Payment for environmental services as a strategy to influence land use change dynamics

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Abstract

Payments for environmental services (PES) consist of a recent and direct way of promoting conservation by rewarding landowners to promote conservation strategies and influence the land use change dynamics. This study proposes an approach to quantify three different strategies for PES implementation and analyze if different social and environmental contexts would benefit equally from each process. To quantify the strategies to influence the land use change dynamics, we defined the following milestones: (a) characterize current land use; (b) characterize the agricultural aptitude; (c) determine protected areas by law; (d) identify land uses in protected areas; (e) identify land uses in low aptitude areas; and (f) contrast the socioeconomic contexts and the strategies influenced by PES. Strategies oriented to restore anthropized protected areas are less important than those aimed to increase the natural land value. The voluntary retirement can equally benefit different socioeconomic context. It is fundamental to develop public policies related to payment for environmental services that promote local communities' ties and development, and amplify the PES scopes to adopt strategies that can support equally different socioeconomic realities.

Keywords: Landscape; Agricultural potential; Land use; Environment

Introduction

Natural ecosystems provide several environmental services, including retaining rainfall, water regulation, soil protection, biodiversity, food, temperature regulation, and others (Pagiola and Platais 2002). About 1/3 of the land on the planet has already been altered by human use by a process known as land use change, usually emphasizing the functional role of land for economic activities (Paul and Rashid 2016; Winkler et al. 2021).

The United Nations has declared 2021–2030 the Decade of Ecosystem Restoration, focusing on strategies to support and expand efforts to prevent, halt and reverse ecosystem degradation (UN, 2019). Payments for environmental services (PES) have been adopted as high-level policy in many countries to promote conservation and influence the land use change dynamics (Ruhl et al. 2021). PES can be defined as a direct mechanism of promoting conservation by rewarding landowners based on the achievement of outcomes instead of undertaking conservation actions (Wunder, 2015).

Fundamentally, the land use change dynamics can be influenced by returning anthropogenic landscape to its natural form by mean of restoration (flows b, c and d; Figure 1), or avoiding land use change (flow a, Figure 1). The land use change can be motivated by converting it to some productive processes (e.g., agriculture, silviculture, livestock farming, etc.) or to access a natural resource followed by the land abandoned (flow a, Figure 1). If abandoned, the area will gradually return to its natural status (Hasan et al., 2020), based on its ecosystems' resilience mechanisms (Weise et al. 2020) (flow c, Figure 1).

