Appendix for

Adding the temporal dimension to spatial patterns of Payment for Ecosystem Services enrollment

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Details on materials and methods

PES definition

We follow the definition of PES proposed by Wunder (2015) that encompasses "*voluntary transactions between service users and service providers that are conditional on agreed rules of natural resource management for generating offsite services"*. Wunder (2015) identifies a special PES case where governments act as the highest level of user aggregation and we consider that the Argentine program falls into this special PES case (see program guidelines).

Program details and money allocation guidelines

The Argentine Native Forest Law (Congreso de la Nacion Law 26,331), which was implemented in 2007, aimed to promote natural resource conservation, and regulate the agricultural expansion. It also aims to improve and maintain ecological and cultural processes that occur in native forest, and enrich, conserve, and restore Argentine native forests (Garcia Collazo et al. 2013). The Native Forest Law has two main components, namely, a native forest zoning component and a PES component. For the native forest zoning component, each provincial government identifies three zoning categories for all forested lands (Fig. 1). Landowners who enroll in the program under category I (Red zone) can use non-timber forest products, or conduct projects that "conserve or improve the conservation value of the land" (a.k.a., conservation plan). Land clearing in this category is prohibited. Landowners who enroll in category II (Yellow zones) can propose a conservation project for their land, but can also submit a request to sustainably use

timber or non-timber forest products, or have silvopastoral activities (via a management plan), but land can also be allocated for sustainable use (sic), tourism, and scientific research. In this category, land clearing is prohibited but sustainable selective logging is allowed. Landowners who enroll in category III (Green zones, lowest conservation priority) can submit conservation or sustainable management plans, as well as land-use change plans, although there is no funding provided for land-use change. Landowners can submit a land-clearing permit only in category III (Green zones). Provincial governments defined Red, Yellow, and Green zones mainly based on importance for biodiversity conservation, although specific criteria varied by province (Garcia Collazo et al. 2013)

The Native Forest Law acknowledges that native forest ecosystems generate Ecosystem Services such as hydrological regulation, biodiversity conservation, soil and water quality, capture of greenhouse gas emissions, landscape beauty and diversification, and defense of Argentine cultural identify, and that these services benefit the inhabitants of Argentina (Article No. 5, Law 26,331). To ensure continued provision of these services, the Native Forest Law establishes a voluntary PES component to compensate landowners for maintaining or improving ecosystem services provided by their native forests (Article 11, Jefatura de Gabinete de Ministros, Res. No. 826, August 13, 2014). These payments are conditional on landowners providing and implementing a plan (in Spanish, “certificado de obra”) where landowners commit to conduct activities to maintain or enhance ecosystem services (Article 11, Jefatura de Gabinete de Ministros, Res. No. 826, August 13, 2014), according to the land uses allowed under each zoning category and thus, meeting the conditionality requirements of PES outlined

by Wunder (2015). Plans include a detailed one-year or multi-year plan that specifies the activities proposed for the land, as well as biodiversity inventory that will serve as a base line. Landowners that wish to voluntarily participate in the program by enrolling their land in one of the designated conservation categories must meet land-tenure requirements and submit a management proposal (Jefatura de Gabinete de Ministros, Res. No. 826, August 13, 2014). The law also stipulates that peasant or indigenous communities, who in case of not having official property titles, can still participate in the PES program as a "beneficiary group". In such cases, a beneficiary group must either show ownership by prolonged occupation of the land (squatter's right), or by having the expressed consent of the landowner. In cases where a local community lacks the funds or technical abilities to write a land-use plan, then the local government may request additional funds to ensure participation of small landholders, indigenous or peasant communities. Duration of enrollment varies for each program participant and is defined at the time of enrollment (Table S-1) and re-enrollment is possible. The National Forest Law specifies that Provincial governments will prioritize enrollment requests (Article 9, Law 26,331), however does not outline prioritization criteria.

After passing the law in 2007, each province was responsible for implementing financial incentives to enroll areas in Red, Yellow, and Green (incentives in Red > Yellow > Green). However, a national resolution was passed in 2014, which standardizes how financial resources are distributed among participating provinces and for each conservation category (Jefatura de Gabinete de Ministros, Res. No. 826, August 13, 2014). The amount of resources that each province will receive depends on two components: a) a native forest component, which is determined by the surface

occupied by all native forest relative to the total provincial surface; b) a conservation component for each province, which is determined by the amount of native forest in each of the three conservation categories and by a multiplier r which penalizes land in yellow areas (r = 0.6 of money in red) and in green areas (r = 0.05 of money in red; Jefatura de Gabinete de Ministros, Res. No. 826, August 13, 2014). There is no penalty for red areas as the aim of this program is to attract the greatest number of participants to these areas.

