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Considering farmer land use decisions in efforts to 'scale up' Payments for Watershed Services

Ryan C. Richards[a,b,*], Chris J. Kennedy[a], Thomas E. Lovejoy[a], Pedro H.S. Brancalion[c]

[a] Department of Environmental Science and Policy, George Mason University, MSN 5F2, 4400 University Drive, Fairfax, VA 22030, USA
[b] Center for Conservation and Sustainability, Smithsonian Conservation Biology Institute, National Zoological Park, Washington, DC, USA
[c] Department of Forest Sciences, "Luiz de Queiroz" College of Agriculture, University of São Paulo, Avenida Pádua Dias 11, 13.418-900 Piracicaba, Brazil

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ABSTRACT

Significant effort is being devoted to the expansion of payments for watershed services (PWS) programs at national, regional, and local scales. This expansion faces logistical challenges, in particular identifying appropriate incentives and enrollment processes to provide additional ecosystem services under budget constraints. In Brazil, PWS programs have mostly occurred at the local level, using formulaic contracts to ensure landowners are compensated for provision of specific types and quantities of ecosystem services. However, it is unclear how these financial incentives will function as programs expand to new areas, as pilot programs report high recruitment costs. Using as an example the Cantareira System, an important drinking water supply for the São Paulo metropolitan area, we review PWS incentives in the context of factors that affect farmer land use decisions. We base our research on a review of policies affecting PWS in Brazil, existing PWS in the Cantareira region, and drivers affecting land use and technology adoption by cattle ranchers, drawing from the literature and interviews with farmers and agronomists in the study region. While financial incentives (payments) account for both the value of ecosystem services and opportunity costs of shifting pasture production to forest, several economic, social, political, and biophysical factors will likely affect landowners' decisions to enroll in PWS. This suggests that, while PWS programs may lead to the provision of additional ecosystem services, the complexity of contracts and diversity of local conditions create challenges to broad deployment in the absence of significant outreach efforts.

1. Introduction

Payments for ecosystem services (PES) programs are a policy approach to promote land uses that provide ecosystem services through payments to land managers by ecosystem service users (Wunder, 2005). These direct payments are more likely to be efficient than indirect approaches to shifting behavior, especially in situations where the desired provision of an ecosystem service involves coordinating large numbers of individuals (Ferraro and Kiss, 2002). Watershed management is one field in which PES has been welcomed, as downstream service users (e.g., public drinking water utilities or hydroelectric power producers) often have a range of actors upstream that affect quality and quantity of water supplies (Landell-Mills and Porras, 2002). The appeal of payments for watershed services (PWS) is reflected in the rapid emergence of programs over the past 20 years. Ecosystem Marketplace, a Forest Trends program that tracks market-based environmental programs, reports over 400 PES programs in operation solely to protect watershed services, with transactions totaling nearly $25 billion (Bennett and Ruef, 2016).

This rapid growth in the number of programs has raised concerns about additionality – the outcomes of programs beyond what would have occurred in their absence (Pattanayak et al., 2010). Research into this issue has primarily been conducted *ex post*, frequently using experimental or quasi-experimental approaches to measure impacts of PES programs on land cover or other variables (Arrigiada et al., 2012; Sills et al., 2008; Robalino and Pfaff, 2013; Jayachandran et al., 2016). This has been useful, helping such programs as Costa Rica's national *Pagos por Servicios Ambientales* program address issues with targeting and other opportunities for improvement (Pagiola, 2008).

However, these evaluation approaches are not available in every context in which PES programs have operated. The scale of Costa Rica's PES program lends itself to quantitative evaluation using spatial data, and planning and partnerships were required to apply randomization of treatments during the implementation of other programs for evaluation purposes. Absent these conditions, other approaches are necessary to identify opportunities to program design and implementation.

Here we describe the results of a research project on challenges and

* Corresponding author at: Department of Environmental Science and Policy, George Mason University, MSN 5F2, 4400 University Drive, Fairfax, VA 22030, USA.

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opportunities for PWS to serve as a tool to increase forest cover on private land in the watersheds of the Cantareira System in southeastern Brazil. The area is the source of a significant portion of the drinking water for the São Paulo metropolitan area, but agricultural activities, in particular pasture for cattle, affect these resources and several PWS programs have been implemented in the region. Several PWS programs have already been implemented in the region, but they have experienced high startup costs and other challenges (The Nature Conservancy-Brasil, 2015; Kfouri and Favero, 2011). Despite these challenges, there is interest in expanding PWS efforts, and a clear need to identify and address potential obstacles to wider landowner participation to secure additional environmental benefits.

We draw from the literature on PWS programs in Brazil to identify the structure of contracts and incentives offered to landowners in the Cantareira watersheds. We then use past research on land use and technology adoption by Brazilian cattle farmers, as well as interviews with landowners and technical staff working in the São Paulo portion of the Cantareira System, to understand drivers of land use change on farms in the region. Using the model of PES adoption proposed by Pagiola et al. (2005), we discuss factors that may affect the additionality of future investments in PWS and lessons for development of this type of program elsewhere in the world.

2. Methods

2.1. Study site description

The Cantareira System is a large reservoir complex used to store drinking water for the São Paulo metropolitan area – the largest urban agglomeration in South America (Whately and Cunha, 2007). The basins that drain into the reservoirs lie within the states of São Paulo and Minas Gerais, covering roughly 230,000 ha (Fig. 1). The entire system is located in the Atlantic Forest ecoregion, a biodiversity hotspot with globally significant levels of plant and animal diversity and endemism (Myers et al., 2000) and only 11–16% of its native vegetation cover (INPE and SOS Mata Atlântica 2015). The Cantareira System is a focal area for forest restoration by the Atlantic Forest Restoration Pact (AFRP), which has a goal of restoring 15 million hectares of forest by 2050 (Melo et al., 2013; Banks-Leite et al., 2014).