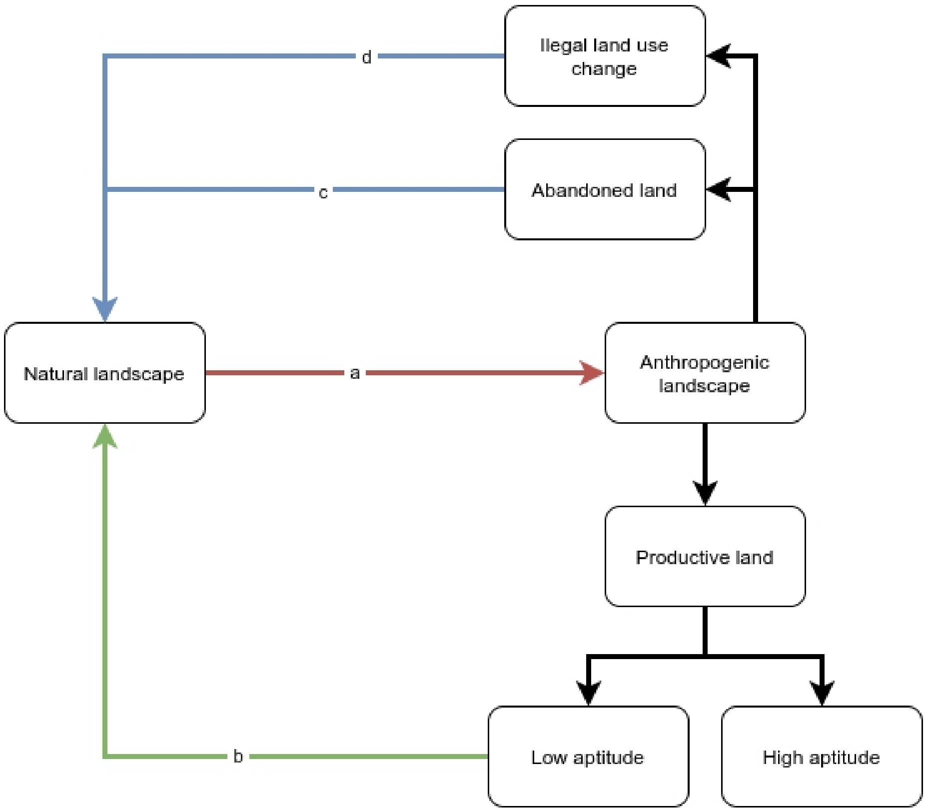

Figure 1. Land use change dynamics. Flow ‘a’ indicates land use change; ‘b’ indicates the land retirement and restoration; ‘c’ indicates voluntary restoration and ‘d’ legal obligation to restore.

One strategy to influence the dynamics is to increase the value of the natural landscape, reducing the economic goals' motivation (flow a, Figure 1). In this perspective, the PES may support the landowner with a regular income to keep natural vegetation and maintain the environmental services. Another strategy is to promote voluntary land retirement (flow b, Figure 1), when a land currently associated with some productive system is voluntarily removed from the process and restored. In this strategy, the income promoted by PES should compete with the income generated by the former land use. A third strategy is to restore abandoned or illegally converted anthropogenic areas (flow c and d, Figure 1). Besides, two different situations (abandoned and illegally converted), they will demand similar interventions. The areas used illegally should be restored by law enforcement, while abandoned places are voluntarily restored. The PES mechanism could be used in all the described strategies.

Brazil was responsible for the most extensive land use change observed globally (Winkler et al. 2021). The lack of public policies aiming at conservation, associated with the increasing of commodity production, are fundamental factors behind the detected land use change. PES can play an important role to promote conservation in Brazil. The same mechanism can potentialize the conservation of a mega diverse fauna and flora (Forzza et al. 2012, Ulloa et al. 2017, Gomes et al. 2020) while contribute to modify socioeconomic realities. Our objective is to propose an approach to quantify different PES strategies and analyze if different social and environmental contexts would benefit equally from each strategy.

Material and methods

To quantify the strategies to influence the land use change dynamics, we defined the following milestones: (a) characterize current land use; (b) characterize the agricultural potential (including livestock farming and silviculture); (c) determine protected areas by law; (d) identify land uses in protected areas; (e) identify land uses in low aptitude areas; and (f) contrast the socioeconomic contexts and the strategies influenced by PES. The workflow was implemented in a biodiversity hotspot territory located in southeast Brazil.

We classified the land use based on Sentinel images obtained between August 2019 and March 2020 from Google Earth Engine repository. All the images available for the period were reduced, considering the median value for each pixel. This procedure eliminates clouds from the image. The final image was manually classified based on actual land use: agriculture, pasture, silviculture, natural vegetation, rocky outcrops, urban areas, and mining.

The agriculture aptitude was determined based on lithology, soil class, and terrain slope. Those factors influence the potential for water recharge, the resistance to erosion, drainage, fertility, and effective soil depth (Costa et al., 2017). The lithology was available on the scale of 1:1,000,000 (available at http://www.portalgeologia.com.br/, accessed on 12/05/2020), and the soil map on a scale of 1:650,000 (available at https://www.dps.ufv.br/?page_id=742, accessed on 12/05/2020). The soil classification followed the Brazilian Soil Classification System (Santos et al., 2018). The slope was computed from the elevation model obtained by the Shuttle Radar Topography Mission (SRTM), distributed by NASA JPL in a resolution of 1 arc-second (approximately 30 m). Each soil, lithology, and slope class was associated with a score between 1 and 5, and the land aptitude for agriculture was computed weighting slope by 50%, soil class by 39%, and lithology by 11%, and summing them up. Score below 2.6 indicates low potential for agriculture (Costa et al., 2017).

