Adding the temporal dimension to spatial patterns of payment for ecosystem services enrollment

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Highlights

- PES schemes are used to conserve natural ecosystems and improve human livelihoods.
- Understanding temporal and spatial enrollment patterns in PES is key.
- This can improve conservation of threatened ecosystems for long time periods.
- We present a large-scale PES program that attracts high conversion threat lands.
- But enrollment of these lands was shorter than lands with lower conversion threat.
- Both temporal and spatial dimensions of PES enrollment are key for informing policy.

Abstract

Payments for Ecosystem Services (PES) programs are increasingly emphasized to address challenges of conserving forests. However, concerns remain regarding the ability of PES programs to ensure long-term conservation of threatened lands. Evaluation of large-scale PES programs, including the spatial and temporal patterns of enrollment, is scarce, especially for programs that aim to protect forest from severe threats such as expansion of industrial agriculture. Using information on PES enrollment across 252,319 km^2 in the Argentine Chaco, we examined both the duration for which lands are enrolled in PES and their suitability for agriculture. Specifically, we examined whether the PES program has resulted in adverse selection not only in space but also in time. We built spatially explicit generalized linear models using information on participants' length of contract and the potential of their land for agricultural use. We found the PES program enrolled land in areas with high agricultural potential, but enrollment of these lands occurred for shorter time periods than lands with lower levels of threat from deforestation. Consequently, adverse selection occurred over time but not in space. Our work demonstrates the importance of evaluating both temporal and spatial dimensions of adverse selection in PES for informing policy.

1. Introduction

Market-based strategies have become increasingly popular approaches to conserve nature and to improve the livelihoods of people engaged in supplying environmental services (Wunder et al., 2008; Bradshaw et al. 2009; Martin-Ortega et al., 2013; Muradian and Rival 2012; Schomers and Matzdorf, 2013; Hejnowicz et al. 2014). Payments for ecosystem (or environmental) services (PES) programs are prominent examples of such strategies where a buyer of an environmental service, such as carbon storage by forests, pays another party for continued provision of the service (Ferraro, 2011; Arriagada et al., 2012; Ingram et al., 2014; Ezzine-de-Blas et al., 2016; Da Ponte et al., 2017). PES can also be viewed as incentives for collective action when participants apply to a PES program as a group. In this way, governments can influence rules that guide the provision of ecosystem services in a hybrid governance arrangement (Muradian and Rival 2012).

PES programs are highly variable. Approximately, 550 PES programs around the globe have been implemented with a variety of governance structures and ecosystem services provision (Salzman et al. 2018). These programs encompass user-financed PES, government-financed PES and hybrid approaches, and the provision of watershed integrity, biodiversity, and carbon storage services (Salzman et al. 2018).

Successful PES programs should offset the pressure to convert land to competing land uses (Wunder et al., 2008; Ferraro, 2011). Thus, the main expected outcome of PES is continued provision or restoration of environmental services that are under threat (Wunder et al., 2008; Armsworth et al., 2012; Drechsler et al., 2017; de Lima et al., 2017). To achieve this outcome, an estimated of US$36-42 B is invested each year globally (Armsworth et al., 2012; Drechsler et al., 2017, Salzman et al. 2018). Perhaps the most well-studied example is Costa Rica's PES program called PSA (Pagos por Servicios Ambientales). In this program, ecosystem services providers are financially rewarded for land uses that maintain or increase forest cover in a region where the local economy is based on livestock and cash crops, such as pineapple, or citrus (Locatelli et al. 2008). While PES may conserve land under high threat of conversion (hereafter referred to as 'threat'), the effectiveness of PES in preventing the conversion of land to uses with high earning potentials, such as industrial-scale intensive agriculture, is still uncertain (Ferraro, 2011; Lennox and Armsworth, 2011; Bremer et al., 2014; Drechsler et al., 2017).

