Dissertationes Forestales 219

A service-dominant perspective on payment for ecosystem service offerings

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Academic Dissertation

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The ecosystem service (ES) approach is a means of evaluating service value flows from ecosystems to humans for their well-being. The approach suggests that ecosystem functions are divided into categories according to the benefits derived and utilized by beneficiaries. The ES approach has become a tool for public and private decision-makers, driven by the need to more accurately incorporate environmental externalities into the value creation processes of economic actors.

This research addresses two knowledge gaps within the ES literature. First, a service-centric approach to ES offerings is lacking, resulting in misuse of the appropriate concepts and terms when discussing their role in value networks and value creation. Second, there is limited available knowledge about how to efficiently internalize ES offerings within value networks.

In the first article, a service-dominant value creation (SVC) framework, with supporting terms and concepts, was developed to guide interdisciplinary discussions about the role of ES offerings within value creation processes. The term *value-in-impact* was proposed as a means for discussing the trade-offs and impacts concerning ES offerings within those processes.

The subsequent three articles addressed the following design aspects of Payment for Ecosystem Service (PES) schemes: (1) sensitivity to parameter inputs, (2) price volatility impacts on service providers, and (3) behavioural economic contributions. Consideration for trade-offs among ES offerings, and between ES offerings and economic objectives were also incorporated. The results indicated that the holistic accounting of ES indicators, to determine the optimal species mixtures, and uncorrelated ES price interactions, to determine the optimal allocation of forest for conservation, led to ecological and financial diversification benefits for service providers. Nudging service providers also led to more socially efficient ES provisioning. In each case, the proposed Ecosystem Service Expectation Value (ESEV) was used to more accurately describe the perpetual provisioning of multiple ES offerings on forestland.

Keywords: ecosystem service, service-dominant, valuation, payment for ecosystem service, trade-off, ecological economics

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Brent D. Matthies

Helsinki, Finland

May 20th, 2016

LIST OF ORIGINAL ARTICLES

This dissertation consists of the following four articles, which are hereby referred to using their assigned Roman numerals, and the summary.

I. Matthies B. D., D'Amato D., Berghäll S., Ekholm T., Hoen H. F., Holopainen J. M., Korhonen J. E., Lähtinen K., Mattila O., Toppinen A., Valsta L. T., Wang L., Yousefpour R. (2016). An Ecosystem Service-Dominant Logic? - Integrating the ecosystem service approach and the service-dominant logic. Journal of Cleaner Production 124: 51-64.
http://dx.doi.org/10.1016/j.jclepro.2016.02.109.

II. Matthies B. D., Kalliokoski T., Ekholm T., Hoen H. F., Valsta L. T. (2015). Risk, reward, and payments for ecosystem services: A portfolio approach to ecosystem services and forestland investment. Ecosystem Services 16: 1-12.
http://dx.doi.org/10.1016/j.ecoser.2015.08.006.

III. Matthies B. D., Kalliokoski T., Eyvindson K., Honkela N., Hukkinen J. I., Kuusinen N. J., Räisänen P., Valsta L. T. (2016). Nudging ecosystem service providers and assessing service trade-offs to reduce the social inefficiencies of Payments for Ecosystem Services schemes. Environmental Science and Policy 55 (1): 228–237.
http://dx.doi.org/10.1016/j.envsci.2015.10.009.

IV. Matthies B. D., Valsta L. T. (2016). Optimal forest species mixture with carbon storage and albedo effect for climate change mitigation. Ecological Economics 123: 95-105.
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DIVISION OF LABOUR IN CO-AUTHORED ARTICLES

	I	II	III	IV
Concept and design	BM, DD, SB, JMH, OM	BM, LV	BM, TK, KE, NH, JIH, LV	LV, BM
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Data analysis	–	BM, TK	BM, TK, NH, JIH, KE, NK, PR	BM, LV
Writing the article	BM, DD, SB, TE, HFH, JMH, JK, KL, OM, AT, LV, RY	BM, HFH, TE, LV	BM, TK, NH, JIH, LV	BM, LV
Overall responsibility	BM	BM	BM	BM, LV

BM – Brent D. Matthies, DD – Dalia D'Amato, SB – Sami Berghäll, TE – Tommi Ekholm, KE – Kyle Eyvindson, HFH – Hans Fredrik Hoen, JMH – Jani M. Holopainen, NH – Nina Honkela, JIH – Janne I. Hukkinen, TK – Tuomo Kalliokoski, JK – Jaana E. Korhonen, NK – Nea J. Kuusinen, KL – Katja Lähtinen, OM – Osmo Mattila, PR – Petri Räisänen, AT – Anne Toppinen, LV – Lauri T. Valsta, LW – Lei Wang, and RY – Rasoul Yousefpour.

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LIST OF ACRONYMS

BAU	Business-as-Usual
BLV	Bare Land Value
CICES	Common International Classification for Ecosystem Services
EEA	European Environmental Agency
ES	Ecosystem Service
ESEV	Ecosystem Service Expectation Value
EU ETS	European Union Emissions Trading Scheme
GD logic	Goods-Dominant logic
JPGM	Joint Production Growth Model
MBI	Market-based Instrument
MCDA	Multi-Criteria Decision Analysis
MPT	Modern Portfolio Theory
NZ ETS	New Zealand Emissions Trading Scheme
PES	Payments for Ecosystem Service offerings
REDD+	Reduced Emissions from Deforestation and Forest Degradation
SEV	Soil Expectation Value
SD logic	Service-Dominant logic
TEV	Total Economic Value
TNV	Trading in Nature/Natural Values

1. INTRODUCTION

1.1. The ecosystem service approach

The ecosystem service (ES) approach is an anthropocentric means of evaluating the flow (i.e. quantity over time) of service value from natural and semi-natural ecosystems' functions for the benefit of human well-being (de Groot et al. 2002; MEA 2005; Turner and Daily 2008; Fisher et al. 2009). Management decisions for ES provisioning have co-current impacts on multiple service offerings, which result in either co-benefits or trade-offs. Therefore, management objectives can lead to reductions in the provisioning of some service outcomes, but a broader identification of ES value in decision-making could likely to lead to better outcomes (Spangenburg et al. 2014). In turn, a boarder identification of value could also address pressures on natural ecosystems. The ES concept was first proposed in 1981 by Ehrlich and Ehrlich, who noted that there was a societal benefit from utilizing the functions and processes of natural ecosystems. Since then, the term and associated concepts have evolved rapidly within the natural and social sciences, and, increasingly, within economics.

The ES approach suggests that there are many natural ecosystem functions and processes useful to humans, that can be divided into various categories according to the type of benefits provided (e.g. climate regulation or biomass). The utilization of these benefits supports the suggested socio-ecological connection, between natural ecosystems and their human beneficiaries, that is prevalent in the sustainable development and ecological economics literature. Utilization of ES offerings translates into value creation opportunities for human beneficiaries, and demonstrates the need to understand the value flows associated with interactions between humans and natural ecosystems.

To better understand how to take ES into account within the process of value creation, Haines-Young and Potschin (2010; 2011) developed the ES cascade framework. The framework serves to account for and classify those ES utilized by human actors (Figure 1). The term 'function' is defined within the framework as the "capacity or capability of the ecosystem to do something that is potentially useful to people" (de Groot 1992; de Groot et al. 2002). Fisher et al. (2008; 2009) designated all elements on the left side in Figure 1 to be 'intermediate services' and on the right side to be 'final services', which was done to address the issue of double-counting within the cascade. Therefore, the difference between 'final' and 'intermediate' service offerings is in the level of connectivity to the beneficiary. Those that directly contribute to an individuals' well-being are 'final' and those that enhance well-being indirectly are 'intermediate' (Johnston and Russell 2011). Final service offerings include cultural (e.g. spiritual value), provisioning (e.g. biomass and food), and regulating (e.g. climate regulation) service offerings (CICES 2013).

The need to identify and classify ES offerings comes at a time when numerous acute global changes (e.g. climate change, biodiversity loss) are wielding considerable pressure on natural ecosystems (Carpenter et al. 2009; Rockström et al. 2009). These pressures are largely shaped by socio-economic drivers and the scarcity of available service offerings, which lead to trade-offs between different ES offerings and between ES offerings and other objectives, such as monetary outcomes (McShane et al. 2011; Howe et al. 2014). Thus, pressures are shaped by drivers and scarcity compounds these pressures.

Trade-offs are defined as a change in the provisioning level for a given service that can negatively impact the provisioning level of other service offerings and are implicitly value-laden (Brauman et al. 2007; Diaz et al. 2011; McShane et al. 2011). Trade-offs have important implications for how natural ecosystems are managed, what service offerings they are managed for, and how the management decisions are made. They also demonstrate that there can be complimentary service provisioning (i.e. co-benefits from different service offerings) or adverse trade-off outcomes (i.e. lose-lose trade-off outcomes). As a result of trade-offs, management objectives can lead to drastic reductions in the provisioning of one or more other service offerings. Polasky and Segerson (2009) note that enhancing the ES approach and broadening its application to economic and business sciences is one way to address these pressures on natural ecosystems.

Within the cascade framework, the maximum potential value of ES offerings that is available to humans is constrained by pressures on the entire system (Figure 1). To address this constraint, policy instruments are required. Policy instruments can have many attributes, for example they could be public or private, voluntary or compliance, decentralized or command-and-control. Market-based instruments (MBI) are one policy instrument that aims to internalize the negative environmental externalities that have emerged as societies adopt a *laissez faire* approach to the utilization of natural ecosystems. MBIs can take many different variations depending on the exact nature of the market failure they are designed to address.