The protected areas followed the local law (Brazil, 2012). The buffer zone around watercourses (30 m) and head springs (50 m) was determined based on the official hydrography network for the Minas Gerais state (available at http://idesisema.meioambiente.mg.gov.br/, accessed on 12/05/2020). Areas with slopes greater than 45° were identified based on the SRTM. The protected buffers and high slopes were merged to form the protected area layer. To identify the conflicts to the law, we overlapped the current land use and the protected areas. Natural vegetation or rocky outcrops on current land use classification represented natural landscapes. The current study did not consider abandoned lands, since it is not possible to map based on the current methodology.

Finally, we analyzed the representativeness of the different strategies in the different socioeconomic contexts of the study area. The comparison was performed using a Pearson's chi-squared test to determine whether there is a statistically significant difference between the frequencies in the contingency table.

We applied the methodology in the central portion of Espinhaço Range Biosphere Reserve (ERBR), Minas Gerais state, southeast Brazil. The area was recognized by UNESCO in 2005, which pointed as key, to conciliate conservation and social development (Andrade et al. 2018). The ERBR consists of a north-south mountainous core 1400 m above sea level. The area contains the headwater of three Brazilian hydrographic basins. The region has a transition of Campos Rupestres (Rupestrian Fields) associated with quartzite and ferruginous outcrops, occurring at high altitudes (Schaefer et al., 2016) and the semi-deciduous Atlantic Forest, the most threatened Brazilian biome (Myers et al., 2000). The Campos Rupestres contains around 15% of the vascular flora in less than 1% of the Brazilian territory (Fernandes et al. 2018; Neves et al. 2018; Silveira et al. 2016). The region also has a unique social, historic, hydrologic, and biodiversity relevance (Echternacht et al. 2011; Mittermeier et al., 2005; Santos et al. 2021).

Results

The land use map indicates that 80.5% (189,848.39 ha) of the area is native vegetation and rocky outcrops. Pasture occupies another 24% (56,612.40 ha) and agriculture 0.04% (1,016.06 ha) (Figure 2a). The agricultural aptitude for the study area had an average of 2.79 (on a scale between 1 and 5 - where 1 represents low potential and 5 very high potential), ranging from 1.08 to 4.64, where 47.5% (112,088.25 ha) of the studied region was classified having low potential for agriculture (score < 2,6) (Figure 2b). The protected area as watercourses, head springs, and slopes greater than 45° (Brazil, 2012) comprises 12.9% (30,310.26 ha) of the region.