The Atlantic Forest is also home to over 125 million people (IBGE 2016) and produces roughly 70% of Brazilian GDP (Melo et al., 2013). Recent droughts have raised concerns over the state of the Atlantic Forest and the impacts of deforestation and land degradation on the drinking water and hydropower supplies that are critical to the country's economy (Nobre et al., 2016; Tafarello et al., 2016).

Although roughly 40% of the Cantareira region is still forested, native vegetation cover is highly fragmented by agriculture. Pasture for cattle and eucalyptus plantations are the dominant agricultural activities by land area, although some municipalities also have high concentrations of greenhouses for vegetable and seed production (São Paulo State Agricultural Extension Service 2008). The total population of the three study municipalities in São Paulo state (Nazaré Paulista, Piracaia, Joanópolis) was approximately 53,208 individuals as of 2013 (IBGE 2016), with 1882 landowners raising cattle for dairy and beef during the last available state agricultural census (São Paulo State Agricultural Extension Service 2008). The municipalities are all close to the São Paulo metropolitan area and accessible by major highways, which has resulted in expansion of housing construction driven by urban demand. This combination of agricultural activity and rural development in an important catchment has made the region a priority for riparian restoration efforts, including PWS, to improve water quality.

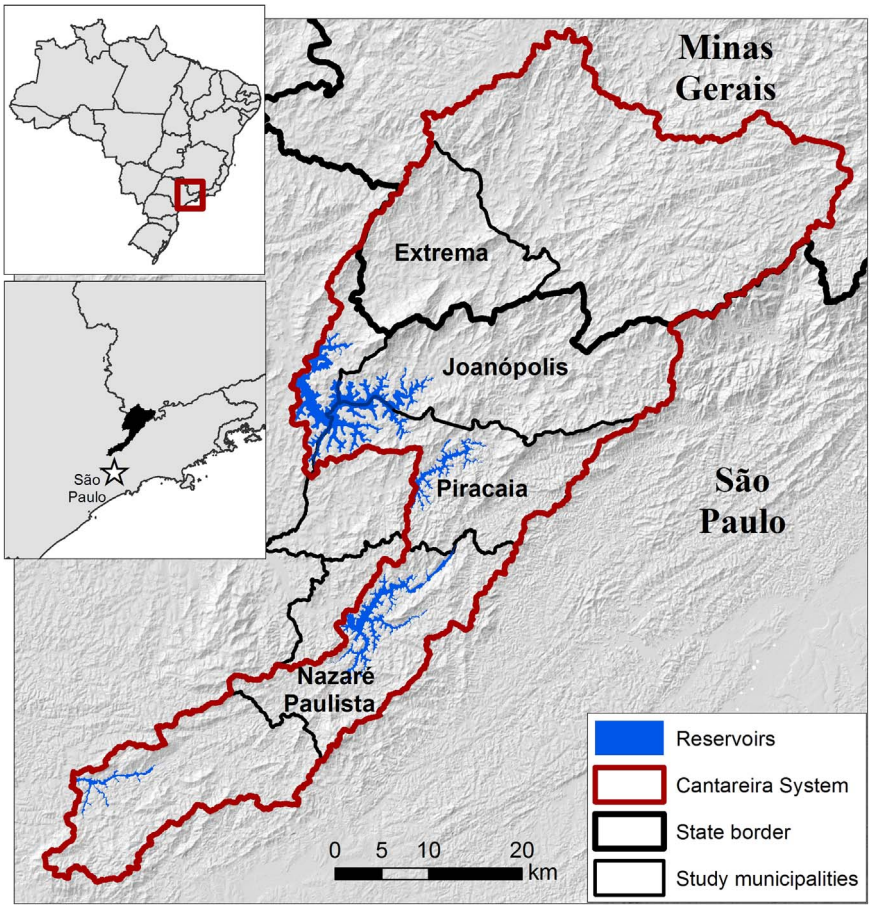

Fig. 1. Map of the Cantareira System, including study municipalities.

2.2. Review of policies affecting PWS in Brazil and of PWS programs in the Cantareira region

Information on environmental legislation was gathered through a review of the legislative history of Brazil and of several policy analyses published after the promulgation of the Native Vegetation Protection Law, which replaced the Forest Code in 2012 (Brancalion et al., 2016). Peer-reviewed publications were added through a purposive sampling process, drawing from the authors' libraries, discussions with government officials in Brazil, and in-depth reviews of material maintained by knowledge centers, in particular the World Bank. Additional information on PWS across Brazil, and specifically within the Cantareira region, was gathered from peer-reviewed literature, as well as grey literature on program development and implementation that is available through PWS partner websites (see Supplementary Material S1 for full reference list).

2.3. Literature review of drivers affecting land use and technology adoption by cattle ranchers in Brazil

Following these interviews, a literature review was conducted to capture in greater detail the issues affecting land use decisions by small-scale beef and dairy producers typical of the São Paulo portion of the Cantareira watersheds. Search terms on the Brazilian cattle industry (Brazil AND agricultur* AND cattle) were used to collect articles published between January 2000 and April 2016 using the Web of Science database. Initial searches returned 1390 publications, of which just 88 were related to farmer decisions (the majority of the results reported on epidemiological and biological research). Of these 88 articles, only 21 explicitly addressed issues (e.g., economic factors) that affected land use. Additional references were drawn from the literature cited by these articles, and from the authors' personal libraries, for a total of 27 articles for review (see Supplementary Material S2).

