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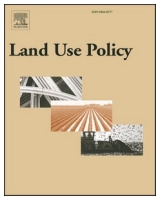

How land property rights affect the effectiveness of payment for ecosystem services: A review

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ABSTRACT

We conducted a qualitative literature review and provided a theoretical discussion of how private, common, and public land property rights (LPRs) uniquely influence the effectiveness of Payments for Ecosystem Service (PES). We considered three aspects of PES's effectiveness: additionality (PES programs typically employ tests to assess whether the payment will result in additional ecosystem services), socioeconomic impacts, and transaction costs. The existing literature has not addressed differences between LPR types with respect to ensuring additionality. Particularly striking is the lack of consideration of additionality on public and common lands. Future research can assess whether private LPRs are more favorable for ensuing additionality than common and public LPRs. We found that most existing tests for additionality are for private lands, likely due to financial payment on private lands having more leverage to change land uses or technology in ways that can result in changes to ecosystem service provisions beyond baseline levels. While existing studies have shown more diverse socioeconomic impacts (e.g., on equity among community members) on common lands than on private and public lands, socioeconomic impacts between private and public lands have been insufficiently compared. Whether public LPR are associated with higher or lower transaction costs than private and common LPRs also remains unclear, although existing literature has indicated some strengths (e.g., reducing the number of PES contracts) and limitations (e.g., mistrust, contested leadership) of common lands for saving transaction costs compared to private lands. Quantitative literature reviews and more empirical evidence from real-world cases are needed to further assess the strengths and limitations of different types of LPR for enhancing PES's effectiveness.

1. Introduction

Ecosystem services (ESs) are the benefits humans receive from ecosystems (Millennium Ecosystem Assessment, 2005). Payment for ecosystem services (PES) are undertaken worldwide to improve landscape conditions and support the provision of ESs (often through changing land use practices). Though few studies have examined the volume of transactions, Salzman et al. (2018) calculated that between 2009 and 2017, the value of PES transactions averaged between US $36–42 billion globally per year. (Salzman et al., 2018). Wunder (2005) defined PES as market-oriented voluntary transactions where a well-defined quantity of ES (or a land use likely to secure that service) is bought by a service purchaser from a service provider, contingent on the service provider securing service provision. However, in practice, PES programs may also integrate government-led schemes (Farley and Costanza, 2010; Salzman et al., 2018). For example, China's eco-compensation involves payments from an upper level of government to lower levels of government for ecosystem restoration (Shang et al., 2018). In another example, the National Forestry Commission of the Mexican government pays voluntary forest landowners for preventing deforestation (Mexican Secretary of the Interior, 2023; Reyes-Hernández, 2023). Third, the government-led national PES schemes in Costa Rica intend to cover the all the country's ecosystems (Costanza et al., 2021; Pérez-Rubio et al., 2021). Thus, Muradian et al. (2010, p. 1205) expanded the definition of PES to include "a transfer of resources between social actors, which aims to create incentives to align individual and/or collective land use decisions with the social interest in the management of natural resources". This broader definition integrates both market-oriented and government-led schemes and is adopted in this paper.

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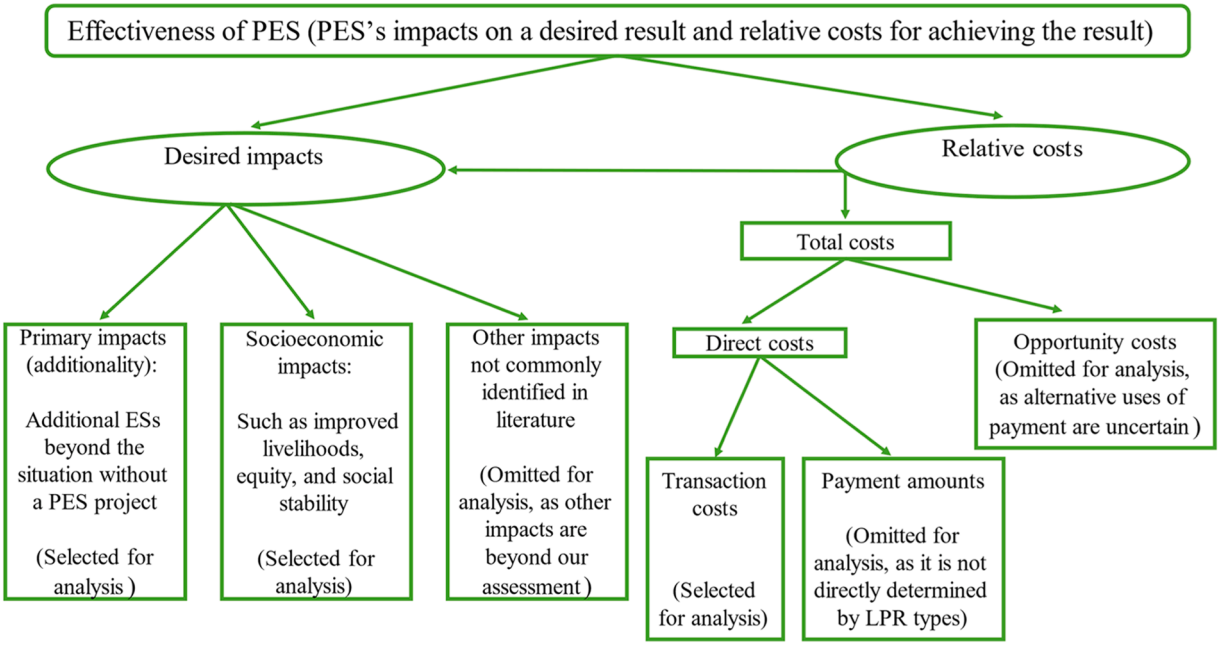

Fig. 1. Main aspects of the effectiveness of PES.

Those who can be paid for supplying ESs are typically those who have property rights over the ecosystems or lands that produce the ESs, unless otherwise specified (Vatn, 2018). While the property rights over a land and other factors that produce ESs, such as trees on that land, may be inconsistent sometimes (Corbera et al., 2007; Folefack and Darr, 2021), this paper assumes these to be consistent and focuses on land property rights (LPRs). LPRs can influence the effectiveness of land management approaches (Ostrom and Hess, 2010; Acheson, 2015), including the effectiveness of PES projects (Wunder, 2005; Muradian et al., 2010; Tacconi, 2012), by determining who makes decisions, who can access lands and use resources, how those decisions can be made, what financial resources are available for management, and who can receive and distribute the benefits from providing ESs (Gong et al., 2010; Mahanty et al., 2013; Lansing, 2014). Ambiguous, unsecured, or contested LPRs may increase conflicts of interest (e.g., unfair distribution of benefits), difficulties in identifying and contracting with ES providers, transaction costs (e.g., cost of bargaining and determining who should benefit), uncertainties regarding future activities of land users, risk of losing motivation to provide ESs, and the eviction of stakeholders (e.g., those whose customary LPRs are not officially recognized) (Murray et al., 2007; Fauzi and Anna, 2013; Mahanty et al., 2013; Fisher et al., 2018; Johnson et al., 2018; Wunder et al., 2020; Bousfield et al., 2021; Cavanagh et al., 2021).

