Ecological Economics 185 (2021) 107027

Contents lists available at ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

Methodological and Ideological Options

# Permanence of PES and the role of social context in the Regional Integrated Silvo-pastoral Ecosystem Management Project in Costa Rica

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A B S T R A C T

We present rare, empirical evidence on the permanence of land use changes induced by a payments for ecosystem services (PES) program. A follow-up study was conducted a decade after the end of the *Regional Integrated Silvo-pastoral Ecosystem Management Project* (RISEMP) in Costa Rica. Econometric analysis found that silvo-pastoral practices persisted in the long term and are not reverted. On average there is also no meaningful intensification of practices after payments ceased. However, there is some heterogeneity on the individual level. We find that farms that increase adoption after the end of the project are farms with slower adoption during the project while some farms that decrease adoption are intense adopters. This indicates a pattern of convergence in the long run. Additionally, we challenge the assumption that payments are mono-causally inducing land use change by investigating non-monetary factors associated practice adoption. We find that not only PES explains adoption of silvo-pastoral practices. While it is challenging to establish clear casual linkages, we find that adoption is associated with the number of social ties to other farmers as well as negatively correlated to the exposure to traditional production paradigms measured as membership, as well as peer membership, in producer organisations.

## 1. Introduction

With approximately 600 million hectares, cattle production on permanent pastures constitutes a major land use in Latin America and the Caribbean region (Pagiola and Arcenas, 2013). Past expansions of livestock production resulted in deforestation and the converted land is prone to degradation and erosion in many mismanaged, tree and shrubless rangelands leading to even further expansions to compensate for the degrading productivity (Ibrahim et al., 2010). This is cause for concern regarding loss of biodiversity, increased greenhouse gas emissions and reduced carbon sequestration (Hänsela et al., 2009; Pendrill et al., 2019). During the past decades, this vicious cycle was addressed by conservation and market-based policies to reduce deforestation (Pagiola and Arcenas, 2013). Funding for policies enhancing the provision of ecosystem services like payments for ecosystem services (PES) is globally increasing and with it, the importance to better understand their effects (Moros et al., 2019).

The success of PES for conservation and reforestation strongly depends on the specific opportunity costs of landowners as forestry constitutes an often-inferior land use and farmers need to be compensated (Wünscher et al., 2008). Alternative to forestry as the primary land use, silvo-pastoral practices were identified to mutually increase the generation of ecosystem services and economic profitability while maintaining the productive landscape of pastures (Pagiola et al., 2016). Silvopastoralism is subsumed under agroforestry which is defined "[…] as the deliberate integration of woody species with agricultural crops and/or pastures on the same land-unit resulting in the integration of economic and ecological interactions between components" thus increasing socio-ecological complexity compared to the standard model of agriculture (Oelbermann and Smith, 2011, p. 125). The introduction of trees and shrubs into open rangeland reduces erosion and increases biodiversity as well as carbon sequestration. Depending on the tree species they can fertilize pastures augmenting forage production which, together with the shade, can increase animal productivity by reducing heat stress (de Abreu and M.H, 2002). Moreover, fruits, fuel wood, fodder from trees and shrubs, timber and diversification of production are additional on-site benefits (Pagiola et al., 2005; Cerdán et al., 2012; Idol et al., 2011). However, obstacles arise as substantial investment costs for tree and shrub planting are required. Moreover, the economic viability of silvopastoral practice relies on on-farm benefits exceeding

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https://doi.org/10.1016/j.ecolecon.2021.107027
Received 30 March 2020; Received in revised form 5 March 2021; Accepted 8 March 2021
Available online 24 March 2021
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maintenance costs which requires several years of plant growth.

While rewarding for off-farm benefits, PES can double down as investment capital and by bridging the time span until practices reach their maximum productivity. Latin America is especially open to market driven approaches for conservation (Pagiola et al., 2010). Specifically, Costa Rica pioneered PES (Pagiola, 2008). PES aims to reward farmers for employing land use practices that provide increased environmental benefits. Direct payments in PES programs are thought to be more effective compared to integrated conservation and development projects as they are assumed to generate more income for suppliers due to improved cash flow, diversification and reduced income variance and because they uncover new sources for financing conservation by the beneficiaries of ecosystem services like industries in need of carbon sequestration options. An example for an integrated conservation and development project, or "conservation by distraction" is pointed out by Nicholls (2004) for the case of community-based ecotourism in which conservation might be a by-product of touristic development. However, an increasing number of opponents are articulating severe criticism as PES would lead to nature commodification and green neoliberalism negatively impacting the resilience of socio-ecological systems (van Hecken et al., 2015a). They argue that PES is a novel way to replicate "histories of colonial and neo-colonial resource alienation in the name of the environment" (Fairhead et al., 2012, p.237). Kosoy and Corbera (2010) dismiss PES altogether as a form of commodity fetishism which undermines the social fabric involved in producing ecosystem services in the first place.

Apart from such fundamental critique, two main issues are discussed with respect to PES and agroforestry practice adoption. First, some authors cast doubt on the mono-causal impact of payments on adoption as they see non-monetary drivers for practice adoption at work (Bottazzi et al., 2018; Muradian et al., 2010). Second, the permanence of PES programs with finite payments is unclear as data is extremely scarce (Calle, 2020; Dayer et al., 2018). What is, at least to our knowledge, not discussed in the permanence literature, are the implications of adoption *intensity* during the project for the persistence of adopted practices thereafter. This is grounded in the fact that most programs do not offer the choice of adoption intensity over multiple years.

### 1.1. Drivers of practice adoption

Economic theory relates to opportunity costs in determining enrolment in PES and might fall short of reality as it ignores many other factors (Arriagada et al., 2009, 2015). Evidence for non-financial incentives were found in a recent PES study in Costa Rica (Arriagada et al., 2015). They concluded that context specific motivations like securing land tenure or the wish to contribute to the public good were likewise important for adoption. This notion is also reflected by a case study of a PES program in Nicaragua which finds that PES is "mistakenly understood as a simple matter of financial incentives" but other characteristics and factors such as farm size, social momentum or information spillover also drive farmer's decisions (van Hecken and Bastiaensen, 2010).

Specifically, the production of ecosystem services is shaped by communication pathways, which matter for adoption decisions (Meijer et al., 2015; Robalino and Pfaff, 2012). Garbach et al. (2012) found that farmer-to-farmer communication significantly contributed to the adoption of silvopastoral practices in a PES program. According to Garbach et al. (2012), communication decreased the adoption of riparian forest. A positive impact of social diffusion is exemplified by the statement of a farmer in the Sacrameto River Valley confronted with new environmental policies: "[…] people will change their minds by talking to neighbours and seeing the practices work" (Lubell and Fulton, 2007, p. 137). A PES program impact evaluation report likewise highlighted the role of knowledge exchange and shared norms for adoption behaviour (Vaessen and van Hecken, 2009). According to Arriagada et al. (2009), experts state that PES program participation in Costa Rica was "also driven by a collective fever to participate and see what will happen" which indicates that peer interactions are sometimes more important than outcome expectations. In a follow-up study for a Nicaraguan PES program, van Hecken et al. (2015a) speculated that information spillover effects might have resulted in a non-significant difference between treatment groups (PES recipients vs. non-payment group). That is, attitudes towards, and information about silvopastoralism might likewise disseminate in relevant social networks. However, according to Yoder et al. (2019), social connectedness is often only assessed in standard household surveys by asking for the membership in a social group which ignores the individual *degree* of social connectedness and group context. Thus, empirical evidence on the degree and type of social connectedness is limited.

A review of agroforestry adoption studies by Meijer et al. (2015) shows that the literature rarely acknowledges drivers of adoption which are beyond the limited scope of homo oeconomicus. Bottazzi et al. (2018) bundled the financial motivation of payments with pro-social and pro-environmental motivations in a motivational set explaining program participation and found that pro-environmental motivations are explaining program participation in a Bolivian PES watershed project. Further, motivation theory postulates that "much of human action can be explained through the concept of perceived self-efficacy" (Frank et al., 2011, p.67). A direct relation exists between adoption decisions and perceived self-efficacy which is defined as the belief of being capable of performing particular tasks (McGinty et al., 2008) or the "confidence in one's abilities with reference to domain-specific applications" (Wuepper and Lybbert, 2017, p. 387). Self-efficacy is an established concept in psychology looking back to four decades of research (Roy, 2009). According to Kuruppu and Liverman (2011), perceived self-efficacy is vital for adoption intention. However, perceived self-efficacy in the pastoral context has rarely been assessed with some exceptions (Drysdale et al. 2017, Roy, 2009, Wuepper and Lybbert, 2017; Wuepper and Sauer, 2016).

In short, the acknowledgment that payments do not exist in a social vacuum commands to reconsider the complexity of adoption decisions in the context of PES (Garbach et al., 2012). In this paper, we aim to contribute along these lines by providing empirical insights on non-monetary aspects of practice adoption.