2.4. Field assessments with farmers and agronomists

To understand the factors that may affect landowner participation in PWS, focus groups on challenges facing those involved in agricultural production were conducted with farmers in the Cantareira region as a part of pasture management courses run by a Brazilian NGO (Instituto de Pesquisas Ecológicas – IPÊ) during June and July 2015. Two focus groups were held, with a total of 7 participants (see Supplementary Material S3 for survey questions). In order to augment the low number of participants, individual in-person and Skype interviews were conducted with agricultural extension officials (N=4) working in this region of São Paulo state, and with individual farmers who had partnered with IPÊ on past projects.

2.5. Individual interviews with farmers in the Cantareira

Data from the individual interviews with landowners and agronomists and the literature review were complemented by survey data from 189 individual interviews with landowners from September to November 2015. These data were collected in the study municipalities of Nazaré Paulista, Piracaia, and Joanópolis, in each municipality's rural zones. To minimize bias in sample selection, researchers did not rely on existing social networks or contacts to arrange interviews. Instead, landowners were approached during neighborhood visits. Surveys lasted approximately 45 min and included questions on household and property characteristics (see Supplementary Material S4).

3. Results

3.1. Development of PWS in the Cantareira Region

There is a long history of environmental legislation in Brazil (Dean, 1997), including some of the world's first decrees to restore native forests and several iterations of national land laws (referred to as the "Forest Code") that mandate retention of areas of native vegetation on private land. The current Native Vegetation Protection Law, commonly referred to as the "New Forest Code", is the primary major legal instrument for addressing land degradation and promoting ecosystem services in Brazil.

The earliest version of this legislation (1934) was intended to secure fuelwood reserves close to cities and industry and maintain ecosystem services mediated by native vegetation in riparian buffers. The 1965 Forest Code mandated conservation and restoration of riparian and other environmentally fragile areas, such as steep slopes and mountaintops (Brancalion et al., 2016). These land use mandates were categorized as either Legal Reserves (LR), (i.e., a minimum percentage of farm area to be maintained with native vegetation) or as Areas of Permanent Preservation (APP), (i.e., environmentally fragile areas that must be protected) in addition to LR. Landowners are required to conserve or restore native vegetation on portions of their property categorized as LR and/or APP or face legal repercussions.[1]

Historically, the enforcement of the Forest Code has been weak, due in part to gaps in legal instruments (see Hirakuri, 2003) and enforcement capacity (e.g., monitoring compliance and subsequent administration of fines) (Sparovek et al., 2012; Hirakuri, 2003). For larger landowners and businesses, enforcement has become more frequent as the Environmental Crimes Law (Lei n°9605/1998) and public pressure and attention has increased. The 2012 law is intended to improve compliance for smaller landowners through the introduction of a rural land registration system (CAR), mandatory for private properties, that includes spatial data for a property including its environmental information (Garcia et al., 2013). Enrollment is being coordinated by the environmental secretariat in each municipality, and registration closes in May 2017. However, restoration costs remain a major obstacle for many landowners (Pinto et al., 2014). On a per-hectare basis, seedlings and maintenance can cost roughly R$17,000/hectare (US$4,800/ha) in the Cantareira region,[2] which is higher than upfront investments for most agricultural products.

Payments for ecosystem services have been proposed as a means to foster legal compliance by small- and medium-sized landholdings through reductions in compliance costs, and to date several PWS programs have been implemented in the Brazilian Atlantic Forest, ranging in scale from watershed sub-basins to states (Brancalion et al., 2012; Pagiola et al., 2013; Banks-Leite et al., 2014). The new Forest Code includes a chapter – the Program for Environmental Compliance (*Programa de Regularização Ambiental* – PRA) on financial incentives for restoration, with an emphasis on payment programs (Packer, 2015; Garcia et al., 2013). This chapter, in conjunction with other environmental legislation, enables development of PES contracts with landowners who have registered in the CAR.

Funding for PES for restoration can originate from a range of sources. The National Water Law of 1997 established a framework to facilitate creation of watershed committees to manage water resources

[1] The relative sizes of the Legal Reserve and Area of Permanent Protection vary by ecoregion and characteristics of an individual property. A good summary of these requirements can be found in the supplementary material of Soares-Filho et al., 2014, in Garcia et al., 2013, and Brancalion et al., 2016.

[2] Conversion used the USD-BRL exchange rate as of 4 June 2016. Cost estimates are from the Insituto de Pesquisas Ecológicas (IPÊ, Ecological Research Institute), a Brazilian NGO that owns a nursery and works with landowners on restoration projects in the Atlantic Forest, and include material and labor for both planting and 3 years of site maintenance to improve survival.

(Veiga and Magrini, 2013). This framework recognizes water as a public good, which users must compensate producers for, and notes that user fees should be used to protect water sources. Each watershed committee is comprised of government representatives (either state or federal, depending on the jurisdiction for a given river), civil society representatives, and stakeholders, such as landowners and water users. These committees collectively decide how to (i) allocate water; (ii) implement new development projects; (iii) arbitrate conflicts among stakeholders; and (iv) impose pollution control restrictions (Porto and Kelman, 2000). National level actors still exert heavy influence on water management, and these committees provide a voice for local actors in project management and implementation. To date, three committees in the state of São Paulo already collect usage fees – Paraíba do Sul, Sorocaba/mid-Tietê, Piracicaba-Capivari-Jundiaí – which have been used in part to support pilot PWS (Padovezi et al., 2012).

