as Robusta coffee, for 35 %, the remaining 1 % belongs to the other species of coffee (Jürgen & Jannsens, 2011). Arabica and Robusta coffees are different in many ways, including their ideal growing climates, physical aspects, chemical composition, and characteristics of the brew made with the grounded roasted seeds (Bicho-Cavaco, et al., 2011). Coffee is among the most important agricultural commodities on the world market: it is cultivated worldwide on approximately 10.3 million hectares and represent the sole economic income for more than 25 million families. The crop is produced and exported by more than 60 nation and ranks as one of the top cash crops in developing countries (Jürgen & Jannsens, 2011).

Coffee has been for decades the most commercialized food product and most widely consumed beverage in the world besides water. Since the opening of the first coffee house in Mecca at the end of the 15th century, coffee consumption has greatly increased all around the world (Farah, 2012). It was introduced to the New World in the early 18th century and coffee cultivation expanded throughout Latin America after countries in the region gained independence from Spanish and Portuguese rule in the 1820s and 1830s, respectively (Pendergrast, 1999).

The global market classifies coffee into four main categories according to their origin: Brazilian Naturals, Colombian Milds, Other Milds and Robustas. The Brazilian Naturals coffees come mainly from Brazil, Ethiopia and Paraguay. The Colombian mild coffees come from Colombia, Kenya and Tanzania. Other milds are produced in Bolivia, Burundi, Costa Rica, Cuba, El Salvador, Ecuador, Guatemala, Haiti, Honduras, India, Jamaica, México, Nicaragua, Panamá, Papua New Guinea, Peru, Dominican Republic, Rwanda, Venezuela, Zambia and Zimbabwe. Finally, the Robustas are produces in Angola, Republic of the Congo, Philippines, Ghana, Guineam Indonesia, Liberia, Carmeroon, Ivory Coast, Equatorial Guinea, Uganda and Vietnam. (Bicho-Cavaco, et al., 2011).

It is common that after the harvesting process, the coffee is stored in bags with a capacity to hold 60 kg, therefore, a coffee bag is a widely spread measure unit within the coffee industry.

South America is the world's leading coffee producing region with an annual production averaging 52.5 million bags (each of 60 kg) since 1991, a level representing 46.6% of the total. Average production was 36 million bags during the period 1964 to 1990, accounting for 47.2% of the world's total production. For crop year 2013 total production in the region is estimated at 67.6 million bags compared to 42.8 million bags in 1990. Total production in the region follows a regular biennial cycle of increases and decreases over successive crop years, except in a few cases of increases over successive years, particularly from 1990 to 1993 (ICO, 2014).

This pattern in the region's total production is largely attributable to the cyclic pattern of Brazilian production. Brazil produce an annual average of 35.7 million bags for the period 1991 to 2013 compared to 22.6 million bags for 1964 to 1990. Despite the pattern of Brazilian production from year to year, it has increased substantially over the last 50 years, from 23.2 million bags in 1964 to 50.8 million bags in 2013. Production for crop year 1990 was 24.5 million bags. Apart from the biennial cycle characterizing its Arabica production, the marked volatility of Brazilian production is attributable mainly to the impact of climate-related phenomena like frosts and droughts (ICO, 2014)

Within this region, coffee is notable not only for its economic and social importance but also for its variety of growing systems. These various management types can be ordered along a gradient of increasing intensification (Moguel & Toledo, 1999). As intensification increases in coffee systems, the diversity and complexity of tree cover decrease, and coffee plant density rises. Depending on a variety of factors such as: local climate, coffee variety, and use of chemical inputs, it is also important to notice that yield may also increase with intensification (Soto-Pinto, Perfecto, & Castillo-Hernandez, 2000; Perfecto, Vandermeer, Mas, & Pinto, 2005).

It has been discoursed that diversified agricultural systems are more effective in supporting ecosystem services and minimizing disservices (Kremen & Miles, 2012); however, low-diversity and high-intensity conventional systems have become the norm throughout the world, a possible reason for this could be that intensive systems generally do produce more coffee per hectare; however, it is unclear whether these increases result from increased planting densities, use of sun-tolerant varieties, or other aspects of management like a higher chemical and labor inputs (Jha, et al., 2011).

Brazil's Arabica production is forecast to jump to 7.8 million bags to a record 43.9 million as yields improve. Good blossoming between September and November 2015 was followed by ideal weather during the fruit-set and fruit development period in Minas Gerais and Sao Paulo, two regions that account for about 80% of the national production (USDA, 2016).

Different coffee production systems vary not only in inputs like labor and agrochemicals, but also in their conservation value and their provision of ecosystem services. The maintenance of biodiversity is one of the most extensively studied ecosystem services provided by shaded coffee plantations (Perfecto, et al., 1996; Moguel & Toledo, 1999; Donald, 2004; Philpott, Arendt, & Armbrecht, 2008).

Intensified coffee systems may include some shade, but the height and shade cover is greatly reduced and shade trees themselves may be a near monoculture of fast-growing trees. In Latin America, these are commonly native nitrogen-fixing species, from the Leguminosae family, for example: *Inga* spp. and *Erythrina* spp., although exotic species like *Grevillea robusta* (Proteaceae family) have been observed (Perfecto, et al., 1996). These trees may be subject to substantial pollarding and removal of epiphytes to decrease shade cover.

Un-shaded or sun coffee, as is commonly known, is the most intensive coffee production method; it gets its name because the shade layer is eliminated altogether, with dense plantings of high-yield coffee. Intensive systems like this, generally do produce more coffee per hectare; however, it is unclear whether these increases result from increased planting densities, use of sun-tolerant varieties, or other aspects of management like chemical and labor inputs low or no-shade systems generally require (Jha, et al., 2011). This coffee production system is widely spread throughout Brazil, and it is the most used in the coffee-growing region of Rio de Janeiro.

Permanent, intensive cropping systems like sun coffee are frequently driven by short-term profit incentives and where capital is available; this is usually accompanied by the addition of fertilizers, pesticides, and herbicides. These short-term gains can be seriously eroded by a gradual decline in crop yields induced by increasing soil acidity, pesticide and herbicide-resistant weeds. However in many tropical countries, like Brazil, the widespread and often uncontrolled removal of land cover continues to deplete soil reserves leading to a significant reduction in environmental services and water quality, and often with a dramatic loss in biological diversity (Gillison, et al., 2004).

Agricultural expansion will continue to be one of the major drivers for the loss of biodiversity and other ecosystem services for many years to come. In order to significantly lessen pressure on ecosystem services it is imperative to promote the development, assessment, and diffusion of technologies that could increase the production of food per unit area sustainably without harmful trade-offs related to excessive consumption of water or use of nutrients or pesticides (Millennium Ecosystem Assessment, 2005).

Due to the attractive economic incentives to produce coffee, it is common to clear lands and for farmers to expand their coffee plantations thus modifying the ecosystem and the services it provides. Bearing in mind the environmental problems that intensive agriculture systems cause, it is imperative to propose a plausible alternative that contributes by minimizing such environmental impacts, while still allowing primary production and economic development to take place in the region.

Therefore, the objectives of this thesis are:

3 OBJECTIVES

3.1 General objective

To determine as a pre-feasibility study, the likelihood of implementing a PES scheme in the coffee growing region of Rio de Janeiro in order to push towards a more sustainable method of coffee production.

3.2 Particular objectives

- To determine an available local ES with a high likelihood to be commercialized.
- To determine the landowner's ability to participate in a PES scheme.
- To determine the target payment for which landowners would subscribe to a PES scheme.