### 1.2. Permanence of PES programs and persistence of practices

Next to the discourse on non-monetary drivers of adoption, open questions remain with respect to the effectiveness of PES in practice (Pattanayak et al., 2010). An especially under-researched aspect of PES effectiveness is the question about program permanence (Pagiola et al., 2016) – which is a second research gap this paper is targeting. Permanence, a term originating from the carbon sequestration literature (Jayachandran et al., 2018), is given if practices adopted under PES are still practiced in the long term and in the absence of PES. It was empirically rarely analysed simply due to the scarcity of long-term data and it is unclear if permanence is actually created by programs (Engel et al. 2008, Börner et al. 2017, Yoder et al., 2019). Among both proponents and opponents of PES, there is a consensus that introducing environmentally friendly practices which are unsustainable after intervention ends, entails the danger of destroying pro-nature ethics and weakening institutions (Worldbank 2019, van Hecken and Bastiaensen, 2010). On the ecosystem side, a short-term habitat induced by a finite program might become an ecological trap which is likewise to be avoided (Dayer et al., 2018). Differences exist in candidate explanations for the phenomenon. In the stricter economic interpretation of permanence of PES programs, only asset building PES schemes are thought to permit a continuation of practices without further payments in the future as such assets could generate revenues in the future decreasing opportunity costs (Pagiola et al., 2016). Pagiola et al. (2007) expressed doubts with respect to whether the investment in silvo-pastoral practices would pay off for farmers without additional income from PES in the long-term in Nicaragua. Pagiola et al. (2016) investigated the matter for a Columbian program. They found that environmentally beneficial land use changes, that were presumably induced by RISEMP, persisted even after payments ended. However, no additional adoption took place after that point. Specifically, they concluded that PES increased the profitability of practices and not just helped overcoming financing constraints. In fact, Pagiola et al. (2016) and Calle (2020) are, to the best of our knowledge, the only studies which empirically assessed the permanence of an asset-building PES program with long-term adoption data. With respect to conservation PES programs, only a Worldbank study (Jayachandran et al., 2018) in Uganda looked into the matter empirically. Dayer et al. (2018) investigate the issue from a broader, and more theoretical perspective and term the continuation of land use practices after short-term incentives ceased as "persistence". A discontinuation or de-adoption of practices is termed reversion. The term persistence is also used in non-land use related adoption studies (Dayer et al., 2018). Outlining a conceptual framework for persistence, they depict five pathways to persistence encompassing cognitive, motivational, behavioural, economic and social explanations. The authors mention, however, that data availability for empirical investigation of those pathways is extremely limited. Also, Bottazzi et al. (2018) cannot add long-term data to underpin the proposed role of motivational drivers for persistence. Some of the pathways to persistence do overlap with the economic understanding of permanence of PES programs. Dayer et al. (2018) stress the importance of opportunity costs and state that persistence is more likely for practices that involve timber harvesting as they provide additional financial benefits. Also, the potential pathway of "crowding-in" of intrinsic motivation due to incentives is a concept used by PES scholars who point to financial objectives in this regard. Here, crowding-in, and crowding-out for that matter, refers to increase or decrease of intrinsic motivation by external events respectively. Intrinsic motivation drives actions originating from self-interest in contrast to external constraints and motivators. Cognitive drivers in the rational choice approach of PES are limited to changes in perceived (financial) value of land uses (Worldbank 2018).

A topic not dealt with in particular by the discourse on permanence, and persistence for that matter, is the fact that most research on program participation considers adoption to be the single, binary decision to adopt or to not adopt (Pagiola et al., 2010; Pattanayak et al., 2003). That is, a common, but implicit, assumption underlies the discussion of potential pathways and economic reasonings for persistence and permanence: the narrative of a single, binary decision to continue the once adopted practice or to dis-adopt. To our knowledge, only one study on a PES conservation program did quantify by how much exactly permanence was not met (Worldbank 2018). Consequently, permanence, or non-permanence for that matter, is understood as a post-interventional change in adoption beyond the duality of continuing and reverting as de-adoption and additional adoption are more, or less intense. Heterogeneity in adoption behaviour during intervention was not considered in the Worldbank study as adoption intensity was not a program feature necessary for conserving forest in the area. However, the provision of ecosystem services in productive landscapes could arguably be more or less intense and vary between farms. Programs that offer differentiated payments for alternative adopted practices, do allow for a heterogenous and dynamic adoption pattern to emerge. In those settings an additional question arises: Do those emerging adoption patterns during intervention matter for the permanence in adoption thereafter? Specifically, is there a path dependency evident in adoption intensity? In line with Kay (2005), we understand path dependency as the determination of phenomena by the order in which events are occurring. With respect to silvo-pastoralism, it could be theorized that a certain intensity of adoption during the project could lead to permanence as it was just the right amount of effort put into the establishment of practices to sustain them in the long run. What is "right" can exist in economic, ecological or other dimensions. Too low and too strong efforts might result in other trajectories of post-intervention adoption behaviour as their outcomes might not meet expectations; do not satisfy. Shedding light on this question might contribute to a new understanding of PES effects, or at least in the generation of a new hypothesis, in terms of adoption dynamics.

This paper contributes 1) to the literature on non-monetary drivers of adoption in PES schemes by asking what role they played in the Regional Integrated Silvo-pastoral Ecosystem Management Project in Costa Rica and 2) to the question of PES permanence by analysing long-term data from this first PES scheme that targeted silvo-pastoralism. Regarding the second objective, we distinctively ask if induced practices are permanent in Costa Rica and how is permanence is influenced by past adoption intensities.

### 1.3. *The regional integrated silvo-pastoral ecosystem management project*

The Regional Integrated Silvo-pastoral Ecosystem Management Project (RISEMP) was a PES scheme that pioneered payments for silvo-pastoral practices. RISEMP was coordinated in Costa Rica, Colombia and Nicaragua from 2002 until 2008 by CATIE[1] and funded by the Global Environmental Facility (GEF) and the Worldbank (Pagiola et al., 2005). PES beneficiaries were livestock producers in the three countries. The scheme improved existing PES approaches in several respects. First, it allowed farmers to decide on the *intensity* of silvopastoral efforts and thus reduced the inefficiency of paying a per hectare flat fee. RISEMP offered PES beyond the binary choice between adoption and non-adoption and captured a gradient of adoption strength. As such, farmers were introduced into a set of silvo-pastoral practices which differed in terms of their value for biodiversity and carbon sequestration and thus in their adoption intensity and corresponding payment. Payments were retrospectively made based on yearly outcomes which enabled capturing adjustments of farmers' adoption intensities. Second, it allowed for differentiated monitoring by the creation of biodiversity and carbon sequestration indices. Both indices were combined to produce the environmental service index (ESI) which is explained in more detail in the next section. The clarity and explicitness of the evaluation and monitoring framework of the RISEMP study is a fortunate exception among PES programs (Wunder, 2007). Third, compared to other PES programs it also pioneered with an experimental design by introducing a control group. The program was designed to evaluate the effect of PES on land use decision making and for assessing improvements of livestock production as the result of newly introduced distinct silvo-pastoral practices.

Inducing the adoption of silvopastoral practices on over 12,000 ha, the project was deemed a remarkable success right after the project has ended (Pagiola and Arcenas, 2013). That success story was solely attributed to PES, ignoring social or psychological factors. Moreover, as payments were finite, the permanence of PES of silvo-pastoral practices in the case of RISEMP is unclear. The hypothesis was that payments would "tip the balance" for farmers as they would increase the net present value of cattle production and reduce liquidity constraints for initial investments. Benefits were assumed to pay off in the long run (Pagiola et al., 2010; Pagiola et al., 2007; Vaessen and van Hecken, 2009).

In contrast to the Colombian case, the question of permanence is still unanswered for RISEMP in Costa Rica.

## 2. Material and methods

### 2.1. *Study area*

In Costa Rica, CATIE implemented RISEMP in the Esparza region from 2002 until 2008. The region is around 300–500 m above sea level and dominated by dual purpose livestock production systems. Annual precipitation is about 1800 mm with a six-month dry season. Farms are

[1] Centro Agronómico Tropical de Investigación y Enseñanza

owned by local residents being mostly smallholders. Back then, 130 farms participated in the project. From the start, 30 out of the 130 were control group farms which did not receive any payments throughout the whole project length (referred as non-payment group hereafter). Farms were randomly assigned to the groups and the area was selected under the premise that no recent deforestation or conversion to silvo-pastoral production took place. In Costa Rica, payments were made by FONAFIFO (National Forestry Fund) which coordinates and facilitates national PES schemes. Payments ended 2007 for the 100 participating farms. Workshops and technical assistance were carried out to inform farmers about the ecological impacts of different land uses. The PES recipients were paid annually based on the accrued ESI points of the last year which means that land use changes were not predetermined by the project (Ibrahim et al., 2011).

### 2.2. Data collection

Two principal data sources were used for this study which are the measurements of ESI in several years as well as two household surveys.

#### 2.2.1. ESI

The ESI was evaluated as a baseline before project start in 2002 and monitored yearly until 2007. A follow-up assessment was conducted in 2016. All ESI data was collected by CATIE. The underlying biodiversity and carbon sequestration indices aggregated in the ESI, differentiate the environmental effects of a variety of land use practices. The ESI is continuously scaled between 0 and 2 and computed on a hectare level per farm. Baseline and monitoring as well as the follow-up assessment used remote sensing techniques and ground truthing (Quickbird, Landsat and Geo-referencing). The biodiversity index was validated by matching land uses with bird counts, and secondary information on other species, using the circular-plot method (Ibrahim et al., 2010). Carbon sequestration for individual land uses was validated by an initial soil sampling design assessing total C, oxidizable C, total N, P, CEC, pH, soil texture and bulk density (Amézquita et al., 2004). A list of land uses and according indices for biodiversity, carbon sequestration and the ESI can be found in Table 1. For this study we use farm specific ESI points for the years 2003 until 2007 and 2016. In 2016, 108 farmers were included in the ecological follow-up assessment which encompassed 85 payment recipients and 23 non-payment farms. The farms which dropped out were either sold or not accessible in 2016.

**Table 1**
Biodiversity, carbon sequestration and ESI for different land uses monitored.

| Land use | Biodiversity index | Carbon index | ESI |
|---|---|---|---|
| Degraded pasture[a] | 0.0 | 0.0 | 0.0 |
| Natural pasture without trees | 0.1 | 0.1 | 0.2 |
| Improved pasture without trees | 0.1 | 0.4 | 0.5 |
| Natural pasture with low density trees (<30 ha/ha) | 0.3 | 0.3 | 0.6 |
| Improved pasture with low density trees (<30/ha) | 0.3 | 0.6 | 0.9 |
| Fodder bank with woody species | 0.4 | 0.5 | 0.9 |
| Natural pasture with high density trees (>30/ha) | 0.5 | 0.5 | 1.0 |
| Diversified perennial fruit crops | 0.6 | 0.5 | 1.1 |
| Diversified woody fodder bank | 0.6 | 0.7 | 1.2 |
| Improved pasture with high density trees (>30/ha) | 0.6 | 0.7 | 1.3 |
| Diversified timber plantation | 0.7 | 0.7 | 1.4 |
| Scrub habitats (tacotales) | 0.6 | 0.8 | 1.4 |
| Riparian forest (>10 $m^2$ basal area) | 0.8 | 0.7 | 1.5 |
| Mature or primary forest | 1.0 | 1.0 | 2.0 |
| Simple live fence (per km) | 0.3 | 0.3 | 0.6 |
| Multi-strata live fences or windbreaks (per km) | 0.6 | 0.5 | 1.1 |

Source: from Ibrahim et al., 2011.
[a] Pastures with less than 50% cover of desirable grasses and shrubs and with evidence of soil erosion.