3.1.1. PWS programs in the Cantareira

The Cantareira Region has been the focus of the earliest efforts to develop PWS in Brazil, and four programs have been implemented within the watersheds. These include the municipal Water Conservator (*Conservador das Águas*) program in Extrema, Minas Gerais, the Water Producer (*Produtor de Água*) program in the Piracicaba-Capivari-Jundíai watersheds, the state-level Water Mine (*Mina d'Água*) program in São Paulo state, and the state-level Green Bag (*Bolsa Verde*) program in Minas Gerais (Table 1).

The development of PWS in Brazil was initiated in 2001, when the National Water Agency (ANA) developed a country-wide Water Producer program (*Produtor de Água*) to support incentives for sustainable land use and restoration by watershed committees (Pereira et al., 2010). The initial task for the program was the development of legal and administrative frameworks to propose financial incentives to improve land use, and demonstrate their practicality in a field setting (Padovezi et al., 2012; Agência Nacional de Águas, 2011).

Following the creation of the conceptual frameworks, pilot Water Producer projects were developed in several municipalities. The first of these was the Water Conservator (*Conservador das Águas*) program in Extrema. Launched in 2005, contracts were first implemented in one small basin (Posses) in the municipality in 2007 (Pereira et al., 2010). The program expanded to an additional basin (Salto) in 2009 and as of 2015 has produced contracts with 53 landowners that have resulted in a 60% increase in forest cover in the program areas (Richards et al., 2015).

A second project was launched in the São Paulo state portion of the Cantareira System, called the Water Producer – Piracicaba-Capivari-Jundiaí program (*Produtor de Água – Piracicaba-Capivari-Jundíai*, or PdA-PCJ). Planned in 2005, the PCJ watershed committee secured fees to finance pilot PdA-PCJ contracts with landowners, beginning in 2009 (Padovezi et al., 2012). Two subwatersheds in the Cantareira System were selected for the PdA-PCJ project, in the municipalities of Nazaré Paulista and Joanópolis. The Moinho (Nazaré Paulista) and Cancã (Joanópolis) microbasins collectively cover 4,212ha, and as of 2016 320 ha had been enrolled in the PdA-PCJ program as part of over 40 contracts (Tafarello et al., 2016).

The state of São Paulo advanced its commitment to PWS through its 2009 State Climate Change Policy (PEMC – Política Estadual de Mudanças Climáticas). In 2010, the São Paulo Environment Secretariat adopted Resolution No. 61, building on a series of riparian restoration and sustainable land use programs to create a framework for PWS to conserve or restore springs that supply drinking water (Pagiola et al., 2013). Implementation began in 2010 with the development of municipal legislation enabling financial transfers from public entities to private landowners. This enabled the first round of contracts with five landowners in Piracaia in 2012 (von Glehn et al., 2012; São Paulo Environment Secretariat, 2015).

The government of Minas Gerais created its own PES program in 2008, with a focus on restoration of riparian areas to improve water supplies and improve connectivity for biodiversity (de Oliveira et al., 2013). Small agricultural operations are the priority audience for participation in the Green Bag *(Bolsa Verde)* program, in particular family farms and properties of less than 4 'fiscal modules'[3] (Santos et al., 2012). Enrollment proposals may be submitted by property owners individually or in groups, and are awarded based on point scores that consider current levels of forest cover on a property, existing conservation activities, agricultural practices, and other socio-economic factors.[4] As a statewide program, the enrollment in this program is much larger than the other programs in the Cantareira (Pagiola et al., 2013), but the majority of the enrolled areas are elsewhere in the state.

Details of enrollment requirements and contract incentives offered by the PWS programs are described in Table 2. All contracts had relatively short lengths (2–5 years) and provided both legal and technical assistance to the participating landowners. Payments varied in their complexity, ranging from Extrema's CdA program paying landowners a fixed rate for every hectare of an enrolled property to the more complicated formulas of the Water Mine (*Mina d'Água*) program to calculate per-hectare payments for specific management actions. In each program, civil society organizations and other groups were involved in design and implementation activities to assist landowners in conducting PWS practices. All programs shared common requirements, such as legal documentation, to enter into contracts, but several restricted eligibility based on agricultural practices or farm size. This targeted the types of landowners that were unlikely to maintain forest on their property without some form of support.

3.2. Literature on behavior of cattle producers in Brazil

Literature in agricultural economics and international development identifies a range of factors affecting production and land use (Mendola, 2007). Economic issues, such as distance to markets, infrastructure, price fluctuations, technology adoption, credit access, and labor constraints, affect production potential. In addition, social, political, and cultural factors, including trust in institutions, education, and social networks, interact with each other and with economic factors to influence land use decisions.

Brazilian cattle production is generally characterized by relatively low per hectare stocking rates, and the potential for intensification is considered an opportunity to create space for large-scale forest restoration (Latawiec et al., 2015). However, both dairy and beef production require significant upfront investment in livestock and infrastructure, and sensitivity to these costs varies with household and property characteristics. For example, Haddade et al. (2005) modeled profitability of intensive pasture management (e.g., rotational grazing) for dairy production, and found it to be highly sensitive to fluctuation in prices for milk and production inputs, leading to high risks of losses that may be unacceptable for some landowners. Mendes (2006) observed that ear tagging, a monitoring tool, was adopted mainly by large landowners in Santa Catarina state, which was attributed to the high cost of the system and financial restrictions faced by smaller operations. In Extrema, many enrollees in *Conservador das Águas* are retired, and conducting only limited agricultural operations as they draw pensions (Richards et al., 2015). This may, in addition to the larger PWS payments offered through the program, make management practices required by PWS more tolerable for participants.

[3] A fiscal module is measured in land area and comprised the minimum area needed to be under agricultural production to support a family using the dominant crop/livestock type in a given municipality. As a result there can be high levels of variation in the size of a fiscal module across states and regions.