When stakeholders enroll land that is at low or no threat in a PES program, the overall conservation effectiveness of the program is hindered (Fig. 1), especially if enrolling these lands limits finances to enroll other more threatened lands—a process known as adverse selection (Ferraro, 2011). In government-financed programs, enrollees can choose between government-approved land uses. For example, in Costa Rica's PES program where stakeholders can choose between land uses such as forest conservation, reforestation, and agroforestry, 71% of PES contracts were allocated to lands with little to no agricultural potential that were unlikely to be converted to other uses (Locatelli et al. 2008; Ferraro, 2011). In recognition of this potential failure of PES, much of the literature has focused on understanding the spatial patterns of PES enrollment to decrease adverse selection (Ferraro, 2008; Arnold et al., 2013; White and Hanley, 2016; Drechsler et al., 2017). Yet, even if threatened land is enrolled in a PES program, the duration of enrollment is important. If threatened lands are enrolled for short durations, then long-term provision of environmental services is uncertain and the effectiveness of PES is unclear (Fig. 1 Lennox and Armsworth, 2011; Ando and Chen, 2011; Ezzine-de-Blas et al., 2016).

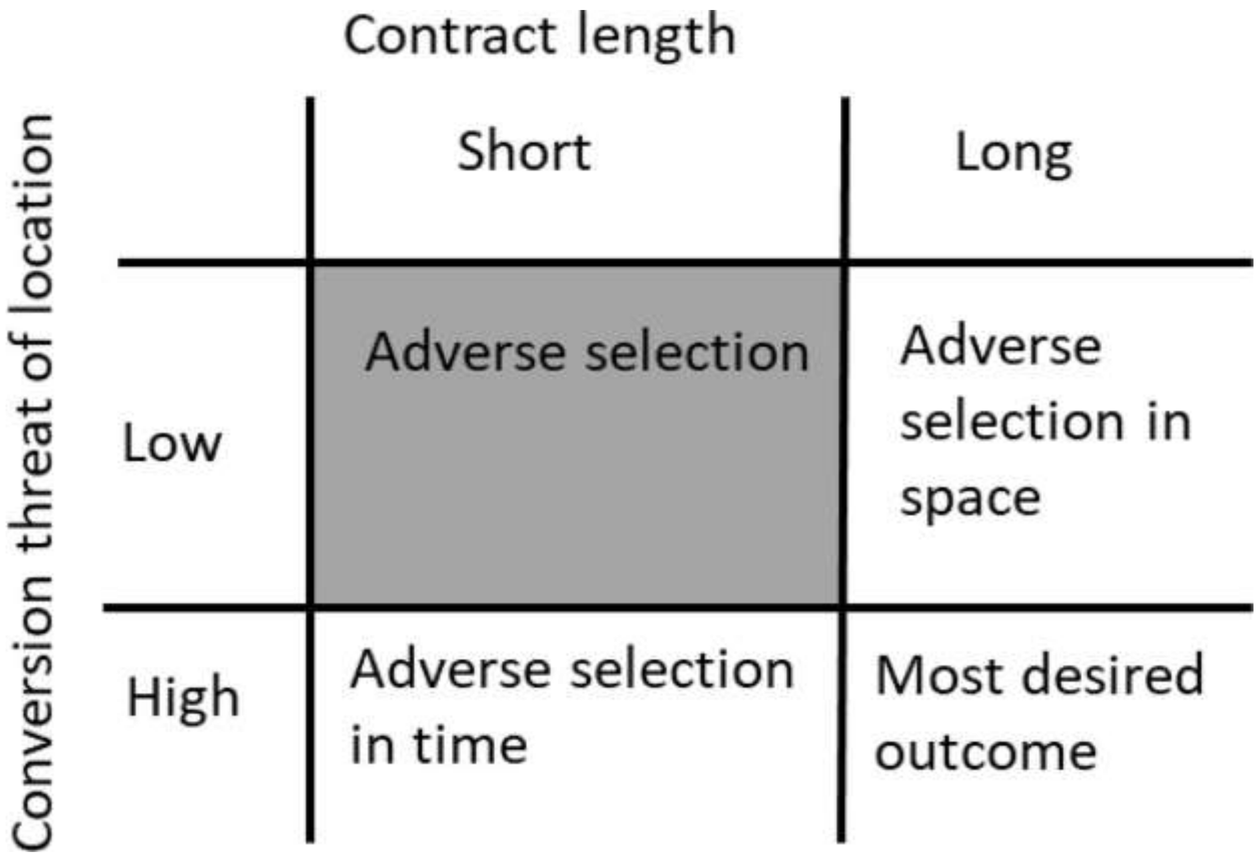

Fig. 1. Spatial and temporal dimensions of adverse selection. Adverse selection occurs when land with low levels of conversion threat enrolls in the program, and as a result, PES directs funds to conserve land that would likely be conserved in the absence of the program (top two quadrants; Ferraro et al., 2015). Adverse selection in space can occur when land with low conversion threat levels enroll in PES for long periods of time (top right quadrant). Adverse selection in time can occur when threatened land is enrolled for short time-periods (bottom left quadrant). Avoiding both time and space dimensions of adverse selection would require enrolling land under high levels of conversion threat for long periods of time (bottom right quadrant).