4 Study area

4.1 Rio de Janeiro State

This study was developed within the state of Rio de Janeiro, which is located within the Brazilian geopolitical region, classified as the Southeast. Rio de Janeiro shares borders with all the other states in the same Southeast macroregion; at north with Minas Gerais, at the NE with Espírito Santo and at south with São Paulo. It is bounded on the east and south by the Atlantic Ocean. Rio de Janeiro has an area of 43,653 km^2 and a population of 15,989,929 inhabitants (IBGE, 2010).

The state is part of the Mata Atlântica biome and is made up of two distinct morphological areas: a coastal plain, known as baixada, and highlands, which are disposed in parallel fashion from the shoreline on the Atlantic Ocean inland.

Tropical forests used to cover more than 90 % of the territory of Rio, but large portions of it were devastated for urbanization and for plantations mainly of coffee and sugar cane; nowadays preserved forest areas are mostly found in the steepest parts of the mountain chains.

Specifically, the fieldwork was sustained in the municipalities of Varre-Sai and Porciúncula, which are located in the northwest part of Rio de Janeiro State.

Varre-Sai is the farthest away municipality of Rio de Janeiro from its capital, the city of Rio de Janeiro, and it is located 363 km from the center. It has an elevation between 600 and 1,100 m.a.s.l., it occupies an area of 190.06 km^2, with a population of nearly 10,000 habitants in 2015 (IBGE, 2010), and population density of 49.85 persons/km^2. On the other hand, Porciúncula has an area of 291.05 km^2 with a population of more than 18.000 habitants (IBGE, 2010), with a population density of 58.80 persons/km^2. Figure 1 shows the location of these municipalities within the state of Rio de Janeiro.

Figure 1 Study area

The state of Rio de Janeiro has two main geological domains: one of crystalline rocks, which cover about 80 % of its territory, which include all of the North-west region where Varre-Sai and Porciúncula are located, it also has a set of coastal sediments near the Atlantic Ocean (Martins, et al., 2008).

Specifically, the geology of the study area is composed by granite and granitoids (SIAGAS, 2015). In the surface, the area is dominated by regular as well as deformed granitoid complexes, which have been deformed due to natural occurring pressures and movement the plates.

Granite is probably the best known out of all igneous rocks, is a plutonic or intrusive rock in which quartz makes up between 10 and 50 percent of the felsic components and alkali feldspar accounts for 65 to 90 % of the total feldspar content, it is a light-colored igneous rock with grains large enough to be visible with the unaided eye. It forms from the slow crystallization of magma below Earth's surface. Granite is composed mainly of quartz and feldspar with minor amounts of mica, amphiboles, and other minerals. This mineral composition usually gives granite a red, pink, gray, or white color with dark mineral grains visible throughout the rock.

Below this layer, there is a complex composed by granite, gneiss and other granulates. Gneiss usually forms by regional metamorphism at convergent plate boundaries. It is a high-grade metamorphic rock in which mineral grains recrystallized under intense heat and pressure. This alteration increased the size of the mineral grains and segregated them into bands, a transformation which made the rock and its minerals more stable in their metamorphic environment. Although gneiss is not defined by its composition, most specimens have bands of feldspar and quartz grains in an interlocking texture. These bands are usually light in color and alternate with bands of darker-colored minerals with platy or elongate habits. The dark minerals sometimes exhibit an orientation determined by the pressures of metamorphism (Tarbuck & Lutgens, 2005).

4.1.1 Climate

In the study area, according to Köppen & Geiger classification is listed as humid subtropical (Cfa), which means it is a humid temperate climate with hot summer (IBGE, 2016).

In this type of climate the average air temperature of the three coldest months stays between -3 °C and 18 °C, the average temperature of the warmest month is above 10 °C, and it has a well-defined summer and winter resorts. It is also classifies as a humid weather with rainfall occurring in every month of the year (IBGE, 2010).

In the study area, the average mean temperature is 20.0 °C, June is the coldest month with an average temperature or 9.6 °C and February the warmest with 28.9 °C. The mean precipitation is 1296 mm, June is the driest month with 24 mm, and the month of highest rainfall is December with an average of 233 mm (IBGE, 2010).

4.1.2 Hydrology

The Southwest Atlantic hydrographic region has 214.62 km^2, an area equivalent to 2.5 % of the country. Its main rivers are the Paraíba do Sul and the Doce, respectively 1,150 and 853 kilometers long. In addition to these, the Hydrographic Region is also made up of many small to large rivers that form the following basins: St. Matthew, St. Mary, Magi, Benavente, Itabapoana, Itapemirim, Jacu, Ribeira and coasts of Rio de Janeiro and São Paulo. (ANA, 2015)

Around 80 % or the area of Varre-Sai and 40 % of Porciúncula are located in Itabapoana basin, and the rest of the area is comprehended in the Paraíba do Sul basin. The Itabapoana basin has an area of 6,084 km². The headwaters of the river Itabapoana are located in Caparaó National Park, located between the states of Espírito Santo and Minas Gerais. The main tributaries of the river Itabapoana are the St. John River Caparaó that originates in Minas Gerais and the Preto e Veado River, initiate in Sierra Caparaó, Espírito Santo. The drainage basin area is 4,800 km², and its rivers flow directly into the Atlantic Ocean (Wigneron Gimenes, 2005).

Meanwhile the Paraíba do Sul basin occupies an area of approximately 62,074 km², extending from the states of São Paulo, Rio de Janeiro and Minas Gerais, covering 184 municipalities in total. In Rio de Janeiro, this basin covers 63 % of the total area of the state, in São Paulo, 5 % and Minas Gerais, only 4 %. The main tributaries of the Paraíba do Sul river are: Jaguari, Paraibuna, Pirapetinga, Dove and Muriaé, Una, Bananal, Pirai, Piabanha and Dois Rios (CEIVAP, 2015).

Throughout the whole municipality, Varre-Sai possess seven micro-basins, which are: Riberão Varre-Sai, Inverno, Riberão da Onça, Barro Vermelho, Riberão Água Doce, Riberão capoeirão and Córrego Boa Sorte (Rio Rural, 2014).

Equally, the municipality of Porciúncula also has seven micro-basins: Ouro, Bonsucesso, São Mamede, Córrego do Ouro, Córrego Perdição, Caeté and Ribeirão do Onça (Rio Rural, 2014).

4.1.3 Soils

Within the study area different soil types can be identified, and since the main activity in the area is farming, soil is one of the limiting factors, because a balanced contribution of soil nutrients and components is necessary to facilitate crop growth; the soil types present in the area are:

4.1.3.1 Oxisol

This type of soil is usually found in the B horizon, and presents more yellowish colors, due to relatively low contents of Fe_2O_3, normally between 70-110 g/kg (EMBRAPA, 1988). This type of soil can be found in very different climate conditions, from dry areas in northern Rio to mountainous regions with forest vegetation.

4.1.3.2 Cambisol

Cambisols are characterized by the absence of a layer of accumulated clay, humus, soluble salts, or iron and aluminum oxides. They differ from unweathered parent material in their aggregate structure, color, clay content, carbonate content, or other properties that give some evidence of soil-forming processes. They possess a favorable aggregate structure and high content of weatherable minerals, therefore, can be usually exploited for agriculture subject to the limitations of terrain and climate.

4.1.3.3 Podzol (Red-Yellow)

This soil classification comprises mineral soils that are not hydromorphic, with textural B-horizon of color ranging from red to yellow and contents of Fe_2O_3 of less than 150 g/kg. In general they are deep and well drained soils, with sequence horizons A-B-C or A-E-B-C. The horizon A may be of any type except chernozemic, and it has a medium texture class.