[4] For a full scorecard, see de Oliveira et al. (2013), p. 149.

Table 1
Attributes of PWS within the Cantareira System.

	Year Founded *(First Contract)*	Focal Activities	Funding Sources	Program Municipalities (Watersheds)	Stakeholders
Conservador das Águas	2005 *(2007)*	• Forest restoration • Erosion control • Soil Conservation	Municipality through city taxes; TNC	Extrema (Posses and Salto)	• Municipality of Extrema • Mina Gerais State Institute of Forests (IEF) • PCJ Watershed Committee • The Nature Conservancy • SOS Mata Atlântica
Produtor de Água - PCJ	2009 *(2010)*	• Soil conservation • Forest restoration • Forest conservation	PCJ committee	Joanópolis (Cancã); Nazaré Paulista (Moinho)	• National Water Agency (ANA) • São Paulo State Secretariat of the Environment (SMA) • São Paulo State Agricultural Extension Service (CATI) • Municipal governments (Joanópolis, Nazaré Paulista) • The Nature Conservancy • Associação Mata Ciliar (NGO)
Mina d'Água	2010 *(2012)*	• Spring protection through forest restoration or conservation	Paid through the state of SP	Piracaia (city-wide)	• São Paulo State Secretariat of the Environment • São Paulo State Agricultural Extension Service (CATI) • São Paulo Fund to Combat Poverty (FECOP) • Municipality of Piracaia
Bolsa Verde	2008 *(2010)*	• Forest conservation • Forest restoration	MG government (8 sources)	Camanducaia, Extrema, Itapeva (state-wide program)	• Minas Gerais State Institute of Forests (IEF) • Minas Gerais Water Management Agency (IGAM) • Minas Gerais Office of Rural Extension and Technical Assistance (EMATER) • Agrarian Reform Secretary (SEARA) • Minas Gerais Land Institute (ITER) • Agricultural Federation of Minas Gerais (FAEMG) • Federation of Agricultural Workers of Minas Gerais (FETAEMG)

Table 2
Enrollment requirements and contract features for PWS in the Cantareira System.

Eligibility requirement	Enrollment requirements	Contract length	Payments
Produtor de Água - PCJ	• Minimum portion of APP must be forested • Legal documentation of property	3 years	Set using 3 factors: 1) Relative use of soil conservation practices (25–50/50–75/75–100% of recommended), R$25–75 per ha/yr. 2) Riparian forest restoration (2 classes) with either R$83 or 125 per ha/yr. 3) Conservation of riparian forest, with payment by the class of forest and engagement of landowner, R$43–125 per ha/yr.
Conservador das Águas	• > 2 ha • Landowner must reside on property • Legal documentation of property	4 years, renewable	Fixed payment of R$176/ha/yr (opportunity cost of pasture)
Mina d'Água	• Family farms only • Active agricultural practices • Legal documentation of property • Owner may not be in arrears to the state	2–5 years	Based on a reference value with a maximum of R$150/ha and the following formula: Payment = $0.2V_{ref}$ x (protection factor) x (importance factor)[a]
Bolsa Verde	• < 4 fiscal modules • Landowner must reside on property • Legal documentation of property	5 years	R$200/ha/yr (for both the conservation and restoration of native vegetation)

[a] For full formula, see von Glehn et al., 2012 (Available at: http://documents.worldbank.org/curated/en/2012/10/19457353/o-projeto-mina-d%C3%A1gua-em-s%C3%A3o-paulo-brasil).

Policies to improve credit access for smaller agricultural operations are relatively recent, with a historical focus on large-scale agriculture (Carrer et al., 2013). PRONAF, a government support program that extends credit to family farmers[5] for infrastructure, technology, and market access (e.g., the creation of cooperatives), has yet to achieve broad impacts on production for smallholders, including investments in on-farm milk cooling equipment or other infrastructure that would aid farmers in improved their outputs (Guanziroli et al., 2013). Barbosa et al. (2013) find that access to credit is a significant factor affecting returns to scale of agricultural efficiency throughout Brazil. Merry et al. (2004) notes that farmers in the Brazilian Amazon frequently used informal contracts instead of formal credit to establish cattle herds, despite the fact that small ranchers typically lost money and bore most of the risk.

The 2007/2008 Agricultural Census in the state of São Paulo (referred to as LUPA in Portuguese), reports only 15.38% of agricultural producers using rural credit programs (São Paulo State Agricultural Extension Service 2008). Considering credit usage at this scale includes large agricultural operations producing sugarcane or cattle, which are common in the interior of São Paulo state. Selecting data only from the three municipalities that cover the majority of the São Paulo portion of the Cantareira watersheds reveals that only 4.3% of the landowners involved in agricultural activities reported usage of rural credit programs. This does not include informal credit and may be confounded by the smaller size of operations in the region, but suggests that barriers to usage of credit remain.

Labor constraints also have a strong effect on cattle production at different scales. Many family farms depend on labor from the household or from extended family, with farm managers and additional permanent workers only present on larger operations (Hostiou et al., 2015). The quantity and capacity of available labor affects production costs, as many efficiency measures (e.g., use of milk cooling equipment and record-keeping practices) require significant labor investments (Dill et al., 2015; Diniz et al., 2013).

Social and cultural factors affect capacity to adopt new practices and land uses. Rural family agriculture is deeply rooted in Brazilian cultural history, and the appeal of the profession plays an important role in farmer identity and the avenues through which information and technology enter communities (Hostiou et al., 2015; Gil et al., 2015). Social networks have been observed to positively affect intentions to alter pasture management (Borges and Lansink, 2015), adoption of economic management practices (Dill et al., 2015), and capacity for bargaining and negotiating contracts (de Brito et al., 2015). Dill et al. (2015) observe the adoption of accounting and other management practices among dairy farmers in Rio Grande do Sul to be correlated with association membership, and with internet access.