Understanding the temporal dimensions of PES enrollment is important when considering both the institutional complexity and ecological consequences of PES implementation (Fig. A1). Short-term contracts might be advantageous if environmental services materialize quickly. In this instance, short-term contracts may increase program acceptance among landowners, give more flexibility to governmental agencies to adjust payments, and be suitable for lands with low opportunity cost (Ando and Chen, 2010; Lennox and Armsworth, 2011; Drechsler et al., 2017). However, short-term contracts increase costs related to project evaluation and negotiation (i.e., transaction costs; Juutinen et al., 2014). In locations with high deforestation rates, long time periods are required for forest conservation and restoration, as short-term contracts are unlikely to secure long-term provision of ecosystem services. Long-term contracts might also be preferred when future site availability for conservation is uncertain or to ensure the provision of slowly-maturing or highly-targeted ecosystem services (Ando and Chen, 2010; Lennox and Armsworth, 2011; Juutinen et al., 2014; Fig. 3). However, long-term contracts might decrease participation and increase the costs of funding PES programs (Ando and Chen, 2010; Drechsler et al., 2017).

Real-world examples of how spatial aspects of PES enrollment interact with temporal aspects are lacking. Here, we examine spatial and temporal enrollment patterns of a national-level PES program in Argentina to assess if adverse selection occurs. This PES program is part of Argentina’s Native Forest Law (law 26331, Ley de Presupuestos Mínimos de Protección Ambiental de los Bosques Nativos, or Ley de Bosques Nativos). This program aims to preserve forest and its environmental services, such as biodiversity and forest cover for carbon storage, in the face of industrial-scale agriculture in one of the most threatened forested ecosystems in the world, the Chaco forest (Hansen et al., 2013; Nunez-Regueiro et al., 2015; Kuemmerle et al., 2017). This dry forest has suffered high levels of deforestation fueled by rapid expansion of agriculture, mainly to produce soybeans and pasture for cattle (Grau et al., 2008; Hansen et al., 2013; Volante et al., 2016; Fehlenerg et al., 2017). The Argentine PES program is among the largest in the world in terms of land covered, where participants voluntarily enroll their land for a time period of their choosing, and it has a permanent source of funding dictated by law (Garcia Collazo et al., 2013; le Polain de Waroux et al., 2017). We focused our study in four provinces of northern Argentina that hold the largest tracts of Chaco forest: Chaco, Formosa, Salta, and Santiago del Estero, comprising an area of 252,319 km^2 (Fig. 2).

