Research paper

Reframing Biodiversity and Social Capital Through Incomplete Contracts

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Abstract

Terrestrial biodiversity conservation is severely limited due to a lack of knowledge about impending biodiversity losses. We introduce the application of incomplete continuous contracting theory to less or more biodiverse land trading in developed countries, where ownership levels between trading parties differ significantly, thereby diminishing social capital. We find that biodiversity can be preserved (1) when there is one price reflecting the equal cost and value of the land, and (2) when price differentials are large and the value is no less than the cost of the land. Biodiversity is harmed when the initial value of biodiversity is higher than the cost of acquiring it. With repeated contracting, aggrievement (a party's perception of being treated unfairly based on a deviation from a reference point) and shading (a deliberate reduction in performance or cooperation by one party in response to feeling aggrieved) occur. These preliminary results indicate that different outcomes can be achieved with varying information about the value of biodiversity, providing strong support for the monetary valuation of biodiversity.

Keywords: Natural Capital · Nature Crisis · Social Capital · Contract Theory · Developed Countries

1. INTRODUCTION

Biodiversity loss is happening now. It is caused by human action and diminishes future benefits derived from nature by humans (Isbell et al., 2017). At the same time, in efforts to raise the standard of living and the benefits we obtain from the consumption of goods and services, we produce more and more of them, and the economies grow. Here, we consider the dilemma of biodiversity conservation in the face of increasing resource consumption and demand for final products, both now and in the future. We abstain from the possibility of a gradually vanishing population without optimal allocation, in which case, knowledge and living standards stagnate (Jones, 2022). At the same time, we place the economic interactions in the framework of incomplete contract theory. This allows us to consider trade in goods that are impossible to describe nominally due to a lack of knowledge, as in the case of the value of biodiversity to humans.

When does this dilemma of biodiversity conservation versus economic growth bring about especially harmful results? In considering the world with an increasing population, a significant problem arises from the interplay between economic growth and biodiversity conservation, notably when technological progress is lacking. This is because improvements in production efficiency often necessitate the depletion of natural capital (Czech, 2008). Without human intervention, it would comprise habitats for other species (*ibid.*, 2008). The decoupling of growth from environmental impacts and biodiversity has not been particularly successful at the global level, and the absolute decoupling implied by the Kuznets curve has also failed (Otero et al., 2020). That is to say, wealthier nations do not, in the aggregate, turn from environmentally degrading activities at low levels of wealth to environmental protection at high levels (Stern, 2004).

Why is it so? Land abandonment is the key biodiversity pressure (Pla et al., 2024). Biodiversity can also be saved when protecting common, rare, and endangered species (Amos, 2024). Why can we not agree on

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terrestrial biodiversity conservation when we know who owns the land and recognise that upcoming biodiversity losses are making us worse off by diminishing the pools and fluxes of materials and energy in nature and, thus, ecosystem services? (Isbell et al., 2017) Might the way we contract be the cause? Henceforth, we consider a world where continuing relationships between individuals who are becoming less socially connected in a globalised, multi-option society tend to co-occur with continuing short-term contracts. These contracts, in turn, govern the long-term trade of land resources, which is solely determined by the land's biodiversity value. Thus, we take upon an original research question aiming to formalise how biodiversity value is determined by market mechanisms and contracts and, in doing so, reach for an analysis of biodiversity instead of natural capital at large, as it has been previously analysed (Yang et al., 2025).

We investigate the question of instances when biodiversity is conserved and when it is harmed in this setting of incomplete and short-term continuing contracts. We find that biodiversity is harmed if the initial value of biodiversity is higher than the cost of acquiring it. Value and cost differentials are used as a reference point, inducing aggrievement (a party's perception of being treated unfairly due to a deviation from a reference point) and shading (a deliberate reduction in performance or cooperation by one party in response to feeling aggrieved) in the provision of highly biodiverse land. Following the theoretical backdrop described in Hart and Moore (2008), this result highlights the importance of uncovering information about the true value of the land's biodiversity, assuming that such information is reflected in prices almost immediately and that market imperfections are minimal. Biodiversity can also be preserved when there is one price for the land, with cost and value being equal. It can also be maintained when the price differential is large, and trade occurs conditionally, provided that the value is no less than the cost of land.