#### 2.2.2. Household surveys

Prior to project start, an extensive socio-economic household survey was conducted with all participants in 2002 by CATIE. Although very extensive (over 300 question), the baseline survey did not entail questions along the dimensions of psychology and social networks. Thus, another household survey also containing questions on self-efficacy and peer contacts was conducted in 2018 (Fig. 1) by a cooperation between the authors and CATIE (see online supplementary material).

In order to account for the task specificity of self-efficacy, questions were framed as self-stated statements of farmers' believes in their capabilities to successfully manage certain silvopastoral practices along a 5 point Likert scale (Bandura, 2006). Questions elucidating a peer network of farmers, asked respondents for their most frequent contacts by names which were used to construct a directed graph of connected participants. The latter enabled us to construct variables of social connectedness and of peer attributes. All questions on self-efficacy and social networks were asked only for the presence as considerable recall bias was expected. The questionnaire also contained open ended questions on farmers' motivation for persistence. Interviews for the second survey in 2018 were made with 82 RISEMP farmers consisting of 67 payment and 15 non-payment farms. Table 2 presents all ESI and household survey data sources for an overview and reference.

### 2.3. Analysis of permanence

The analysis of permanence is based on the intersection of the ESI datasets 2003 until 2007 and 2016 (Data sources A and B in Table 2) which equates to 85 farmers from the payments and 23 farmers from the non-payments group.

#### 2.3.1. Are practices permanent and if not, how much were they not?

In order to answer the question if practices are permanent and to look into the degree of non-permanence, we present a descriptive analysis of the distribution of total ESI points per year, of net changes in ESI points and of individual farm level developments of ESI points over time. Additionally, we use paired *t*-tests and independent sample t-tests to statistically test if average ESI points change during (2003–2007) and after the project (2007–2016) and between the groups respectively. Those descriptive methods as well as the test conducted allow to draw important conclusions for the question of PES permanence. Additionally, they give insights in the intensity of change in adoption which is further quantified to answer the second research question.

#### 2.3.2. Is adoption intensity during the intervention explanatory for permanence?

In order to answer that question, we derive several measures to describe past adoption behaviour (during 2003–2007) and use this to explain permanence in the period after payments have ended. Specifically, we aim to explain change in ESI points between 2007 and 2016 (as a measure for permanence) by measures of past adoption behaviour using a regression. We operationalize past adoption behaviour along the following variables:

I. Net change of ESI between 2003 and 2007

Net change of ESI during intervention is the focal variable of our analysis as it aggregates the intensity of adoption when the project was still active.

II. Standard deviation of ESI between 2003 and 2007

We measure the variation of adoption intensity during the intervention in order to capture the heterogeneity between more stable and more wavering adopters.

**Fig. 1.** Farm visit in the Esparza region in 2018.

**Table 2**
Data sources with years and number of observations per group.

| Data source | Years | Payment group (N) | Non-payment group (N) |
|---|---|---|---|
| A. ESI Project | 2003, 2004, 2005, 2006, 2007 | 100 | 30 |
| B. ESI Follow-up | 2016 | 85 | 23 |
| C. Socio-economic baseline survey | 2002 | 100 | 30 |
| D. Socio-economic follow-up survey | 2018 | 67 | 15 |

III. Presence of a year during the intervention which resulted in a decrease of ESI points

A dummy variable captures if a farmer exhibited a year during the project in which he actually dis-adopted indicative for experimentation or reversion during the project.

IV. ESI points in 2003

We include ESI points in 2003 to capture the baseline heterogeneity in ecosystem service provision at program start

V. PES recipient

To control for non-payment induced changes, we include a dummy variable indicating if a farm belonged to the payment group or to the non-payment group.

To explore the question to what extent adoption patterns during the intervention are relevant for permanence we are particularly interested in the estimated effect for the variable "Net change of ESI between 2003 and 2007". First, it is interesting to explore to what extent past adoption intensity is a significant determinant for changes after 2007. Second, the estimated model is used to derive the predicted relationship between ESI change in 2003–2007 and changes in 2007–2016. By looking at the slope as well as at the location of the predicted relationship, conclusions about convergence behaviour as well as permanence can be derived. A negative slope would indicate a convergence pattern while a positive slope would imply further divergence. Beside the slope, also the location of the predicted relationship is crucial for the interpretation. If predicted values are predominantly negative a negative slope parameter would indicate that there is no permanence (in the sense that observations with larger positive changes during 2003–2007 have larger negative changes in 2007–2016; i.e. convergence by cutting back on ESI). However, if predicted values are predominantly positive, a negative slope indicates a catch-up behaviour (in the sense that the increases in 2007–2016 are larger the smaller the changes during 2003–2007 had been; i.e. convergence by catching-up).

### 2.4. *Analysis of non-monetary effects on long term adoption*

#### 2.4.1. *Did payments contribute to long-term adoption and what role do non-monetary factors play?*

In order to take a long-term perspective, we measure long term adoption as the total net change of ESI from 2003 until 2016 (data sources A and B, Table 1). Taking this long-term perspective, we do not aim to distinguish between adoption intensity during 2003–2007 and the permanence, or persistence, during 2007–2016 as we did for the two first research questions. Instead, we aim to explore the relationship between the long-term effects (2003–2016) and certain characteristics of farmers. Next to the question if payments have an effect, we are particularly interested in the effects of non-monetary determinants. While the dataset provides a unique opportunity studying long term effects, exploring the non-monetary effects is challenging given the available data. As described in Table 1, we have observations on the ESI for several time periods but the data of non-monetary aspects is only collected in 2018 (data source C, Table 1). Additionally, we have other control variables that are taken from the baseline survey (data source D, Table 1). To address the research question, we regress the long-term change (2003–2016) in ESI on variables capturing non-monetary aspects (taken from the survey in 2018) as well as additional farm characteristics (taken from the survey in 2002). Given that the non-monetary aspects are observed at a later stage, we need to be very cautious with any causal interpretation. Nevertheless, estimating the correlation between those socio-psychological variables and the long-term adoption effects, allows to speculate about potential effects and pathways. Due to the intersection of the four data sources, the number of observations matches the smallest data set of the 2018 survey ($N = 82$). Independent variables of interest are:

I. PES

The dummy variable indicates belonging to either the payment or to the non-payments group - Payments are a direct monetary incentive for intensifying adoption. Belonging to the payments group, which was known by farmers prior to project start, is thus assumed to increase net ESI point changes.

Variables measured in 2018 are:

II. Social connectedness

The continuous variable is measured as the total number of contacts including self-cited contacts (directed to peers) as well as other farmers citing the individual as contact (directed from peers). Depending on the assumed causal direction one assumption is that A) a stronger social network supports practice adoption via observation and peer comparison. It is the mediator of spill-over effects. B) Conversely, if we assume that the strength of the personal social network in 2018 is a result of increased adoption intensity in the past, a possible interpretation is that intense adopters also intensified their social contacts in order to exchange experiences and success stories among themselves.

I. Membership in producer organisation

The binary variable indicating the membership in a producer organisation is often associated with positive effects arising from social networks. However, in the context of innovative silvo-pastoral practice adoption, producer organisations a thought to A) promote traditional production practices, hence the relationship with adoption is uncertain or B) conversely, membership in producer organisations propagating traditional practices is the consequence of turning away from silvo-pastoral practices by dis-adoption.

II. Peer membership in producer organisation

The continuous variable reflects the percentage of peers in a famer's network that are members in a producer organisation. It is assumed to reflect the strength of exposure or involvement in groups practicing conventional livestock production and follows thus the same argumentation as above.

III. Perceived self-efficacy

We consider farmers' perceived self-efficacy to manage a specific silvo-pastoral practice/task which is one of the most demanding ones in terms of its complexity: the management of forage banks. Discussions with farmers revealed a higher variability of attitudes towards this practice and farmers mentioned high labour demands as well as the problem of attracting pests (e.g. snakes). The latter was also found by Garbach et al. (2012). Farmers were asked to value their belief of being capable to perform that practice successfully on a five-point Likert scale. The variable was transformed to a [0,1] scale. Assumptions are that A) believing in being capable to implement and to maintain one of the most demanding silvo-pastoral practices reduces psychological barriers towards adoption or that B) a high perceived self-efficacy in 2018 is the result of successfully managing forage banks indicating that self-efficacy was uplifted by being successful in the past.

The distribution of each of the five variables of interest are presented in form of violine plots in the appendix (A1). Additionally, in order to limit omitted variable bias we include several control variables which might have a direct effect on the dependent variable but might also be correlated to the variables of interest. For each of the control variables we discuss each of these relations in the following:

*2.4.1.1. Farm size.* Although ESI points are computed on a per hectare basis, efficiency advantages arising from economies of scale might be mirrored in an increased adoption of practices as well (Rajasekharan and Veeraputhran 2002). Farm size is assumed to be potentially reflected in social status and thus correlated with a higher social connectedness. Likewise, managers of bigger farms might be more likely members in producer organisations due to increased need for e.g. market access.

*2.4.1.2. Age of HH head.* Age is correlated with experience and is thus thought to increase adoption (Pagiola et al., 2010). Age is potentially correlated with the strength of social connectedness. Here, younger or older farmers might be better connected depending on whether social connectedness is increasing or decreasing throughout the lifetime of farmers. Age is potentially also correlated to perceived self-efficacy as more experienced farmers might show a stronger conviction in their own capabilities.