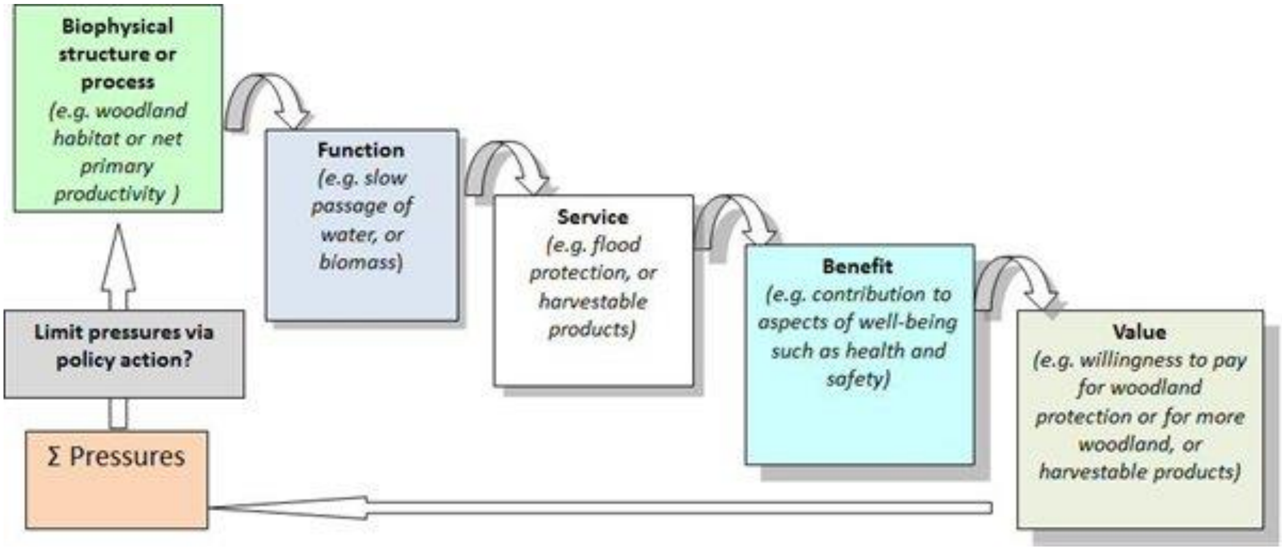

Figure 1. The Ecosystem Service cascade framework (Adapted from Haines-Young and Potschin (2010)).

The cascade framework has been integrated within many decision-making approaches for natural ecosystem management (e.g. spatial impact assessment models), and provides a basis for ES classification systems like the Common International Classification of Ecosystem Services (CICES) scheme. CICES is a standardized tool that was developed by the European Environmental Agency (EEA) for environmental accounting, which now extends to mapping and valuation of ES offerings.

Payments for ecosystem services (PES) (or 'service offerings') are one emerging MBI that aims to address the negative externalities associated market economics by monetizing and 'bringing to market' ES offerings. Wunder (2005; 2007; 2015) defines PES as a voluntary transaction for one or more well-defined ES offerings with, at least, one buyer and one service provider meeting the conditionality principle (i.e. service provider secures service provisioning).

In recent years, numerous PES and PES-based schemes have emerged, from the Trading in Nature (Natural) Values (TNV) biodiversity conservation scheme in Finland to the Reduced Emissions from Deforestation and Forest Degradation (REDD+) climate mitigation schemes found in multiple countries from Asia to Latin America (e.g. Indonesia, Costa Rica, Ghana), and they demonstrate, in some cases, that there is potential for MBIs to account for the intended market externalities. Therefore, the monetization of ES offerings has been promoted to help ensure that minimum levels of ES provisioning are achieved. This is accomplished through more sustainable ecosystem management decisions, and internalization of the social value of service offerings within the ES cascade (Engel et al. 2015).

Despite broad acceptance of the monetary valuation of ES offerings, there are criticisms of this approach (e.g. see Spangenburg et al. 2014). Usually these criticisms focus on the negative aspects of the commodification of ES offerings. Kosoy and Corbera (2010) define the process of commodification as (1) framing ecological functions as service offerings, (2) eliciting and assigning an exchange value to that service, and (3) creating a market for the exchange between service systems (i.e. economic agents, social actors). Still, Gómez-Baggethun et al. (2010), Daily et al. (2009) and others have given their support for valuation as a pragmatic short-term tool to address the urgency of global change pressures on natural ecosystem functions and processes. This disagreement about value creation processes and the ES approach underlines the challenge of recognizing the total potential value of all the ES offerings utilized by humans within our economies and societies.

1.2. Purpose of this research

The literature pertaining to the ES approach has, in recent years, expanded considerably. Interest in the ES approach has not been restricted only to the natural sciences, but is increasingly found within the social, economic and business sciences. The resulting outcome is further impetus for the wider business community to start addressing ES challenges associated with their business strategy and practices (Waage and Kester 2014; D'Amato et al. 2014).

The purpose of this research was to address two knowledge gaps that still existed or continue to exist within the ES and PES literature. First, a review of the current literature indicates that there was a lack of research directed at linking the terminology and concepts of business and natural science approaches to service-dominant (SD) and value creation-based research (Berghäll et al. 2014; Lusch and Vargo 2014). Although there are examples from within the ES literature of authors who have tried to close these gaps (e.g. Daily et al. 2009; Polasky and Segerson 2009; Gómez-Baggethun et al. 2010; Spangenburg et al. 2014), no studies had fully harmonized the existing service science literature with the ES literature. The lack of a service-centric language in the ES approach has limited the presence of natural sciences within the wider service value creation discussion, and resulted in a lack of congruent service-based terminology and concepts that can be agreed upon and shared between business and natural sciences. A set of harmonized terms and concepts was presented in Article I, which considered the need to provide a SD theoretical platform within the ES approach.

Second, there are many studies looking at different aspects of the equity, effectiveness, and efficiency of PES schemes (e.g. Pagiola et al. 2005; Wunder et al. 2008; Suich et al. 2015). Despite the plethora of publications, there are still gaps in our understanding about how to design efficient (i.e. social and economic) and effective PES schemes. In Articles II, III, and IV, various aspects of PES scheme design were evaluated in order to facilitate a more multifaceted understanding of their role in improving the efficiency of those MBIs.

In Article II, the role of PES price risks, for risk averse natural ecosystem managers and investors, were evaluated using Modern Portfolio Theory (MPT) to determine if there are financial diversification benefits from participating in a PES scheme. Currently, there are only a few studies (e.g. Hiedanpää and Bromley 2014) that have evaluated the potential role of behavioural economic approaches in designing PES schemes. In Article III, nudging, a behavioural approach also referred to as 'framing', was tested to determine if it might address geographic connectivity and social efficiency challenges within PES scheme design. The trade-offs between complimentary ES offerings were also evaluated in that article to determine if bundling ES offerings within a PES scheme provides further social efficiency gains. Finally, in Article IV the effect of input parameter uncertainty on PES policy recommendations was tested. A joint production mixed forest growth model was developed to evaluate albedo parameter uncertainty effects on a forest carbon offset scheme. The trade-offs between different tree species' ES provisioning potentials were considered in evaluating the results.

2. THEORETICAL BACKGROUND

2.1. Towards a service-dominant approach to ecosystem service value creation

Recent papers have moved both the ES approach and service science thinking towards a convergence in describing service value creation (see Gómez-Baggethun et al. 2010; Berghäll et al. 2014; Lusch and Vargo 2014; Spangenburg et al. 2014). Despite these efforts, no previous authors have clarified the main gaps in the concepts and definitions. Rather, there has been a proliferation of 'silo-thinking' that has resulted in an expansion of field-specific approaches. However, those approaches do not integrate fluidly with those used in other fields of study.

From the service science perspective, Lusch and Vargo (2014) have identified the relationship between their proposed SD logic on value creation and the ES approach. Still, their identification of the linkage falls short of the complexity found within natural ecosystems and the requirement to acknowledge the socio-ecological relationship that drive value creation between the natural and social spheres. Spangenburg et al. (2014) contrast that approach by identifying the role of use and exchange value (referred to as value-in-use and value-in-exchange by Vargo and Lusch (2004)), but do not complete the link with service sciences. Vargo and Lusch (2006) provide a definition of value-in-use as the "value [that] is always uniquely and phenomenologically determined by the beneficiary" originating from the interaction of different service systems (Matthies et al. 2016). By contrast, value-in-exchange provides a "way of measuring relative value within a context of surrounding systems" (Vargo et al. 2008).

Both the ES approach and SD logic take similar views on the concept of a 'service' and the role of SD approaches to value creation. The ES literature defines 'service' as "an ecological function or process that is considered useful to human beings" (Haines-Young and Potschin 2010). That definition is highly compatible with the one used in marketing, where a 'service' is a "process of doing something beneficial for and in conjunction with some entity" (Vargo and Lusch 2008a). Therefore, the failure of previous studies to identify the complementarity of the ES approach and SD logic is both surprising and unfortunate. There are numerous potential benefits of harmonizing business and natural science approaches. One major benefit is the integration of human-based service systems within the ES cascade framework, and, with them, the service-centric views on value creation. Haines-Young and Potschin's cascade framework fails to address the human to human (or actor to actor) interactions that result in impacts on ES provisioning. In the original cascade framework, these interactions are only implied through the 'value' box located on the right side of the cascade.