This work aims to connect the incomplete contract theory with the biodiversity outcomes of land trade to extract the outcomes for biodiversity depicted from the contract theory, and in doing so, bridges the research streams by:

- Applying incomplete contracts to short-term contracting of land trade;
- Considering the case of continuous contracting;
- Acknowledging the social capital role in contract theory.

At the time of writing, we were unable to locate research on incomplete contracting in relation to biodiversity issues. However, there is related research on river pollution and claims of problems (Yang et al., 2025). This situation is worrisome, as biodiversity represents a typical example of incomplete information regarding the traded land characteristics. We fill this gap by applying the theory to land trade with lower or higher biodiversity levels in developed countries, where contract enforcement is less of an issue. We also do not find an explicit consideration of social capital in contract theory. With this work, we aim to fill this gap and consider social capital characteristics that may influence contracting and trade, namely the short-term nature of commitment to people and goods, which is characteristic of a multi-option society.

The following work is organised as follows. Section 2 provides an overview of environmental problems in the context of economic growth, explicitly addressing biodiversity valuation (Section 2.1) and ownership, efficiency, and social capital (Section 2.2). Section 3 describes the evolution of contract theory, and Section 4 links the theory with biodiversity, proposing the configurations in which biodiversity will be harmed or conserved. Finally, Section 5 discusses the results, and Section 6 concludes.

2. ECONOMIC GROWTH AND ENVIRONMENT

We now examine the intersection between economic growth and the environment. First, we describe current socio-ecological conditions, then examine biodiversity markets from the perspective of monetary valuation, and conclude with an overview of biodiversity ownership.

Before examining the socio-ecological conditions, we explore the primary question of the relationship between growth and the environment. One can conclude that the projected population and consumption growth imply increases in food demand. For farmers to invest in land improvements and fully utilise their land, securing land titles is of utmost importance (Tuck & Zakout, 2019). Moreover, national water leaders recognise water use by other countries as one of the major challenges (Water Policy Group, 2023) and as being beyond their immediate control. The primary anthropogenic driver of global biodiversity loss is changes in land and sea use (Maechler & Boisvert, 2024). Thus, the question shifts solely from decision-making to "Who owns the asset, and how does it affect incentives?"

2.1 Current Socio-Ecological Conditions

Current socio-ecological conditions can be characterised by a high risk of biodiversity changes in the future, which are already unfolding today (Isbell et al., 2017). As Berardo (2014) establishes, high-risk conditions are characterised by a cooperation problem that negatively affects the sustainability of resources, such as biodiversity. With uncooperative behaviour rather exclusive, bonding communication structures between actors emerge (*ibid.*, 2014). These bonding communication structures allow for an easier flow of redundant information, which helps detect and punish defection (Berardo, 2014; Coleman, 1988). On the other hand, perceived riskiness, either today or in the future, can be rather low in the case of biodiversity loss due to the soft perceived impacts on individuals. When individuals perceive the environment as low-risk, coordination problems may arise if they share the same goals but have different actions to achieve them. This may lead to the creation of a star-like bridging social capital structure that is better adapted to flows of non-overlapping information, allowing the spread of innovative solutions (Berardo, 2014).

2.2 Biodiversity Markets and Monetary Valuation Perspective

Because of the question posed at the end of the introduction of Section 2, one may want to study ownership of environmental resources, dropping the perspective of authority, hierarchy, and delegation. Because the Coasian renegotiation implies that parties bargain for an efficient outcome using side payments after the uncertainty is resolved, only asset ownership should matter in analysing firm boundaries (Hart & Moore, 2008). Within the environment ownership question in a capitalistic and micro-based world, just posed, firm boundaries will signify the integration between individuals in friendships formed. Thus, applying the incomplete contract theory, we will study how social capital is integrated with environmental decision-making.