However, there remains an insufficient understanding regarding which LPR type offers more advantages or poses greater limitations in enhancing the effectiveness of PES projects compared to the other types of LPRs. This paper aims to enhance this understanding through reviewing and discussing how private, common, and public LPRs uniquely influence three aspects of the effectiveness of PES: (1) additionality (PES programs often require tests to infer whether the ESs generated by the payment are greater than what would have occurred without the payment), (2) socioeconomic impacts, and (3) transaction costs. Sections1.1 will explain what effectiveness means and why we focus on these three aspects, while Section 1.2 will provide an overview of LPRs. We anticipate that a deeper understanding of each LPR type's role in PES projects in PES projects will help researchers, managers, and policymakers associated involved in land uses, ESs, or PES projects to assess, select, design, or adjust LPRs for effective implementation of PES projects.

1.1. Effectiveness of payment for ecosystem services

The effectiveness of an intervention can be considered as the impacts of the intervention, which denote the difference in a desired result before and after the intervention, and/or with and without the intervention (Gertler et al., 2016; CBD,2017; Karousakis, 2018). However, development within the social sciences, and especially economics, has expanded the concept of effectiveness to include the relative cost of an intervention in achieving a desired result or making a desired impact. The relative cost can be considered as the ratio between the total cost and desired impacts of an intervention (either the impacts generated by per unit of cost, or the cost required for per unit of the impacts); the assessment of the relative cost may involve comparing which among multiple alternative interventions incurs the lowest expenses in achieving the same objective; determining which among various alternatives, sharing the same cost, yields the most favorable outcomes (Wätzold and Schwerdtner, 2005; Karousakis, 2018); or assessing whether the benefits derived from an intervention outweigh its costs (Rowe et al., 2012).

In short, effectiveness can be thought of as (1) an intervention's impacts on a desired result and (2) its relative cost for achieving the result (UNEP, 2019; Chen et al., 2023). Fig. 1 illustrates how we determined the aspects of PES's effectiveness for analysis. In terms of the impacts of PES, PES primarily aims to produce additional ESs beyond those that would have occurred without PES, which is also referred to as additionality (Tacconi, 2012; Valatin, 2012; Vedel et al., 2015). Namely, additionality is the primary expected impact of PES and hence is selected for analysis in this paper. Meanwhile, PES is also increasingly expected to generate positive (or prevent negative) socioeconomic impacts. These include improvements in income and livelihoods of ES providers, social stability, equity (e.g., empowerment of vulnerable people), community norms, and trust and relationships between ES providers (Pagiola et al., 2005; Farley and Costanza, 2010; Tacconi, 2012; Cacho et al., 2013; Benra et al., 2022; Chen et al., 2022; Kaiser et al., 2023). Thus, socioeconomic impacts influence the wellbeing of the stakeholders of PES and are a crucial aspect of PES effectiveness selected for analysis in this paper. The relative costs of implementing PES projects depend on both the impacts of PES explained above and the total costs of PES. Therefore, the total costs are also an important aspect of PES effectiveness. While

Table 1
Common types of LPRs.

LPR types	Definitions	Examples
Private LPR regime	Where an individual, a private group (e.g., a family or corporate entity), or a single user has the title and legal claim to the land, the ability to exclude others from using or benefiting from the land, and the right to manage (e.g., holding, trading) the land voluntarily (Choe and Yun 2017)	Individual lands, private forest; private farms
Public LPR regime	Where land ownership and benefits are dedicated to the public but land uses and access are often managed by the a government agency on behalf of the public (Clarke and Kohler 2005)	National parks owned by governments, state-owned reserves
Common LPR regime	Either defined by government legislation or derived from customary practices, where LPRs are shared by members of a clearly demarcated community who may use and access to the lands under certain rules and exclude outsiders from the lands (Corbera et al. 2007; Lant et al. 2008; Ostrom and Hess, 2010). Notably, this regime should not be confused with open access expressed as the "tragedy of the commons" (Hardin, 1968). This regime can be alternatively referred to as a community, communal, or collective LPR regime.	Some Ejidos in Mexico (Flesch and Esquer, 2020); Community land trust in Scotland (Skerratt, 2013); Collective rural lands in China (Tian et al. 2020); Native American Reservations in the US (U.S. Department of the Interior, 2017).

the total costs include both the direct costs and opportunity costs of foregoing alternative uses of payment, this paper does not consider the opportunity costs, because alternative uses of payment are uncertain and beyond our assessment. The direct costs consist of both the payment amounts and transaction costs, but this paper focuses solely on the transaction costs and omits the payment amounts. This is because the payment amounts may be more related to the values of additional ESs as well as the costs required by the ES provider to conserve or enhance ESs (including direct costs and opportunity costs of forgoing alternative land uses) (Börner et al., 2010; Liu et al., 2010; Chen, 2020). In summary, the effectiveness of PES in our review focused on: (1) additionality, (2) socioeconomic impacts, and (3) transaction cost.

1.2. Land property rights

Property rights typically include the rights to access, withdraw, manage, exclude, and transfer (sometimes referred to as the right to alienation) (Schlager and Ostrom 1992; Ostrom and Hess, 2010). Table 1 presents three globally common types of LPRs, outlining their different owners, decision makers, management strategies, and purposes.

2. Review methods

We followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guideline (PRISMA Executive, 2024) to search related peer-reviewed literature in Scopus, including determining a search term, identifying the total records related to the search term, screening the eligibility of the total records, excluding the records without strong relevance or eligibility for review, and reporting the final records selected for review.

Specifically, the terms directly related to the title of our paper include "payment for ecosystem services" and "land property rights". However, "payment for ecosystem services" may also be referred to as "eco-compensation", "payment for environmental services", or "payment for ecological services"; similarly, "land property rights" might be known as "land tenure" or "land ownership". Consequently, the search term we ultimately used was: '("payment for ecosystem services" OR "eco-compensation" OR "payment for environmental services" OR "payment for ecological services") AND ("property rights" OR "land tenure" OR "land ownership")'. As we attempted to maintain a comprehensive search, the search term did not integrate "additionality", "socioeconomic impacts", or "transaction costs", otherwise the search scope would be narrower. Furthermore, the time frame for the search was by the end of 2023, as the latest search was conducted in early 2024. To be transparent about the comprehensiveness and robustness of our review, we first conducted a search without setting a limit to where the search term occurred, and this search yielded a collection of 2638 papers; however, to ensure that the papers selected for review were directly related to our topic, we screened the titles, abstracts, and