Origin of funds for PES and allocation

Each year, the funds that finance PES originates from a) at least 0.3% of the yearly National Budget, b) 2% of all export retention taxes from agriculture, cattle-ranching, and silviculture, c) loans or subsidies given by national or international organizations explicitly aimed at funding this program, d) donations, e) other contributions to the fund, f) profits generated by sales of publications or other services from the forestry sector, and f) financial resources not allocated in previous years (Article 31, Law 26,331). Seventy percent of the funds will be allocated to compensate public or private landowners that participate in the PES program. The remaining 30% of the funds are allocated to each province to support native forest monitoring programs and to provide technical assistance to small landowners such as campesinos and indigenous communities (Article 35, Law 26,331)

Program compliance and monitoring

Each year, landowners that participate in PES must submit a report that outlines the activities that were implemented to maintain or improve ecosystem services on their land (Jefatura de Gabinete de Ministros, Res. No. 826, August 13, 2014). Provincial and

Federal authorities can perform on-the-ground inspections to assess the accuracy of reports (Article 11, COFEMA, Res. No. 277, May 8, 2014).

Regulations regarding unenrollment or penalties for non-compliance are not detailed. If landowners wish to unenroll before the end of their contract, then Federal together with Provincial authorities will evaluate on a case-by-case level if their case is admissible (Article 25, COFEMA, Res. No. 277, May 8, 2014). Also, the Native Forest Law stipulates that a National Record of Violators will be created for participants that violate National or Provincial laws and establishes fines breaking the National Forest Law that can include a legal warning, a monetary fine (between 300 and 10,000 minimum wages), and landowners suspension from the program or revoking deforestation authorizations (Articles 27 and 29, Law 26,331). The law is not explicit in terms of consequences for landowners that receive PES but fail to submit an annual report for their activities on their land.

Data gathering and analysis

We obtained information about all program participants in May 2015 from the Argentine Ministry of Environment. Information included location of the land enrolled in the program (*x, y* coordinates that reflect centroid of land enrollment), type of program (i.e., plan for sustainable use or conservation plan), year of enrollment, duration (in years) of contractual obligations between program participants and governmental authorities, amount (i.e., area) of the land enrolled, and amount of money allocated for each project. The National Ministry of Environment also provided geo-referenced maps of zoning categories (red, yellow, and green areas) for the four provinces in the study area.

The Argentine National Institute of Agricultural Technology provided geo-referenced information about agricultural suitability for the study region. This information came in a 30 × 30-m resolution GIS raster grid where each pixel included an index of land suitability for the main agricultural land uses of the area (primarily soybean and pasture for cattle ranching; published on 2013 and accessed on May 20, 2015; for more details on this layer please see http://geointa.inta.gov.ar/web/index.php/suelos-de-la-republica-argentina/). Suitability for agriculture was calculated by modeling information on crop and pasture requirements with soil type, slope, and rainfall. Agricultural suitability values were standardized (0-100 units of suitability) for each province (SAGyP – INTA 2013). We also compared this dataset with a similar layer with agriculture suitability values not standardized for each province provided (range of index from 0 to 8). Both layers provided similar values for agriculture suitability (GLM model results using values from one layer to predict values of other layer: ß = -4.49, S.E.= 0.07, t-value = -64.16, p-value < 0.01). We used the provincial-level standardized values because standardization aids in adjusting for provincial-level differences in production costs and profits and had a greater range of suitability values.

We generated random points in locations that were not participating in the PES program to assess if locations enrolled have higher agricultural in comparison with land that did not enroll in the program. Random points were generated at a distance equal or greater than radius of the average landholding size that participated in PES. Randomly assigning location to either a participating or a non-participating group would have provided a more robust design (Bruer 2016). However, this was not feasible because we were not involved in the development stage of this program.

Spatial analyses

We put the data into a Geographical Information System (GIS) to evaluate how program participants and non-participants differ in terms of money allocation, duration of enrollment, and agricultural suitability. In each participating and non-participating location, we extracted the values of all relevant raster data (e.g., agriculture suitability, PES zoning category). Manipulation of GIS layers was done using ArcGIS 10.2.2 and in program R (R Development Core Team, 2008) using the "raster" package (Hijmans & van Etten 2012). We then used this dataset for statistical analysis in R. For all models, we used the "ncf" package to test for spatial autocorrelation using spline correlograms with raw response data and 95% point-wise bootstrap confidence intervals (Bjornstad & Falck 2001). However, we found no signs of spatial autocorrelation (Nunez-Regueiro 2016).

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Table A.1. Summary of main characteristics of the Argentine Payment for Environmental Service (PES) program for the Chaco forest and PES zoning categories within each province. Note: Some projects enrolled in the PES program have land in more than one category which is signaled by multi-zoning nomenclature in the table. US$ calculated using conversion rate from May 2015.