Building on the Coasian perspective, as previously suggested, we consider the market to be free of complications from imperfect information (for a start; later, we include incomplete contracting as well) or poorly defined property rights. Indeed, we consider the developed country context, where property is well-defined and transaction costs are low enough to allow efficient bargaining.

Land governance ("the rules, processes and structures through which decisions are made about access to land and its use, [..], the way that competing interests in land are managed", (Fricska et al., 2009)) prevails as a consequence to trade where at least two actors are engaging in land trade and land is characterised by land tenure, a socially constructed system whereby rules of tenure define how land rights are assigned within societies (right of use, control, transfer, and associated responsibilities and restrictions) (ibid, 2009). It is, therefore, key to understanding the process of less or more biodiverse land use due to its contracted trade. We maintain that ideas such as commitment to long-term contracting are developing relational social norms and, therefore, forming land tenure in a developed society through contracting (Gundlach et al., 1995). As each land proprietor's (or planner's) interests, which we assume are well-defined to derive the most value from the land plot, do not always coincide with those of society's members, the lack of coincidence in goals leads to an incentive conflict. This can be resolved, as discussed further, through continued trade. The actors engaging in trade would be the general, *unengaged* society member whose best interest is to preserve the biodiversity value of the land of which she is not a proprietor, the high-socioeconomic status individual (the proprietor of the land whose interest is to maximise the value she obtains from the land in the period she owns it until the next trade), and the next-period high-socioeconomic status individual who owns the land in the next period after the trade, whose interest is to obtain a higher-biodiversity land to deliver to her land use goals. We abstain from modelling for state interests. However, the global biodiversity market, or – more generally – the economic valuation of nature, is also not empirically confirmed as the appropriate tool to manage and safeguard biodiversity (Maechler & Boisvert, 2024). In this paper, for simplicity, we look over the previously well-defined natural capital's value equal to land cost and instead propose that only biodiversity, which makes up a part of natural capital, is sufficient to determine land cost in general. The authors show that monetary valuation is challenging because it is future-oriented and promise-based. To align with this thesis, a non-monetary valuation may be called in for, or at the very least, monetary valuation can be abstracted from.

However, some of the key findings of biodiversity research confirm that nature has a measurable economic value, typically undervalued and ignored in markets (Sukhdev et al., 2010) and economic and policy systems (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), 2019). Moreover, it has been argued that nature is our most precious asset, and it has been reassured that biodiversity loss results from institutional and market failures (Dasgupta & Great Britain. Treasury., n.d.).

2.3 Biodiversity Ownership, Efficiency, and Social Capital

We abstract from monetary valuation and instead focus on the ownership in terms of social individuals contracting over environmental actions due to the service economy-induced multi-option societies; ecological effects are not yet known. At higher levels of wealth, economies turn into service economies and knowledge-based economies (Baunsgaard & Clegg, 2015). These are economies where the majority of value is created in the service sector, and the majority of jobs are in services (Stahel, 1997). Innovation involves both human networks and technology (Hacklin et al., 2005), leading to long-run growth and flourishing (Hanushek & Woessmann, 2023). When the use of skills tends to be increasingly emphasised in the service economy, the knowledge economy results (Miles, 2003), resulting in growth, among other drivers, from innovation (Feldman & Kogler, 2010). Knowledge can be categorised as know-what, know-why, know-how, and know-who (Lundvall & Johnson, 1994), of which the latter is of interest here.

When know-who is reduced in importance, economies may still grow but develop multi-option societies where commitment to goods or people is short-term (Gross, 1995, as cited in Stahel, 2017). Achieving a wealthier state with impaired know-how may still be possible. However, the ecological consequences of such growth remain uncertain, and it is likely to erode social capital within society. Theoretically, wealth without resource consumption may be achieved by both demand and supply side solutions, that is, with a reduction of volume (supply side efficiency), speed (supply and demand side efficiency), or of both (system solutions), thus improving the ecological conditions (Stahel, 1997).