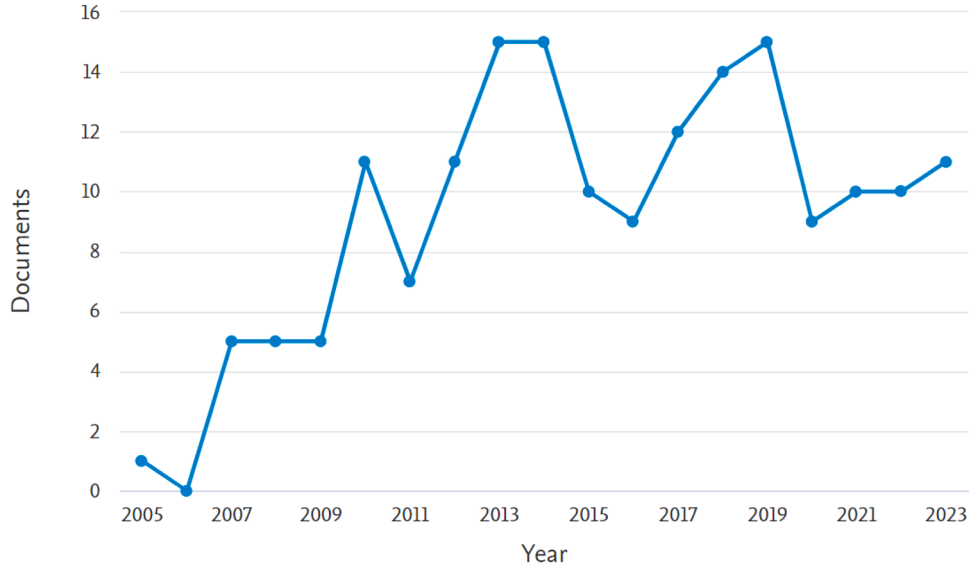

Fig. 2. Search results from 2005 to 2023 with the search scope limited in titles, abstracts, and keywords (from Scopus).

Table 2
Number of studied conducted by research institutions from different countries/regions with the search scope limited in titles, abstracts, and keywords.

Countries/regions	Number of publications	Countries/regions	Number of publications
United states	59	Argentina	2
United Kingdom	30	Belgium	2
Germany	18	Ethiopia	2
Australia	16	Madagascar	2
Mainland China	17	New Zealand	2
Indonesia	12	Tanzania	2
Spain	10	Tunisia	2
Switzerland	9	Vietnam	2
France	9	Botswana	1
Mexico	8	Burkina Faso	1
Norway	8	Cameroon	1
Brazil	7	Cote d'Ivoire	1
Canada	7	Croatia	1
Italy	7	DR Congo	1
Kenya	7	Denmark	1
Chile	5	Finland	1
Costa Rica	5	Ghana	1
Netherlands	5	Hongkong	1
Colombia	4	India	1
Sweden	4	Iran	1
Cambodia	3	Laos	1
Ecuador	3	Lithuania	1
Japan	3	Monaco	1
Peru	3	Panama	1
Singapore	3	Poland	1
South Africa	3	Soloman Islands	1
Unidentified	3		

keywords of the document, and found 176 results in total spanning between 2005 and 2023 (Fig. 2) and conducted by research institutions from a wide variety of countries/regions (Table 2). Among the 176 documents, we excluded 9 articles written in non-English language. To improve the time efficiency of the review, we further excluded 2 documents that are full books. Eventually, we reviewed the full texts of 165 documents.

Though we referred to the PRISMA guideline to search literature, we did not integrate every aspect of the PRISMA guideline, such as quantitative review or meta-analysis of the literature we found. Instead, we focused on theoretical and qualitative assessment and comparison of how private, common, and public LPRs influence the effectiveness of PES projects. To achieve this, during the process of reviewing the full texts of the documents we selected, we searched for and summarized information regarding the following questions: what are additionality, socioeconomic impacts, and transaction costs of PES projects? Has existing literature studied the connections between these three aspects of PES's effectiveness and LPRs? If yes, how LPRs, regardless of the type (private, common, or public), matter to the three aspects of PESs's effectiveness? More importantly, how each type of LPRs influence these three aspects of PES's effectiveness uniquely? Information of these questions is organized and presented in Section 3. Then in Section 4, we identified research gaps in previous literature and suggested future research directions, including some hypotheses for future tests, as well as the rationales for proposing the hypotheses. In addition, we discussed our research limitations and suggested relevant potential solutions. We adjusted the PRISMA flow diagram to adapt to our review and to present our methodological framework in Fig. 3.

3. Results

3.1. LPRs and additionality

Inferring additionality requires secure and clearly defined LPRs, as researchers have indicated (Barbier and Tesfaw, 2013; Caro-Borrero et al., 2015; Maldonado et al., 2019; Liu and Dou, 2022; Kaiser et al., 2023). This is because LPRs determine who is responsible for providing ESs, affect land uses that can change supply of targeted ESs, safeguard long-standing commitment to conservation, and exclude outsiders of PES contracts (e.g., preventing damage to ecosystems). While a variety of potential terminologies exist for additionality, we adopted the terminology used by the United Nations Framework Convention on Climate Change Clean Development Mechanism (UNFCCC-CDM, 2017) in this paper. Additionality assessment is primarily about comparing target ESs in the situation with a PES project to a baseline of the ESs or to the ESs in the situation without the PES project. However, when it is challenging to assess additional ESs, for example due to the difficulty and uncertainty