Spangenburg et al. (2014) have tried to ameliorate this limitation (see Figure 2). They integrated the concepts of use and exchange value within the ES cascade framework, but did not address the role of service value flows in social and economic interactions (i.e. value networks) and how those flows can be utilized by different actors (e.g. firms) to create further value. Those are important points to integrate into the framework, which could better address the relationship between the ES approach and economic processes to use ES offerings for value creation. Spangenburg et al. (2014) did note that there is a challenge in equating the term 'value' only with subjectively-derived monetary values for non-market service offerings. To address those issues, they suggested that both monetary and non-monetary valuation be applied (Polasky and Segerson 2009; Farley and Costanza 2010). To clarify this difference in valuation, Gómez-Baggethun et al. (2010) have identified the main aspects of how value creation is viewed within the current ES approach.

The dominance of value-in-exchange is connected to the common neo-classical approach to value creation in the ES literature. This approach has not been ubiquitous regarding 'land' and 'natural resources' throughout the history of economic thought. The classical economists Ricardo (1871) and Marx (1891) viewed natural ecosystems as 'serviceable' to improve human well-being through value-in-use. They did not consider natural ecosystems as contributing towards exchange value (Gómez-Baggethun et al. 2010). This view shifted under the neo-classical paradigm in the early 20th century, when the benefits from natural ecosystem functions were interpreted through marginal prices. If the definitions given by Vargo and Lusch and other marketing theorists are taken into account, then the either-or dichotomy of exchange or use value is inseparable and is instead a combined approach to determining the total value potential of a given service offering. It should be noted that the suggested combination of value-in-use and value-in-exchange is not the same as the concept of total economic value (TEV), which has previously been advocated as a means of valuing ES offerings within the economics literature (e.g. Richardson and Loomis 2009). Contrastingly, the TEV approach advocates the determination of an exchange value, using valuation methods like willingness-to-pay, to capture both use and non-use value of ES offerings. It is the view of this author that TEV represents a goods-dominant (GD) approach.

In Table 1 on the following page, it is clear that as 'land' and 'natural resources' have increasingly been incorporated as natural capital in economic theory there has been a strong shift away from value-in-use towards value-in-exchange. The shift from predominantly value-in-use to value-in-exchange has important implications for how firms, and other human-based service systems, incorporate their impacts on ES provisioning into their own value creation processes.

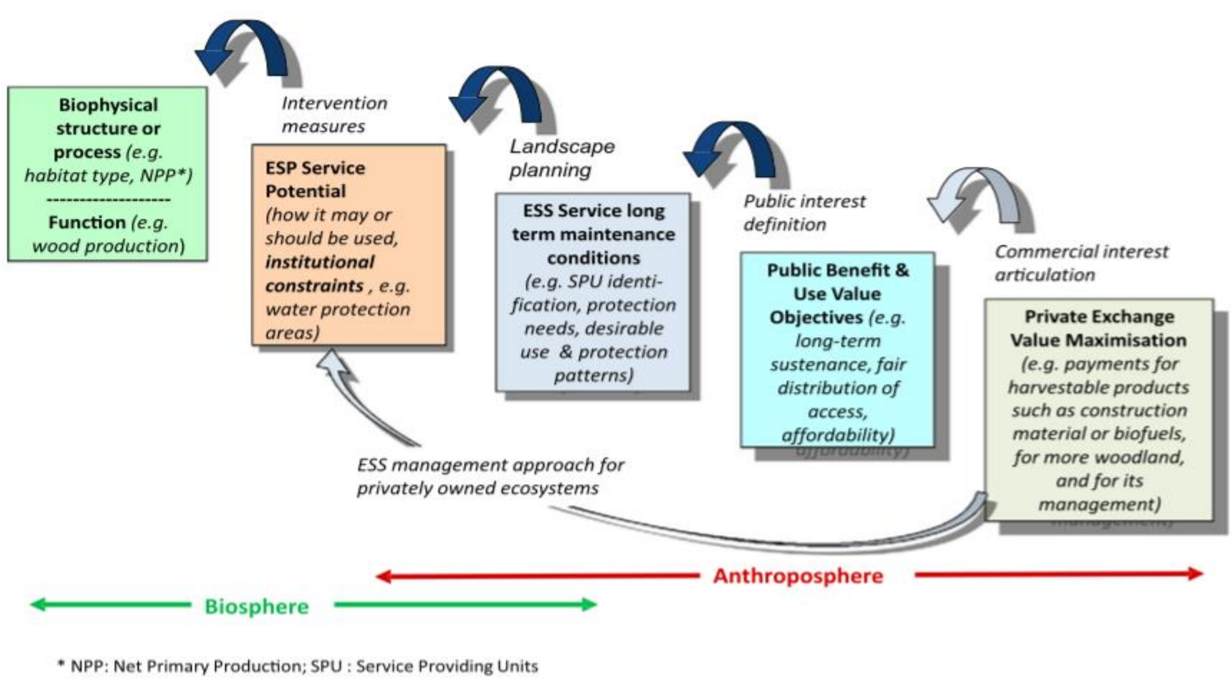

Figure 2. The Enhanced Ecosystem Service cascade framework or 'Stairways of Landscape Management' (Adopted from Spangenburg et al. (2014)).

According to Vargo et al. (2008), the value creation process is carried out jointly through interactions between service systems and their resource integration processes. The purpose of this is the creation of superior value propositions for beneficiary systems. Operand resources (e.g. biomass) act as service vehicles, and are, therefore, those resources that are acted upon or integrated. The process of resource integration comprises the application of operant resources (i.e. resources that act upon operand resources – like knowledge and skills) and/or the system's competencies to operand resources (Vargo and Lusch 2004). Each service system (i.e. temporally and spatially dynamic and self-reconfiguring system based on hard/soft contracts for value creation – a firm, individual, social grouping, natural environment) acts within one or more value networks throughout their business ecosystem (Vargo and Lusch 2011). Vargo and Lusch (2004) call this service-centric approach to value creation the SD logic, because it represents a shift away from the neo-classical 'exchange only' GD logic. For ease of comparison, the differences between these two approaches, in the context of value creation, are outlined below in Table 2.

Table 1. Stages of how Ecosystem service value creation is perceived in the peer-reviewed literature (Adapted from Gómez-Baggethun et al. 2010).

Tentative period	Stage	Conceptualization	Action	Value	Influential Publications
1960s-1990s	Utilitarian framing	Ecosystem functions as service offerings**	Ecosystem functions framed in utilitarian terms	Value-in-use***	Daily 1997; de Groot et al. 2002; MEA 2003
Starting in 1960s, boosts in 1990s	Monetization	Ecosystem service offerings** as valuable / monetizable	Refinement of methods to value ecosystem services in monetary terms	Value-in-exchange***	Costanza et al. 1997; Stern 2006; EC 2007
Starting in 1970s, boosts in 2000s	Appropriation	Ecosystem service offerings** as appropriable	Clear definition of ecosystem property rights (e.g. land titling)	Value-in-exchange***	Coase 1960; Hardin 1968
Ongoing*	Exchange	Ecosystem service offerings** as exchangeable	Institutional structures created for sale/exchange	Value-in-exchange***	Wunder 2005; Engel et al. 2008

*Gómez-Baggethun et al. did not include a period here, but 'ongoing' has now been added.
**Gómez-Baggethun et al. use 'services' here, but this has been adapted to be 'service offerings' beneficiaries.
*** Gómez-Baggethun et al. use 'use value' and 'exchange value' here, but this has been adapted to be 'value-in-use' and 'value-in-exchange' beneficiaries.

Table 2. Goods-dominant (GD) logic versus Service-dominant (SD) logic on value creation (Adapted from Vargo et al. 2008).

	GD Logic	SD Logic
Value driver	Value-in-exchange	Value-in-use or value-in-context
Creator of value	Firm, often with input from firms in a supply chain	Firm, network partners, and beneficiaries*
Process of value creation	Firms embed value in "goods" or "services", value is "added" by enhancing or increasing attributes	Firms propose value through market offerings, beneficiaries* continue value-creation process through use
Purpose of value	Increase wealth for the firm	Increase adaptability, survivability, and system well-being through service (applied knowledge and skills) of others
Measurement of value	The amount of nominal value, price received in exchange	The adaptability and survivability of the beneficiary system
Resources used	Primarily operand resources	Primarily operant resources, sometimes transferred by embedding them in operand resources (i.e. goods)
Role of firm	Produce and distribute value	Propose and co-create value, provide service
Role of goods	Units of output, operand resources are embedded with value	Vehicle for operant resources, enables access to benefits of firm competences
Role of customers	To 'use up' or 'destroy' value created by the firm	Co-create value through the integration of firm-provided resources with other private and public resources

*Vargo et al. (2008) use 'cusomters' here, but this has been adapted to be beneficiaries.