Policy-makers traditionally focus their attention on supply-side efficiencies in a structure-oriented fashion to resolve resource problems, but with new problems arising, demand management and non-structural approaches, in general, are taking the lead (FAO, n.d.). Demand management has traditionally been the centre of the workings of land management, where property rights are well established and incentives due to the price system prevail (Dales, 1968). Thus, demand-efficient solutions altering the permissions and restrictions of consumers may provide incentives to save these resources (FAO, n.d.), that is, the ownership in the sense of residual rights of the use of the assets (Grossman & Hart, 1986).

However, one might argue that the conceptual domain regarding individuals' agreement on the usage of environmental resources—specifically, residual rights of control—is quite fragmented and largely grounded in the concept of property rights in relation to land. Conversely, in the context of water management, it is founded on the principle of political determination. The fragmentation of societies due to the service economy is somewhat abstract, and a possible decrease in social capital is swept under the carpet. Thus, ecology typically studies individuals, while economics focuses on a macro perspective. Given this, the incomplete contract theory gives a refreshing microeconomic perspective on the relations of non-integrated but income-differing individuals contracting over land assets' ownership and residual use, ultimately deciding on biodiversity.

2.4 Methodological Approach and Conceptual Framework

Regarding definitions of concepts, insofar as biodiversity is discussed, we aim to define it as a combination of richness, evenness (equity of relative abundance), and dominance (concentration of abundance) (Isbell et al., 2017), as it best reflects the maximal value biodiversity delivers to humans. As for social capital, its concept for this consideration lies in the economic connectedness measure, as it was defined by Chetty et al. (2022).

We are setting the analysis within the conceptual framework of contract theory, discussed in the following Section 3 and depicted in Figure 1. We theorise about four key propositions, as this theory involves identifying the key constructs (biodiversity and social capital) and linking them to definitions found in the literature, forming relationships between them, and thus creating propositions based on contract theory. We abstain from testing these propositions empirically due to the lack of available direct microdata.