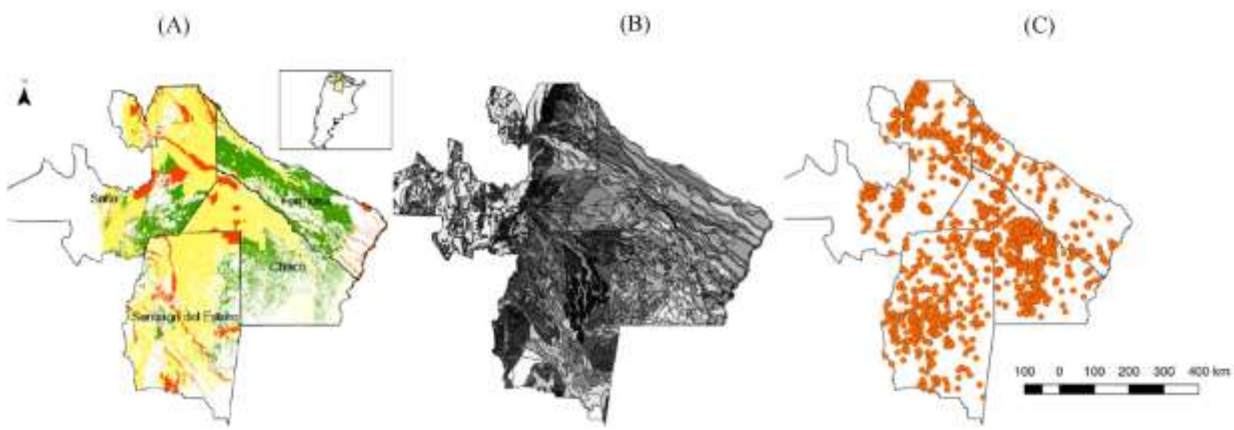

Fig. 2. (A) Study area in the four provinces inside the Chaco forest of Argentina and their corresponding land-use zoning categories (Green, Yellow, and Red categories). (B) Agricultural suitability index for the study area. Highest suitabilities are represented with darker colors. (C) Location of project participants in our study region.

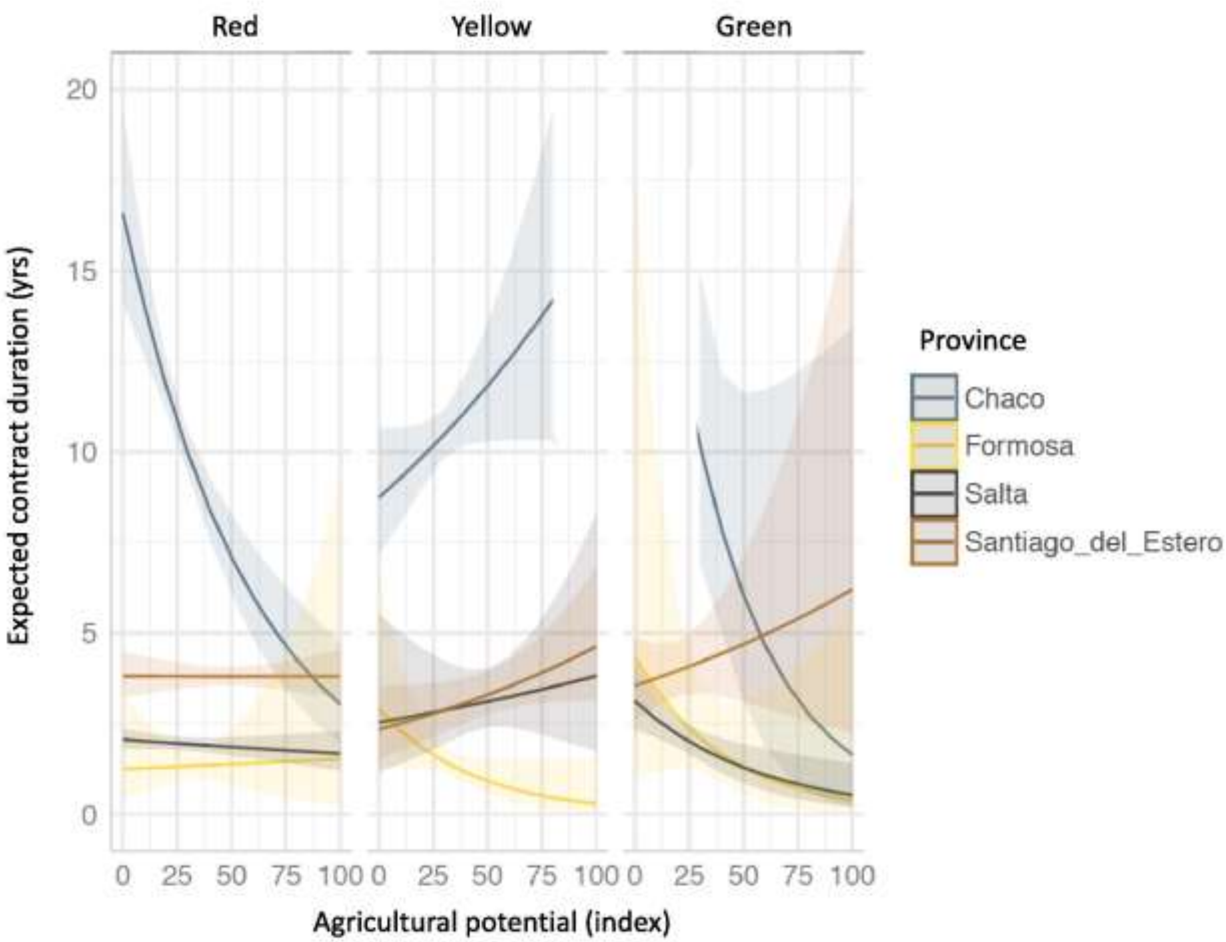

Fig. 3. Relationship between contract duration and the index of agricultural potential of land by province (Chaco, Formosa, Salta, and Santiago del Estero) in zoning categories (Red, Yellow, and Green; see Appendix for more details). Shaded areas represent 95% confidence intervals.