4.1.4 Flora and fauna

The Atlantic Forest is present both in the coastal region, the highlands and inside the mountains of Rio Grande do Norte to Rio Grande do Sul, along the Brazilian coast. The central mountain ranges are the "Serra do Mar" and the "Serra da Mantiqueira", covering the states of São Paulo, Minas Gerais, Rio de Janeiro and Espírito Santo (Rizzini, 1997), throughout its length, the Atlantic Forest features a variety of formations, and encompasses a diverse set of forest ecosystems structures and quite different floristic composition.

The Atlantic forest possess a total area of 1.3 million km^2, (Morellato & Haddad, 2000), it once covered the entire state of Rio de Janeiro and 16 other states throughout Brazil, but the biome was so consumed by human occupation, which today remains only about 11 % (Ribeiro, et al., 2009). The dominant vegetation in the study area, is a semi-deciduous forest, where between 20 and 50 % of the trees shed their leaves at some point during the year, some of the most common species are: *Albizia poycephala*, *Bauhinia foficata*, *Caesalpinea echinata* (national Brazilian tree), *Cedrella fisilis*, *Eugenia uniflora* and *Hyminaea coubaril*, among many others.

The fauna of the Atlantic Forest is one of the richest in species diversity and is among the five world regions that have the largest number of endemic species. It is closely related to vegetation, having a great importance in pollinating flowers and dispersing fruit and seeds (Morawetz & Raedig, 2007).

Regarding the mammals species that distribute within the study area there are: *Oligoryzomys nigripes* (Delta Pygmy Rice Rat), *Nectomys squamipes* (South American water rat), *Oxymycterus dasytrichus* (Atlantic Forest Hocicudo), *Alouatta fusca* (Brwon howler monkey), *Callithrix aurita*, *Calomys tener* (Vesper mouse), *Marmosa paraguayanus* (Marmosa paraguayana), and *Abrawayaomys ruschi* (Ruschi's rat).
Birds contribute greatly to the dispersion of seed along great areas, in the area several migratory and non-migratory species can be found, such as: *Tangara cyanomelaena*, *Antilophia bokermanni*, *Pauxi mitu*, and *Crax blumembachi.*
Regarding the reptiles and amphibious, some local species are *Bokermannohyla lange*, *Brachycephalus quiririensisvive*, and *Physalaemus soaresi* (Fundaçao SOS Mata Atlantica, 1996; Eterovick, et al., 2005; Freitas-Lucci, 2014).

4.1.5 Economic Activities

In Varre-Sai, possess a per capita GDP of 12,881.52 $R, the main economic activity is coffee, which accounts for a third of the gross domestic product of the municipality. Possessing about 38.4 % of the coffee plantations of the State of Rio de Janeiro, Varre-Sai stands as the largest coffee producer of the state, producing something close to 200,000 bags/year. The average coffee yield in this municipality is 1,200 kg/ha, and in the 2014 harvest of this plantation, was estimated to have an economic value of R$ 23,500,000. Other important activities are bovine husbandry with approximately 9,400 cows, and rural tourism (IBGE, 2016).

On the other hand, in the municipality of Porciúncula, has a per capita GDP 14.560,98 $R, the average coffee yield is 900 kg/ha, and in the 2014 harvest of this plantation, was estimated to have an economic value of R$ 12,478,000. Bovine husbandry and milk production also play an important role in the economy of this municipality with its nearly 20,000 cows, out of which 8,046 are milk cows, in average, each one of this cows produced 9,535 liters of milk in 2014 (IBGE, 2016).

5 Materials and methods

This work was developed in the northwest region of Rio the Janeiro state in the municipalities of Varre-Sai and Porciúncula, within the context of INTECRAL project, which is an international cooperation agreement between the German Federal Government and Rio de Janeiro state, with an ultimate goal of thriving towards sustainable development in rural areas.

Although Varre-Sai is a very small municipality with few inhabitants, it is the largest coffee producer of Rio de Janeiro state, therefore, it has a great number coffee farmers, in total there are 940 persons registered in this activity (9.5 % of the total population). It is important to mention that a lot of them are not exclusively coffee producers and may have another source of income, for example: husbandry, horticulture, citrus production and various businesses like restaurants and pharmacies. In the municipality of Porciúncula, the situation is rather similar, there are a total of 890 registered coffee producers, (5 % of the total population) in both cases, most of them are small-scale farmers with a few exceptions.

In order to collect the required data about land tenure, methods of production, possible ecosystem services that could be traded, willingness to participate in a scheme, and other relevant information, a topic-specific survey was developed and applied to local coffee farmers during the months of April and May of 2016, in total, 26 interviews were done, 19 in the municipality of Varre-Sai and 7 in Porciúncula.

In addition to the coffee growers survey, and with the intention to obtain different perspectives around the implementation of a PES scheme, some expert interviews were carried out; one was made with a local government interviewee working at EMATER, which is a rural extension service with offices distributed over all of Rio de Janeiro State, this means that it is the direct link between farmers and most government programs and they also provide technical assistance to the farmers when they needed. Another interview was made also with a government employee, but this time it was with Rio Rural, this agency is focuses in the rural sustainable development of Rio de Janeiro's micro basins. One more interview was done with the restaurant "Curto Café" which is focused on selling specialty coffee, and at the time of the interview, held the first place in the ranking for coffee shops in Rio de Janeiro on both Foursquare™ and Tripadvisor™ websites. This interview was done with the intention to obtain knowledge from someone who is in the hospitality/coffee business and who could also take part as a buyer of the ecosystem service in a PES scheme.

5.1 Ecosystem service selection

As described above, the selection of the ecosystem service is a crucial part of the process in order to establish a PES scheme; in order to determine the best option, the following criteria was taken into consideration:

- How marketable is the selected ES?
- Ability to provide the ES from a great part of the interested coffee producers
- Willingness to trade that ES

The first step was to create list of the potential ecosystem services that could be traded in the region, and then in concordance with de Groot, Wilson, & Boumans, (2002) only the ones with the higher market prices remained as further possibilities; in the neighbor states of the study area, Minas Gerais and Espiritu Santo, there are a number of PES schemes that are already on ongoing projects that focus on improving water quality (Zanella, Schleyer, & Speelman, 2014), this shows that the conditions in the surrounding area to implement a PES scheme are already there.

Since it is highly beneficial that the producers of the ES are well motivated and convinced of their actions, the preferences of the producers on the selection of ES were taken into account.

During the interview process, farmers were presented with a list of 12 pre-defined activities that could help to improve an ES and protect biodiversity, which was divided in three major categories: water, soil and biodiversity-related ES; under each individual category a list of four concrete activities that would enhance an ES or biodiversity were shown. Then, each farmer was asked to select the activities that they would be most interested in realizing and of course that would be fitting to their farming process, after each category of activities they were also asked if they could come up with other unlisted-activities that could benefit the ES. In the event where farmers selected more than one activity, they were asked to put a number in decreasing order in every activity they had selected according to their preference to do such activity, being number one their top choice, number two their next favorite and so on until there were no more selected activities. This process gave an unambiguous idea of what the coffee growers consider a priority in their land an which service they are willing to sell.

5.2 PES

According to Pagiola *et al*., (2005), regarding the ES providers, there are three main groups of factors that must be taken into account during the planning phase of every PES scheme, those groups are the eligibility, desirability and the ability factors.