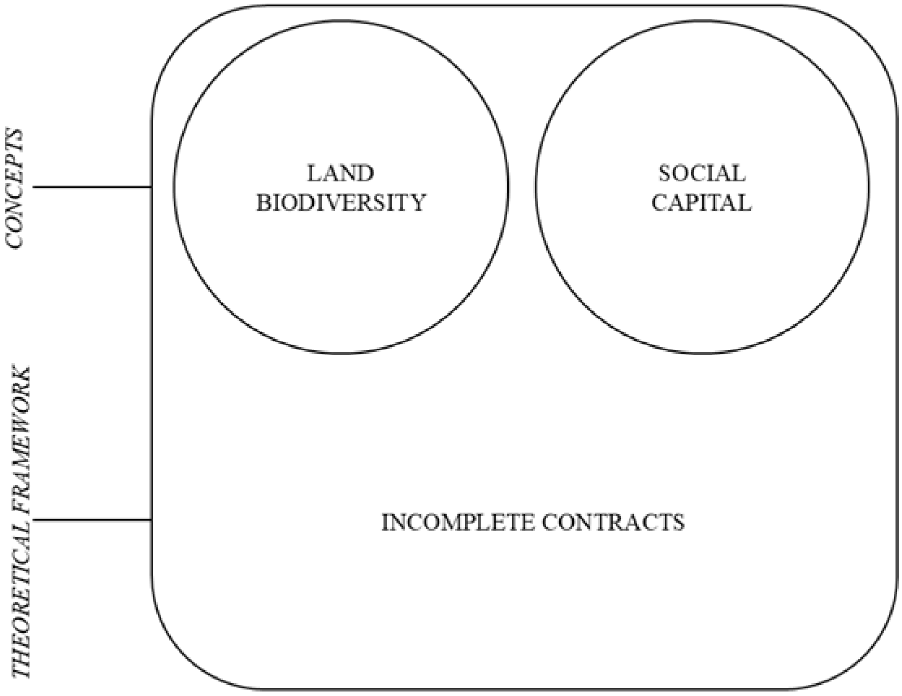

Figure 1. Conceptual Framework

3. FOUR STAGES OF CONTRACT THEORY RESEARCH

The four approaches of contract theory build upon the (1) fundamentals of Edgeworth efficient exchange with no uncertainty and no asymmetric information, then (2) adding uncertainty and (3) asymmetric information to the mix, and (4) repeated or dynamic contracting. Finally, (5) incomplete long-term contracting has been studied. The research streams applied to biodiversity studies become wider, and the contract theory stage becomes more developed.

(1) Since Edgeworth (1881) proposed the noncoercive trade between two agents with contracting until the point is reached where nobody is worse off than before the bargaining and contracting. This model has been applied to study deforestation (Das & Das, 2014) and genetic diversity (Gowdy, 1993).

(2) Uncertainty in contract theory concerning future outcomes involves a more developed research stream in ecological economics. For example, contracting in an uncertain future ecological environment has been studied to find that it generally has little effect on short or long-term contract selection (Lennox & Armsworth, 2011). Biodiversity as insurance has been studied, distinguishing the effects of biodiversity on the mean and variability of ecosystem properties (Loreau et al., 2021).

(3) Asymmetric information, when one contracting party has more information than the other, including dual asymmetric information, has been studied extensively in biodiversity settings, for example, with payment for ecosystem services contracts – schemes where biodiversity protection is contracted between the landowner and the regulator. Asymmetric information research finds that with circumstances reflecting those in practice, the first—best may be achieved with incentive compatibility (Arguedas et al., 2008).

(4) Regarding optimal contract length and the dynamics of contracts, Juutinen et al. (2012) have determined the optimal contract length in relation to privately managed and unmanaged lands. Groth (2008) experimentally investigates repeated auctions for conservation contracts and finds the cost-effectiveness gains compared to flat-rate payment. Strange et al. (2006) find efficiency gains for conservation value where non-reserve areas are concerned.

(5) Incomplete contracts fail to specify everything related to trade in advance and, therefore, are not complete, at the same time, perhaps, resembling the real world most closely. Research on biodiversity contracting, with incomplete specifications, has distinguished between buyer-seller

short-term contracts and landowner-banking long-term contracts (Alvarado-Quesada et al., 2014). The focus of the analysis here is the former. When there is incomplete enforcement but strong institutions, with carbon price increases, payments rise, and vice versa (Synes et al., 2019). That is, buyers' and sellers' values and prices follow each other.

4. TOWARD A MORE FORMAL PERSPECTIVE OF BIODIVERSITY OWNERSHIP

Contracts do not always specify everything related to their trades. In its extreme form, contractual incompleteness may mean that no contract can be written ex-ante specifying a trade in the future. Most long-term contracts are incomplete in their dealing with decisions and transactions determined later, so they do not deal explicitly with all possible contingencies (Bolton & Dewatripont, 2004). Incompleteness may arise from the inability to describe future events relatively instantly, jointly agree on future transactions, or those agreements being too costly and/or with limited enforcement (Bolton & Dewatripont, 2004). Incompleteness may, therefore, be due to the lack of allocation of ownership titles, control rights, discretion, authority, and decision-making rules, to name a few. In most cases, incompleteness arises from unforeseen future contingencies, difficulty negotiating individual plans, and enforcement (Hart, 1995).