According to the SD logic, value networks are comprised of a dynamic set of interactive experiences and activities, often economic activities, to improve each beneficiaries' well-being (Maglio and Spohrer 2008; Spohrer et al. 2008; Grönroos 2008). All of these interactions are voluntary and mutual; occurring between different service systems over temporal and spatial scales (Payne et al. 2008). Therefore, value is ultimately based on the perceptions of the beneficiary who phenomenologically determines the value of a service. It is the responsibility of the other service systems, who are proposing the value creation opportunity, to maximize the potential value of the proposition. In this way, maximizing the total potential value that is available during the process of value co-creation with the beneficiary means considering both use and exchange value. The total potential value of any service offering is always comprised of two components: value-in-exchange and value-in-use.

Matthies et al. (2016) have proposed an additional term *value-in-impact* as part of value-in-use and -exchange. This was done to better integrate and isolate the portion of value-in-use and value-in-exchange that pertains to the provisioning and management of ES offerings. *Value-in-impact* is defined as "a spatially and temporally dynamic component of value-in-use and value-in-exchange, which represents the co-creation and co-destruction of potential value (positive and negative impact) attributed by beneficiaries to how ES are managed, facilitated, and utilized by human-based service systems over the value network" (Figure 3). Therefore, this component of total potential value can be used to discuss the phenomenologically determined value potential that is available to beneficiaries of ES offerings over the value network.

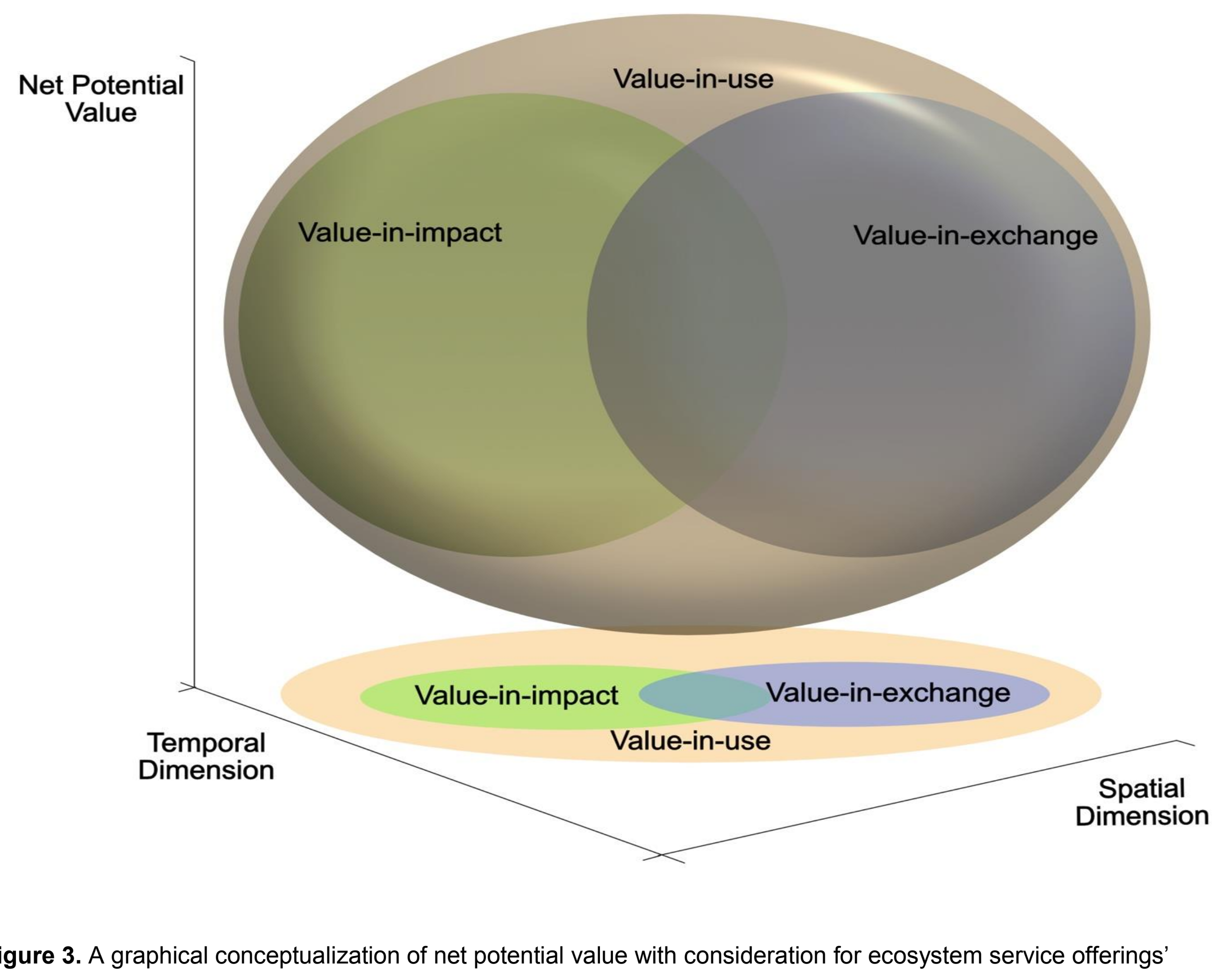

Figure 3. A graphical conceptualization of net potential value with consideration for ecosystem service offerings' integration in the value creation process in three dimensions and, for clarity, in two dimensions below (Adapted from Matthies et al. (2016)). Where the concept of *value-in-impact* is presented as a portion of the value-in-use and value-in-exchange of a service offering. *Value-in-impact* is both spatially and temporally dynamic, and can be either part of the positive or negative impacts on maximum potential value over the value network.

By integrating the SD logic with the ES approach, there is a shift away from describing the social-ecological system as a complex and dynamic set of 'demand-supply' relationships towards a SD value creation approach (Anderies et al. 2004; Folke 2007). That approach still considers the non-linearities, thresholds, and pressures on ES offerings, but aims to emphasize a more complete view on value rather than one based solely on the exchange value (i.e. price) of ES offerings. The 'demand-supply' relationship reflects a GD logic that considers only the value-in-exchange through estimated value of either 'goods' or 'services' that are produced by firms and taken to a market (Table 2) (Vargo et al. 2008). In the SD logic view, beneficiaries, rather than 'final' customers who consume the 'final good', are the receivers and co-creators of value (Lusch and Vargo 2014). Therefore, in an SD approach service value is embedded within operand resources rather than a produced good. Then the focus is shifted away from the supply and demand of 'goods' via price towards one based on the opportunities for value creation through the provisioning of service offerings (Vargo and Lusch 2011).

It is important to note, that Vargo and Lusch (2008a) highlight the non-synonymous nature of 'value-in-use' and 'utility'. They state that Adam Smith, who first discussed value-in-use did not intend the current approach to 'utility,' where it has "dwarfed" value-in-use and been "morphed into value-in-exchange". On that basis, service sciences prefer to use the term value-in-use rather than 'utility,' which has taken a new definition within economics relative to its original intended use. Accordingly, the term value-in-use considers the collective or individual value of beneficiary's utilization preferences. These preferences are based on experiences that occur over non-linear temporal and spatial scales (Vargo and Lusch 2008b; Vargo and Lusch 2011).

When the SD approach to value creation is considered in a harmonized framework along with the ES approach, then the two approaches together account for all of the value creation opportunities between society and the economy, and between human-based service systems and natural ecosystems (Matthies et al. 2016). The result, in Figure 4, is a constellation of dynamic and co-current value networks that involve the interactions of multiple service systems that co-create value through voluntary exchanges.

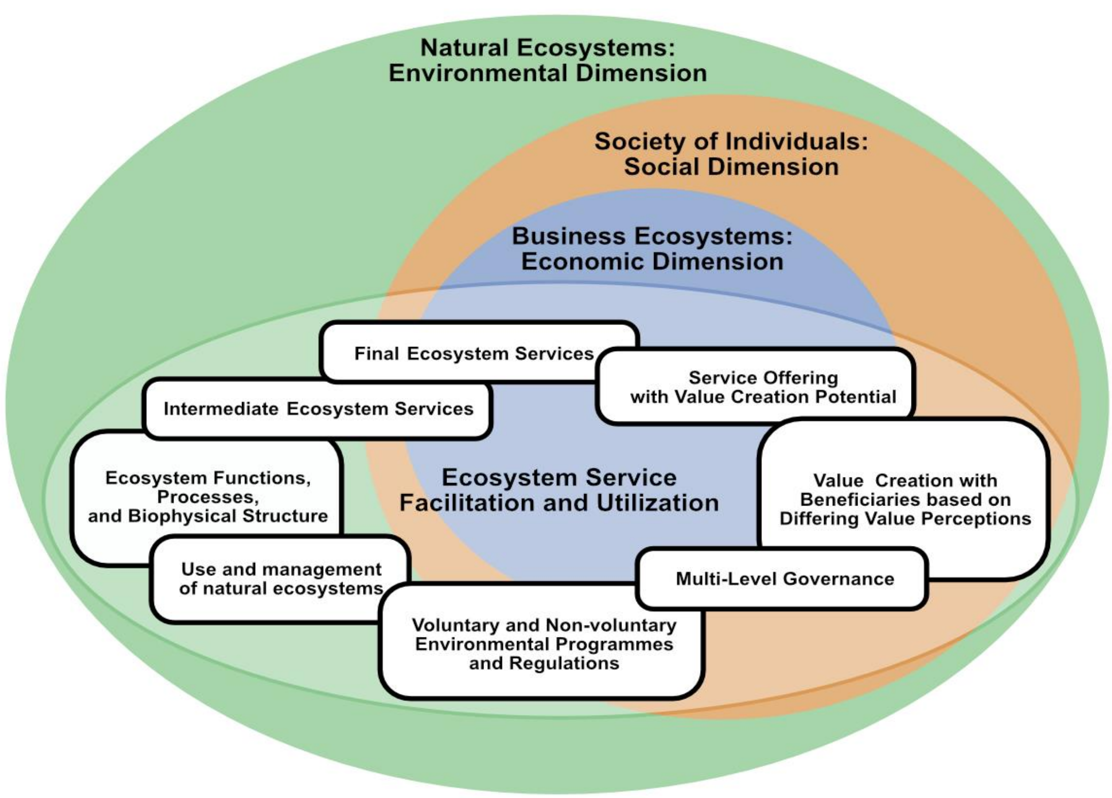

Figure 4. A service-dominant value creation (SVC) framework for the facilitation and utilization of ecosystem service offerings (Adopted from Matthies et al. (2016)).