We address two unresolved questions regarding this market-based strategy to conserve forests in the context of adverse selection. First, does this PES program result in enrollment of lands with high agricultural suitability, i.e. lands that are at high risk of conversion? Second, is long-term enrollment of lands with high conversion risk attained by the PES program? The conservation effectiveness of PES depends on the enrollment of lands with high agricultural suitability for long periods of time to reduce the threat of deforestation and avoid low-return investment in lands at minimal risk of conversion (Ferraro, 2011).

2. Materials and Methods

2.1. Study area

The Chaco forest of Argentina, Bolivia, and Paraguay is the second largest forested ecoregion in South America after the Amazon (Fehlenberg et al., 2017). It is a key global conservation area because of high levels of biodiversity and endemism, which is threatened by large-scale agricultural conversion (Grau et al., 2008; Kuemmerle et al., 2017). Sixty percent of the Chaco occurs in Argentina where many rural and indigenous communities rely on it to sustain their livelihoods. The Argentine Chaco is a patchwork comprising remnant forest strips, small forest patches, and some larger forest blocks embedded in a matrix of large farms primarily used for soybeans or pasture for cattle (Núñez-Regueiro et al., 2015).

2.2. PES program

To halt steep rates of deforestation, Argentine legislators passed an innovative federal-level law in 2007 that established a minimum annual federal budget for environmental protection and for enrichment, restoration, conservation, and sustainable management of native forests and the environmental services they provide. The law required national-level, land-use planning to classify native forests into three zoning categories: Red, Yellow, and Green (Fig 2a). These categories differ in their importance for local communities and ecosystem services and biodiversity conservation, and each varies in restrictions regarding conversion of land to agricultural development (i.e., deforestation). Lands in the Red category represent the highest level of conservation priority, followed by Yellow, and then Green (Garcia Collazo et al., 2013).

The law stipulates financial compensation for each participating province based on the amount of land in each zoning category and to individual program participants who voluntarily enroll their land in the payment program (Garcia Collazo et al., 2013). Enrollees are compensated annually per area of land enrolled in government-allowed land-uses (e.g., conservation, restoration, silviculture, and silvopasture). Payment levels are in decreasing order of conservation priority (i.e., payments in Red > Yellow > Green) and are conditional on landowners implementing an approved land management plan. Contract duration varies (range: 1 - 21 years) and is defined for each participant at the time of enrollment (Table 1, Table A1). The PES program also allows re-enrollment, has monitoring and compliance mechanisms in place, and has allocated over $45 million to 1,341 projects among four provinces between 2010 and 2015 (Table 1). This investment resulted in almost 43,000 km^2 of land enrolled (equivalent to 17% of available land that could potentially be enrolled). See Appendix for more details.

2.3. Data sources and analysis

To assess if land enrolled in the PES program had higher agricultural suitability than land not enrolled, we compared agricultural suitability for enrolled areas (n = 1,341) and an equal number of randomly selected, non-participating locations in forested areas. Agricultural suitability information was in a raster grid (30 m resolution) where each pixel included an index of land suitability for the main uses of the area (i.e.,

Table 1. Summary of main characteristics of the Argentine Payment for Environmental Service (PES) program for the Chaco forest by province.