Methodologically, the contracts can then be analysed by who makes these decisions or who benefits from control or ownership protections (ownership, governance, and internal organisation), that is, who is remunerated by monetary means and who benefits in other ways. This is to study how the ex-post efficient outcome may be generated by reducing the ex-ante underinvestment, which itself arises because parties recognise that the renegotiation of the contract leads to the sharing of non-contractible relationship-specific investment benefits with the other party (Hart & Moore, 2008). Table 1 shows the propositions:

Table 1. Overview of the Four Propositions and Their Respective Outcomes

Proposition summary	Outcome
Ownership disparities reduce social bonding	*Theoretical foundation*
Single price (cost = value)	First-best trade (biodiversity preserved)
Large price differentials (value ≥ cost)	Trade occurs (biodiversity preserved)
Continuous contracting	Biodiversity is harmed if the initial value > cost

This brings us to the first proposition with the suggested application in Box 1, that is:

Proposition 1: Individuals will differ in ownership statuses embedded into the individual's socio-economic status, implying less social bonding.

Box 1. Testing Proposition 1 via Experimental Design.

We suggest testing this proposition with macroeconomic data or through experimental methods. While data on land ownership and use are available from the US Census and the Tenure, Ownership, and Transition of Agricultural Land survey, recent datasets on social capital are also accessible. Furthermore, one can conduct a laboratory experiment by giving some agents more property (for example, pens or coffee mugs) than others and engaging them in a social game that tests their community spirit and social bonding.

The economic connectedness of individuals as defined by the high socioeconomic status friends among individuals with low socioeconomic status (Chetty et al., 2022) is a measure of social capital, and socioeconomic status is determined mainly by income (Supplementary Information B of Chetty et al., 2022), which forms a major domain of the socioeconomic status concept (Cutler et al., 2008). One can substitute socioeconomic status for property ownership in predicting highly established outcomes (Lockwood et al., 2018). Property ownership, or land ownership more generally, is embedded in an individual's socioeconomic status.

Furthermore, these ownership levels will differ between individuals because more competition prevails in an individualistic society (Leibbrandt et al., 2013). With more competition, as per Deutsch (1949), when individuals see others as rivals, social bonds are disrupted as individuals prioritise economic self-interest (Sommet & Elliot, 2023).

Assuming that socioeconomically connected individuals transact following the logic that firms use to integrate, they are characterised by Grossman and Hart (1986). By ownership of assets, the relations during interactions become important as feelings of entitlement have been found to impact future contracting behaviour (Hart & Moore, 2008). Because entitlements are seen as subjectively perceived rights that may focus on historical claims (Gächter & Riedl, 2005), the commitment may change in response to changes in entitlements.

Commitment is a pledge of relational continuity, implying a willingness to pay in the short term when long-term benefits can be realised, and it forms the basis for the development of social governance norms (Gundlach et al., 1995). As previously suggested, commitment only aligns incentive structures when corresponding commitments are considered; with disproportionate commitments, one party is vulnerable to opportunism (Gundlach et al., 1995). Current social relations correlate positively with later commitment inputs and long-term commitment intentions (Gundlach et al., 1995). More specifically, with contracts being short-term but relations running long-term, the efficiency of short-term contracting requires investment in relationship-specific capital (Crawford, 1988).

There is a reversible investment and a sunk-cost investment between individuals forming communities. Short-term contracting only destroys relationship-specific investment when (i) there is no need to smooth consumption over time and (ii) sunk costs dominate reversible investment. Short-term sequential contracting is efficient when short-term contracts allow for complete control over the relationship's organisation within each contract period throughout the relationship's lifespan; removing the control and perfect foresight of the parties, the bargaining environment created by the earlier contract influences subsequent agreements (Crawford, 1988).

More recent literature also recognises the timing of the contract. Considering that contracts are not only short-term and long-term but may instead be continuing in the meaning of specifying trade in the first period and including commitment, promise, or understanding of fairness or reasonableness to negotiate a future contract (Halonen-Akatwijuka & Hart, 2020), the continuing contract case is being raised when a contract is seen as a reference point for the revision to be seen as fair (Hart & Moore, 2008) and therefore, reducing costs of argument or bargaining, problems concerning outside options may arise as changes inside the relationship are viewed differently from those outside (Halonen-Akatwijuka & Hart, 2020).