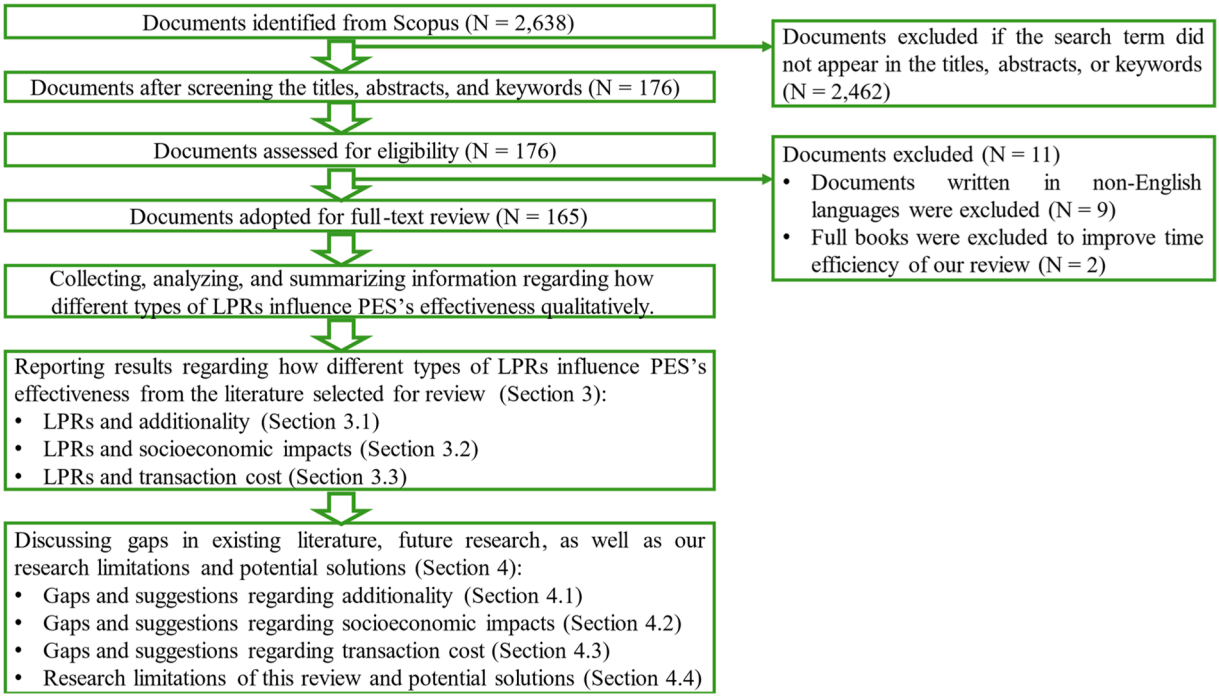

Fig. 3. Adjusted PRISMA flow diagram.

in establishing a baseline or a counterfactual of ESs, inferring additionality might include alternative tests.

An alternative test, in this context, does not measure the quantities of additional ESs directly, but is an assessment of whether a project satisfies certain criteria. Regulatory (also known as 'legal' or 'institutional'), financial (or 'economic' or 'investment'), and common practice (or 'technological') tests are commonly used in academic papers and official literature of international organizations (McFarland, 2011; Gillenwater, 2012; Valatin, 2012; World Bank, 2016; Ruseva et al., 2017; UNFCCC-CDM, 2017), especially in the context of carbon sequestration. However, they are also applicable to other ESs. These tests will be further explained in Sections 3.1.2 – 3.1.4. If a PES project passes a regulatory, financial, or common practice test, then the ESs produced by this project may be considered additional. There are guidelines (UNFCCC-CDM, 2017; American Carbon Registry, 2020; Salway et al., 2022) that provide detailed instructions for conducting additionality tests. The following subsections will link different types of LPRs to additional ESs, as well as the alternative tests for additionality.

3.1.1. Additional ESs and LPRs

LPR holders' incentives for managing ESs can affect whether PES projects produce additional ESs. Several notable studies (Glück, 2002; Lant et al., 2008; Cao et al., 2009; Costanza, 2020) have assumed that private LPR owners, being self-interested, are more motivated to produce and trade private goods that are rivalrous (where one's consumption of a good/service diminishes the amount available for another) and excludable (where one's consumption of a good/service can prevent others' consumption) to maximize their own benefits as compared to public goods. Consequently, public ESs, which are both non-rivalrous and non-excludable, are not usually considered in the decision-making framework of private LPR holders completely, as public ESs often lack a market for monetizing or realizing their values (Chen, 2020). Therefore, individuals may not be inclined to voluntarily provide public goods at their own expense (Lant et al., 2008; Olson, 2009; Farley et al., 2015; Oza et al., 2021), although public ESs will sometimes be provided in private LPR settings as a by-product of market-based management (e.g., habitat provision in a commercially managed forest stand). In other words, payment to private landowner can motivate them to produce additional ESs.

Conversely, studies (Glück, 2002; Costanza, 2020) may assume that rational holders of public and common LPRs are more likely to consider the holistic wellbeing of the public and communities and pursue integrated goals that encompass environmental efficiency, fair distributions of benefits from lands, and environmental sustainability (e.g., carbon emission reduction, biodiversity conservation). As a result, the social benefits of ESs may be already incorporated into the decision-making process and public management baselines regardless of external payment.

Common lands comprise more than 50 % of lands in rural Global South (World Resource Institute, 2017; Nguyen et al., 2022; Kaiser et al., 2023), and tend to have larger population (Jones et al., 2023) than public and private lands. Several studies examining common LPRs note that free-riding (receiving a benefit without contributing to it) exists within common lands to achieve the targets of a PES project, potentially decreasing the overall effectiveness of the PES project (Kerr et al., 2014; Kaczan et al., 2017; Hayes et al., 2019; Naime et al., 2022). To prevent free-riding on common lands, policy makers should design contracts that are conditional on additional actions and prioritize agreements with communities that have strong internal governance and enforceable rules (Kaczan et al., 2017).

In addition, decision-making on private lands tends to be more direct and individualized, whereas it may involve a bureaucratic process on public lands (Bettinger et al., 2016) and more complex collective process on common lands (although in some cases the leader of a common land may make decisions independently) (Izquierdo-Tort et al., 2022; Kaiser et al., 2023). The rules or processes for making decisions under different LPRs may also affect regulatory tests explained below.

3.1.2. Regulatory tests and LPRs

A PES project accomplishes a regulatory test when it produces a higher quantity of ESs than what is already required or resulting from regulations, laws, or policies that are already in place (Gillenwater et al., 2007; McFarland, 2011; Costanza et al., 2021). For example, compensation for the cessation of logging on lands where logging prohibition is already in place and enforced pursuant to law does not lead to additional Ess. If a legal instrument aimed at ES improvement is intended but has not been adopted, a PES project can be considered legally additional until the legal instrument takes effect (Salway et al., 2022). If there is a pre-existing legal instrument that is not enforced due to funding shortfalls, and the payment enables its enforcement, a regulatory test can be accomplished (Karsenty et al., 2017). This scenario is also related to financial test, which will be further discussed later.

Accordingly, existing laws, rules, or regulations influence a regulatory test. An increasing number of legal resources (e.g., regulations, laws, mandatory policies) are being developed to meet the growing demand for ESs (Lant et al., 2008; Aragao et al., 2016). Although private lands may still follow some mandatory rules to prevent damages to public resources (e.g., clean water, wildlife), they typically face fewer regulatory restrictions and have more freedom to pursue individual objectives than public lands (Glück, 2002; Fahey et al., 2010; Bennett et al., 2011; Frohlich et al., 2018; Oza et al., 2021; Kelly and Crandall, 2022). Although there may be exceptions, common LPRs also tend to involve more rules (e.g., tree harvesting rules) than private LPRs (Rodríguez-Robayo et al., 2020; Kaiser et al., 2023; VonHedemann, 2023).

It is also important to note that moral hazard exists in conducting a regulatory test, as there might be perverse incentives for issuing regulations (McFarland, 2011). For example, if a region enacts regulations to halt logging, it may face a reduction in external PES funding for halting logging and an increase in its own expenditure, because the PES funding in this case cannot pass the regulatory test. Such moral hazards may vary depending on the LPR. As previously mentioned, public land managers (e.g., governments) may change public regulations through bureaucratic processes. Private land manager may influence regulations through regulatory capture and lobbying (Godwin et al., 2012), whereas common land managers may change regulations via customary collective decision-making processes (Izquierdo-Tort et al., 2022).