5.2.1 Eligibility factors

This was determined primarily with the location of the service providers, hence they must be located within the study area, or otherwise they will not be able to participate in the program. Since this study is focused on coffee production, another pre-requisite for the landowners to be eligible is for them to be growing coffee in at least part of their property.

5.2.2 Desirability factors (willingness to participate or determination of payment)

The willingness to participate can be translated in the expectation that participation in the scheme will be profitable, it will also focus on determining the payment for which landowners would enter a PES scheme.

After the process of selecting an activity in order to improve an ES, each farmer was asked to determine a quantity that they would consider a fair remuneration ($R/ha/year) in exchange of performing a particular activity that would benefit an ES. In case the farmers selected more than one activity, remuneration for each activity was requested. Farmers could choose from a predetermined list of prices that started in 200, then 300, 400… all the way up to 1000 $R/ha/year. Or, if they felt like this remuneration was too low, they could state any other quantity that would better satisfy their needs.

5.2.3 Ability factor

This factor depends greatly on land tenure, as PES payments are made to particular land uses, it may not be possible to undertake a PES program if tenure is insecure, especially if a long-term investment is required. This could be particularly a problem in rural areas, where traditional land and resource management systems fail owing to population increase and the diminishing of land leading to overuse. Skewed land distribution often compels the poor to survive by cultivating marginal land, leading to soil erosion. Without tenure and often with only passing claims on the land they cultivate, the poor are less likely to make investments to protect natural resources (van Noordwijk, Tomich, & Verbist, 2002). So, every interview was made with the decision maker of the land, and during which it was established if they were owners, if they were subletting, if they were in the process of acquiring land, or any other situation that may arose.

It also depends on the transaction costs such as: contract, negotiating and mapping of the property. In this case, such costs were not taken under consideration on the landowner's side, this under the assumption that the monetary retribution they stated in the previous steps would only cover the costs of the activities necessary to improve the ES, thus any extra cost would have to be negotiated or covered by the buying party, either government or a private enterprise.

6 Results

6.1 Coffee farms

6.1.1 Tenure

Regarding this aspect, it was found that 24 out of the 26 interviewed farmers are the legal owners of the land where they where the coffee growing activities are carried out and hold the proper documents to demonstrate such statement. One farmer is currently renting the area where he grows coffee and, the remaining coffee grower is currently carrying out the process of acquiring the farm; thus he lacks the proper documentation.

Since most of the farmers are the owners of their land, they are in total control of the farming practices that are currently being executed within their properties, this means that they have the decision power to change such activities if they are convinced that an alternative method of production would be more beneficial to them.

6.1.2 Area

Due to the great diversity of purchasing power in the region, coffee farms vary greatly in size. Table 1 presents a summary of basic information about farm size and the area that is destined for coffee growing of all the farms that were considered for this study.

Table 1 Coffee farm characteristics

	Farm area (ha)	Coffee plantation (ha)
Average	29.75	12.55
Std. deviation	33.44	15.51
Minimum	2.20	0.32
Maximum	120.00	72.00
TOTAL	**743.79**	**313.66**

Here it is important to notice that not necessarily the biggest farm possess the biggest coffee plantation, this is due because a lot of farmers have other sources of income besides coffee production, like cattle, sugar cane, citrus fruits, etc., thus the area destined to each activity varies according with the landowner preferences, however as an average, 41.2 % of the farm area is destined to coffee production.

6.1.3 Coffee production

6.1.3.1 Coffee varieties

The most cultivated varieties of coffee in Brazil are: Red and Yellow Catuaí with 45 % of the total area, Mundo Novo e Acaiá with 40 %, and Yellow Bourbon and other varieties with 15 % (Fazuoli, 2012). Regarding coffee production, Table 2 shows the role of the study area within the Brazilian context.

Table 2 Comparison between Brazil's national average and the study area

	Brazil	Study area
Coffee production (bags)	35.7 million	159,250
Yield (bags/ha)	24.43	28.7
Coffee production (%)	100	0.44

Based on data from Instituto Brasileiro de Geografia e Estatística (IBGE)

During the development of the interviews, four main varieties of coffee plants were detected in the area, according to its abundance there is: Catuaí, Catucaí, Mundo Novo, and Icatu (Table 3). It is important to mention that at the same time, there are sub-varieties of Catuaí and Catucaí coffee plants, and they could present either red or yellow colored fruits when full maturity is reached. In this cases, the farmers pointed out that the yellow fruit tend to ripen a little earlier that the red fruit, this is a particularly useful trait in harvest season, because farmers can plan and distribute the coffee collecting and processing work over a longer period of time. This four coffee varieties belong to the *C. arabica* species, but differ is some aspects that are described below.

Table 3 Coffee varieties used in the study area

Coffee varieties description				
Coffee variety	Catuaí	Catucaí	Mundo novo	Icatu
Growth Height (m)	2.0-2.4	2.2-2.8	3.0 to 3.8	2.5 to 2.9
Diameter (m)	1.7-2.1	1.7-2.1	1.4 to 2.7	2.2 to 2.4
Flowering season	Sept/ Oct	Sept/ Oct	Sept/ Oct	Sept/ Oct
Fruiting season	May and June	April-July	April-July	April-July
Fruit weight (g)	1.13	*	1.2	1.18
Weight of 1000 seeds (g)	112.5	*	127.8	125
Flat type seeds (%)	85.6	*	84.9	85.4
Average production (kg/ha)	2,100	*	1,800	2,550

*Highly variable data due to the great number of Catucaí coffee varieties

Table based on information provided by the "Consórcio Pesquisa Café" (CPC, 2011)

6.1.3.2 Agricultural practices

As it was expected, a wide range of different agricultural practices were observed during the development of the fieldwork, and in fact, as a whole, the exact practice was not observed to be repeated by two or more different producers. This diversity of practices on such a small scale hints to a diversified use of agricultural practices at larger scale.

The standard practice in the region is to establish an intensive method of production; this implies the establishment of coffee plants without any other plants or trees (including shadow trees), and this is done with the intention to ensure that the resources and nutrients are only used by coffee plants.

Despite the trend towards intensive production, it was found that four of the farmers produced organic coffee, two of which are certified as organic producers, and the other two are currently undergoing the certification process.

The crop density in coffee farms was found to be dependent on a series of factors, the first is the slope of the terrain, with steeper slopes, farmers tend to increase the distance between lines to make sure they have enough space to work during harvesting season, another important factor is the coffee variety that it is being used, as the height and diameter of each plant is different, and finally it depends on the farmer's preferences and techniques. Keeping all this factors in mind, it was found that the average plant density is 3,027 plants/ha, being 762 plants/ha the lowest and 7,000 plants/ha the highest registered in the region.

6.1.3.2.1 Fertilizer

When the supply of nutrients in the soil is large, the crops are likely to grow better and produce higher yields. However, if even one nutrient necessary is scarce, the plant growth is limited and crop yields are reduced. In consequence, to obtain high yields, fertilizers are necessary to provide crops with nutrients the soil is lacking.

Chemical fertilizers provide display on its label the NPK acronym, showing percentage of the product that contains the most important elements for plant growth: nitrogen (N), phosphorus (P) and potassium (K). Nowadays, there is an enormous variety of available fertilizers in the market, and it is up to the farmer, sometimes with the help of a technician, to determine the ones that will suit their needs. Figure 2 shows the fertilizers that are most frequently used in the study area. The dosage that is shown, is an average value estimated from survey data.