In Figure 4, each service system (i.e. individual, firm) can be a social and economic actor co-currently, and human-based systems rely on the utilization of natural capital to drive the processes of value creation. In this way, the ES cascade is integrated with all other service systems and resource integration processes (i.e. application of skills and knowledge) by human-based service systems aim to maximize the value co-creation opportunities across a given value network.

Human-based service systems, through their utilization and facilitation of ES offerings from natural ecosystems, are both co-creators and co-destroyers of the value propositions (i.e. ES functions) made by natural ecosystems. Consequently, natural ecosystems are the largest service system creating value through the application of functions and processes. Although the service value flows from natural ecosystems are intended for the benefit of all of the dynamic and non-linear aspects of natural ecosystem functioning (i.e. by all species, and the inherent processes of evolution), the value creation opportunities are still integrated into the socio-economic system for human utilization.

Interactions between human actors and the environment are carried out with the aim to maximize the potential value that can be co-created through the provisioning of ES offerings. Accordingly, the stock of natural capital represents the total potential value that is held by all of the ecosystems in the biosphere. The positive and negative impacts that service systems have on ES value creation should be taken into account in the value creation process, as the temporal and spatial implications of not doing so could be catastrophic for future generations.

Impacts on natural ecosystems can have important implications for the resilience of those systems; potentially leading to adverse shifts in provisioning of certain ES and important trade-offs (Polasky and Segerson 2009). To properly address potentially adverse impacts, policy instruments have been proposed to ensure minimum levels of service provisioning (Segerson 2013). Examples of these include PES and corporate sustainability disclosure (Prakash and Potoski 2012; Segerson 2013). These policies should aim to reflect both the use and value of ES offerings. Matthies et al. (2016) note that, to better achieve that goal, integrating the SD and ES approaches aims to connect all social and governmental stakeholders with their ecological surroundings, "as endogenous components of the value creation process" (Vargo et al. 2008).

2.2. Payments for ecosystem service offerings as a policy instrument

Governance interventions should have the aim of alleviating the socio-economic pressures on environmental management. There are numerous previous approaches to developing a framework for the concept of ES, and nearly all have included a 'governance' element to address the pressures on service provisioning (e.g. Turner and Daily 2008; Polasky and Segerson 2009; Haines-Young and Potschin 2010). The inclusion of multi-level environmental governance has the goal of ensuring a safe minimum level of provisioning (i.e. within planetary boundaries) over both temporally and spatially dynamic scales (Segerson 2013). PES are one instrument that can be applied to internalize the environmental externalities associated with ES provisioning pressures.

In the past two decades there has been a greater effort within economics to account for ES offerings through the internalization of the associated environmental externalities (Kroeger and Casey 2007; Engel et al. 2008; Gómez-Baggethun et al. 2010). This recognition has created a proliferation of different monetary valuation methods ranging from revealed preference (e.g. hedonic pricing, travel cost) to stated preference (e.g. contingent valuation) methods, with the aim to monetize (i.e. price) those non-market ES offerings that were previously un-priced. A major aspect of this commodification of ES offerings has been covered within the literature on environmental policy. PES are one policy that accounts for the voluntary transactions of monetized ES offerings between buyers and sellers on the basis of conditionality and additionality of service provisioning (Wunder 2005; Cathcart and Delaney 2006). As a result of the proliferation of monetary valuation methods, PES schemes have become widespread, in both developed and developing countries, and across the global north and south (Pagiola et al. 2005; Wunder et al. 2008; Balvanera et al. 2012; Leimona et al. 2015; Suich et al. 2015).

Evaluating the structure of and the potential benefits from any given PES scheme requires that numerous social, economic, and environmental aspects are accounted for. Three key elements to account for are the equity, effectiveness, and efficiency of the schemes' design and implementation. Accounting for these three elements requires an understanding of the dynamic and interactive nature of the aforementioned aspects (i.e. environment) (Pagiola et al. 2005; Engel et al. 2008; Pascual et al. 2010; Leimona et al. 2015). Within a PES scheme, equity is measured by evaluating the benefits that are distributed between service providers and their beneficiaries (Pagiola et al. 2005). Effectiveness is measured by assessing the schemes' ability to meet the stated environmental objectives (Wunder et al. 2008). Finally, efficiency (e.g. social, financial) is measured through an appraisal of the service provisioning outcomes, and the distance between the

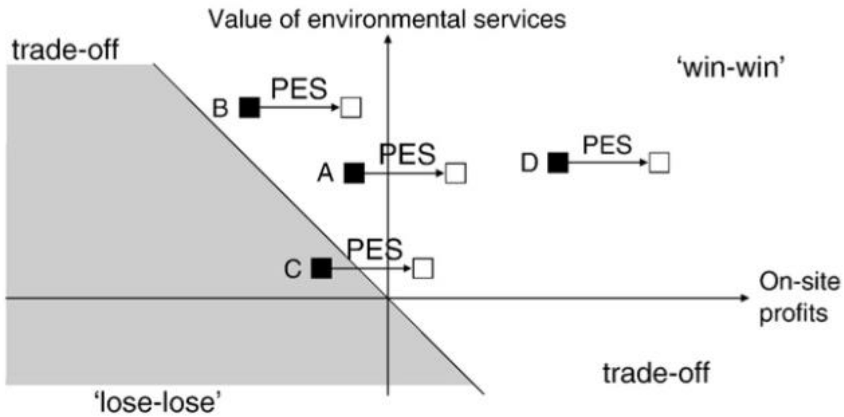

Figure 5. A framework to analyze the efficiency of payments for ecosystem service offerings. (Adopted from Pagiola (2005) and Engel et al. (2008))

achieved outcomes and the optimal level and cost of provisioning (i.e. benefits) (Engel et al. 2008; Kemkes et al. 2010). Thus, the marginal level of provisioning and cost of environmental achievement can demonstrate their efficiency for decision-makers.

The efficiency and effectiveness of a PES scheme depends on the additionality of the scheme (i.e. does it provide additional benefits above those provided under 'business-as-usual' management), if there are mechanisms to address leakage (i.e. ensure that environmental damage does not occur outside of the scheme area as a result of the scheme), and mechanisms to ensure that benefits extend past the duration of the scheme (Engel et al. 2008). In Figure 5, the efficiency framework given by Pagiola (2005) and adapted by Engel et al. (2008) is presented to outline these aforementioned policy design challenges. This framework is used to identify the net potential value of the PES scheme with regard to the trade-offs between economic objectives and net ES offering benefits. In the figure, the socially and financially efficient outcome that results from introducing a PES scheme is represented by case A. In that instance, the unprofitable, but socially-desirable, management becomes profitable for service providers as a result of introducing a PES scheme. However, the other three cases represent instances of inefficiency, where (b) service offering payments do not sufficiently lead to adoption of socially-desirable management outcomes, (c) socially-desirable outcomes are induced at a higher cost than the service offerings' value-in-exchange and -use, and (d) are payments made for practices that would have otherwise been adopted (Engel et al. 2008).

Consideration for these inefficiencies of PES scheme design have been the subject of numerous recent papers (e.g. Pagiola 2008; Porras et al. 2011), which point to some further important considerations (e.g. trade-offs). Pascual et al. (2010) note that there is an important trade-off between efficiency and equity when implementing PES schemes. Those trade-offs extend further to different forms of efficiency (e.g. social versus financial) and between efficiency and other policy objectives (e.g. effectiveness).

To address these considerations, some authors suggest the inclusion of a trade-off analysis within the evaluation of economic policy proposals. Polasky and Segerson (2009) suggest that non-monetary valuation or a blended approach might help to overcome the limitations of a 'monetary-only' valuation approach. Those authors note that a normative ecological-economic approach to ES valuation should also consider co-currently the trade-offs associated with individuals' stated preferences. This also includes aspects of risk aversion, threshold effects, and the concepts of irreversibility (i.e. safe minimum standards, precautionary principle) (Polasky and Segerson 2009). Berg (2003) takes this further in comparing between behavioral and neoclassical economic paradigms, and notes that the methods used to evaluate possible policy outcomes (i.e. techniques of analysis) "are idiosyncratic by nature and exhibit inherent systematic tendencies" whether they are neoclassical or behavioral. Thus, the policy prescriptions made by researchers have an importance influence in the methods that are used to create those prescriptions. Berg (2003) proposes the use of multiple methods to understand economic phenomena and for making normative claims. Together these recommendations represent the growing shift towards a blended approach in economic research.