*2.4.1.3. Education of HH head.* A higher level of education might be associated with higher adoption intensity as it could be argued to foster the ability to correctly assess economic implications of changes to the status quo management system. The level of education is possibly related to the likelihood of being a member of a producer organisation.

*2.4.1.4. HH size.* A larger household size is assumed to increase the adoption intensity as it implies increased family labour availability assisting in introducing and maintaining silvo-pastoral practices. It might as well be directly related to the number of contacts a farmer might have.

*2.4.1.5. ESI points in 2003.* A high baseline production of ecosystem services might reduce the options to increase ESI points compared to a low baseline production. A high baseline production might be positively correlated with perceived self-efficacy as the believe of being capable to implement silvo-pastoral practices might have resulted in pre-existing practices before the PES program started. The same reasoning accounts for social connectedness. For both regressions, we report ordinary least squares (OLS) regression outputs for usual as well as heteroskedasticity consistent standard errors. The OLS is a regression that aims to fit a linear relationship between one observed variable and one or more other variables with the aim to minimize squared errors. In our case we use it for example to estimate to what extent changes in ESI depend characteristics of the farmer. To judge how sensitive results are to the type of standard errors, we report the 95% and 90% confidence intervals for normal and for robust standard errors for the independent variables.

An OLS regression.

## 3. Results

### 3.1. Analysis of permanence

As outlined above, permanence is analysed by means of the ESI. We analyse if practices are permanent and if past adoption behaviour mattered.

#### 3.1.1. Are practices permanent?

The distribution of ESI points for several years is presented in Fig. 2 using violine plots. Each dot shows the individual farm average per-hectare ESI value for all farms.

The violine plots of ESI points per year and farm are showing a stronger increase in ESI points from 2003 until 2005 and a more consolidating pattern in 2006 and 2007. The latest distribution of ESI

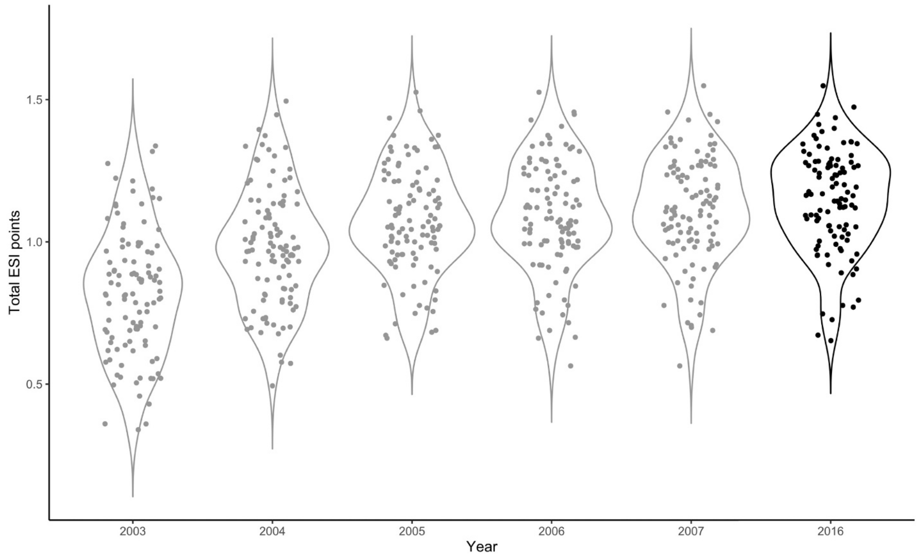


**Fig. 2.** Total ESI points per year on farm level.
Note: dots are individual farm ESI points. The violine plot for 2016 is darker to distinguish active project years from post-intervention.

points in 2016 does not exhibit a major shift to either increased nor to decreased ESI points. The spread of the 2016 distribution of ESI points is slightly less pronounced (lower variation) compared to the one from the last year in the project (2007) and, more so compared to the first years of the project. A disaggregated change in terms of land uses over time can be found in the appendix (Table A.1). Another perspective on ESI points over time is presented by the frequency diagrams in Fig. 3 and Fig. 4 showing the frequency of net change in ESI during the project (2003–2007) and in the years after the project had ended (2007–2016), respectively. Both histograms distinguish between the payment and the non-payment group.

Fig. 3 shows that all farmers, but one, did increase their ESI points. No negative changes of ESI points occurred during the project. Further, we find a higher mean net ESI change and a larger spread of frequencies of net ESI changes for the payments group compared to the non-payment group. However, the mean net ESI change of the non-payments group is positive and it accounts for approximately half of the change of the payments group.

Fig. 4 shows lower mean net changes in ESI for both groups after the project has ended. Both means are in proximity and are slightly positive. Both group modes are at a zero change in ESI and both distributions are much steeper around their modes compared to Fig. 3. Only one farmer from the non-payment group (0.4%) presents a negative ESI change whereas 13 farmers from the payment group (16%) experienced a reduction of their ESI. Nevertheless, in both groups the frequency of positive change is much larger than that of negative change. In order to present a description of the dynamics of individual farm ESI points, a line graph connecting all ESI data points on farm level is shown in Fig. 5. The figure distinguishes between payments and non-payments groups.

Several observations are made: 1) the non-payment group starts from a, on average, higher ESI level at program start, 2) the payment group overcompensates the initial difference by outperforming the non-payment group at project end and in the long term, 3) considerable variation and heterogeneity with respect to individual, farm specific ESI

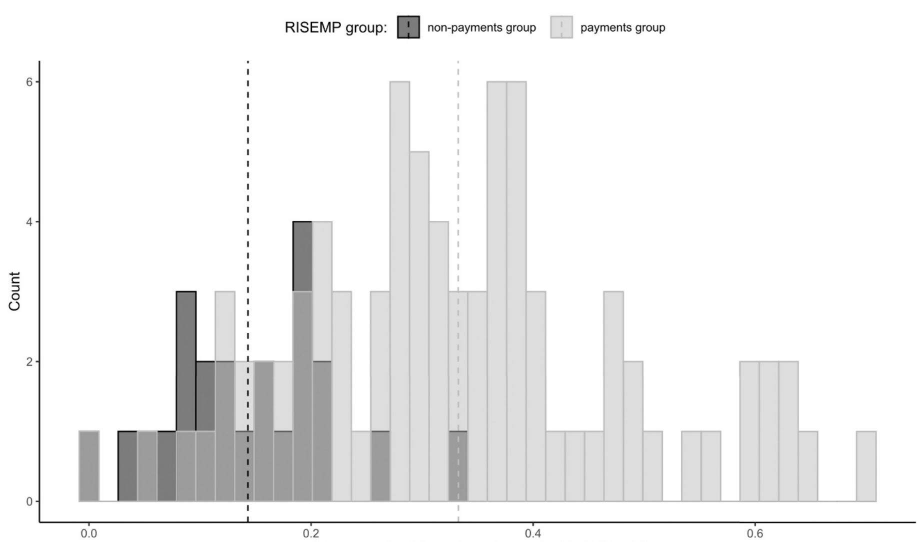


**Fig. 3.** Frequency of ESI net changes for payments and non-payments group during intervention years (2003–2007).
Note: Dashed lines represent the means of net changes in ESI of the non-payments (black) and the payments group (grey) during active project years. A third shade (medium-grey) does indicate where the groups overlap.

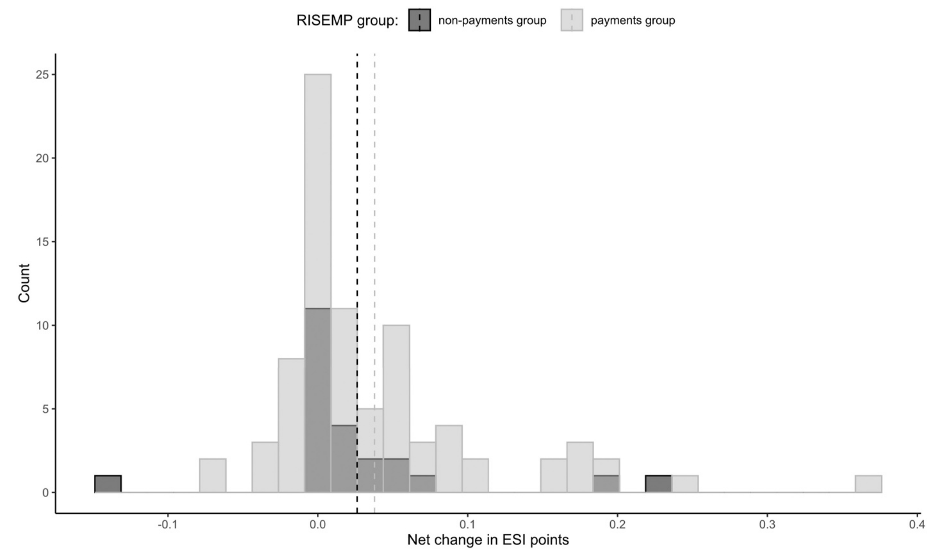


**Fig. 4.** Frequency of ESI net changes for payments and non-payments group after intervention years (2007–2016).
Note: Dashed lines represent the means of net changes in ESI of the non-payments (black) and the payments group (grey) during post-project years. A third shade (medium-grey) does indicate where the groups overlap.