Beyond social networks, perceptions of government also affect land use decisions. Despite Brazil's long history of land use regulations, many properties remain out of compliance with APP and LR mandates. This may be attributable to restoration costs, but low probability of enforcement, economic benefits of grazing in riparian areas, and barriers to working with government and civil society groups also likely play a role. Entry into a PWS contract with a government entity depends on the perceived reliability of the fulfillment of contract terms. Although some of the benefits of PWS contracts are delivered early in the contract (e.g., forest restoration and legal documentation), payments are typically contingent on monitoring and paid annually or semi-annually, and so participating landowners would need to be confident in their eventual delivery. Zanella et al. (2014) identify prior connections with environmental NGOs to be correlated with PWS participation, which may reflect landowner values, or higher trust in PWS administration and objectives.

Biophysical characteristics of a property also affect landowner decisions in a number of ways. Chief among these is the productivity of land as pasture, which varies with characteristics such as water availability, soil type, and slope. Although most of the Cantareira is hilly and relatively inefficient for cattle, especially compared to other regions in Brazil, eucalyptus is the main alternative (Ditt et al., 2008). Plantations do not generate income as quickly as cattle, and so lose appeal for some landowners. However, some portions of land are highly sloped and require higher labor or generate production risk (through the loss of cattle to falls), making intensification of pasture management untenable and shifts to eucalyptus or abandonment more likely. Distance also restricts development options on some properties, as infrastructure in the region is poor and dominated by dirt roads on steep slopes that are difficult to traverse during wet periods.

A final issue is perceived risk associated with forest cover near a property. In a pilot study on the potential use of auctions to allocate PWS contracts in São Paulo state, Hercowitz and Figueiredo (2011) note that security concerns affected perceptions of forest restoration, in particular poaching of native palms and robbers using forests as cover to steal livestock. Security services are relatively weak in rural Brazil, with farmers often relying on neighbors to monitor threats, and so maintaining open sightlines to mitigate the potential for loss of stock to

[5] "Family farmer" is an official classification, defined by the Brazilian government using property size, on-farm labor, and household dependence on agricultural income.

Table 3
Descriptive statistics of surveyed landowners.

	Mean	Std. Dev.	Min	Max
Gender (proportion male)	0.842	–	–	–
Age (years)	54.15	13.73	18	88
Education (years)	7.59	5.49	0	30
Monthly income[a](% of sample)				
< 1	5.29	–	–	–
1–3	49.74	–	–	–
4–10	33.86	–	–	–
> 10	11.11	–	–	–
Off-farm income (%)	59.02	37.85	0	100
CAR registration (% of sample, Nov. 2015)	56.08	–	–	–
Property Size (hectares)	41.98	61.56	0.6	453
Pasture (% of property)	65.17	26.52	7	100
Forest (% of property)	16.04	15.51	0	70
All APP forested (% of sample)	25.40	–	–	–

[a] Categories calculated using number of Brazilian monthly minimum wage units (R $788, approx. US$230).

theft is a serious consideration for small-scale farmers.

3.3. Field assessments and farmer interviews

Descriptive statistics of demographic variables for survey participants are included in Table 3. All of the surveyed individuals maintained pasture for livestock, which was a requirement to participate in the survey. The population is relatively old, with an average age just below the minimum for pension collection in Brazil. Education and income levels are highly variable. Across the population roughly 60% of income was reported from off-farm sources, but the distribution was highly varied. Eighteen percent of farmers are wholly reliant on on-farm activities for income, while nearly 40% reported less than 10% of their earnings from agriculture on their property. Other farmers reported a more equal mix of on- and off-farm income streams, which was attributed to dual income households as well as pensioners, as retirement benefits were considered off-farm income in the survey questions.

Over half (56%) of households reported having completed the CAR registration process for their property. However, only 25% of households reported that the APPs on their land were fully forested. A variety of factors were suggested during interviews for the lack of forest cover, including the specific orientations of springs and streams on properties, and the presence of forest cover elsewhere on the property or on other properties owned by the landowner. The density of streams on properties (meters/hectare) was highly variable (mean =30.41, std. dev. =56.92), with several farmers expressing skepticism about the possibility of maintaining cattle production and complying with land use laws, despite the maximum restoration requirements established under the 2012 law.

The surveyed population reported little usage of formal credit sources, with many individuals complaining either of paperwork or risk involved in working with banks. Only 27% of farmers (51) reported the use of credit within the past 5 years, while 76% (143) reported having invested in physical improvements on the property in the same time period. Focus group participants mentioned the use of social and family networks to procure informal loans during crises, and reluctance among many of their peers to utilize PRONAF or other lines of formal credit. The reasoning behind this preference for informal or formal credit is unclear, but it was suggested that the bureaucracy required for formal credit presents challenges to farmers with lower levels of education, and that some landowners were skeptical of financial institutions.

Focus group participants observed that adoption of improved pasture management in Nazaré Paulista has spread through specific landowners in the municipality who have close familial ties to other farmers and rent tank space to neighbors for milk storage. Informal training sessions have also been organized with neighbors and extended family to demonstrate pasture management techniques. Participation in agricultural extension programs is low, only 26% of the survey participants reported attending a course offered by government agricultural extension offices, NGOs, or rural producers' associations.