3.1.3. Financial tests and LPRs

A financial test may be conducted when a ES-producing activity is proven to be either (1) not financially viable without PES support (meaning the conservation activities require financial assistance and PES is the sole source of funding), or (2) not the most financially advantageous option (under the assumption that more financially beneficial activities would have been financed by other sources in the absence of PES projects) (UNFCCC-CDM, 2012). In essence, a financial test aims to examine the necessity of a PES project for financially enabling an ES-producing activity. Such necessity is determined by either the financial infeasibility (prior to the receipt of external funding) and/or financial unattractiveness of the ES-producing activity.

Private, common, and public lands may all experience funding shortfalls and require external funding. For example, public lands, such as stated-owned protected areas, may lack sufficient government funding to achieve their conservation targets (Chen, 2021), while private lands and common lands may lack market mechanisms to generate revenues for conducting conservation activities (Wilson et al., 2017). However, there is no established theory or statistical analysis to determine which type of LPR faces greater financial infeasibility. Meanwhile, we did not find any study concluding whether ES-providing activities are more likely to be financially unattractive on private, common, or public lands.

3.1.4. Common practice tests and LPRs

A common practice test aims to examine (1) whether an ES-producing practice funded by a PES project has essential distinctions from and higher efficiency than existing common practices within the relevant geographic region (under the assumption that if an ES-producing practice is similar to existing common practices, it would be applied anyway in a business-as-usual scenario) (McFarland, 2011; Valatin, 2012) and/or (2) whether an ES-producing practice would have slower adoption and difficulties in application without financial incentives (World Bank, 2016). A PES project can pass a common practice test if the adopted ES-producing practice it funds is innovative, exceeds the business-as-usual adoption rate, and/or overcomes existing implementation barriers (e.g., lack of resources, technologies, and skills) as a result of receiving the payment (Barnes et al., 2014; World Bank, 2016; UNFCCC-CDM, 2017). For example, suppose a group of farmers had adopted a carbon-sequestering practice on only 5 % of their land previously but expanded the practice to 50 % of their land due to the financial incentives provided by a PES project, this PES project would pass a common practice test and demonstrate additionality (Thamo and Pannell, 2016). However, no study has shown whether private, common, or public LPRs are more beneficial for PES projects to pass a common practice test.

Table 3
Ostrom's eight principles and their connections with socioeconomic impacts.

Principles (Ostrom, 2008)	**Connections with socioeconomic impacts**
#1 Clearly defined boundaries: the boundary of resource system and the individuals or households with rights to use resources are clearly defined. Shared identity and purpose is required.	Clear boundaries determine the areas included in a PES project, identify legitimate payment recipients, and outline who benefits from its socioeconomic impacts. They also help avoid conflicts over the distribution of socioeconomic benefits and costs.
#2 Proportional equivalence between benefits and costs: rules specifying the amount of resource products that a user is allocated are related to local conditions and to rules requiring labor, materials, and/or money input.	PES projects must adapt to local ecological, economic, and social conditions. By aligning with local contexts and considering local needs, PES schemes are more likely to offer fair compensation, encourage commonly accepted ES-producing practices, and generate positive socioeconomic outcomes for local communities.
#3 Collective-choice arrangements: most individuals affected by harvesting and protection rules are included in the group that can modify these rules.	Involving local communities and stakeholders in decision-making ensures that PES agreements are tailored to local conditions, empowering communities and promoting fair allocation of socioeconomic benefits.
#4 Monitoring: monitors, who actively audit biophysical conditions and user behavior, are at least partially accountable to the users and/or are the users themselves	Monitoring is essential in PES projects to verify that participants are implementing agreed-upon land use activities and delivering desired outcomes. It builds trust, discourages opportunistic behavior (e.g., freeriding), and ensures fair distribution of benefits. Additionally, monitoring can create local jobs, contributing to the economy.
#5 Graduated sanctions: users who violate rules in use are likely to receive graduated sanctions from other users, from officials accountable to these users, or from both.	Graduated sanctions in PES projects may start with warnings and move to penalties or exclusion from the projects for repeated rule violations. Graduated sanctions not only encourages adherence to PES agreements and corrects rule violation, but also helps avoid excessive punishment or immediately exclusion, which could negatively impact livelihoods.
#6 Conflicting-resolution mechanisms: users and their officials have rapid access to low-cost local arenas to resolve conflict among users or between users and officials.	This aims to ensure that disagreements or conflicts do not derail PES projects, providing stability and reducing the risk of social unrest, which can negatively impact local economies and participation. This also facilitates equitable sharing of socioeconomic benefits and costs.
#7 Minimum recognition of rights to organize: the rights of users to devise their own institutions are respected by external governmental authorities, and users have long-term tenure rights to the resource.	With this recognition, local communities are more likely to engage in PES, because this recognition protects their rights to benefit from PES projects and allows them to tailor PES projects to their specific socioeconomic needs.
#8 Nested enterprises: there should be collaborative and coordinated efforts, including resource provision, monitoring, enforcement, and conflict resolution, with multi-layered rule-making authorities at local, regional, and national levels.	Nested enterprises aim to ensure that local PES initiatives are supported by broader policies and institutions, providing coordination across scales, attracting additional resources, and securing political legitimacy. This helps create a more stable and predictable PES system, securing long-term benefits and job opportunities.

3.2. LPRs and socioeconomic impacts

Although we did not find standardized classification of socioeconomic impacts, PES can generate a variety of socioeconomic impacts, regardless of the LPR types. Specifically, PES directly influences the income and livelihoods of ES providers. PES also affects the security of LPRs (security denotes the assurance that LPRs are upheld by participants) because successful implementation of PES requires demarcation of lands, continuous monitoring of practices, and clear land use rules (Jones et al., 2020). For example, in a PES project on the Highland Andean grasslands of Ecuador, half of the communities recognized that the project enhanced their land security by building an alliance with a governmental agency, protecting land boundaries from external encroachment, and helping them gain respect from their neighbors (Bremer et al., 2014). However, when merely focusing on a single socioeconomic goal (e.g., income compensation), PES may ignore other needs (e.g., cultural and spiritual wellbeing) of participants (Chen, 2020). Moreover, PES can either enhance or impair equality between ES providers and others (e.g., those who did not participate PES, ES buyers) through providing additional education, income, or resources to ES providers (Brownson et al., 2019), engaging historically marginalized groups into ecosystem management (vonHedemann, 2020), or distributing unequal benefits. As a positive example, Grieg-Gran et al. (2005) found that multiple PES programs in Brazil, Bolivia, and Costa Rica significantly improved the livelihoods of poor participants and mitigated the income inequality between them and richer community members. As a negative example, Peskett et al. (2011) found that PES programs in Uganda might benefit those who had lands through paying them for reforestation but left out the poorest who did not have lands to plant trees, exacerbating income inequality.