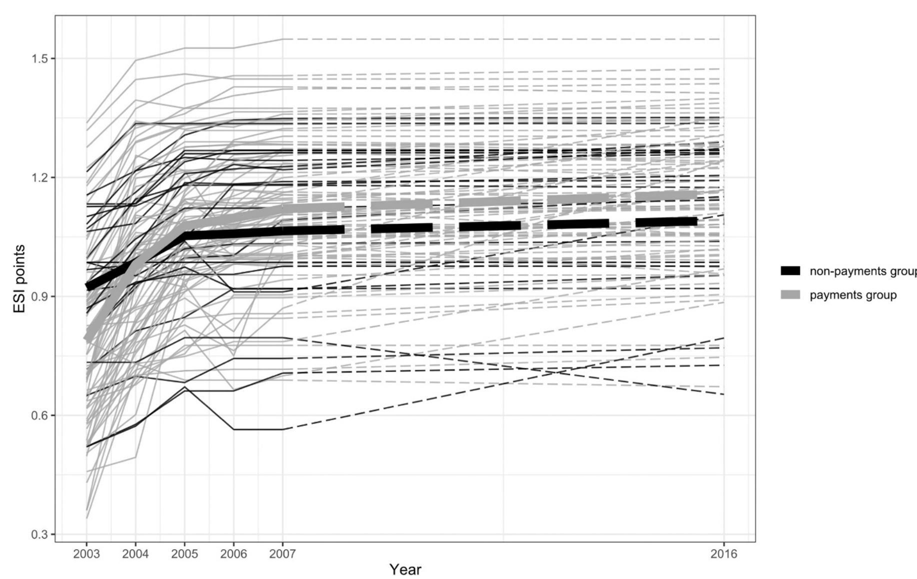


**Fig. 5.** Line graph of ESI point development per farm for the payments and non-payment groups during active project years and nine years later.
Note: Thick lines are means of ESI points of the non-payment (black) and of the payments group (grey). Dashed lines indicate the absence of ESI data for the individual years between 2007 and 2016.

point development with temporary dis-adoption of practices took place during the active project years and 4) some farms with relatively lower ESI points after project end catch up until 2016. Next, *t*-tests are presented in order to detect statistical differences in mean ESI points between years and groups.

*3.1.1.1. Difference in means of ESI points between 2003 and 2007 (paired t-test).* Mean ESI points in 2003 (M = 0.79, SD = 0.22, $n$ = 82) were significantly lower than mean ESI points in 2007 (M = 1.12, SD = 0.18, n = 82) for the payments group, t (81) = −19, $p < .001$. A significantly lower value is also detected for mean ESI points in 2003 (M = 0.92, SD = 0.19, $n$ = 23) compared to ESI points in 2007 (M = 1.065, SD = 0.22, n = 23) for the non-payment group, t (22) = −9.0061, p < .001. That is, both groups increased average ESI points during the project.

*3.1.1.2. Difference in means of ESI points between 2007 and 2016 (paired t-test).* Mean ESI points in 2007 (M = 1.12, SD = 0.18, n = 82) were significantly lower than mean ESI points in 2016 (M = 1.16, SD = 0.17, n = 82) for the payments group, t (81) = −4.78, p < .001. However, mean ESI points in 2007 (M = 1.06, SD = 0.22, n = 23) were not significantly lower compared to mean ESI points in 2016 (M = 1.09, SD = 0.21, n = 23) for the non-payments group, t (22) = −1.78, $p$ = .09. That is, during post-intervention, the payment group marginally increased in ESI points on average whereas the non-payment group did not change on average.

*3.1.1.3. Differences in means of ESI points between payments and non-payments group (independent sample t-test).* In 2003, mean ESI points for the payments group (M = 0.79, SD = 0.22, n = 82) compared to the non-payments groups (M = 0.92, SD = 0.19, n = 23) were significantly lower, t(38) = −2.8, $p$ = .008. For 2007, the payments group (M = 1.12, SD = 0.18, n = 82) and the non-payments group (M = 1.06, SD = 0.22, n = 23) were not significantly different t(31) = 1.1, $p$ = .27. Likewise, no statistical difference in mean ESI points was found between the payments group (M = 1.16, SD = 0.17, n = 82) and the non-payments group (M = 1.09, SD = 0.21, n = 23) in 2016, t(30) = 1.4, $p$ = .16.

To summarize, the payments group did increase mean ESI points during and after the project. Albeit on a much lower level after the project ended. The non-payment group did only increase their mean ESI points during the project to a level equal to the payment group in 2007. However, the non-payments group showed a higher mean ESI level at project start resulting in a lower net change during the intervention. No statistical difference could be found between both groups in the long term. On an average level in terms of mean ESI points, no dis-adoption or reversion took place for both groups which constitutes average permanence of practices. However, Fig. 5 indicates heterogeneity and variance with respect to the adoption and permanence behaviour of individual farms. This observation leads over to a further analysis of permanence by relating it to past adoption behaviour.

### 3.1.2. *Is permanence influenced by past adoption intensity?*

In order to answer the second research question, we perform a regression analysis on post-project change in ESI points. The corresponding identification strategy involved the independent variables of 1) net adoption intensity during the project (past intensity), 2) standard deviation in ESI points during the project (past variability), 3) a dummy variable if the farm had a year of dis-adoption during the project (past dis-adoption), 4) ESI points in 2003 (starting ESI) and 5) a control for belonging to the non-payments or non-payments group (No PES). The coefficient table in Table 3 presents regression results for a standard OLS regression and for a regression with heteroscedasticity-robust standard errors. Fig. 6 regression coefficient plots showing 90% and 95% confidence intervals for the standard OLS regression and for the one with robust standard errors as bars.

Results from Table 3 and Fig. 6 show that our focal variable of interest, past intensity, has a negative effect on post intensification, with the 90% confidence intervals completely in the negative range in both model specifications. This is an indication of some form of convergence pattern. Additionally, we find significant negative effects of the variable measuring ESI at project start in 2003 ("Starting_ESI") on post project change in practices. The estimator of past variability has a positive influence on post-interventional adoption, with the effect being significant for the standard OLS model but not with the robust standard errors. Being in the non-payment group has a negative but non-significant effect on permanence. Overall, the regression explains 13% of the variation in permanence.

**Table 3**
Regression on net ESI increase between 2007 and 2016 – coefficient table.

| Independent variables | Est. | OLS | | | Dependent variable | | |
|---|---|---|---|---|---|---|---|
| | | | | | ESI net increase 2007–2016 | | |
| | | | | | Robust standard errors | | |
| | | 5% | 95% | $p$-value | 5% | 95% | p-value |
| Intercept | 0.15 | 0.07 | 0.22 | < 0.001 | 0.07 | 0.22 | < 0.001 |
| Past Intensity (ESI points) | −0.58 | -0.58 | −0.95 | 0.01 | −1.12 | −0.03 | 0.08 |
| Past variability (SD ESI points) | 1.19 | 0.23 | 2.14 | 0.04 | −0.28 | 2.65 | 0.18 |
| Past dis-adoption (yes = 1, no = 0) | 0.01 | −0.01 | 0.04 | 0.29 | −0.01 | 0.04 | 0.32 |
| Starting ESI (ESI points) | −0.09 | −0.15 | −0.03 | 0.01 | −0.16 | −0.03 | 0.02 |
| No PES (yes = 1, no = 0) | -0.03 | −0.06 | 0.00 | 0.11 | −0.05 | 0.00 | 0.06 |
| N | 105 | | | | | | |
| Rsqr | 0.17 | | | | | | |
| Adj Rsqr | 0.13 | | | | | | |

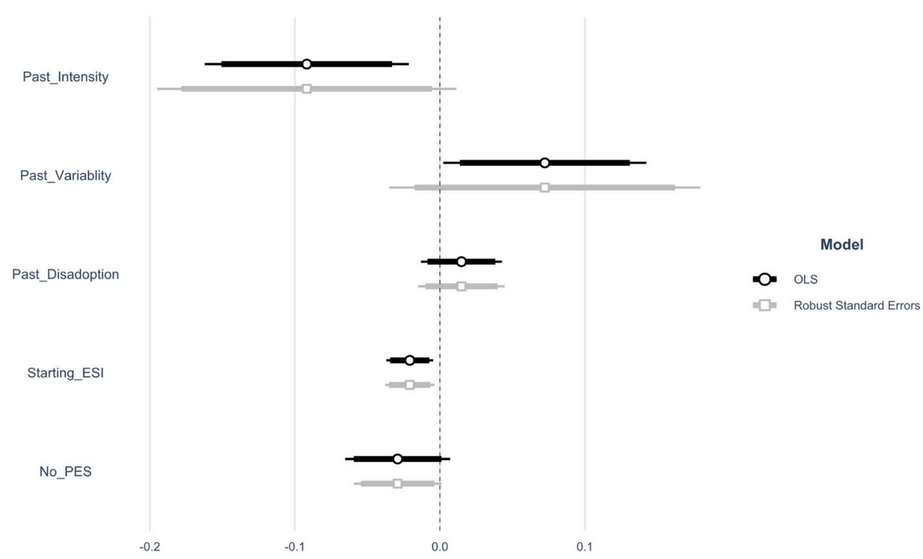


**Fig. 6.** Confidence intervals for regression on ESI change between 2007 and 2016.
Note: Thicker, inner lines represent 90% confidence intervals and thinner outer lines the 95% confidence intervals. Independent variables are statistically significant if bars do not include the 0.0 on the x-axis.

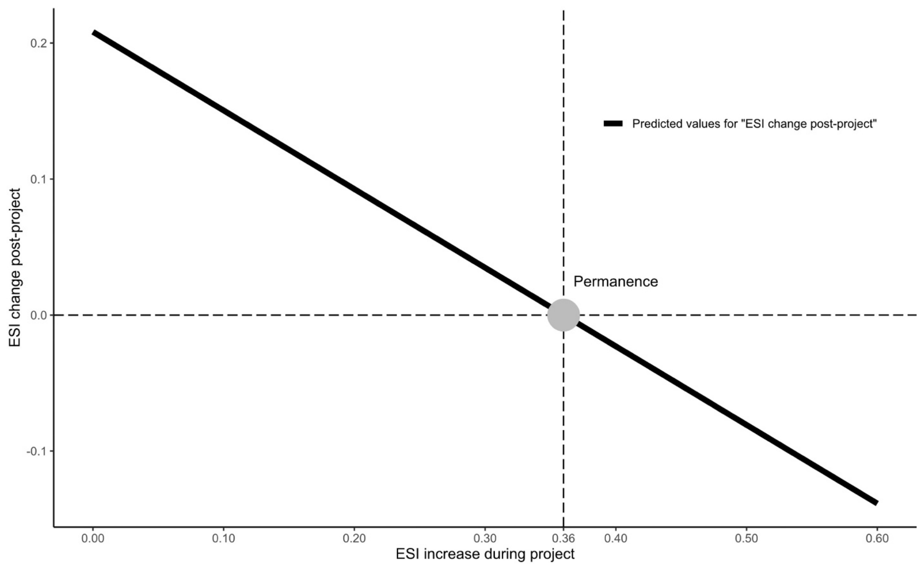


**Fig. 7.** Predicted values for ESI change post-project for values of adoption intensity during the project.
Note: The function is the estimated regression function from Table 3. All other variables are set to their means.