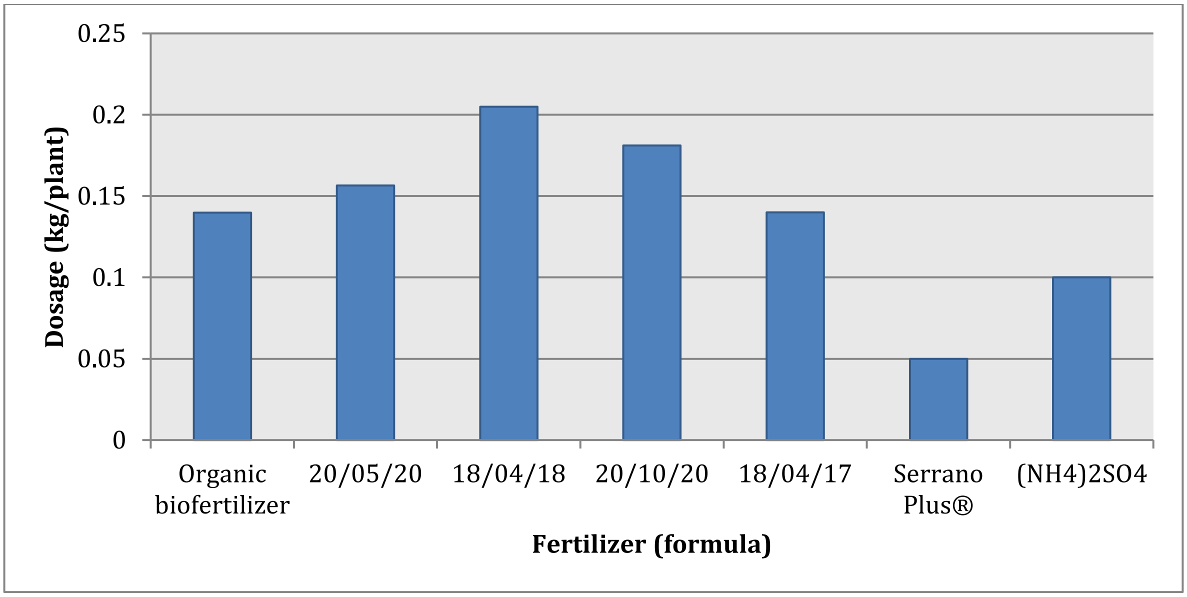

Figure 2 Fertilizers used in the study area.

It is a common practice among farmers to apply these amounts of fertilizers two or three times per year depending on the need and on the amount of economic resources available, also, farmers could use one or more different fertilizers depending on their specific necessities at that time of the year.

All of the interviewed farmers declared to use fertilizers, so, on average, each farmer applies 18.9 t of fertilizer/year, creating an expense of about $R 22,640/year. However not all of the farmers have access to proper technical support, only 42.3 % of the farmers stated to receive technical support from a government agency, 7.7 % of farmers receive technical guidance from a private technician, one producer is certified as an organic technical consultant and provides guidance for two other organic producers (users of biofertilizer), while the remaining 38.4 % of producers stated that they do not obtain any technical advices from a third party. This lack of counseling and guidance, can lead to a misuse of fertilizers and other agrochemicals (see next sub-chapter), which then can lead to the accumulation of nitrates, phosphates or other compounds in the subsoil, where leaching will occur, incorporating these substances into the groundwater and other water bodies.

6.1.3.2.2 Plagues and pesticides

According to FAO, a pesticide is any substance intended for preventing, destroying, attracting, repelling or controlling any pest including unwanted species of plants or animals during the production, storage, transport, distribution and processing of food, agricultural products or food animals.

As with any other agricultural crop, coffee can suffer from attacks by pests and diseases that may cause a serious impact in its production. The most commonly found plagues in the region are: Phoma (*Phoma costaricensis*), Coffee rust (*Hemileia vastatrix*), coffee leaf miner (*Leucoptera coffeela*), Nematodes (*Meloidogyne* spp.) and Berry Blotch (*Cercospora coffeicola*). Even though all of the coffee plantations show some sign of infestation, only 65% of the farmers use pesticides on their property, the main reason for this is because farmers do not like to use such a highly toxic product in their farm and also, they consider that such plagues are sufficiently under control and do not represent a serious threat to their coffee production. Figure 3 presents the most commonly used pesticides in the region and its recoded dosage.

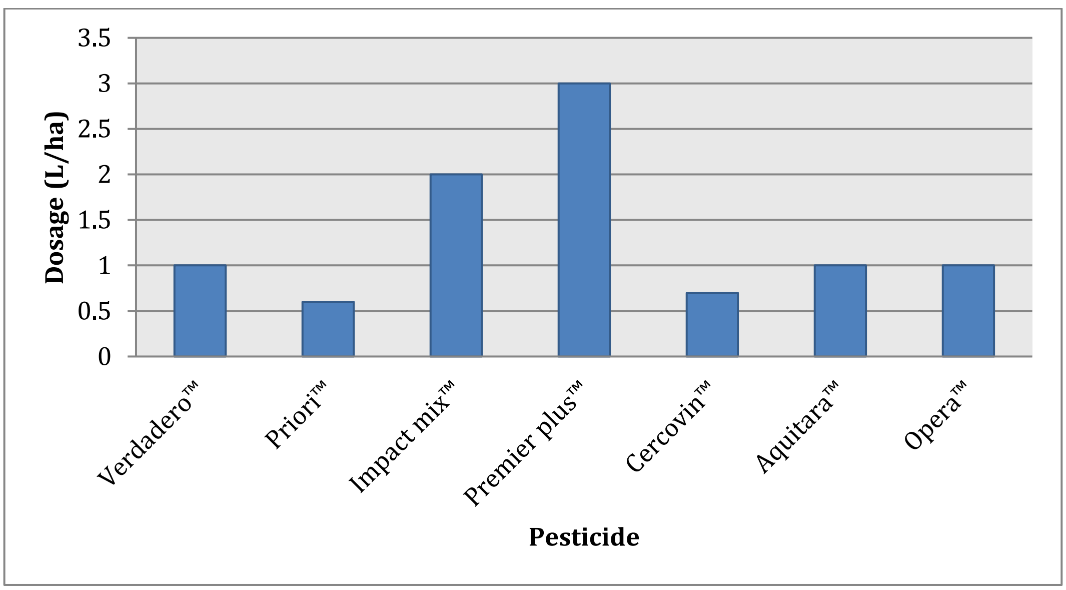

Figure 3 Pesticides used in the study area

The dosage and the overall applied quantities of pesticides are significantly lower than those of fertilizers. On average, every farmer that utilizes pesticides, applies 104 liters of pesticides per year, and spends around $R 10,912.8 on this products.

6.1.3.2.3 Coffee processing

The coffee fruit usually ripens in the period between May and July and once a coffee plant has more than 70% ripe fruits; it is ready to be harvested. There are several ways in which coffee can be harvested. In the region, the predominant harvest technique, consists on removing by hand or with the help of hand tools, all of the fruits of the plant (including immature fruits), collecting them in a basket and transferring it to the warehouse, where the fruit will continue to be processed.

There are two post-harvest processes that are used in order to obtain a clean unroasted coffee seed that is commonly known as green coffee, each of these processes have advantages and disadvantages:

The first is the wet process; it gets this name because it involves the use of large quantities of water during the pulping phase. This process consists firstly on separating the coffee seed from the rest of the fruit with the help of specialized equipment, and secondly in drying the seed, which ends with obtaining the dried coffee seed, commonly known as coffee bean ready to be roasted or stored.

The other method is the dry process, it consists on first drying the entire fruit, and then mechanically removing the outer layers, thus obtaining the coffee seed, which then is packed and stored.