The Uganda example above also implies that greater security of LPRs means more power to make profits from PES projects, as well as a higher magnitude of socioeconomic impacts of PES (McDermott et al., 2013; Howell, 2022). Other factors that may affect the magnitude of a certain type of socioeconomic impact include the amount of financial investment, the number of participants, and the pre-existing income and livelihoods of the participants (Yang et al., 2018; Wu et al., 2021). For example, the national eco-compensation in China that transferred over 14 billion Chinese yuan from the central government to individuals between 2016 and 2020 lifted over 3 million people out of absolute poverty (State Council Poverty Combatting and Development Office 2020). In contrast, local PES programs, such as that in West Lombok, Indonesia (Diswandi, 2017), may only contribute to poverty alleviation within their respective communities.

Compared to private and public lands, PES projects on common lands often lead to more complex and diverse socioeconomic impacts. Specifically, unlike a PES contract on private land, which deals with an individual, a PES contract on a common land must consider community norms and institutions. For example, Ravikumar et al. (2023) are concerned about that PES projects on Peru's Ampiyacu-Apayacu watershed

have undermine indigenous institutions, such as pushing communities to replace an Amazonian tradition of mutual aid and shared labour for subsistence livelihoods with commodity production and employer-employee relationships. Moreover, PES projects on common lands need more varied benefit-sharing systems that consider the differing needs of community members (Izquierdo-Tort et al., 2022). The complexity in socioeconomic impacts on common lands partly is because PES projects on a common land influence not only the equity between an ES-providing community and others but also the trust and equity within the ES-providing community itself. Internal equity concerns include equitable participation in PES, fair representation in the decision-making process, and balanced distribution of earnings among PES participants (Calvet-Mir et al., 2015; Naime et al., 2022).

However, the fact is that inequities based on gender, ethnicity, property size, or tribal/political affiliation still exist on common lands (Peters, 2009; Locatelli et al., 2014), hindering the production and equitable distribution of positive socioeconomic outcomes. For example, lands owned or controlled by women account for less than 50 % of those owned or controlled by men as of 2016 in some African countries, such as Kenya, Nigeria, Zambia, Ghana, and Tanzania (International Land Coalition, 2020). Users with higher levels of wealth, more secure LPRs, greater land control, better resource access, or more power to influence community rules often receive more benefits from PES compared to others. For example, using household-level survey data in Bolivia, Kenya, Mexico, and Uganda, Coleman and Liebertz (2014) found PES participants with more extensive LPRs or more power to influence how community rules received a larger share of profits from the PES projects. A household-level survey in 130 villages in Brazil, Cameroon, Indonesia, Peru, Tanzania, and Vietnam (Andersson et al., 2018), as well as a study on two Kenya cases (Kariuki et al., 2018), also found similar results. Such unequal benefit sharing can, in turn, exacerbate pre-existing inequality (Brownson et al., 2019). For example, unequal distributions of PES projects' benefits due to traditional gender inequity in Kenya's communal lands (Kariuki and Birner, 2021) and unequal size and forest cover of lands distributed to community members in Southern Chile (Benra and Nahuelhual, 2019) further worsened these inequalities.

Furthermore, divergent views of desirable land uses and contested leaderships, which are not issues on private lands, present additional obstacles on common lands to generating positive socioeconomic and ecological outcomes. For example, the disputed perceptions of the justice of PES benefits resulted distrust among community members in the Nyungwe National Park in Rwanda (Martin et al., 2014). The lack of rule enforcement and competition for different land uses in PES projects on Vietnam's community lands has led to illegal resource encroachment and even conflicts among the people (Nguyen et al., 2022). A survey in a rural community of Chiapas, Mexico, found that conflicting goals among group leaders (e.g., deciding which land should be designated as a conservation area) resulted in social conflicts in the community (Corbera et al., 2020).

To generate positive impacts, Costanza et al. (2021) emphasized that PES under common LPRs need to adhere to Elinore Ostrom's eight core principles, which are specified in Table 3. In other words, the success and improved socioeconomic outcomes of PES depend not only on the financial returns from PES but also on well-functioning local institutions and norms, strong social networks, rule enforcement, and trust among community members (Kariuki et al., 2018; Kaiser et al., 2023). For example, due to increasing surveillance for illegal activities, government mediation in conflicts, and clarification of land tenure rules, PES projects in Ecuador's Amazonian and Northern regions enhanced community confidence, cooperation, organization, engagement (e.g., increased adherence to community rules), norms, and justice (Jones et al., 2020). If a PES project allows the wealthier population to contribute more and the poorer population to benefit more, it may also help reduce wealth disparity (Wang et al., 2017). Meanwhile, communities with high levels of trust might use funds from PES not only to benefit individual community members but also to invest in conservation, resource management activities, and infrastructure or agricultural development (Hayes et al., 2019).

Public, private, and common lands are all crucial components of global terrestrial ecosystems, each holding crucial potential to protect biodiversity and enhance a variety of ESs through land management approaches (Mumaw and Bekessy, 2017; Kremen and Merenlender, 2018; Acharya et al., 2019; Kauffman et al., 2022; Barral and Guillet, 2023), including PES projects. However, we found no study comparing socioeconomic impacts of PES between public and private lands.

3.3. LPRs and transaction costs

Regardless of the LPR types, each PES contract typically has transaction costs of conducting a variety of activities to fulfill it. These can include the technical work required to establish linkages between an ecosystem and the services it provides; defining, defending, or trading LPRs; designing contracts; seeking out buyers and sellers; forming negotiations and agreements; monitoring progress of the project; and certifying deals (Kemkes et al., 2010). The transaction costs can manifest as both additional monetary expenses and as additional time required from participants (Banerjee et al., 2017). As mentioned previously, insecure LPRs, whether private, common, or public, result in higher transaction costs. Higher transaction costs can disincentivize the existing implementation and future development of PES (Liu and Dou, 2022), and may lead to market failure when they exceed the benefits expected by both the ES buyers and providers from PES projects (Scheufele et al., 2018).

Existing literature has compared transaction costs between private and common LPRs. Kaczan et al. (2017) suggested that it may be less costly to measure baselines and outcomes on a large tract of land than on multiple small, separate parcels. Some studies have shown that combining separate contracts with numerous private landowners into fewer collective agreements on common lands can reduce the total number of PES contracts and hence reduce the transaction costs for ES buyers to design, negotiate, and implement PES contracts (Kerr et al., 2014; Kaczan et al., 2017; Hayes et al., 2019; Kaiser et al., 2023). However, this strategy may shift some negotiations from being between ES buyers and ES providers to being among the ES providers themselves, transferring some transaction costs from ES buyers to ES providers (Kosoy et al., 2007).