	Chaco	Formosa	Salta	Santiago del Estero
Number of projects	441	145	322	428
Money allocated 2010-2015 (US$ of May 2015)	$7,923,834	$3,767,297	$16,658,122	$17,067,732
Mean (range) enrollment duration (yr)	10.1 (1-21)	1.5 (1-6)	2 (1-16)	3.7 (1-20)
Total area enrolled (ha) (% of available area)	313,957 (6.4%)	347,465 (7.9%)	3,048,000 (36.8%)	589,485 (17.0%)
Number of projects enrolled under land uses allowed by PES				
Conservation-Restoration	135	127	23	169
NTFP-Silviculture-Silvopasture	225	6	5	74
Formulation	81	12	304	185

soybean and pasture for cattle; agriculture hereafter). We identified participating locations using geo-referenced information on program participants that included location of land enrolled, length of contractual obligations, and the type of land use specified by each project. Allowed land uses vary in financial potential and were as follows: conservation-restoration (i.e., land uses with low financial potential), non-timber forest products (NTFP)-silviculture-silvopasture (i.e., land uses with high financial potential), and formulation projects that are the initial stage of enrollment where a base line study is conducted before choosing among the previously mentioned land uses (data sources: Argentine Ministry of Environment, National Institute of Agricultural Technology; see Appendix for details).

We modeled program participation as a function of agricultural suitability, zoning categories at the pixel level (i.e., location of each point), and provinces using a generalized linear model (GLM) with a logit link function and assuming a binomial error distribution. Monetary allocation per unit of land and total size of land differ in the three zoning categories (Table 1). Thus, we included zoning categories in our model to control for differences in total area and financial incentives in each category. To understand how contract length in the PES program varied among participants in different areas of agricultural suitability, we used a GLM with duration of program contract (years) as a response variable, with agricultural suitability, zoning categories, and provinces as explanatory variables. In this model, we used a log link function, and assumed a Poisson error distribution. Finally, we tested for potential interactions between suitability of lands, land-uses, and provinces.

3. Results

Enrollment of land in PES was not related to potential suitability of land for agriculture (β = 0.002, 95% C.I = -0.09, 0.1). Furthermore, the interactions among potential suitability of land, land-use zones, and provinces did not explain the probability that land was enrolled in PES (Table A2). However, locations enrolled for longer periods of time had lower agricultural potential than locations enrolled for shorter periods (Fig. 3; β = -0.02, C.I. = -0.02, -0.01). This pattern was stronger in some zones and provinces, particularly the Red and Green zones for Chaco, the province with the greatest number of projects, and to a lesser degree the green zones for Formosa and Salta (Fig. 3, Table A3). The most notable exception was the Yellow category in the Chaco province, where locations that enrolled for long time-periods also had high agricultural potential (Fig. 3, Table A3). Mean enrollment duration was 4.3 years. Enrollment duration in the provinces of Formosa and Salta was lower on average than in Santiago del Estero and Chaco (1-2 years and 4-10 years, respectively; Table 1, Table A.1, see Appendix for details). In the province of Chaco, a greater number of participants enrolled land under land-use categories with high financial potential (i.e., non-timber forest products, silviculture, and silvopasture) compared to categories with low financial potential (i.e., conservation and restoration; Table 1). The pattern was reversed in the provinces of Formosa, Salta, and Santiago del Estero: more projects were submitted with land uses that had low financial potential in comparison to projects with high financial potential (Table 1).

4. Discussion

Adverse selection can potentially hinder the success of PES programs and evidence for lower enrollment of lands of high conversion threat compared to lands of low conversion threat is widespread (Ferraro, 2011; Drechsler et al., 2017). Additionally, where PES programs offer variable lengths of contracts, adverse selection linked to enrollment time may be an important issue, but one that has received little attention to date. Assessment of both spatial and temporal characteristics of PES enrollment are necessary for understanding the potential for long-term conservation success of PES (Fig. 1).

With an average payment of US$2/ha/yr. we expected that Argentina's PES program would seldom attract participants in areas with high agriculture potential when alternative land uses can yield 50 times more revenue (e.g., soybean production). However, our results show that lands of both high and low agricultural suitability were enrolled across all provinces, which suggests limited adverse selection across space. If only the spatial dimensions of PES enrollment in the Chaco forest are considered, then the program appears to have avoided failure. Indeed, enrolling lands of high agricultural suitability is arguably one of the program's greatest successes, given that agriculture is the main driver of deforestation in this region (Grau et al., 2008; Hansen et al., 2013; Volante et al., 2016; Fehlenerg et al., 2017; Nolte et al., 2017). Yet the lack of relationship between agricultural suitability and enrollment across different land-use categories may suggest a limited ability of the land-use zoning process to direct enrollment of areas of high conversion risk, especially in zones of conservation priority (i.e., Red category). Furthermore, our results indicate that lands under high threat of deforestation were frequently enrolled for shorter durations than areas with lower threat of deforestation, i.e., adverse selection occurred across time.