In the case of PES, the current approach often only expresses priced service offerings through the exchange value of the service. As a result, by recognizing ES offerings' value only through monetization (i.e. market prices) there is often an exclusion of value-in-use from the valuation process. Although PES schemes do not alter the total potential value, they do restrict the maximum value potential that is recognized by resource integrators (e.g. firms) for value creation opportunities with beneficiaries. The previous alternative was no consideration (i.e. zero value) for many ES offerings in the decision-making process (Daily et al. 2000). Neither of these outcomes are preferable, and recognition of exchange value does move towards a greater acknowledgement of ES overutilization. Therefore, the inclusion of value-in-exchange is a vital, albeit imperfect, step towards ES internalization in decision-making.

Taking stock of these shortcomings in the current approach, it has become increasingly common to integrate behavioral approaches into PES research to help determine equitable, effective, and efficient schemes (e.g. Borner and Vosti 2013). This has been coupled with increasing scrutiny of the use of and types of trade-off approaches employed in evaluating the expected costs and benefits of those schemes (McShane et al. 2011; Howe et al. 2014). By taking a blended approach to policy decision possibilities using numerous methods, including those previously not included in the decision-making sphere, the resulting policy prescriptions will be more robust and precise than with a single tool (Berg 2003). Some of the possible approaches that had previously received limited exploration in PES research include: behavioral economic methods like nudging and the use of normative portfolio theory to evaluate the financial efficiency of different schemes. Also, the inclusion of behavioural approaches may also allow for the integration of non-monetary valuation in the assessment.

3. METHODOLOGY AND RESULTS

The four articles that comprise this dissertation contribute towards further exploration of the terms, concepts, and methods that determine the way that the ES approach is used and discussed. A framework for a SVC framework for ES was discussed and proposed in Article I (See Section 2.1; Figure 4). The framework is shown again in Figure 6; with overlapping squares to demonstrate the parts of the framework addressed by each of the articles and their relationship to one another. The three empirically-based articles (II, III, and IV) each incorporated aspects of the framework into their background theory, methods, and results. They also addressed one or more aspects of the role and design of PES in the ES value creation process that has previously received limited attention in the literature

In Articles II, III, and IV various design aspects of PES schemes were analyzed using different economic optimization methods. Theses aspects include: (1) sensitivity of policy design to parameter inputs (Articles II, III, and IV), (2) price volatility impacts on service providers (Article I), and (3) the potential for behavioural economic approaches to policy design (Article II). In Articles II and III trade-offs within the ES cascade and between ES and other provisioning outputs were also incorporated into the analysis.

In Figure 7, the contributions of each of the articles to the current literature, from their background theory, data, methods, and results, are demonstrated graphically. The integration of the SD logic and ES approach have been discussed in Section 2.1, and is not addressed further here. The data contributions include some of the first data on the use of nudging, from a behavioural economics approach, in the context of PES design. Articles II, III, and IV incorporated the role of forests not only in storing carbon across multiple carbon pools, but also with consideration for the radiative forcing role of the albedo effect. Previous research has demonstrated that the inclusion of these other climatic interactions are important when considering PES for climate regulation through forest management (e.g. Betts 2000; Bonan 2008; Thompson et al. 2009).

Articles II, III, and IV all used economic optimization methods to address the diversification of economic risks, in the context of PES, and socially efficiency of PES design. By incorporating the aforementioned data, it was possible to use normative decision tools (e.g. MPT, Multi Criteria Decision Analysis (MCDA), Joint Production Growth Model (JPGM)) to better address the connection between ES and environmental concern, phenomenological views on value creation, and diversification trade-offs.

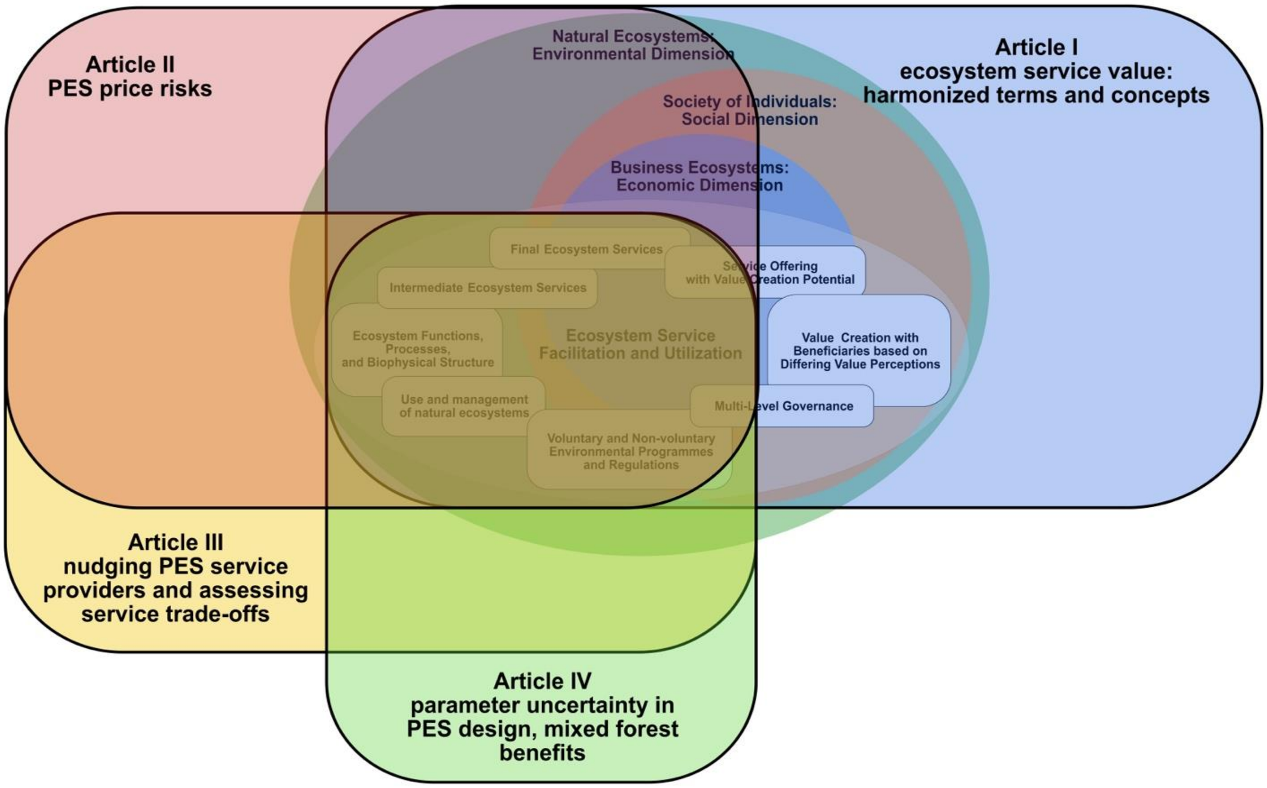

Figure 6. A graphical representation of the relationship between the four articles and service-dominant value creation (SVC) framework for ecosystem service value creation (see Figure 4).

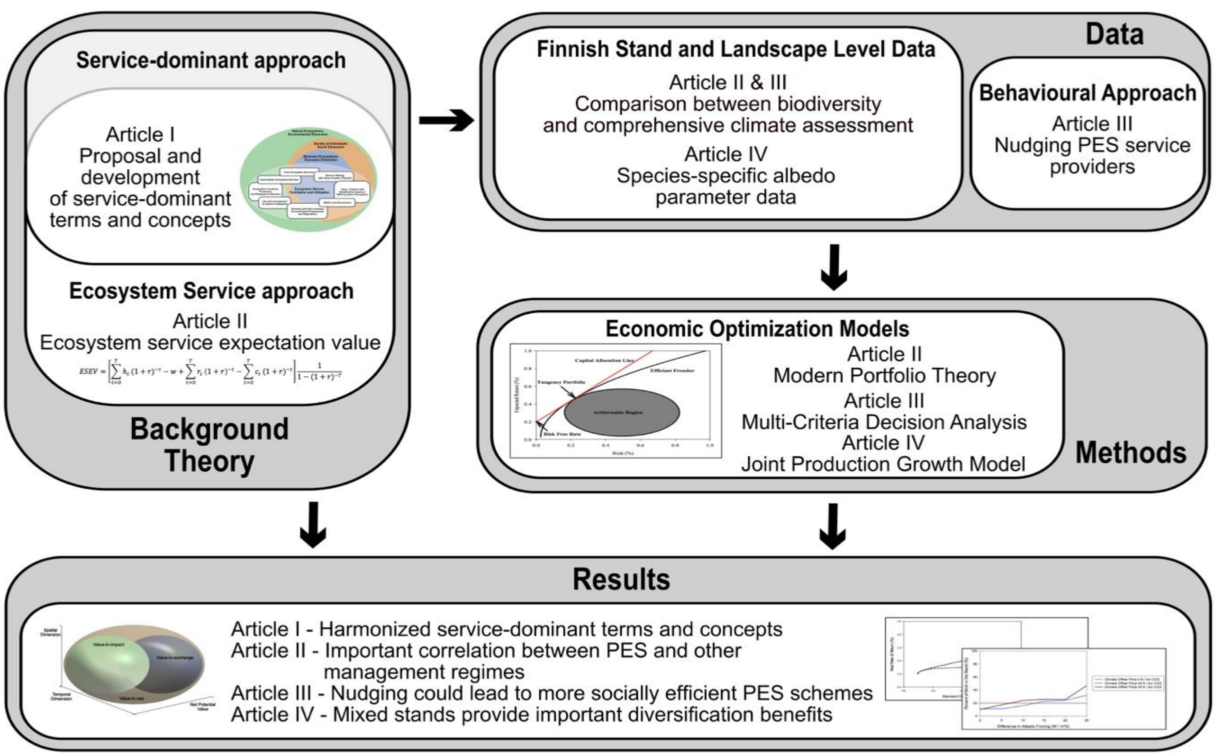

Figure 7. Contributions of this research to background theory, data, methods, and results in ecosystem service and payments for ecosystem service offerings research.