Regarding our main variable of interest, ESI change during the project period, the result indicates a certain degree of a convergence. However, as discussed above, in order to determine if this convergence is either a process of reverting practices or rather a catching-up behaviour, we need to take into account the specific relationship predicted by the model. Fig. 7 presents predicted values of change in ESI after the project ended for various levels of changes of ESI during the project (variable "Past_intensity") with all other variables kept on average values (ceteris paribus). The range of past intensity changes, from 0 to 0.6, covers most of the empirically observed changes (see Fig. 3). We find that predicted ESI change in the post-project era is positive for within-project changes up to 0.36, while it is negative above that value. This indicates that the convergence pattern is primarily a catch-up behaviour with some reverting behaviour for farmers with larger changes during the project period.

To summarize, when interpreted in a strict sense, permanence of practices does emerge for an intensity of adoption of 0.36 ESI points (dashed lines in Fig. 7.) assuming all other variables at their average. As already indicated in Fig. 4, most farms arrive at permanence. All other non-permanent farmers reduce or increase efforts of adoption; adapting their efforts in the post-intervention time towards the average of efforts during the intervention (Fig. 3) which leads to the conversion of total ESI points as indicated by the reduced variance over time shown in Fig. 1.

### 3.2. *Analysis of payments and non-monetary effects on long term adoption*

#### 3.2.1. *Did PES lead to long-term practice adoption and what roles do non-monetary factors play?*

In order to identify the relevance of PES, social and psychological aspects related to long-term practice adoption, we conduct a regression analysis considering the total time span on adoption in terms of ESI points from 2003 until 2016 which subsumes post-project adoption behaviour. That is, the dependent variable of the analysis is net ESI change from 2003 until 2016. A descriptive overview over the variables of interest (PES, social connectedness, member in producer organisation, peers being members in producer organisations and perceived self-efficacy) are presented in the appendix (Figs. A1-A5). Analog to the regression analysis of permanence, we present a standard OLS and a regression with robust standard errors in the coefficient table (Table 4) as well as confidence plots for both models including the 90% and 95% confidence intervals in Fig. 8.

**Table 4**
Regression on net ESI increase between 2003 and 2016 – coefficient table.

| Independent variables | Est. | OLS | | | Dependent variable<br>ESI net increase 2003–2016<br>Robust standard errors | | |
|---|---|---|---|---|---|---|---|
| | | 5% | 95% | p-value | 5% | 95% | p-value |
| Intercept | 0.44 | 0.25 | 0.62 | < 0.001 | 0.25 | 0.63 | < 0.001 |
| PES (yes = 1, no = 0) | 0.11 | 0.04 | 0.17 | 0.01 | 0.05 | 0.17 | < 0.001 |
| Social Connectedness (nr Contacts) | 0.02 | 0.01 | 0.02 | 0.01 | 0.00 | 0.03 | 0.02 |
| Member Producer Organisation (yes = 1, no = 0) | −0.05 | −0.11 | 0.00 | 0.09 | −0.11 | 0.00 | 0.12 |
| Peers Member Producer Organisation (%) | −0.14 | −0.21 | −0.08 | <0.001 | −0.21 | −0.08 | <0.001 |
| Perceived Self-Efficacy [0,1] | 0.02 | −0.01 | 0.05 | 0.19 | 0.00 | 0.04 | 0.13 |
| Starting ESI [0,2] | −0.32 | −0.43 | −0.21 | <0.001 | −0.42 | −0.22 | <0.001 |
| Farm Size (ha) | 0.00 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.03 |
| Household Size (#) | 0.02 | 0.01 | 0.04 | 0.03 | 0.01 | 0.04 | 0.02 |
| Age (years) | 0.00 | 0.00 | 0.00 | 0.43 | 0.00 | 0.00 | 0.44 |
| Education (years) | 0.00 | 0.00 | 0.01 | 0.59 | 0.00 | 0.01 | 0.52 |
| N | 74 | | | | | | |
| Rsqr | 0.60 | | | | | | |
| Adj Rsqr | 0.54 | | | | | | |

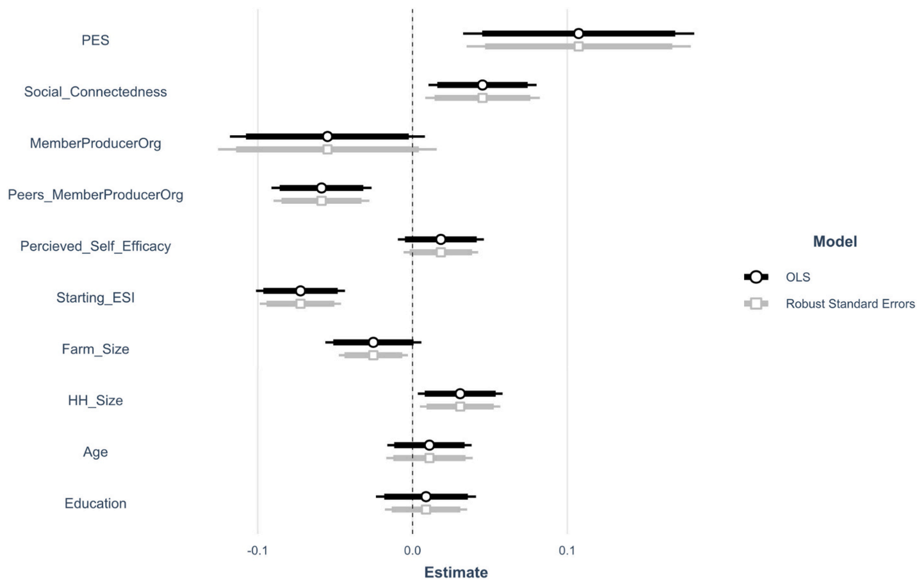


**Fig. 8.** Confidence intervals for regression on ESI change between 2003 and 2016.

According to Table 4 and Fig. 8, variables with a significant positive impact in both models are PES, social connectedness and household size. Variables with a significant negative sign in both models are the share of peers being members in producer organisations and the starting value of ESI points in 2003. Membership in a producer organisation and farm size are found to have a negative effect with the confidence interval below or just covering the zero. Perceived self-efficacy, as well as age and education, have a positive effect, however, none of the effects is statistically conclusive with the 90% confidence interval covering zero in all cases.

## 4. Discussion and conclusion

### *4.1. Are practices permanent?*

Our results contribute to the scarce empirical evidence of PES permanence. We found that the majority of farmers did not revert practices adopted during the asset building scheme. Permanence, measured in ESI points, remained unchanged for most farms nine years after the project had ended (see Fig. 4). This is congruent with Pagiola et al. (2016) who attested a non-reversal of practices after project end, albeit a halt of further adoption of silvopastoral practices in Colombia. Compared to PES conservation schemes, our results add further support to the intuition that asset building schemes have a higher potential for permanence (Worldbank 2019, Dayer et al., 2018).

On average, Costa Rican farms that had received payments during the project phase marginally increased their ESI points after project end whereas the non-payment group stayed constant on average. However, the increase among the payment group after 2007 is small and thus the implementation of silvopastoral practices did not continue to increase on a meaningful scale after initial payments induced their adoption and allowed farmers to experience the advantages. As the latter aligns also with the findings from Pagiola et al. (2016) and Calle (2020), the observation casts doubt on an inherent, self-enforcing diffusion of silvopastoralism in the region.

Our results are in contrast with findings from a follow-up study of the Nicaraguan RISMEP project. There no difference in ESI points between the payment and non-payment groups could be found during the project phase, and after the project end farmers did relapse into previous land use practices. According to van Hecken et al. (2015b), the latter could be attributed to power asymmetry and inequality in the region being a former agricultural frontier where competition continues to be fierce. Larger farms were able to capture the majority of payments and smaller farms ended up in the non-payment group which led to discontent and reversion. Such unequal social structures were not evident among the Costa Rican' project participants. However, a further inspection of individual farm level data over time revealed heterogeneity and variation of adoption intensities and permanencies between farmers. This observation led us to investigate the impact of past adoption behaviour during project implementation on permanence.

### *4.2. Is permanence influenced by past adoption behaviour?*

In answering this research question, we do not specifically prove or disprove economic, social or psychological rationales of PES permanence and practice persistence which thus remains an important research gap. In fact, our dataset does not allow for an investigation of socio-economic determinants specifically explaining the concept of permanence as no such data is available for the end of the project in 2007 enabling us to make causal inferences. Moreover, the statistical ability to detect determinants of permanence is reduced as we observe a high share of permanence and thus low variation.

However, we found a specific, path-dependent behaviour in the sense that change in adoption after the project depends on the change of adoption during the project. Lower and higher adoption intensities during the project led to further adoption and dis-adoption after the project, respectively. The model is controlled by the baseline ESI points in 2003 and membership in the non-payment group both reducing the level of adoption intensity predicting permanence. Surprisingly, higher variability of ESI points during the project has a positive impact on ESI changes thereafter as it is associated with dis-adoption during the project. However, this is not significant with robust standard errors applied. We found no significance of interim dis-adoption during the project. While we are not able to provide statistical evidence for the underlying causes, we might speculate based on the theoretical considerations and other research outlined so far in order to generate a hypothesis to be tested in further research on permanence.

#### *4.2.1. An information diffusion hypothesis on permanence*

The high variation of farm level ESI points during the project years could mean that farmers iteratively adapted their efforts towards a satisfying fit of silvo-pastoral practices to their socio-ecological context.