Proposition 2: If incomplete contracts with previous outcomes taken as reference points are effectuated, the value and cost of biodiverse land traded are not verifiable, and only the buyer's value, dependent on biodiversity, varies. Then, the first-best in the trade may be achieved when the trade price is unique and equal to the cost of the land.

Box 2. Testing Proposition 2 via Macroeconomic Econometric Analysis

We suggest testing this proposition using experimental or survey data analysed either through conjunctural analysis or econometric methods. A macroeconomic analysis could also be applied, such as evaluating the price and cost of the traded land, where the true land cost remains unobserved, but the buyer's value is influenced by a biodiversity index for the land. The type of contract would then be assessed by the first-best scenario, where price equals cost or otherwise. Seller effort and trade success would be the outcome measures regarding buyer satisfaction.

The major assumption here is that the sole criterion on which the value of the land to the buyer depends is the land's biodiversity, which is known by both parties equally transparently but is not verifiable. That is to say, the value of biodiversity cannot be accurately determined. Furthermore, the value of the land varies because of the biodiversity changes (Isbell et al., 2017) taking place in the current and future contracting periods. In this configuration, when a trade price is unique and equal to the cost of the land, the first-best in trading can be achieved with a simple contract where there is no range of trade prices (Hart & Moore, 2008). In this setting, first-best means the trade occurs, and no aggrievement is caused by dissatisfaction with the levels of biodiversity quality of the land traded. The authors tested this theoretical proposition experimentally to find that the payoff uncertainty model largely applies in the real world (Fehr et al., 2011).

Proposition 3: If the incomplete contracts with previous outcomes taken as reference points are effectuated, and the value and cost of biodiverse land traded is not verifiable and value positively dependent on biodiversity varies, then with a large interval in trade prices, trade occurs if the value is no less than the cost of the land.

Box 3. Testing Proposition 3 via Simulation

We recommend testing this proposition empirically or through simulation. If one tests using probit or logistic regression, where trade is a binary outcome of occurring or not occurring, and explanatory variables are the buyer's value minus the seller's cost, then simulation could be employed if there is no real data, which is likely the case.

Continuing with the same assumptions, namely that biodiversity is the sole criterion determining the value of the land, that there is no asymmetric information, and that the value of the land is unverifiable, the first-best may be achieved when prices differ. Trade is realised when the value to the buyer is no less than the cost of the land to the buyer. In this way, when biodiversity is higher in value than the cost to acquire it, the trade will occur where no aggrievement and thus no shading will come about, and therefore, biodiversity will be preserved compared to the pre-trade state of the land immediately after the trade. This rests on the assumption that biodiversity can be impacted relatively quickly between the trades, but the research warranting this is limited.

Proposition 4: If the incomplete contracts with previous outcomes taken as reference points are effectuated, and the trade will occur until the cost and value of the land merge, biodiversity will be either harmed or supported, depending on the initial relative cost and value positions and differences.

Box 4. Testing Proposition 4 via Simulation.

Since there is likely no real panel data to test this proposition, we suggest a time-based simulation where biodiversity is first defined, along with the seller's cost, buyer's value, and price. It is assumed that in each period, agents use the previous period as a reference for adjustments. Then, biodiversity is positively or negatively influenced by the difference in outcomes resulting from changes in biodiversity.

If we continue with the same assumptions, as in Propositions 2-3, trade will occur with non-simple contracts (when prices in the market differ). Suppose the biodiversity value initially starts higher than the cost of acquiring it. In that case, it will be downgraded due to continuous contracting, where value and cost differentials will be taken as reference points, while the price differentials shrinking over time imply that the price will eventually stabilise at the value of biodiversity, reflecting the multiperiod value. This price will not necessarily demand that voluntary trade occur because the gains from trade will be zero. No land conversion occurs in this setting, and biodiversity does not change. This result again rests on a very strong assumption that biodiversity is tied to the area of the land and that its changing hands affect both the value and price of the land. This assumption of biodiversity being dependent on land trading finds its roots in the theoretical model by Galioto and Musotti (2023), who establish that land management – intervention or abandonment – depends on landholding fragmentation, which, in turn, relates to trading.