It was found that 77% of the farmers utilize the dry process to manage their harvest, 11.5% use wet process, and the remaining 11.5% of farmers use both processes to obtain clean coffee beans. According to some leading experts in the subject, a higher quality coffee bean is obtained through the wet process (Borém, 2010).

Regarding governmental aid for the coffee-growing activities, 57.7% of the producers stated that they have received some support, the main organizations that provide this support are: the National Family Farming Strengthening Program (PRONAF) and Rio Rural, the financial aid these institutions provide is destined to the construction of infrastructure like concrete patios to sun-dry coffee beans (Figure 4) and warehouses or, in some cases, for the acquisition of equipment like coffee dryers (Figure 5 and Figure 6).

Figure 4 Concrete patio to dry coffee beans

Figure 5 Rustic oven (under construction) to dry coffee beans.

Figure 6 Mechanical coffee dryer

Altogether the 26 farmers produce 9880.5 bags/year, so the mean production is 380.01 bags/year, however due to the different conditions and crop management, the yield varies greatly with each farmer, as it can be appreciated in Figure 7.

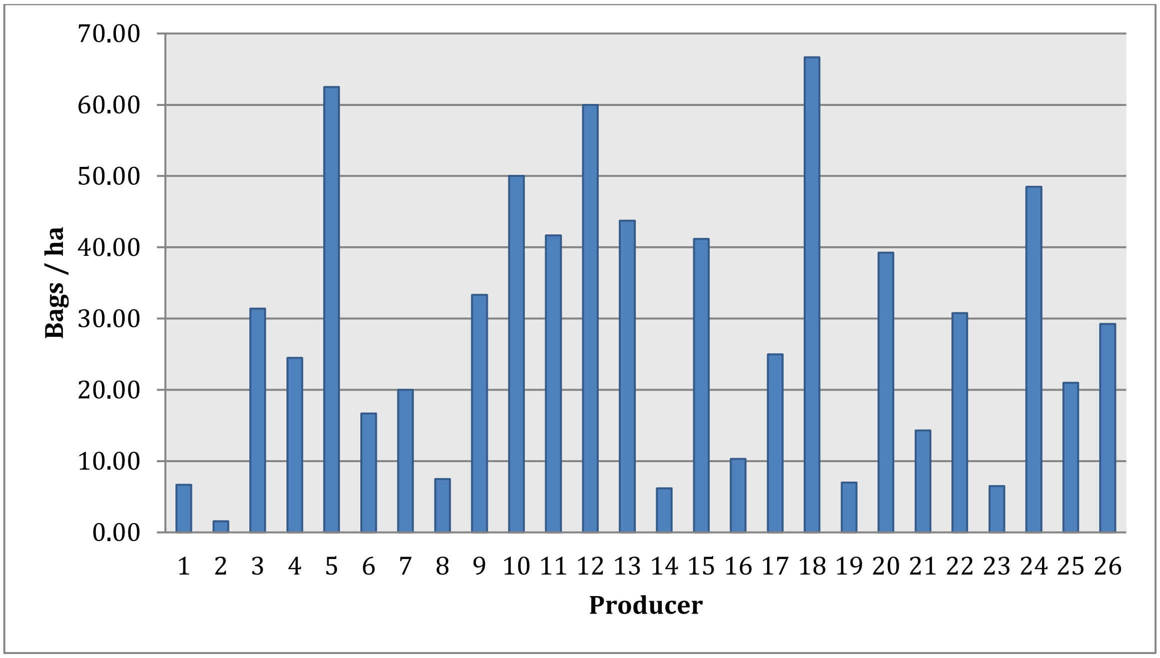

Figure 7 coffee yields of interviewed producers

The average yield in the area is 28.67 bags/ha, which is a little over the national average of 24.43 bags/ha, the largest yield was 66.67 bags/ha, and it was obtained by one of the larger producer in the region, meanwhile the smallest yield was 1.56 bags/ha, obtained by a new small-scale organic producer that has been a coffee grower only for two years, so the plants still have not reached full maturity, consequently his production is expected to increase over the following years.

6.1.3.3 Coffee selling price

Coffee prices are directly linked to its quality, which is mainly determined by the aroma, richness, body and flavor consistency of the beverage. According with the information obtained in some expert interviews, the vast majority of the coffee produced in the region, is ranked as a medium to low quality coffee.

All but two of the producers sell their production as green coffee, which means that there is no added value to the product. The product is packed in 60 kg bags, and it is usually sold to a middleman, who then resells it to roasters, distributors or other larger clients. In this case, the average selling price is R$ 352.17 per bag, with a standard deviation (SD) of R$ 54.47.

Of the remaining farmers, one is an organic producer, and the other one is a conventional producer. They add value to their product and sell it roasted, grinded and packed in bags of 250 or 500 g., the organic coffee is sold directly to the final consumer for R$ 35/kg, and the conventional coffee is sold for R$ 16.5/kg.

Concerning the diversification of income, 61.5 % of the producers have another source of income besides coffee production; this can be either other crops or completely unrelated activities like sales, government officer, manager, etc.

6.2 PES

6.2.1 Ecosystem service selection

Farmers were presented with a list of 12 pre-defined activities that could help to improve an ES and protect biodiversity, from this list they could select the ones that they would like to do and, that would fit their farming practices, they ranked the selected activities in order of preference, being their first choice, the activity that they would like to do the most, then their second most preferred activity, and so on.

Figure 8 presents the number of producers and the ranking for the ecosystem service improving activities in which more than 10 % of the farmers showed some interest in executing.

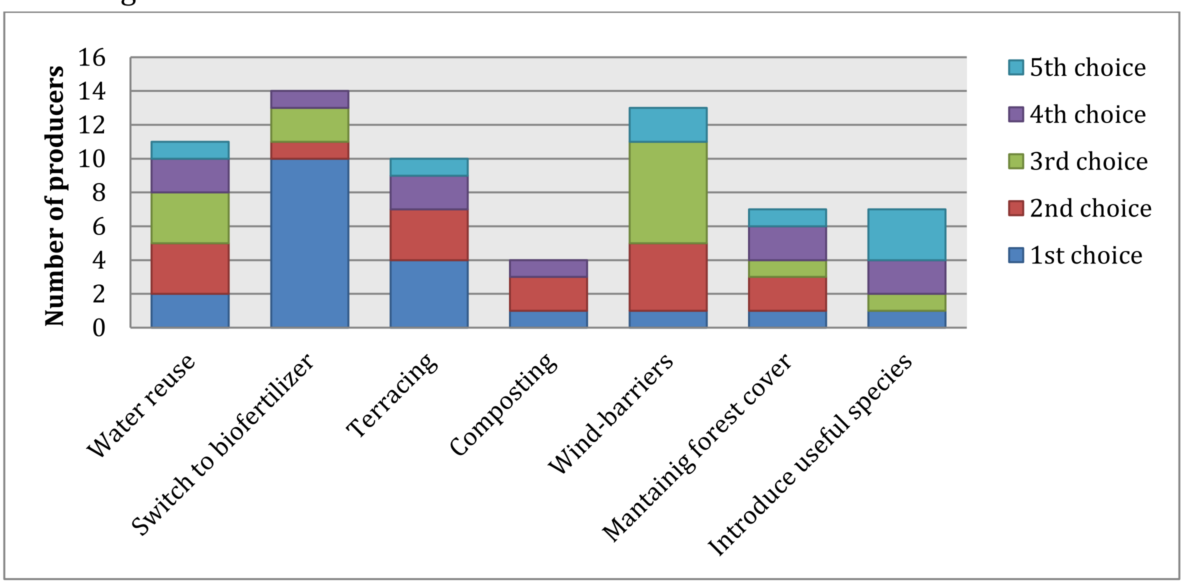

Figure 8 Preferred ecosystem service improving activities.