Farmers are well connected among each other[2] and could have experimented and exchanged information among themselves about which set of practices leads to satisfying, and thus permanent, results. This would explain the high share of adoption intensities leading to permanence. And again, satisfaction might be multi-dimensional including economic and other aspiration levels. The fact that farmers with non-permanent behaviour are adapting their adoption towards those levels which have historically led to permanence is also hinting at a timely lagged diffusion of information and convergence towards permanence. Additionally, the fact that the non-payment group converged with the payment group in terms of total ESI points in 2007 strengthens the thesis of an information spill-over effect triggered by the "noise" generated by the project (van Hecken and Bastiaensen, 2010; van Hecken et al., 2015a; Calle, 2020). In both cases, information would refer to experiences other farmers have made with the implementation of silvo-pastoral practices. We can summarize our hypothesis with a direct quote from van Hecken and Bastiaensen (2010) which postulate for the Nicaraguan RISEMP project an "emergence and articulation of sufficient social momentum crystallizing into coherent collective action that enables collective pathways of change"[3] (p.436). In the Costa Rican project, that collective pathway of change might have led to permanence. The hypothesized mechanism would also be in line with Muradian et al. (2010) suggestion that PES can be an incentive for collective action. It sparked experimentation in the first place.

#### *4.2.2. Other explanations for permanence*

An explanation based on the stricter rational choice paradigm would suggest that silvo-pastoralism needed PES to become profitable and that there is thus no meaningful further adoption but also no dis-adoption after payments have ceased (Pagiola et al., 2016). That payments tipped the balance for adoption is a plausible explanation in the absence of reversion. However, the adoption of silvo-pastoral practices, although being less intensive, by the non-payment group somewhat weakens that assumption.

A third thesis for permanence might be pro-environmental motivations (Bottazzi et al., 2018). Along these lines, farmers did not revert as they share a common set of ecological ethics which might have been there from the start or which might have been crowded-in by the PES program (Calle, 2020). In both cases, PES did not seem to crowd-out pro-environmental attitudes as reflected in answers to an open-ended interview question asking for the reason of sustaining practices (supplementary material, question 44). Here, 47% of farmers express explicitly that their motivation for sustaining practices is to contribute to environmental health. Twenty-five percent of farmers did additionally mention socio-economic benefits exemplified by one farmer stating that he will continue with silvo-pastoral practices because they are: "beneficial for the animals, for the nature and for the people". Only one farmer stated that he will discontinue practices.

Those responses are in contrast with those which Bottazzi et al. (2018) recorded for a Bolivian program, where a significant proportion of landowners already planned to revert land use change during the project. Statements of Costa Rican farmers reflect pro-environmental perspectives blurring the line between ecosystem service providers and sellers. That is, famers might, in part, stick with their practices because they enjoy contributing to a healthy environment (Dayer et al., 2018).

### *4.3. Did PES lead to long-term practice adoption and what roles do non-monetary factors play?*

The last research question took a broader stance and looked into the factors correlated with long-term adoption which could be understood to subsume permanence but not explaining it specifically. We quantified the impact of payments on long term adoption and investigated correlations with social, psychological and farm level variables.

First, payments are highly significant in explaining adoption intensity. The presence of rewards for ecosystem services increases long-term adoption of silvo-pastoral practices. We found it to be significant for all confidence intervals investigated. Supported by the statements of farmers outlined above, this observation does not allow to suggest that PES did crowd-out intrinsic motivations for environmentally friendly behaviour (Ezzine-de-Blas et al., 2019). Thus, payments in Costa Rica contributed to a sustainable, long-term adoption of ecologically beneficial practices.

Second, we find that the more contacts a farmer has in 2018, the higher is the net adoption intensity in the long run. Owned to the nature of available data, it is more difficult to infer cause and effect in this respect. However, both possible alternative explanations for the correlation are interesting to consider. We cannot say if high connectedness was a characteristic of farmers when the program came into live or if it evolved due to intensely adopting farmers wanting to share their involvement with likeminded peers or even if a positive feedback between both elements was playing out. However, combining the observation with the information diffusion hypothesis of the permanence discussion above, we see that those groups of farmers which are more densely connected, and are thus thought to more intensely share information and experiences, are showing more intense adoptions. While our results do not allow to establish a clear causal link of whether interaction is a driver or an outcome of adoption, in either way, it illustrates that adoption has an important social component to be considered.

Third, the exposure to conservative production systems as promoted by producer organisations is negatively correlated with long term adoption. However, own membership in producer organisations is only significant corresponding to a 90% interval in an OLS regression without robust standard errors. Clearer is the relevance of the degree of exposure measured as the share of peers being members in producer organisations as it is highly significant across all models. It is also exhibiting a negative correlation supporting the internal validity of the measure. It is noteworthy that the measure is partly indirect as it is not requiring the farmer to be a member in a producer organisation herself. The significant correlation hints, once again, to the relevance of peer interactions in the process of adoption. Here, it is a negative relation similar to the one found by Garbach et al. (2012) for more interacting farmers characterized by reduced shares of riparian forests in her follow-up PES study. Thus, peer interaction does not per se support adoption but context and framing of social groups do matter.

Fourth, perceived self-efficacy has a positive impact but is not significant with a $p$ value of 0.13 in the model with robust standard errors. Thus, the direction of influence is as assumed but the uncertainty of the estimate refrains us from further interpretation.

Finally, among the control variables only the baseline ESI points in 2003 and household size are significantly impacting long-term adoption where the first does have a negative and the second a positive effect. Intuitive explanations are 1) higher efforts needed to produce additional ESI points and 2) increased wage labour supporting implementation of practices. The latter was also found by McGinty et al. (2008) in her review of agroforestry adoption studies. However, their finding that age has a negative impact cannot be supported by our study. The same accounts for education. Farm size is only significant in the model with robust standard errors and has a negative impact. This result does not give support to the notion that larger farms adopted silvo-pastoral practices more intense as happened in Nicaragua.

Apart from the interpretation of the econometric model, the plain

[2] only one farmer did not refer to other RISEMP farmers as frequent contacts in an open-ended question

[3] It is worth noting that this observation was only related to initial adoption and not to permanence in their case

fact that the non-payment group did increase their ESI points during the time when the project was active, and their halt in further adoption after the project has ended, is indicative that non-monetary determinants were relevant for the principal adoption decision.

To summarize, as did van Hecken and Bastiaensen (2010) state for Nicaragua, we likewise cannot provide convincing evidence that payments alone were responsible for adoption of silvo-pastoral practices in Costa Rica. Our results do underpin the importance of payments alongside support for the importance of social dimensions of adoption.

### *4.4. Limitations, policy implications and future research*

Although we could answer the critical question if changes towards silvo-pastoralism were sustainable, we cannot provide a formal comparison of land use changes elsewhere due to the behaviour of the non-payments group (Pagiola et al., 2007). However, as outlined, that very behaviour of adopting even in the absence of payments might point to what the rational choice paradigm of PES ignores: spill-over effects mediated by non-financial aspects. It would be valuable if future research could also take other farms in the region into account which were not associated with the project. Another limitation, which we share with the majority of studies on permanence, is the lack of data shedding light on the probability of pathways to persistence (Dayer et al., 2018). Due to data limitations, we cannot make a clear causal identification with respect to social network variables and long-term adoption. Such data should ideally be collected at the very beginning of a program followed by re-assessments at the end and in the long run. In order for this suggestion to make it in the design of future PES programs, PES as an economic research strand, must acknowledge that the effects of payments are not isolated and in a social void (Bottazzi et al., 2018).

Whatever the specific pathways of persistent practices might be, the silvo-pastoral practices adopted by the Costa Rican farmers in our case study are fulfilling the characteristics of practices postulated to be likely persistent by Dayer et al. (2018). As those practices proved to be in fact persistent, permanence of silvo-pastoral asset building schemes appears to be likely for similar, future PES schemes if the design is able to avoid that existing power structures are capturing program benefits as happened in Nicaragua.

## Declaration of Competing Interest

None.

### *Acknowledgement*

We primarily thank all participating famers of the RISEMP project in Esparza. We are moreover grateful for all the scientific and logistic support from CATIE and EARTH university. This work is funded by the German Research Foundation under a Research stipend RA2461/1-1-382306163 and under Germany's Excellence Strategy, EXC-2070 - 390732324 - PhenoRob.