5. DISCUSSION

Incomplete contract theory provides a perspective to explore land trading between buyers and sellers and the respective biodiversity outcomes. Although the various perspectives of incomplete contract theory are complementary, they cannot be easily and coherently merged when payoff uncertainty is explicitly considered in the biodiversity value to the buyer case. Thus, in this work, we focus on contracts serving as reference points in the sense of Hart and Moore (2008).

The three results for biodiversity imply that (1) with the same price in the market, biodiversity is preserved. (2) When a significant price differential and trade occur, biodiversity does not change either. The most disadvantageous aspect of biodiversity is when (3) biodiversity value starts higher than the cost of acquiring it, so it gets downgraded due to continuous contracting, where value and cost differentials will be taken as reference points. In this setting, biodiversity suffers.

This means that if the biodiversity value is uncertain, both trading parties know it is higher than its acquisition price. With continuing contracting, it will be downgraded. This result leads to three possible tools for biodiversity safeguarding policies: price-related, value-uncovering-related, and mixed tools. The most actionable of the toolset is the biodiversity value-uncovering actions. Such economic biodiversity valuation initiatives, such as the Economics of Ecosystems and Biodiversity study group, have already successfully identified nature's values and are accounting for them more formally (Sukhdev et al., 2010).

The strength of the contract theory applied lies primarily in its formalistic treatment of buyer and seller relations when the land resource is concerned, as land acquisition is the primary means to protect terrestrial biodiversity (Ferraro & Kiss, 2002). The weaker points include the simplifying assumptions of biodiversity being the only characteristic that determines the value of the land. Moreover, only continuous short-term contracting is considered, neglecting the long-term contracts between the banking system and landowners. This case is better addressed in Lennox and Armsworth (2011) when dealing with both ecological and socio-economic uncertainties in conservation contracts.

Regarding the applicability of results and outcomes, the direct linkage with real-world land trading is rather weak, especially considering the assumption that biodiversity is the sole determinant of land value. However, by acknowledging or at least approximating the actual value of biodiversity in calculations made by contracting parties before the trade, the value of land may become increasingly impacted by its biodiverse value, especially if there is a rise in calculated relative value or impact. Moreover, we shall warn readers that the claims made here should be taken cautiously and have not yet been tested. Therefore, the four propositions are rather speculative in nature.

As for future directions, innovative contracting may be explored, for instance, considering stronger use of technology, which allows for better use of available information and possibly even lower social bonding. Studying the optimal contract length, also considering social and cultural ecology, would merge the two branches of economics and sociology that are not frequently joined.

6. CONCLUSION

The problem of biodiversity conservation in the face of short-term contracts is taken as a reference point in the sense of Hart and Moore (2008), which arises when there is continuous contracting (Halonen-Akatwijuka & Hart, 2020). Biodiversity's value is initially higher relative to the cost of acquiring it, but it continuously decreases until the two values equal one another. The key finding, perhaps, is the further approval of the monetary valuation of biodiversity in order to bring the information about it to the market and allow it to be reflected in the prices of the land. Although it is said to be future-oriented and promise-based, it has not been empirically confirmed as the appropriate tool for biodiversity management (Maechler & Boisvert, 2024).

The significance for future research is related mostly to the fact that, within the terms of contract theory, it is easier to include the social and cultural ecology when ownership is considered, and it shall be considered as differing in the developed world, where income inequality is high and rising (Chancel et al., 2021).

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AUTHOR CONTRIBUTIONS

Anna Auza: Conceptualisation, Data curation, Formal analysis, Investigation, Methodology, Visualisation, Writing—original draft.
José Aberto Fuinhas: Funding acquisition, Investigation, Supervision, Validation, and Writing—review and editing. All authors have read and agreed to the published version of the manuscript.

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