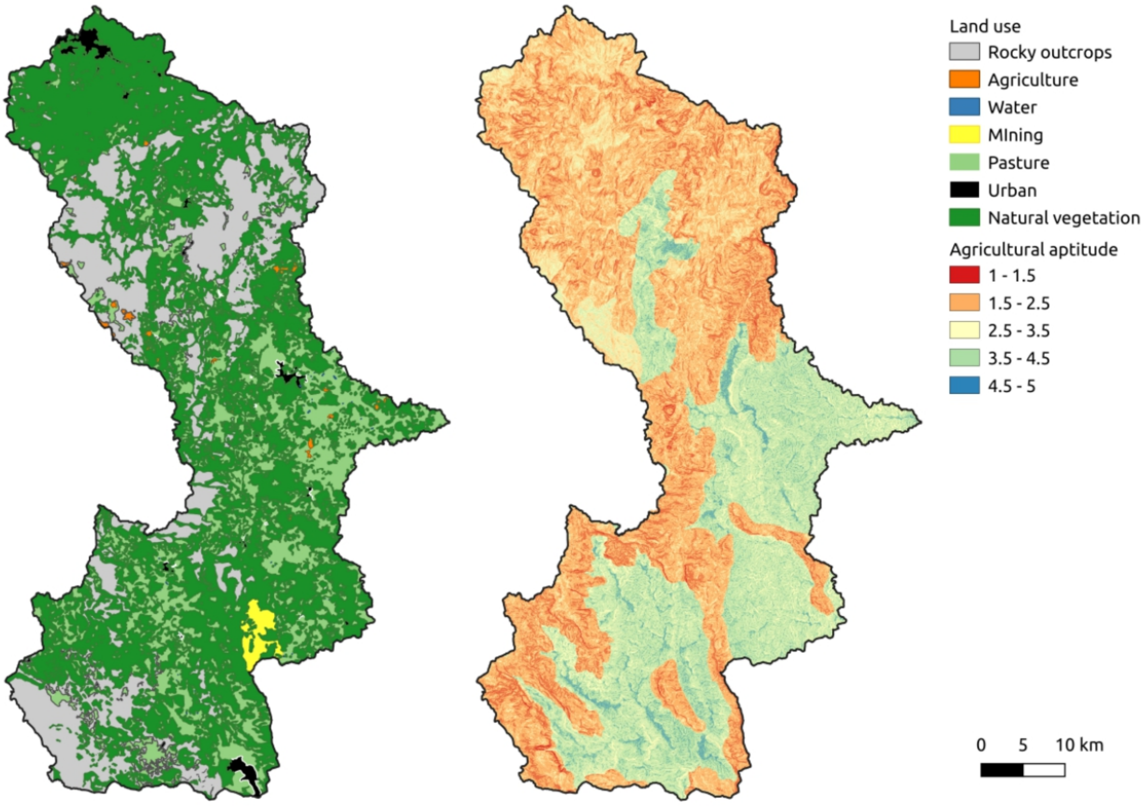

Figure 2. Factors directing the three conservation PES strategies: a) land use; b) agricultural potential (including livestock farming and silviculture).

The study area is largely covered by a natural landscape (80.5% - 189,848.39 ha), divided between native vegetation and rocky outcrops (Figure 3a). The northern portion of the study area concentrate the natural landscape. Our analyses indicate that 30,310.26 ha (12,9%) of the study area should be regulated as protected zones by environmental law, however 20.8% (6,319.84 ha) have been already anthropized (Figure 3b). The anthropization occurred mainly in the south portion of the study region. The most common land use associated to protected areas is livestock farming (6,266.73 ha). Currently, 11,003.10 ha of low aptitude lands are used for some agricultural porpoise (Figure 3c).