Besides these actions, farmers were asked if they could come up with other actions that would be feasible and protected an ES, and some of them proposed maintaining vegetation near the water springs in order to protect them and to collect more water, other farmers proposed building "caixas secas" or dry boxes; these are nothing more than dug holes into the slopes on the banks of the roads that captures rainwater and sediments carried by it. This technique avoids runoff, gullies, and siltation of rivers and depredation of roads, while contributing by recharging supply of groundwater and river flows. However since this activity was not included in the survey since the beginning, not all of the interviewed people considered it, thus it cannot be compared under the same conditions with the other activities.

6.2.2 Willingness to participate and economic remuneration

The willingness to participate in a PES scheme is a key aspect of the program in order for it to succeed, in this case 88.5 % of the producers agreed to take part in the scheme as service providers in exchange for some kind of compensation.

All of the coffee producers that agreed to participate in the scheme were asked to state a quantity that they would consider a fair economic remuneration in order to carry out one of the listed activities that would benefit the ecosystem service (**Figure 9**).

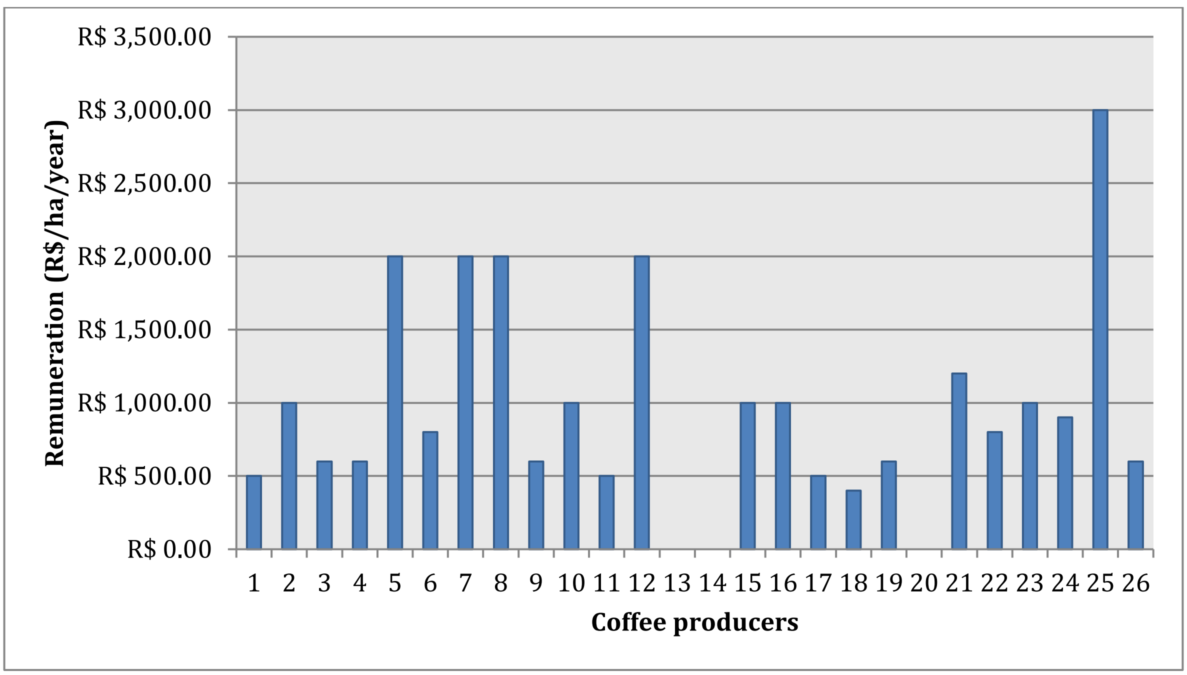

Figure 9 Stated ideal economic remuneration by coffee producers

The average remuneration value for which farmers agreed to adhere to a PES scheme is R$ 1,090.91, with a standard deviation of R$ 700.85; this data shows the great variability of perception and opinion regarding the value of their work in coffee production because there is no correlation between the stated remuneration and the value of their coffee production (R=-0.14).

Taking into account that on average, in each hectare are produced 28.67 bags of coffee, each bag would need to be sold with an overprice of R$ 38.05 in order to achieve the average compensation payment for ecosystem services.

7 Discussion

7.1 Selection of ecosystem service

Of the great variety of ecosystem services that could be traded, in the area, only a few of them can generate sufficient interest to be taken into consideration, the results of the survey are conclusive regarding the available services that could be commercialized:

Terracing was the 4th most frequently selected activity, it could potentially bring a lot of benefits like reducing soil erosion, retaining water by minimizing run-offs and even by providing a leveled surface for the workers to perform the harvesting activities, however, due to the diversity of micro-topographies that are present in the area which include small hills and in some areas nearly no slopes, this would be a beneficial activity only for those who selected it, thus limiting the range of action for it within the scheme. Terracing, could be considered as a safer alternative to the “caixas secas” propose by the farmers, because these are big holes in the ground on the side of the road without rails or any other proper warning signals, so, if drivers are unfamiliar with the road and are not paying full attention, an accident is likely to occur.

The third most frequently selected activity was water reuse; the aim of this is to make an efficient use of water utilized in farms, and to prevent any pollutant discharges to rivers, lakes, or even to the forest. However, observing the local conditions and farming practices where there is no crop irrigation and the main post-harvest technique to process coffee is the dry method, which, in comparison requires a small amount of water, it is considered that, establishing this activity in the PES scheme would have a very little effect over the water quantity and quality.

The next most popular activity was to establish wind barriers, this measure got a total of 13 persons interested in participating; the aim of wind barriers is to protect the soil by diminishing erosion and improving soil structure. The main reason some farmers would not select this activity is because in order to establish such barriers, they would have to remove some coffee plants, and the perception was that it would have a negative impact upon the yield, and since the area is not dominated by large and dry plains where the wind can reach high speeds to provoke some serious erosion this option was also ruled out.

Finally, desisting on the use of chemical fertilizers and switching to bio fertilizers, was the most selected activity as the first choice and it also gathered the most interest over all the other possible options, with a total of 14 persons interested on participating out of whom 10 stated that it would be the best option for them.
Reducing the use of chemical fertilizers, would produce an improvement over the water quality of the region, because when nitrates, phosphates or other chemical compounds that are present in the fertilizers combine with high-precipitation climate conditions like in the study area, the chemical compounds could easily be dragged away from the crops and transported downstream where they can cause pollution and eutrophication, therefore, the efforts to implement a PES scheme in the region should focus on the ecosystem service of water quality through the reduction of chemical fertilizers.

Water is not only an essential natural resource, with multiple human and biodiversity functions, but it is connected to a wide variety of other ecosystem services such as landscape, culture and the wider environment (Thomson, et al., 2014), and according to a study performed by Groot et al., (2002) water-related ecosystem services possess a high market price, this characteristic highlights the great importance of such services.

Overall, only a small number of schemes have been purely private sector initiatives (particularly linked to water quality), two remarkable cases have been the PES schemes developed for both Vittel® and Perrier® (DEFRA, 2010). This shows that currently, not only governments have a strong interest to preserve water, and that some enterprises see PES as a viable alternative to their current standard practices.