The proximity of the Cantareira to some of the country's largest urban areas has affected labor supply for landowners. Contracting day laborers (*mão-de-obra* in Portuguese) is preferred for construction and infrequent maintenance tasks, but urban expansion has contributed to labor market constraints. The factories of Guarulhos and the greater São Paulo area are relatively close, and farmers have commented that the labor pool for daily contracts appears to have been negatively affected by this urban expansion and more lucrative employment opportunities. Migration away from cities is also having an impact, as the construction of second homes and infrastructure for tourism around the reservoirs and rivers of the region has resulted in increased subdivision and sale of agricultural land.

It was not clear that political and economic crises in Brazil affected perceptions of the validity of PWS contracts with the government, but it was apparent that historical political issues continue to affect landowner opinions. In addition to negative perceptions of agricultural extension programs and wariness to seek credit, trust in government institutions in the Cantareira region is further complicated by the development of reservoirs in the 1970s. When the Atibainha reservoir was completed in 1973, the government relocated many families in the municipality of Nazaré Paulista to less productive land in the hills around the reservoir, which limited family farmers' capacity to support themselves and created a lasting legacy of distrust of government (Ditt et al., 2008).

4. Discussion

Brazil has developed a legal framework for PWS, including governance structures to manage watersheds, generate financing, and identify ecologically beneficial activities. This framework has been augmented by state and municipal laws, which have, in turn, spurred development of a range of small-scale and pilot programs. In some instances these programs have targeted priority areas for ecosystem services provision, while others allow for interested participants to enroll across broader geographic scales. However, much of the participation in PWS programs in the Cantareira has been a product of focused recruitment and support from government and civil society actors (The Nature Conservancy-Brasil, 2015; Zanella et al., 2014; Kfouri and Favero, 2011). This type of recruitment is expensive, and results from the Cantareira suggest that several factors will need to be addressed if development of PWS participation is to become a cost-effective.[6]

The first obstacle that may affect recruitment of eligible landowners into PWS is the structure of contract incentives (see Fig. 2). All of the PWS programs in the Cantareira have payments that are lower than the annual land rental rate for pasture (~R$450/ha), and this has been cited in program evaluations as an opportunity for improvement (The Nature Conservancy-Brasil, 2015). This is likely to affect the landowners who participate, selecting for those individuals with stronger off-farm income sources or diversified on-farm activities (e.g., horti-

[6] The costs and benefits of using PES to encourage ecologically-significant biome-wide restoration in the Atlantic Forest has recently been debated in the literature. See: Banks-Leite et al., 2014. Using ecological thresholds to evaluate the costs and benefits of set-asides in a biodiversity hotspot. *Science* 345 (6200), 1041–1045; Finney, C. 2015. Comment on "Using ecological thresholds to evaluate the costs and benefits of set-asides in a biodiversity hotspot". *Science* 347(6223), 731-a.; Banks-Leite et al., 2015. Response to Comment on "Using ecological thresholds to evaluate the costs and benefits of set-asides in a biodiversity hotspot". *Science* 347(6223), 731b.

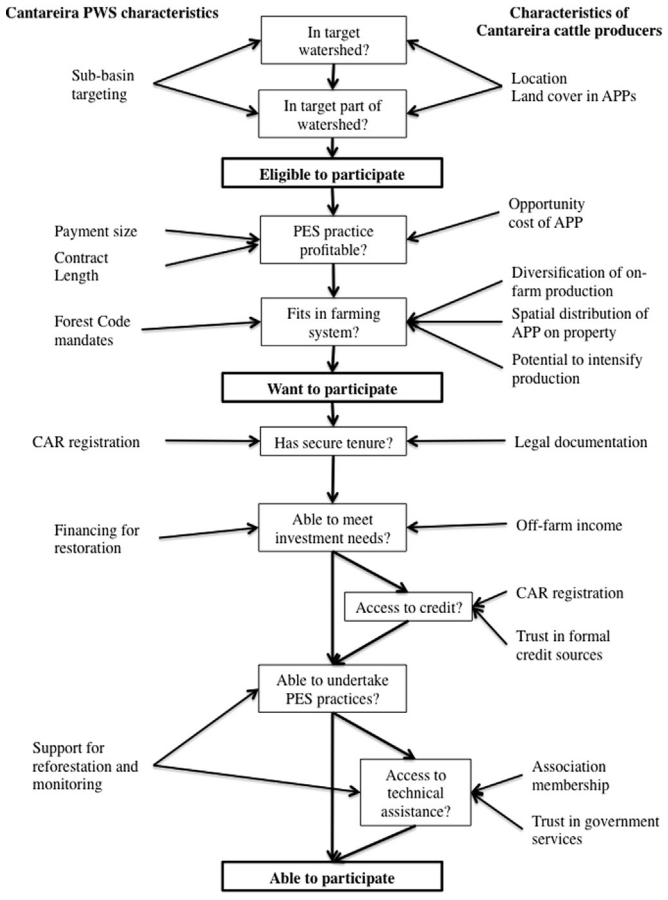

Fig. 2. Factors affecting participation in PWS programs. (Adapted from Pagiola et al., 2005).

culture or eucalyptus as well as pasture). In Extrema's Water Conservator program, which offers higher payments, many enrollees are retired and cattle production is infrequently the sole source of income (Richards et al., 2015). For individuals who are highly dependent on cattle production, or who are interested in maintaining open pasture for future use, the overall payoff of PWS may not be sufficient.

Almost all contracts that have been implemented in the Cantareira region are short-term (2–5 years). In the early stages of program development this shorter length provides both landowners and program staff an opportunity for evaluation while minimizing long-term costs. However, the Native Vegetation Protection Law mandates long-term (permanent) conservation, and program staff may need to establish opportunities for either longer-term contracts or contract renewals to avoid the potentially negative consequences of lost funding for participants after only a few years. Renewals with shorter terms may be more appealing, as an attempt in Extrema to enroll participants in 30-year carbon sequestration contracts was unsuccessful (Richards et al., 2015).