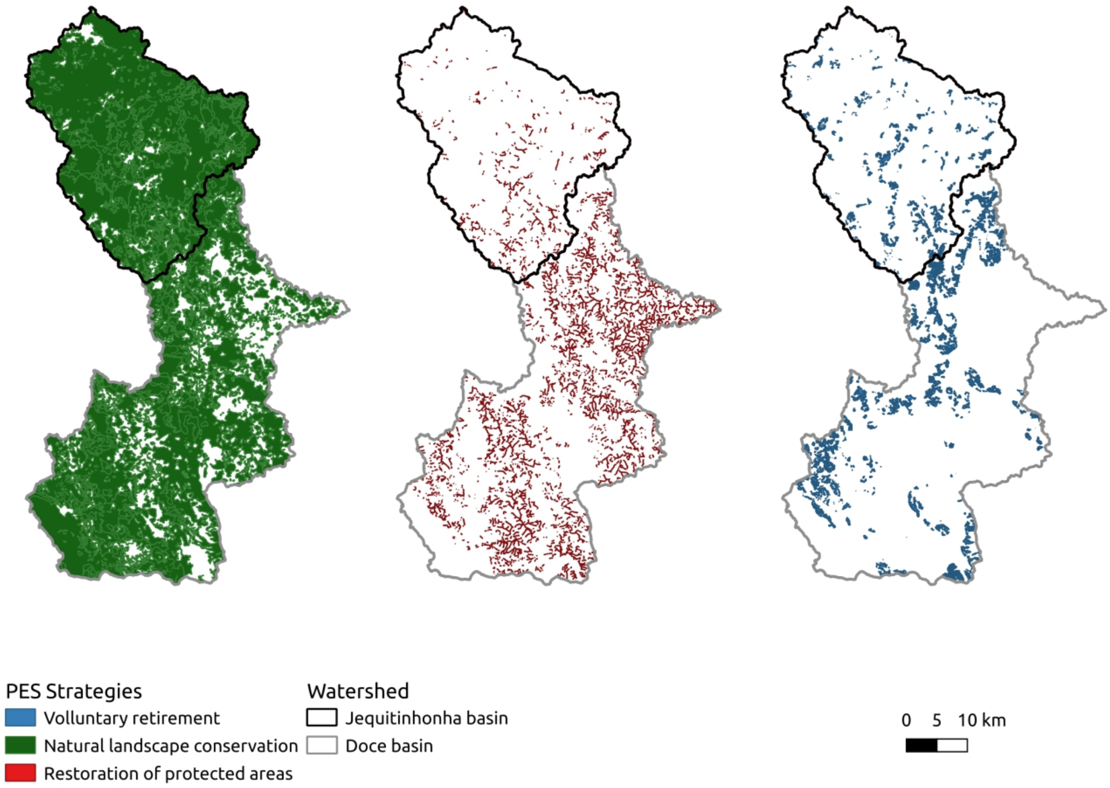

Figure 3. Selected study area showing a) natural landscapes, b) illegal areas where economic land use take place considering Permanent Protection Areas based on Brazilian Forest Code (2012) and c) area with low potential for agriculture coincident with no protected area.

We clearly noticed in our results that north portion is socioeconomic different from the south. We used the hydrographic basin limits to divide the study area, since it is not influenced by any anthropogenic bias. The north basin forms the Jequitinhonha river, and the south basin forms the Doce River. South and north were significantly different by chi-square test (22351.9523, and the p-value is < 0.00001). For the north basin, restoration of anthropized protected areas are less important than the increasing of the natural land value. However, both basins could benefit equally from the voluntary land retirement (Table 1).

Table 1. Number of hectares for each payment for environmental services strategy contrasted by socioeconomic realities.

	Natural landscape	Voluntary retirement	Legal obligation to restore
North basin	2336.23	84805.29	681.91
South basin	8666.86	105037.57	5637.93

Discussion

Under the UN Decade on Ecosystem Restoration (2021-2030) , actions should be taken to halt the degradation and restore ecosystems worldwide (UN, 2019). Healthy ecosystems contribute to at least three important goals: (1) enhance people's livelihoods, (2) counteract climate change, and (3) conserve biodiversity. Several countries have announced political commitments to bring more than 170 million hectares of degraded land under restoration as part of the Bonn Challenge (Almeida et al., 2020). PES could be an important mechanism promote restoration and conservation (Calle, 2020).

This study spatially identified and quantified three strategies where a PES program can contribute. Each process impacts the land use change dynamics in different ways. One strategy increases the natural land value reducing the economic attractiveness for land use change. The second strategy promotes the voluntary retirement of the land, and consequently, restoration. And the third strategy contributes to restore illegally converted land.

Natural landscape (composed of native vegetation or rocky outcrops) that are not assigned by law as protected area comprises 65.6% of the studied region (156,505.06 ha). The main economic activity in the region that puts pressure on the natural vegetation is the extensive livestock and dairy farming. Those activities, in the best scenario, can generate an annualized net present value is US$ 204.00 per hectare (R$ 1224.00). In that sense, a PES program would reduce the economic interest, reducing the economic attractiveness for land use change.

Around 22.5% (11,971.44 ha) of the pastures and 43.8% (419.56 ha) of the agriculture areas are not in protected areas but in regions with low potential for sustainable agriculture. Due to its low potential, it is a risky economic activity and consequently a natural candidate to be voluntarily retired and restored (Lomba et al. 2015, 2020; Ayambire and Pittman, 2021). Our results highlight that a PES program to support voluntary retirement by implementing monetary compensation is the most democratic strategy and can support equally regions with different socioeconomic realities. This strategy also has higher potential for restoration programs, considering the amount of available extent areas.

Promote restoration of illegal land use change is the most polemic strategy, since receiving the incentive could be considered a reward for illegal activity. However, it must be carefully analyzed considering the historical perspective. For several areas, the land use change occurred before the current environmental law was approved. In the study area, those areas are mainly used for small-scale agriculture. In this sense, a PES program can be understood as an incentive to become legal and not as compensation. Many landowners do not have the resources to abandon the area and implement the restoration, even obligated. The cost of restoration is around US$ 2,102.81 per hectare (R$11,944.00) (Benini and Adeodato, 2017). Support the access to restoration funds itself could be a PES program. It may benefit local arrangements and connect population to conservation actions like trees nursery, seed collection, planting, and monitoring activities.