Moreover, transferring an ownership between common lands tends to be more complex than transferring an ownership between private lands. This complexity is partly due to the differences between collective decision-making processes on common lands and individual decisions on private lands, making the integration of common lands into land markets more challenging than private lands (Kaiser et al., 2023). On common lands, community members' differences in wealth, endowments, benefits from land uses, and social-cultural backgrounds can influence mutual trust, benefit distribution, and willingness to collaborate, ultimately affecting the transaction costs (Nguyen et al., 2022). For example, uneven access to land, weak collective action, divergent views of desirable land uses, and contested leaderships can hinder implementation of PES projects (Corbera et al., 2020). Disrespect for community resource management rules, including traditional conservation practices, may also increase the transaction costs (Jones et al., 2020). However, we did not find any studies that compared transaction costs of PES under public LPRs with those of other categories of LPRs.

4. Discussion

LPRs define who has decision-making authority, access to land and resources, control over financial management, and the ability to receive and distribute benefits from providing ES. Different types of LPRs are associated with diverse goals, management strategies, decision-making processes, and legal restrictions, all of which can influence the effectiveness of PES projects. Existing studies have investigated additionality,

socioeconomic impacts, and transaction costs of PES projects on specific lands with certain types of LPRs, recognizing the connections between LPRs and PES effectiveness. However, several research gaps remain, as discussed below.

4.1. Gaps and suggestions regarding additionality

While existing studies have implied the characteristics of each type of LPRs in relation to demonstrating additionality (see Section 3.1), we did not find any study explicitly comparing and assessing which LPR type might be the best suited to generate ESs that qualify as additional. Based on background from our review, we suggest that future research consider whether private lands are more suited for PES projects to produce additional ESs due to the following four reasons. First, private LPRs may be more oriented towards financial profits than common and public lands and hence more motivated to produce additional ESs through changes in land use and management as a response to funding infusions (Lant et al., 2008; Cao et al., 2009; Costanza, 2020). Second, enhancing a single ES might have side effects in certain cases; for example, monocultures of single tree species with a certain strong target ES can increase the risk of biodiversity loss (Osborne, 2015; Horák et al., 2019; Chen et al., 2022). In such cases, well-informed public and common LPR owners ideally need to balance the enhancement of the ES with the maintenance of biodiversity for the collective (Costanza, 2020). Meanwhile, economically rational private LPR owners may still pursue actions to improve the ES for profit-making purposes interest (Farley et al., 2015; Oza et al., 2021). Third, generating ESs for public wellbeing might be inherently integrated into the management goals of public lands (Glück, 2002; Butler and Koontz, 2005; Costanza, 2020), which means more uncertainties in assessing the baseline ES provision on public lands than private lands. Fourth, decisions to change or enact management on public and common lands might require more complex collective processes and a higher degree of planning and certifications than private lands (Kelly and Crandall, 2022; Kaiser et al., 2023; Von-Hedemann, 2023), which means private lands are not as restricted in their decision making as either common or public lands. Instead, they typically face fewer regulatory restrictions and have more freedom to pursue individual objectives.

Moreover, we did not find any study explicitly comparing which LPR category is the mostly likely to pass regulatory, financial, and common practice tests, but we propose the hypotheses below for empirical tests in the future:

(1) Whether private LPRs offer PES projects more opportunities to enable ES-providing activities beyond what is required by regulation, because, as explained in Section 3.1.2, activities on private lands are typically less constrained by laws and regulations.
(2) Whether private LPRs are more likely to pass a financial test than public and common LPRs. If improving a certain ES aligns more with greater public and collective interest, ideal and rational managers of common and public lands might have a higher likelihood to undertake such activities voluntarily (at their own expense) than private landowners, because, as mentioned earlier, private landowners are more oriented towards optimizing private interests. In other words, without compensation or remuneration, voluntary conservation activities are less financially attractive to private landowners. Note that demonstrating the lack of financial attractiveness of an ES-producing activity is an approach to pass a financial test.
(3) Whether the greater flexibility and independence associated with private LPRs may facilitate or accelerate the adoption of innovative ES-producing practices or new technologies, helping to overcome barriers to their implementation, particularly when incentivized by payment. It is true that, with financial support from PES projects, public and common lands that are well-governed and have strong executive capacity can efficiently adopt or popularize new ES-producing practices or technologies. This is especially true if the practices or technologies promote sustainable land use and enhances collective or public wellbeing (Kosoy et al., 2008; Cole, 2010). However, the practices or technologies permissible under public and common LPRs are more constrained by laws, regulations, and bureaucratic or collective processes compared to those under private LPRs.

It's important to note that the hypotheses above do not suggest that PES projects should overlook common and public lands. Instead, common lands in developing countries overall have a larger population and hence more potential ES providers overtime, as well as a larger potential area, than private and public lands (World Resource Institute, 2017; Nguyen et al., 2022; Jones et al., 2023; Kaiser et al., 2023). Hence, more PES projects can be designed and conducted on common lands to conserve and provide ESs in the long term. Future work also needs to establish clear and practical criteria and theories for testing additionality on public lands. This topic remains an open and important area of inquiry, especially because public lands also make up significant portions of terrestrial ecosystems. For instance, 28 percent of the total land area in the USA is owned by the federal government (Vincent et al., 2020). Carbon markets may be a natural first application as there is a large potential for forest carbon sequestration on public lands, and carbon offset markets are already certifying projects under public LPRs. For example, China's Zhanjiang Mangrove Afforestation Project on public lands has been registered on the Verified Carbon Standard (registered ID 2343), the global largest voluntary carbon market (Global Energy Interconnection and Development and Coorperation Organization, 2021). To facilitate PES projects on common and public lands, theories and criteria regarding additionality should be flexible enough to handle multiple PES contexts and different LPRs.

4.2. Gaps and suggestions regarding socioeconomic impacts

PES projects under all types of LPRs may generate various socioeconomic impacts, but we did not find evidence indicating which type of LPRs is most likely to contribute to the largest magnitude of any type of socioeconomic impact. Future research can explore whether LPR categories have a causal effect on socioeconomic impact. If so, it can investigate the mechanisms through which multiple LPR categories influence the magnitude and identify the strengths and weaknesses of each type of LPR in improving the magnitude.

While previous literature (see references in Section 3.2) has compared common lands with other types of lands in terms of the diversity and complexity of PES's socioeconomic impacts, such comparison has not been conducted between private and public lands. Future research may address this gap by exploring several questions. For instance, whether there is a relationship between the number of stakeholders and the ability of PES projects to generate more socioeconomic benefits. Since the ideal decision makers and managers of public lands are supposed to improve public wellbeing (Glück, 2002; Costanza, 2020), but economically rational private landowners are often assumed to maximize their own benefits, are PES projects on public lands more likely to generate positive socioeconomic impacts and to address issues regarding how to distribute socioeconomic benefits in an equitable way? With what conditions or management strategies would public and private lands increase socioeconomic benefits of PES projects?

4.3. Gaps and suggestions regarding transaction cost

While existing studies (see references in Section 3.3) have demonstrated that common LPRs have both strengths and limitations for saving transaction costs of projects compared to private LPRs, a gap to be addressed is whether public LPRs enable PES projects to save more transaction costs than other types of LPRs. To address this gap, we propose the following questions for future investigation. If governments

Table 4
Potential advantages and disadvantages of different types of LPRs for implementing effective PES.