In the following sub-sections, the contributions of these articles and their results are discussed in greater detail. Data for two PES schemes were used in Articles II, III, and IV: (1) a market-based climate mitigation focused PES scheme comparable to the New Zealand Emissions Trading Scheme (NZ ETS) (Jiang et al. 2009) using European Union Emissions Trading Scheme (EU ETS) futures prices to determine compensation, and (2) a government initiated biodiversity conservation focused PES scheme based on the Finnish governments' Trading in Nature (Natural) Values (TNV) scheme that uses private bids for service provisioning contracts (Juutinen et al. 2013). The climate regulating PES scheme was evaluated in all three studies, and the biodiversity conservation PES scheme only considered in Articles II and III.

3.1. An Ecosystem Service-dominant Logic? - Integrating the ecosystem service approach and the service-dominant logic (Article I)

Objective and method: The objective of Article I was to develop a harmonized set of terms and concepts that incorporated the SD logic approach to systems and value creation with the ES approach. A common lexicon between business and natural science approaches for service offerings would facilitate a better understanding of how ES trade-offs and multi-level governance challenges can be addressed in the value creation process. A narrative literature review was conducted focusing on the service science and marketing literature pertaining to service theory. Then an additional review of the comparable ES literature was incorporated. Gaps in both sets of literature were identified regarding their harmonization, and the outcome was a SVC framework (Figure 4) and the term *value-in-impact* (Figure 3).

Main Contribution: In Article I, the main contributions were the identification of gaps in the terms and concepts within the two bodies of literature that were considered, and the development of a combined SVC framework. The framework demonstrates the overlap between the SD logic, which is concerned with service value flows between human-based service systems, and the ES approach, which is focused on the flow of value between natural ecosystems to human-based service systems. Together they cover the main aspects of the sustainable development approach, and provide a basis for incorporating business and natural science literature. The framework itself is presented was Figure 4 in Section 2.1. Previously, no specific SD term existed for discussing the role of ES offerings in value creation processes, and the positive and negative impacts, over the value network. The term *value-in-impact* was proposed in Article I to address that gap, and is defined in Table 3 and discussed further in Section 2.1. The final shifts in terminology and the axioms, presented in Article I, that guide the harmonization of the SD logic and ES approaches are summarized in Table 3.

Table 3. A summary of the suggested adjustments to create a harmonized service-dominant approach (Adapted from Matthies et al. (2016).

Adjustment of…	Current approach	Proposed Integrated approach
Ecosystem Service	'Ecosystem goods and services are the basis of exchange'	Ecosystem service offerings are the basis of exchange, where firms/individuals co-create value with natural ecosystems.
	'Value for ecosystem service offerings is determined through value-in-exchange'	Value for ecosystem service offerings is the total potential value, exchange and use value, perceived and realized by each service system through voluntary exchanges.
Natural Capital	'The stock that yields the flow of natural resources.'	'The stock of potential value held by natural ecosystems for human utilization.'
	'The largest service system is the global economy'	The biosphere is the largest service system and an actor in the value creation process that human service systems interact with and act upon
Service-dominant Logic	'Natural resources are operand resources to be integrated by service systems'	Natural ecosystems provide service offerings with potential value that are utilized or facilitated by other human-based service systems.
	'Service systems integrate natural resources'	Service systems realize and utilize, create further value from, and/or destroy the potential value that is created by natural ecosystems.
Value Network	'Any purposeful group of people or organizations creating social and economic good through complex dynamic exchanges of value.'	'Any purposeful group of people, organizations, or natural ecosystems that create benefit for human well-being through complex dynamic exchanges of value.'
Both approaches	N/A	*Value-in-impact* as a conceptual tool for discussing the positive and negative ES provisioning impacts throughout the value creation process

3.2. Risk, reward, and payments for ecosystem services: A portfolio approach to ecosystem services and forestland investment (Article II)

Objective and method: In Article II the role of volatility (i.e. unsystematic risk), as a measure of PES scheme participation risk, and the expected returns from participation were examined using MPT. Markowitz first presented MPT in 1952, as a method to evaluate the optimal risky portfolio using quadratic programming to identify the minimum-variance portfolio from a set of different assets (i.e. forest management scenarios). This method has a long history of use in forestry investment and management planning problems (e.g. Dowdle 1962; Thompson 1991; Knoke et al. 2008). It has increasingly been used in land use and conservation planning to evaluate the optimal diversification benefits from allocating land to different uses (Knoke et al. 2011). In this article, the two PES schemes, for biodiversity conservation and climate regulation, were analyzed to determine if there were financial diversification benefits from participation in the PES scheme over Business-as-Usual (BAU) management.

In the optimal risky portfolio of forest management regimes, the private forest owner's portfolio could include BAU forest management, a 10-year postponement of harvest by participating in one of the PES schemes, or a similar 20-year postponement. Considerations were also given for the possibility of investing in either Finnish equities or bonds with the rents from harvesting the stand. The data used was based on empirical data from the TNV scheme in Finland and EU ETS carbon futures price data (Juutinen et al. 2013). Within the datasets, macro business cycle trends were evident (i.e. the Great Moderation (1995-06) and Great Recession (2007-12)). Therefore, the data was split into two time periods from 1995 to 2005 and 2005 to 2012.

Economic returns were calculated using the Ecosystem Service Expectation Value (ESEV), which was proposed within this article as an alternative means for “describing and estimating the perpetual production of multiple ES for a given piece of forested land” (Matthies et al. 2015). The ESEV is intended as an alternative to the Soil Expectation Value (SEV) and Bareland Value (BLV) terms used in forest economics literature. The largely semantic nature of the change is acknowledged, and some readers may notice the high similarities between the proposed ESEV and the ‘Hartman rotation’ or ‘Hartman model’ (Hartman 1976). That model considers the monetized ES offerings in addition to provisioning service outputs (e.g. timber). The ESEV was not intended to supplant this previous important work, but it has been noted that, in absence of an ecosystem focused alternative to SEV or BLV, the Hartman rotation has been colloquially described as the ‘SEV with amenity benefits’ or other similar misnomers. The ESEV aims to remedy that, and also moves away from describing the optimal rotation in comparison to a bare land state or under the assumption that provisioning ES outputs have a predominance in determining that rotation. Arguably, the Hartman model can then be seen as one expression of the various possible ESEV models. It is presented here as eq. (1):

$$ESEV = [\sum_{t=0}^{T}((H_t + R_t + C_t) - w) * (1+r)^{-t})]\frac{1}{1-(1+r)^{-T}} \quad (1)$$

Where the ESEV is used for discounting the perpetuity of a given forest stand management regime, then let w = regeneration costs occurred at the year 0; H_t = net harvest income at year t, R_t = all non-timber revenues occurring at time t, C_t = all non-timber costs occurring at time t, t = time when revenue or cost occurs, T = is the time period of perpetual future rotations after the initial standing timber is harvested, and r = real discount rate.

Main contribution: The expected economic returns for all of the forest stands were always dominated by the timber returns component of the ESEV. This resulted in high correlations between each of the forest management regimes for each of the stand types (i.e. starting age classes and site types); both when PES returns were and were not considered. Therefore, the financial diversification benefits of participating in a PES scheme at the considered price levels were limited.

The diversification benefits were tested at the stand level (i.e. considering only diversification between different management regimes for the same stand) and at the landscape level (i.e. considering the diversification between different management regimes for the same stand across a landscape of different stand types). The results of this study indicated that diversification benefits of participating in a PES scheme increased when shifting from the stand level to landscape level. This confirms previous evidence suggesting that voluntary participation in PES contracts increases with land area size (Nagubadi et al. 1996; Wilson 1997; Lynch and Lovell 2003; Milder et al. 2010). In Figure 8, the landscape level efficiency frontiers are shown, both including and excluding other financial asset classes as alternative investments.