Landowners' ability to navigate financial uncertainly or to seize favorable market conditions to clear land for agriculture could help explain observed patterns across all provinces (le Polain de Waroux et al., 2017). On the one hand, the Argentine PES program allows re-enrollment of participants (Garcia Collazo et al., 2013) and landowners could use short-term enrollment in the program followed by re-enrollment as a strategy to get inflation-adjusted payments in the face of financial uncertainty. On the other hand, landowners could be accepting PES payments in return for delaying land conversion for a short duration, which would be inconsistent with conservation of threatened lands in perpetuity (Grau et al., 2005). On average, the Argentine PES contracts are at least 2 years shorter than most successful contracts in other PES programs around the globe (Lennox and Armsworth, 2011; Sattler et al., 2013; Grima et al., 2016; Drechsler et al., 2017), and contract duration likely will be one factor limiting the conservation impacts of this program in the coming years.

At the provincial level, temporal adverse selection appeared stronger in the Chaco province than in Formosa, Salta, and Santiago del Estero, in all land-use categories except the Yellow category. In the Red category in Chaco province, the greatest proportion or enrolled lands were provincial and national protected areas, unlike other provinces where lands managed by the government and private sector comprised over 50% of land enrolled in the Red category (Garcia Collazo 2013). Furthermore, protected areas can be located in areas with low levels of threat conversions (Pfaff et al. 2015). Government enrollees in the Chaco province could be motivated to enroll land for long periods of time in the PES program because they are tasked with the protection of natural ecosystems. In the Yellow category in the Chaco province, however, our results highlighted increasing contract length with increasing agricultural potential; a pattern that was not significant in other provinces. The long contract length for productive lands in Chaco could be facilitated by more lenient land-use regulations in that province in comparison to the other provinces. Chaco province allows complete deforestation of up to 20% of the parcel and allows up to 50% of silvopasture – the rest can be left for conservation (Garcia Collazo et al. 2013). These permitted levels of land-use change are higher than in other provinces, making long-term enrollment of lands more compatible with agricultural production practices (Garcia Collazo 2013). This explanation is in line with our results. The Chaco province had a greater proportion of participants submitting land use plans with high earning potential, such as agroforestry and silvopasture, in comparison to other provinces where the most common land uses under PES had low financial potential, such as conservation projects. Thus, in locations with high agricultural potential in the Yellow category, payments constitute incremental income above income generated by production activities (e.g., silviculture or silvopasture), which can reduce landowners' opportunity cost of not converting their land to agricultural production (Borner et al. 2017). This in turn can incentivize landowners to enroll for longer periods of time.

An analogous trend was observed in a PES program in Colombia (Pagiola et al. 2016). There, long-term adoption of environmentally friendly practices, even after termination of contract, was reported for silvopastoral practices where PES reduced the initial cost of adoption on sites where productive activities were allowed, as opposed to purely conservation activities (Pagiola et al. 2016). Longer-term analysis of the Argentinian program will confirm if PES is encouraging long-term practices that ensure continued provision of ecosystem services, or if conversely landowners choose to deforest upon contract termination.

Different payment mechanisms could act as effective policy instruments to decrease adverse selection in time and space (Figs. 1 and A.1). When considering how to overcome spatial adverse selection, it has been argued that linking payments to deforestation threat levels may help PES programs prioritize enrollment of land under high threat of conversion (Hanley et al., 2012; Reed et al., 2014; Pagiola et al., 2016; White and Hanley, 2016). In the absence of payments linked to deforestation threat levels, spatial adverse selection can reduce available funds aimed at ensuring the continued provision of threatened ecosystem services. An important question is whether tiered payments are sufficient to overcome both spatial and temporal limitations of PES enrollment. When landowners choose long-term contracts, landowners' marginal benefit for remaining in the program declines over time and the marginal opportunity cost rises (Juutinen et al., 2014). Thus, linking PES payments to commodity prices could help keep farmer's marginal benefit constant over long-term contracts (Ferraro, personal communication). To understand how payments could be better structured, further research is needed to understand why landowners enroll in PES programs and their choice of contract length. If appropriately designed, PES programs are a powerful instrument by which conservation professionals and lawmakers may conserve key biodiversity areas that are under threat of disappearing.

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