Provinces-zoning	Num. Projects	Money allocated 2010-2015 (US$) (% of total funds)	Mean (range) enrollment duration (yr)	Total area enrolled (ha) (% of available area)	Mean (SD) land enrolled (ha)	Mean (SD) US$/ha/yr
Chaco						
Yellow	215	3,390,670	10.0 (1-21)	230,273	1,071.0 (10,363.9)	17.7 (23.6)
Yellow-Green	8	794,138	5 (4-10)	58,355	7,294.375 (9,852.9)	273.5 (740.9)
Green	218	3,739,026	10.4 (1-20)	25,329	116.2 (224.2)	50.2 (73.6)
Formosa						
Red	9	274,489	2.1 (1-6)	40,447	4,494.1 (10,652.9)	783.9 (854.4)
Red-Yellow	1	16,968	1.0 (1-1)	20	20 (0)	848.4 (0)
Red-Yellow-Green	2	92,962	1.0 (1-1)	162,705	81,352.5 (94,130.8)	1.1 (0.82)
Red-Green	1	48,711	2.0 (2-2)	100,966	10,0966 (0)	0.3 (0)
Yellow	53	1,183,329	1.4 (1-5)	11,537	217.7 (1,094.3)	501.9 (404.8)
Yellow-Green	10	401,269	1.9 (1-4)	24,591	2,459.1 (5,045.3)	349.7 (640.6)
Green	69	1,749,567	1.4 (1-6)	7,199	104.3 (209.5)	665.9 (633.5)
Salta						
Red	38	2,782,832	2.6 (1-10)	188,367	4,957.0 (4,669.6)	38.1 (104.1)
Red-Yellow	54	4,011,233	1.3 (1-10)	2,188,437	40,526.6 (14,794.4)	13.7 (12.9)
Yellow	206	8,661,554	2.0 (1-16)	631,197	3,064.1 (5,582.0)	40.0 (256.2)
Yellow-Green	7	290,014	1.1 (1-2)	12,128	1,732.6 (2,086.7)	30.2 (12.3)
Green	17	912,487	3.4 (1-10)	27,871	1,639.5 (1,456.8)	21.1 (27.2)

Santiago del Estero						
Red	15	694,136	3.4 (1-6)	98,555	6,570.3 (20,454.7)	107.3 (231.6)
Red-Yellow	8	588,024	4.1 (1-8)	84,262	10,532.7 (28,077.5)	79.5 (92.9)
Red-Yellow-Green	7	377,182	3.7 (3-5)	1,500	214.3 (566.9)	19.9 (42.1)
Red-Green	2	62,010	5.0 (5-5)	1,530	765 (1034)	107.3 (146.1)
Yellow	339	13,133,486	3.6 (1-20)	379,763	1,120.2 (3,480.9)	123.2 (1102.6)
Yellow-Green	12	606,998	4.2 (2-5)	13,876	1,156.3 (1,747.3)	72.8 (87.2)
Green	45	1,605,897	3.6 (1-10)	9,999	222.2 (286.7)	180.3 (215.3)

Table A. 2. Comparison of model AICc score for potential variables driving PES enrollment. The null model is an intercept-only model.

Model variables	DF	logLik	AICc	Delta AICc	Weight
Null model	1	-1273.38	2548.80	0.00	0.71
Ag. Potential	3	-1273.28	2550.60	1.82	0.29
Ag. Potential * Province * Land-use category	30	Did not converge			

Abbreviation codes:

Ag. Potential = Agricultural potential of land

Province = Provinces included in our study area (Chaco, Formosa, Salta, and Santiago del Estero)

Land-use category = Red, Yellow, and Green land-use categories

DF = Degrees of freedom

logLik = Log-Likelihood

AICc = Akaike Information Criterion corrected for finite sample sizes

Delta AICc =Difference in AICc between best model and each individual model

Weight = Model weight (Akaike weight)

Table A. 3. Comparison of model AICc score for potential variables driving contract length in PES. The null model is an intercept-only model.

Model variables	DF	logLik	AICc	Delta AICc	Weight
Ag. Potential * Province * Land-use category	24	-2225.34	4500.00	0.00	1.00
Ag. Potential	2	-3369.30	6742.60	2242.63	0.00
Null model	1	-3388.84	6779.70	2279.69	0.00

Abbreviation codes:

Ag. Potential = Agricultural potential of land

Province = Provinces included in our study area (Chaco, Formosa, Salta, and Santiago del Estero)

Land-use category = Red, Yellow, and Green land-use categories

DF = Degrees of freedom

logLik = Log-Likelihood

AICc = Akaike Information Criterion corrected for finite sample sizes

Delta AICc =Difference in AICc between best model and each individual model

Weight = Model weight (Akaike weight)

Policy and conservation implications

	Contract length		Conversion threat of location	
	Short	Long	Low	High
Advantages of enrolling land	Appropriate for quickly-maturing ES. May increase total acceptance	Appropriate for slowly-maturing ES and for sites where future availability is uncertain	May conserve lands from factors unrelated to land-use change	May conserve lands from strong land-use change pressures
Limitations of enrolling land	Inappropriate for for sites where future availability is uncertain and slowly-maturing ES. May increase total transaction costs	May reduce acceptance from participants.	May protect land that would be protected in absence of program	Might increase total project cost if payments linked to threat levels or commodity prices
Policy outcome/ tools to avoid adverse selection	Adverse self-selection in time	Link payment to commodity prices	Adverse self-selection in space	Auction mechanisms. Link payments to threat levels

Fig. A.1. Summary of policy/conservation implications for adverse selection in time and space and potential mechanisms to avoid adverse selection.

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