Some environmental NGOs have attempted to train farmers pasture management strategies, such as the Voisin grazing system, to help compensate for the conversion of APPs to native forest. However, adoption of these alternative methods has been limited, and varied by municipality and neighborhood. Farmers in Nazaré Paulista reported reliance on *ad hoc* associations with neighbors for information on farming practices, while farmers from Extrema and other municipalities in Minas Gerais have more active farmer associations, in particular SENAR (National Agricultural Learning Service). Other municipalities in the Cantareira devoted greater resources to agricultural extension offices, including equipment rentals, which cultivated greater interactions among farmers and agronomists. Evidence from other regions with PES programs suggest that these social contexts will also affect enrollment (Zanella et al., 2014; Chen et al., 2009).

Taken together, PWS incentives that currently exist in the Cantareira would be expected to enroll landowners with diversified on-farm or high off-farm income, with connections to and trust in institutions, such as government agencies and NGOs, and an intrinsic desire to comply with the APP mandates of the Forest Code to motivate participation. Evidence from an analysis in Extrema (as well as PES projects elsewhere in the Atlantic Forest) suggests that connections to civil society organizations involved in PWS programs are especially important (Richards et al., 2015; Zanella et al., 2014). However, these landowners may also be more willing to replant forest on their own, either through their own investments or mitigation-type programs such as the São Paulo Springs program (*Programa Nascentes*) that link landowners interested in forest restoration with others who need to 'purchase' restoration elsewhere to comply with land use laws. Recruitment of landowners who are unlikely to plant forests on their own would require higher overall payments, greater investment in developing social connectedness, or – absent changes in incentive structures – greater perceived risks to non-compliance through legal enforcement of the 2012 law.

Improving incentives would require actions to address two major administrative challenges – financing and governance. Restoration targets for the Atlantic Forest are large, and will likely require investments from multiple sources (Pinto et al., 2014). The New Forest Law has enabled the use of funding mechanisms to support reforestation, but thus far there are limited examples (such as Extrema) in which resource users have joined permanent fee or tax systems to fund these types of projects. In the Cantareira, one source of funding that has yet to engage in PWS is the state water utility company (Companhia de Saneamento Básico do Estado de São Paulo – SABESP), which manages the reservoirs in the Cantareira System. To date, the company has focused on reforestation within the buffer areas of its reservoirs, but declined to support PWS programs.

Although governance frameworks are legally defined, and both national and state governments have invested in pilot programs to refine management structures and regulations, the watersheds in the Cantareira still fall under the responsibility of multiple authorities, including several municipalities and watershed committees (Padovezi et al., 2012). This complicates planning and decision making, including development of funding mechanisms and support for technical assistance. This is not insurmountable, as evidenced by the existence of several PWS programs already, but it may affect the capacity to modify incentives and financial support to better attract landowners who would not otherwise participate in provision of watershed services.

5. Conclusion

Despite substantial effort to develop PWS programs in Brazil, there have been limited environmental gains. This is due, in part, to the slow process of developing legal frameworks and pilot projects to implement PWS and validate its model. However, observations from the Cantareira suggest that the structure of existing incentives may not be sufficient to encourage enrollment by landowners who are unlikely to reforest portions of their land on their own. This supports a growing body of research on the economic, social, and environmental factors that affect decision making. A better understanding of the preferences and motivations of these landowners is necessary, both to target the landowners who would provide the greatest environmental gains through participation and to better use limited resources.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ecoser.2016.12.016.

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Glossary

Portuguese names in parentheses ().

ANA: National Water Agency (Agência Nacional de Águas)

APP: Area of Permanent Preservation (Área de Preservação Permanente)

CAR: Rural Land Registry (Cadastro Ambiental Rural)

CATI: São Paulo Agricultural Extension Office (Coordenadoria de Assistência Técnia Integral)

EMATER: Minas Gerais Office of Rural Extension and Technical Assistance (Empresa de Assistência Técnica e Extensão Rural)

FAEMG: Agricultural Federation of Minas Gerais (Federação da Agricultura e Pecuária de Minas Gerais)

FETAEMG: Federation of Agricultural Workers of Minas Gerais (Federação dos Trabalhadores em Agricultura do Estado de Minas Gerais)

IGAM: Minas Gerais State Water Management Agency (Instituto Mineiro de Gestão das Águas)

IEF-MG: Minas Gerais State Institute of Forests (Instituto Estadual de Florestas)

IPÊ: Ecological Research Institute (Instituto de Pesquisas Ecológicas)

ITER: Minas Gerais State Land Institute (Instituto Estadual da Terra)

LR: Legal Reserve (Reserva Legal)

PES: Payments for Ecosystem Services

PWS: Payments for Watershed Services

PdA: Water Producer Program (Produtor de Água)

PCJ: Piracicaba-Capivari-Jundiaí

PRA: Program for Environmental Compliance (Programa de Regularização Ambiental)

PRMC: Program for Riparian Forest Restoration (Projeto de Recuperação de Matas Ciliares)

PRONAF: National Program to Strengthen Family Agriculture (Programa Nacional de Fortalecimento de Agricultura Familiar)

SABESP: São Paulo State Water Utility Company (Companhia de Saneamento Básico do Estado de São Paulo)

SEARA: Agrarian Reform Secretary of Minas Gerais (Secretaria Extraordinária para Assunto de Reforma Agrária do Estado de Minas Gerais)

SENAR: National Rural Learning Service (Serviço Nacional de Aprendizagem Rural)

SNUC: National System of Conservation Units (Sistema Nacional de Unidades de Conservação)

TNC: The Nature Conservancy