Aspects of Effectiveness	Private LPRs		Common LPRs		Public LPRs	
	advantages	disadvantages	advantages	disadvantages	advantages	disadvantages
Additionality	Private landowners are typically more focused on individual interests and are less constrained by regulations or collective and bureaucratic processes. Thus, PES can incentivize them more easily to produce ESs.	Private lands may have less potential land area than common lands for producing ESs.	In developing countries, common lands offer a larger potential land area and more participants than private lands for producing ESs.	Community rules and collective decision-making processes may restrict PES implementation.	Public lands constitute a crucial part of terrestrial ecosystems.	Regulatory restrictions and bureaucratic decision-making processes may restrict PES implementation.
Socioeconomic impacts	There are direct individual financial benefits to landowners.	Socioeconomic impacts may be less diverse, especially if a PES project focuses on a single goal only.	There are collective and diverse benefits.	Inequality in wealth, power, and social status among community members, contested views, and conflicts of interests may lead to negative outcomes.	Public lands are ideally managed to enhance public wellbeing	There is a risk of focusing on a single objective, ignoring other benefits.
Transaction costs	Direct interaction between an ES buyer and an ES provider may reduce the transaction cost of each PES contract.	The more landowners involved, the more contracts will be needed, improving transaction costs.	Combing multiple individual contracts into a community contract can reduce the number of PES contracts and negotiations between ES buyers and sellers.	A lack of trust, contested leadership, unfair distribution of benefits and costs, free-riding, and inequality among community members can increase transaction costs.	Conflicts and inequality among community members on common lands may be avoided on public lands.	Bureaucratic burden and corruption can increase transaction costs.

are the sole decision makers for public lands, do public lands incur lower transaction costs than private lands by reducing the number of PES contracts and the number ES providers involved in negotiations? Being that a bureaucratic process (e.g., public involvement, expert consulting, and passing regulatory processes) is fundamental to decision making on public lands, but is not mandatory on private lands (Shahab et al., 2018), does the heavier bureaucratic burden and the risk of corruption on public lands increase transaction costs than private lands? Given that lack of trust, contested leadership, and inequality among community members on some common lands, is it possible that public and private lands avoid the higher transaction costs caused by these issues?

4.4. Research limitations and potential solutions

While the PRISMA guideline is also commonly followed to conduct quantitative review and meta-analysis of literature (PRISMA Executive 2024), this review focuses on qualitative synthesis, analysis, and discussion of the relationships between LPR types and PES's effectiveness. A more comprehensive literature review in the future may involve more quantitative components and meta-analysis, including statistical analysis. For example, potential issues to be addressed may include: what effectiveness assessment approaches have been the most frequently used? Does a certain type of LPRs and a certain aspect of PES's effectiveness draw more attention? Where are the main study areas (e.g., forests or grasslands, urban or rural areas) in existing literature? Addressing these questions may add a more objective estimate of the relationship between existing literature and a certain topic, as opposed to relatively subjective narratives and opinions. This may also enhance the view of the overall trend and pattern of the literature reviewed.

However, we do not mean quantitative analysis is superior to qualitative analysis. Instead, quantitative and qualitative reviews are complementary to each other. It is true that the strengths and limitations of different LPR categories in relation to influencing the effectiveness of PES projects in this study are analyzed, discussed, and compared mainly based on theoretical reasoning. Nevertheless, these theoretical discussions and comparisons can serve as hypotheses for future testing. We look forward to further research that conducts empirical and quantitative comparisons of different LPRs based on real-world cases.

We also acknowledge this paper has only considered three types of LPRs and three main aspects of PES's effectiveness. The other potential types of LPRs (e.g., lands with mixed LPRs) and aspects of PES's effectiveness (e.g., opportunity cost) overlooked in this study require further investigation. Finally, the discussion and analysis in this study is under an assumption that LPRs and the property rights over different ecosystem components (e.g., trees on lands) are consistent and hence simplifies the complex reality that a parcel of land may distribute the property rights over different resources to individuals, public agencies, and communities. For example, water rights, mineral rights, and rights to access the land may all be under different agreements. We anticipate more sophisticated research in the future to address such complexity.

5. Conclusion

Existing literature has noted multiple linkages between each type of LPRs and PES's effectiveness. Specifically, we found that private, common, and public LPRs may have different influences on whether a PES project can produce additional ESs and pass regulatory, financial, and common practice tests, due to different goals, management strategies, decision-making processes, and legal restrictions. The distinctions between multiple LPRs also mean distinct socioeconomic issues and make a difference in stakeholder engagement and benefit distribution, leading to different magnitudes and types of socioeconomic impacts from PES projects. Moreover, potential challenges involved in PES development, such as defending or trading a land ownership, designing, negotiating, and implementing a contract, and monitoring participants, may vary from LPRs, influencing the transaction costs of PES projects.

In general, more secure, more clearly defined, less contested, and more fairly distributed LPRs can enhance participants' willingness to change land-use practices to improve ESs, ensure more predictable socioeconomic impacts, and reduce transaction costs arising from conflicting or redundant decision-making and implementation processes. While we cannot definitively say which LPR type is best for PES in a given context, we have identified characteristics of private, common, and public lands that may either enhance or hinder PES effectiveness, summarized in Table 4. These insights can help land managers and decision-makers choose, design, or refine LPRs to improve PES projects' contributions to ESs and human well-being, while also reducing transaction costs.

Additionally, this paper has identified gaps in existing research and suggested areas for future study. Specifically, a hypothesis for future research could be whether private LPRs may be more suited to ensuring additionality than common and public LPRs, because it may be easier for private to change land use practices or technologies to provide ESs beyond a baseline, regulatory requirements, or financial or technological constraints. However, we also anticipate the development of flexible, practical standards for assessing ES baselines and additionality on common and public lands across different contexts. Another research gap is which type of LPR is the most likely to facilitate production of the largest magnitude of socioeconomic benefits. Moreover, existing studies have not compared socioeconomic impacts between private and public lands. Whether public lands may require higher or lower transaction costs for implementing PES projects than private and common lands also remain unclear. These research gaps require further investigation. Finally, our study is mainly a qualitative review of existing literature, involving theoretical discussion and comparison of the relationships between different LPRs and PES's effectiveness. We anticipate more quantitative aspects of literature review in the future and more empirical evidence from real-world cases to further assess the strengths and limitations of different types of LPRs for enhancing PES's effectiveness. Such empirical assessments may also integrate other types of LPRs and other aspects of PES's effectiveness that have been omitted in this study.

CRediT authorship contribution statement

Evans Samuel: Writing – review & editing. **Chen Haojie:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Sloggy Matthew R.:** Writing – review & editing, Writing – original draft, Supervision, Resources, Project administration, Funding acquisition.

Declaration of Competing Interest

The authors have no conflicts of interest to declare.

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No data was used for the research described in the article.

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