The PES scheme, developed and implemented by Vittel in north-eastern France addressed the risk of nitrate contamination caused by agricultural intensification by financing farmers in the basin to de-intensify their farming practices (Perrot-Maître, 2006), this scheme is considered a success, and during its analysis it was concluded that an important factor for success was the ability to maintain farmer's income level at all times while introducing technological changes.

The activities described in this case, are very similar to the activities that have been identified in this study, and since the Vittel scheme is a success story, although the conditions are different, it showed that economical, social, and environmental improvement is possible through a PES scheme.

Meanwhile, in the south- eastern part of Brazil, as water supply is becoming a serious problem for large cities such as Rio de Janeiro and São Paulo, in an attempt to counteract this trend, The World Bank, as well as NGOs, are now supporting states and municipalities in their attempts to build PES schemes for water resources conservation (Coudel, et al., 2015).

In addition to this, in recent years a tremendous effort to increase and reinforce multilevel governance was realized by the National Water Agency (ANA for its acronym in Portuguese) in an attempt to upscale water-related PES (ANA, 2015). In 2011, this agency launched a public call to identify new initiatives to be included in the Water Producer Program, bur regarding the establishment of PES schemes, ANA does not coordinate the projects, but mediates between the various entities to promote institutional and financial arrangements and technical expertise (Coudel, et al., 2015).

All the previous information demonstrates that PES water-related projects in Brazil are now a growing reality, and several schemes have been established in states like Rio de Janeiro, Brasilia, Sao Paulo, Minas Gerais, and Espiritu Santo, to name a few (Cassasola, 2010; FAO, 2011; Guedes & Seehusen, 2011; Zanella, Schleyer, & Speelman, 2014).

Table 4 presents information about ongoing water-related PES schemes just within the Atlantic Forest region.

Table 4 Water-related ongoing PES projects

Development phase	Number of projects
Implementation	8
Development	20
Planning	12

Based on information from Guedes & Seehusen (2011)

The relatively high number of projects may imply that majority of the inhabitants of the region are in some degree familiarized with the concept of PES, this is considered to be beneficial because farmers may be less reluctant to participate if they know the benefits it could bring. Also, the fact that there are other projects in the region already in place, provides this project with a much more solid starting point regarding legislation, activities, organizations and even lessons learned from other projects.

7.2 Ability to participate

Farmer's ability to participate in a PES scheme, as mentioned before, is determined mainly by land tenure and transaction costs.

The reason land tenure is important is to ensure the continuity of the activities that would improve the ecosystem service in order to obtain the expected results. It was established that 96.1 % of farmers are also owners and decision makers of their farm, thus they are in total control of the management practices and could adhere to the scheme if they chose to do so.

Even though transaction costs like legal costs and mapping the property were not considered in detail during the realization of this work, it is not expected to cause a significant participation problem because under the Brazilian framework, the usual practice is to establish a partnership with specialized entities (firms, public services or non-governmental organizations) to provide the technical services, like property mapping, and extension is generally undertaken by public companies, like EMATER (Coudel, et al., 2015; Polido, 2016), following this strategy, would significantly minimize the transaction costs, thus practically enabling participation in a scheme from all of the farmers who can prove tenure of their farm.

7.3 Economic remuneration

The crop area of the producers that accepted participation in the scheme ads up to a total of 300.82 ha; if producers ought to receive the average estimated payment (R$ 1,090.91) as a payment, the program costs due to remuneration to farmers would be R$ 328,167.54 per year. With the implantation of the PES scheme, taking only into account the sample population, the potential use of 425.66 t of chemical fertilizers could be prevented and it would also reduce the cost of the inputs used in farm. Even though not all farmers stated the same quantity for the remuneration they would like to receive, it would be recommended to pay proportionally the same amount to every participant in the scheme, this way several conflicts or misunderstandings between producers could be avoided.

Regarding the farmer's opportunity cost, in case the use of biofertilizer in the farms results in a diminished production, keeping in mind that the average price per coffee bag is R$ 352.17, then, with the desired compensation, each farmer could withstand a reduction in production of up to 3.1 bags of coffee/ha or 10.81 % without altering their current income.

In a study performed by Guedes & Seehusen, (2011), where they collected and compared data from over 20 water-related PES schemes in the Atlantic Forest region, they found that:

- The costs for the implementation and maintenance of this type of PES schemes are very variable and often reach values between R$ 200,000 to R $ 2.5 million per year.
- Service providers related to the quality and amount of water, receive payments that range from R$ 10.00/ha/year to R$ 577.00/ha/year
- The average payment 319 R$/ha/year.

Taking this data into consideration, it can be estimated that the average payment of this scheme is 342 % higher than the average for water-related schemes in the Atlantic Forest region.

A possible solution to this problem may lie in diversifying the sources of financing or buyers, this would make the cost lower for each buyer while maintaining the desired remuneration for the farmers.

Adjusting the amount of money that the farmers would receive as compensation could also minimize this problem, by following this strategy, a negotiation should take place until a balance point where both parties are satisfied is reached. By reducing the remuneration, the chances that a buyer would be interested in participating would most certainly be higher.

Regarding a possible buyer for the ecosystem service, Curto Café is a coffee shop established in the heart of the city of Rio de Janeiro, it is focused on providing specialty coffee to their clients the company is owned by five partner who share a set of values and a passion for coffee, an interview for this project was held with one of the owners.

Their current coffee suppliers are located in the state of Espiritu Santo, and they have managed to establish direct contact with the producers to get to know the process and quality of the coffee they are selling and also to avoid any middleman that could reduce the income for their coffee producers

During the interview, the owner showed some clear interest in social equity and environmental conservation activities in coffee farms, he stated that currently they pay an overprice directly to coffee producers without being obligated to do so, they do this to improve the livelihood of the producers, and to motivate them to keep producing specialty coffee.

When the owner was asked as an hypothetical case if he would be willing to pay an overprice of R$ 38/coffee bag to help the farmers implement conservation measures in their farms (thus, covering the cost of the desired remuneration for ecosystem services), he replied that he would be willing to do so, as long as the coffee meets the required quality standards, and in fact he found that this amount of money was rather low. Unfortunately, the coffee produced in the study area does not meet the required quality criteria to be bought by this establishment and additionally, the owner mentioned that he is quite content with his current business relationship with the producer and does not intend to change it in the short term.

This shows that the appreciation and monetization for some conservation activities is rather subjective, and the viability or realization of PES projects like this, may rely heavily with the selection and availability of the appropriate buying partner.

8 Conclusions

Payment for Ecosystem Services has become an important tool for environmental conservation. During the realization of this study, a great amount of interest was shown on the producers' side.it was found that improving water quality by desisting on the use of chemical fertilizers would be the ecosystem service most likely to be commercialized. It was also determined that their ability to participate in a scheme could be as high as 96.1 %, and that under the local conditions the limiting factor for participation is land tenure.

Even though the requested remuneration could be considered elevated compared to similar projects, it would be beneficial to establish the scheme to improve water quality, prevent it pollution through the use of agrochemicals and at the same time this would contribute to raise awareness for the parties involved about environmental problems.

Once the expert interviews were carried out, it became clear that the implementation of a scheme with these characteristics it is possible, although it would rely heavily on finding and selecting the appropriate partner as buyer for the scheme.

In order for the scheme to thrive, it is suggested to develop and execute a subsequent phase of this project that provides continuity. In this phase it is recommended establish strong and collaborative relationships with organizations that provide support and expertise in the development of PES schemes, and of course, another important activity to focus on, would be to reach out to a larger number of farmers in the area, this task would require carrying out extensive field work, but it would have a great positive impact in the overall results of the scheme.

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