We detected two very different land use matrices in the study region. The northern portion shows strong constraints to the agriculture development (Domingues et al., 2012; Neves et al., 2016). The environmental factors (e.g. temperature, precipitation, terrain slope and soil) mainly define the low aptitude for agriculture, corroborating the high environmental fragility of the region

(França et al., 2020). The rural economy increases in importance in the southern portion of the study area. The main activity is livestock and dairy farming (Schettini et al., 2021) based on low-tech productive system, supported only by the soil's natural fertility. The agricultural activities are highly dependent on the family labor force. However, in the north portion there is a stronger tradition for families to organize themselves in communities with solid ties to reproduce and disseminate the culture (Souza, 2014). That is why PES strategies should be carefully considered before implementation, since it could have a direct impact in the local socialeconomical reality. The voluntary retirement seems to equally benefit different socioeconomic context.

The studied region has a history of intense natural resources exploitation, mainly for gold and diamond (since the colonial period). More recently, iron, gemstones, ornamental stones, sand, and plant extraction become part of the local economy (Neves et al. 2016). Fire is still used as traditional land management to suppress native vegetation and support for the introduction of invasive monotypic species, such as molasses grass and fern (Almada et al. 2016; Mucida et al. 2019; Santos et al. 2021). The region is heavily dependent on government aid, pensions, and seasonal migrations. The income generated from those sources is usually applied back to local production strategies (Ribeiro, 2007). A PES program has a strong potential for providing biodiversity conservation and water production services, while engage local families to keep connected to the land and strength the community ties (Schettini et al., 2021).

Water is the main motivation to PES programs implementation worldwide. They started to be implements around the world around 1990 (Grima et al. 2016). Costa Rica pioneering implemented a PES program support by taxes from fossil fuel. New York also implemented a famous PES program to protect the head springs of Greene river. Mexico and South Africa also started similar programs to support water supply (Pereira, Alves Sobrinho, 2017).

Current PES programs implemented in Brazil are implemented based on local or regional policies. The existing programs are focused mainly on conservation and restoration of natural landscapes aiming water supply. Most of the ongoing programs aim tropical forest biomes conservation (Amazon and Atlantic Forest) (Coelho et al. 2021). In Minas Gerais State, two pioneering programs have been implemented: Ecocrédito (Montes Claros municipality) and Conservadores das Águas (Extrema municipality). The Ecocrédito program remunerates the landowner by US$ 32.22 (R$ 183.00) per hectare year-1, and the Water Conservative of the Waters program remunerates by $ 47.54 (R$ 279.00) per hectare year-1 (Pereira, 2017). In Espírito Santo State, the Reflorestar Program pays up to US$ 63.87 (R$ 362.76) per hectare year-1, with an initial contribution of US$ 1,438.17 (R$ 8,168.78) for restoration. This program has found great acceptance by rural landowners, expecting to increase the regional forest cover by 230 thousand hectares by 2025 (Espírito Santo, 2018). In the Amazon biome, two programs support traditional families with regular incomes to protect forest biodiversity (ALVES-PINTO et al., 2018). In the south of Brazil, landowners can receive payments to keep and protect individuals of *Araucaria angustufolia* (Tagliari et al., 2019).

PES can promote the restoration and conservation of the natural environment, strengthening the rural populations ties with their communities and land, generating income, and improving life quality (Guedes et al., 2018; Blundo-Canto et al., 2018). For the future, PES program can also support sustainable agricultural systems that can provide some ecosystem services and additional livelihood co-benefits (Calle, 2020). It is fundamental to amplify the PES programs scopes and adopt strategies that can support equally different socioeconomic realities.

Conclusion

Based on the arrangement of its ecosystems, nature provides environmental services, including the maintenance of biodiversity, pollination, water regulation, preservation of watercourses and springs quality, soil protection, and natural disasters' mitigation. The challenge for implementing PES resides in creating a mechanism capable of evaluating the provided environmental services and compensating the efforts of the local population in maintaining natural resources functionalities. The choice about PES strategies has to be carefully considered. While the strategy oriented to restore anthropized protected areas impact less areas than those aimed to increase the natural land value, the voluntary retirement can equally benefit different socioeconomic context.

It is fundamental to develop public policies related to payment for environmental services that promote local communities' ties and development. The program should coordinate actions by extrapolating regional boundaries, involving all governmental agencies related to environmental, agricultural, and extension. There is an urgent need for a paradigm shift in society, adding a service brand to environmental conservation.

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