## Appendix A. Appendix

### *A.1. Violine plots of independent variables vs. long-term ESI adoption*

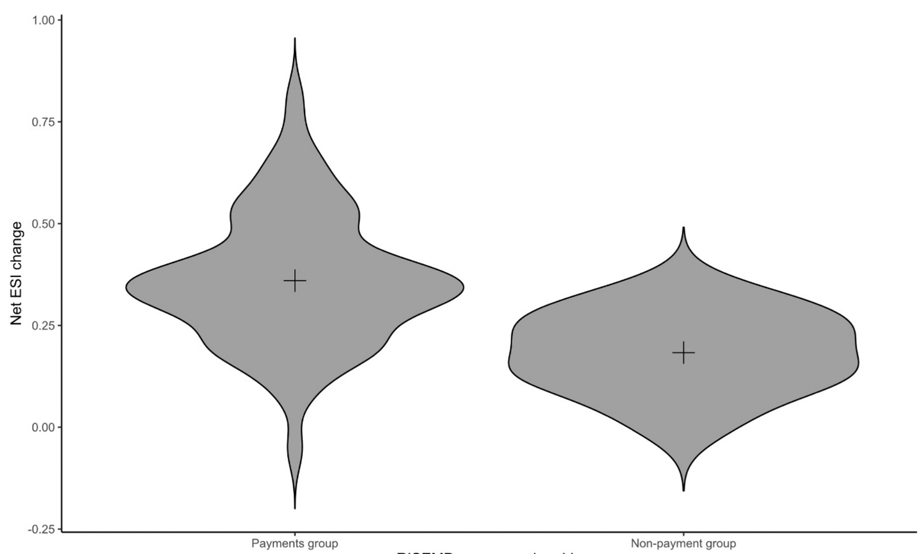


**Fig. A1.** Violine plot – Net ESI change from 2003 until 2016 for payments and non-payment group.

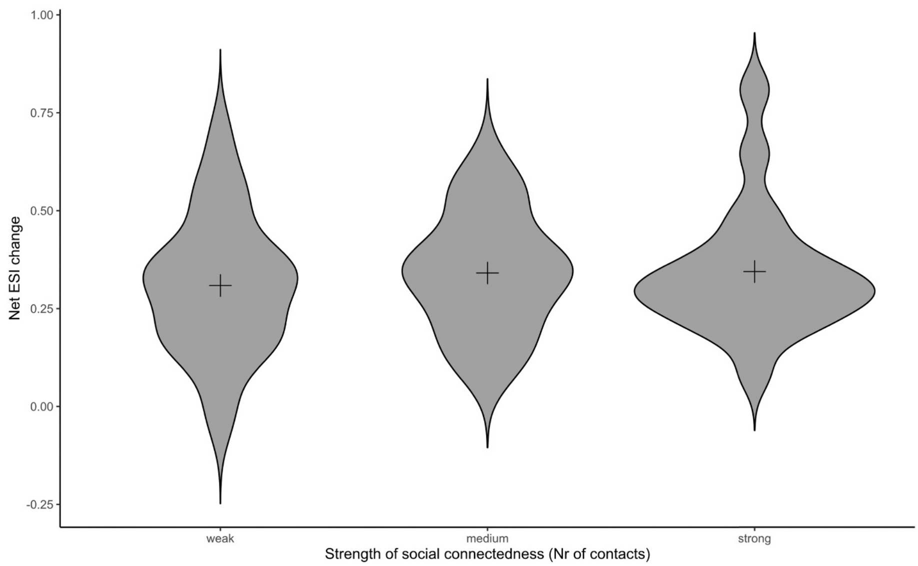


**Fig. A2.** Violine plot – Net ESI change from 2003 until 2016 for different strengths of social connectedness.

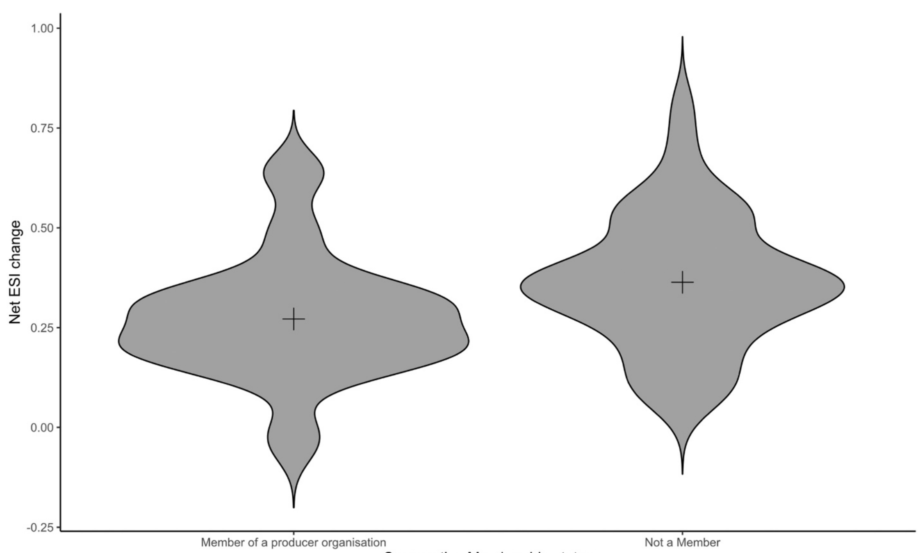


**Fig. A3.** Violine plot – Net ESI change from 2003 until 2016 for membership vs. non-membership in producer organisation.

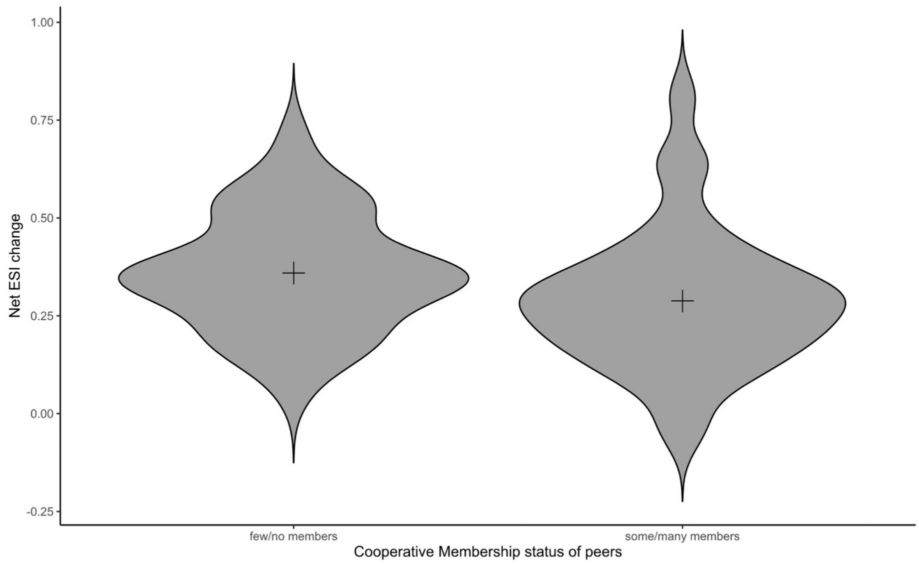


**Fig. A4.** Violine plot – Net ESI change from 2003 until 2016 for share of peers being members in producer organisations.

**Table A.1**
Land uses as shares of total farm in 2003, 2007 and 2016 for PES recipients and control farms alongside respective environmental service points (ESI) per ha.

| Land use | ESI (points per ha) | PES farms | | | Control group | | |
|---|---|---|---|---|---|---|---|
| | | 2003 | 2007 | 2016 | 2003 | 2007 | 2016 |
| Water bodies and infrastructure | 0 | 1.55 | 1.33 | 1.35 | 1.26 | 1.32 | 1.41 |
| Anual crops | 0 | 0.56 | 0.66 | 0.54 | 0.53 | 0.53 | 0.55 |
| Degraded pasture | 0 | 18.18 | 4.13 | 3.18 | 11.02 | 6.21 | 4.95 |
| Natural pasture without trees | 0.2 | 8.48 | 0.11 | 0.04 | 1.05 | 0.02 | 0.02 |
| Improved pasture without trees | 0.5 | 2.01 | 0.56 | 0.62 | 1.18 | 0.32 | 0.41 |
| Semi-permanent crops (plantain, sun coffee) | 0.5 | 0.07 | 0.12 | 0.34 | 1.75 | 0.76 | 0.39 |
| Natural pasture with low tree density (<30/ha) | 0.6 | 24.85 | 7.01 | 4.54 | 9.05 | 4.21 | 3.15 |
| Monoculture fruit crops | 0.7 | 1 | 0.83 | 0.8 | 0.52 | 0.58 | 0.74 |
| Fodder Banks | 0.8 | 0.48 | 0.52 | 0.89 | 0.52 | 1.05 | 2.26 |
| Improved pasture with low tree densitiy (<30/ha) | 0.9 | 6.23 | 27.21 | 28.1 | 27.3 | 29.11 | 28.88 |
| Natural pasture with high tree density (>30/ha) | 1 | 3.96 | 4.63 | 4.39 | 5.35 | 1.58 | 1.03 |
| Diversified fruit crops | 1.1 | 0.54 | 0.62 | 0.58 | 1.24 | 0.53 | 0.53 |
| Shade-grown coffee | 1.3 | 0.16 | 0.16 | 0.33 | 0 | 0 | 0 |
| Improved pasture with high tree density (>30/ha) | 1.3 | 1.63 | 20.28 | 22.18 | 12.78 | 27.36 | 28.98 |
| Timber plantation | 1.4 | 1.16 | 1.55 | 1.49 | 0.92 | 0.88 | 0.99 |
| Shrub habitats | 1.4 | 1.96 | 2.1 | 2.61 | 1.35 | 1.35 | 1.53 |
| Riparian forest | 1.5 | 17.17 | 16.55 | 16.44 | 20.31 | 20.31 | 20.32 |
| Primary and secondary forest | 1.9 | 10.02 | 11.5 | 11.5 | 3.86 | 3.86 | 3.86 |

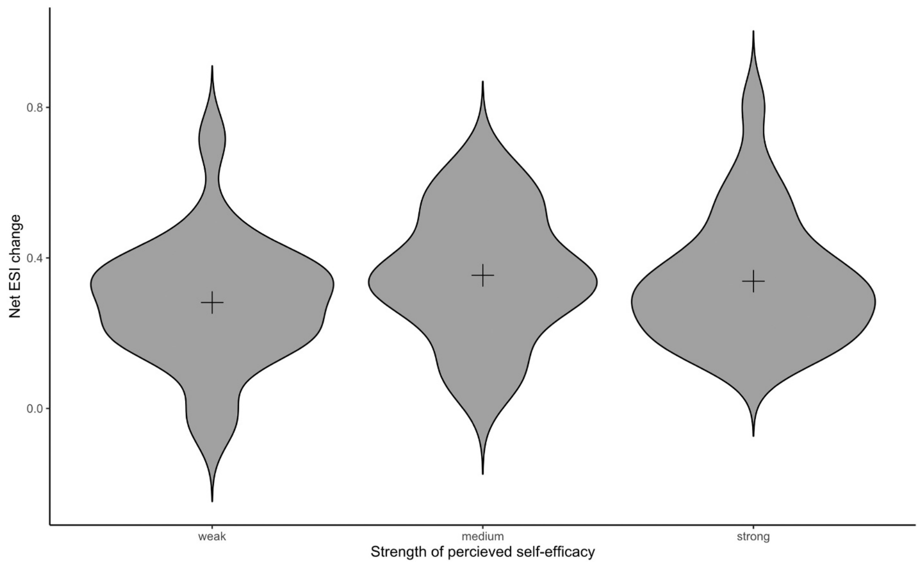


**Fig. A5.** Violine plot – Net ESI change from 2003 until 2016 for different strength of perceived self-efficacy.

## Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecolecon.2021.107027.

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