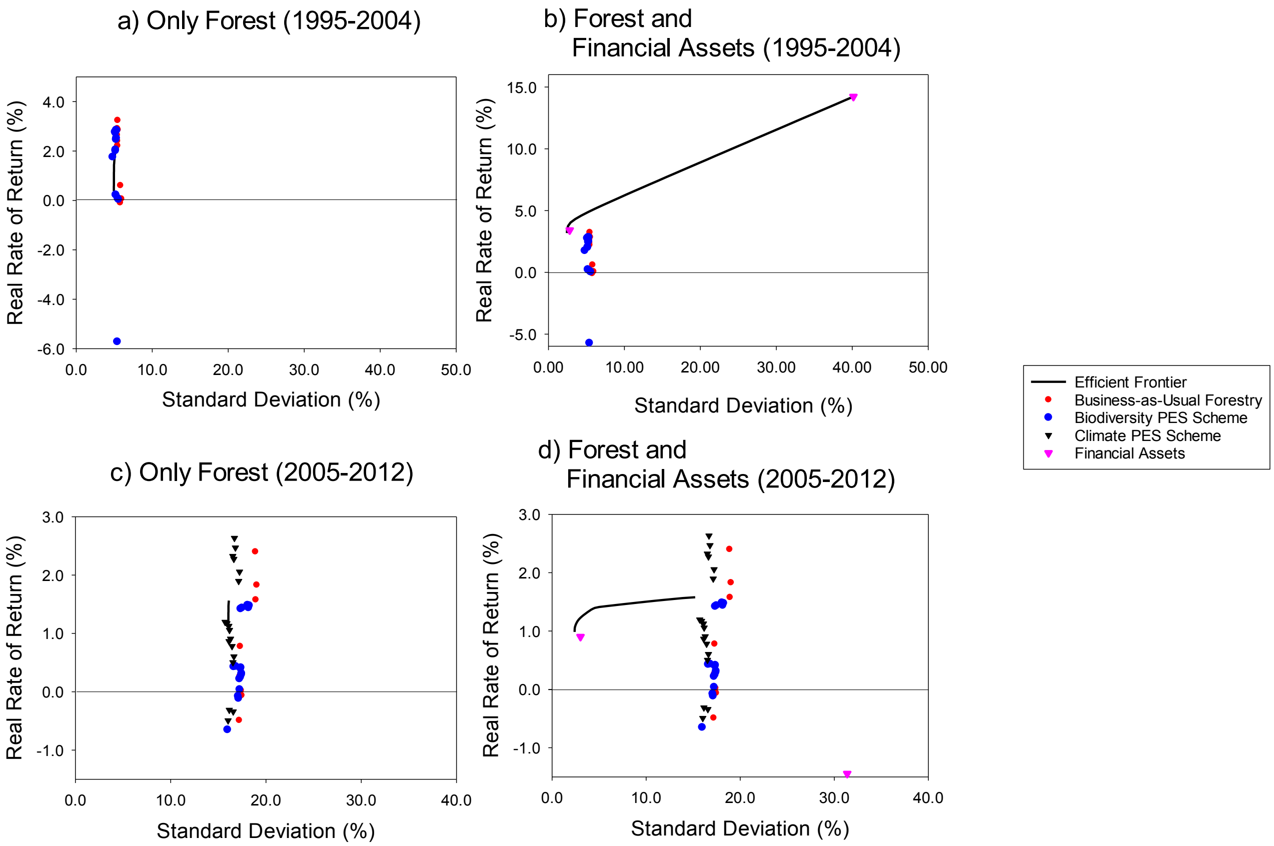

Figure 8. Efficiency frontiers for all stand units and forest management regimes as a landscape of units from 1995-2005 a) excluding financial assets b) and including financial assets, and from 2005-2012 c) excluding financial assets, d) and including financial assets (Adopted from Matthies et al. (2015)). The axes for all plots are unequal due to differences in the range of returns and standard deviations for different periods/portfolios datasets.

The PES scheme for biodiversity conservation only provided financial diversification benefits due to the dominance of timber returns in the total forestland return. Thus, the price levels used in this study were be too low to incentivize financial diversification benefits for service providers. This result coincides with the results of Juutinen and Ollikainen (2010), who modeled the bidding process for the same biodiversity conservation PES scheme and found that the optimal price level was higher than the empirical price levels. Juutinen and Ollikainen (2010) noted that the lower empirical price levels were related to the amenity values of the participating forest owners. In Article II, raising the price level resulted in greater financial diversification benefits. Higher prices may be more typical if the biodiversity conservation PES scheme was to be scaled-up and more forest owners with lower amenity values participated. However, higher prices mean higher marginal costs for society and a higher marginal cost of ES provisioning under the PES scheme.

The climate regulating PES scheme was less correlated with other management regimes and always formed part of the optimal risky portfolio. A lower correlation between management regimes results in less volatile expected returns for stand under PES management (i.e. a lower correlation between expected timber and PES returns as part of the ESEV results in lower returns volatility). Previous research has noted that PES schemes can increase the structural, operational, and financial diversification benefits of given land use (Walker et al. 2002; Bessant 2006; Darnhofer et al. 2010). By considering PES schemes where the expected returns are uncorrelated with those of other parts of the total expected return of the management regime, policy-makers can reduce the exposure of service providers to unsystematic risks. This study demonstrates the need to look beyond only the marginal financial benefits of a PES scheme. It is important to take into account also the relationship between the proposed MBI and the opportunity costs of land use.

In Article II it was shown that there is a policy design trade-off between a PES scheme that is socially efficient (i.e. one where conservation contract prices are highly correlated with the opportunity cost of conservation – see Engel et al. 2015) and one that is privately optimal (i.e. more socially costly, but with a lower correlation to other expected returns from that land use). This means that the socially optimal outcome could lead to a transfer of risk to the land owner through the PES scheme. Also, that highly volatile service markets (e.g. emissions offset markets) can still provide small private land owners with financial benefits through the diversification of expected returns. These diversification benefits are relative to other service offerings and provided through the same management regime (i.e. timber, biomass provisioning). Moreover, policy-makers could inadvertently transfer unsystematic risks to landholders by not providing adequate consideration for the financial risk of a given PES scheme. This could reduce the incentives for private land owners to participate, or reduce their ability to diversify away land use risk. This could have important implications for PES in cases where poverty alleviation and household income support are the primary aims of the scheme.

3.3. Nudging ecosystem service providers and assessing service trade-offs to reduce the social inefficiencies of Payments for Ecosystem Services schemes (Article III)

Objective and method: The use of behavioural approaches to PES have been discussed previously by various authors (e.g. Corbera 2012; Whitten et al. 2013), but most empirical results have only been published recently (e.g. de Martino et al. 2015; Kuhfuss et al. 2015; Laperyre et al. 2015). In Article III the effect of ‘framing’ or ‘nudging’ of the PES scheme and the global change pressures that it was aimed to address were evaluated. Nudging refers to the process of influencing the choices made by individuals, but without inhibiting the ability for those individuals to choose a given outcome or changing the feasibility of the various alternatives (Thaler and Sunstein 2008). The method was used to determine if doing so led to more socially efficient PES schemes, opportunities for targeting geographic areas rather than specific service providers, and, generally, an alternative method for PES scheme design.

Both nudged and neutral private forest owner groups were shown four forest management regimes, and given a survey that asked them their preferred amount of the landscape area to allocate to each regime. Nudged groups received a text that appealed more emotionally to addressing major global change pressures (e.g. biodiversity loss) and neutral groups received a text using more traditional and prescriptive forest management language.

Additionally, the trade-offs between ES (i.e. intra-service trade-offs) that emerge as a result of participation in a PES scheme were calculated. This was done using MCDA techniques to determine the Pareto optimal trade-off curves for six ES offerings (3 provisioning, 2 regulating, and structural diversity of the stand). Constraints on the availability of forest stands by site type and starting age class produced a landscape level forest stand portfolio. The preferences of the nudged and neutral groups were then evaluated as they constrained the optimal levels of ES provisioning. Trade-offs result due to shifts in forest management decisions on the landscape. By evaluating the trade-offs, it was possible to determine if there were further social efficiency gains (i.e. in terms of the aggregate or weighted marginal service provisioning for each PES scheme) and if one of the PES schemes was more equitable in terms of ES provisioning.

Main Contribution: Trade-offs between five different ES and biodiversity were evaluated. These included: net radiative forcing from albedo (RFA), net additional carbon storage (CS), Biodiversity Index Value (BIV), harvested saw log/biomass volumes, harvested pulpwood/biomass volumes, and harvested biomass for bioenergy. The elasticities of the trade-off curves for each of the ES indicators, compared with ESEV values for a landscape level portfolio of forest stands, are shown in Table 4. The regulating ES offerings (i.e. RFA and CS) and bioenergy had a strong negative correlation with economic returns when returns from PES were not included. This indicates that it is necessary to provide a compensation to private forest owners to cover the opportunity costs if management is expected to shift towards more ‘climate friendly’ objectives. Trade-off curves elasticities demonstrate the adverse marginal shifts in the provisioning of ES offerings when proportionally similar marginal shifts in economic returns occur.

Table 4. Elasticities and correlations of trade-off between economic returns and all ecosystem service (ES) indicators (Adopted from Matthies et al. (2016)).

Ecosystem Service Indicator	**Elasticity at different levels of achievement in economic returns (%)**						**Correlation with Economic Returns**
	100% [a]	**50%** [b]		**25%** [c]			
	Point [d]	**Point**	**Arc** [e] **(100-50)**	**Point**	**Arc (100-25)**	**Arc (50-25)**	
Biodiversity (BIV)	-329.35	-1.34	-5.63	-1.05	-2.79	-0.84	-0.97
Carbon storage (CS)	-329.35	-0.98	-5.63	1.79	-2.79	0.15	-0.76
Albedo Effect (RFA)	-329.35	-1.07	-5.63	1.28	-2.79	-0.05	-0.84
Sawtimber harvest	-329.35	-0.50	-5.63	-2.31	-2.79	-0.44	0.95
Pulpwood harvest	-329.93	-1.94	-5.63	-2.73	-2.79	-1.53	1.00
Bioenergy harvest	-329.35	-1.77	-5.63	0.44	-2.79	-0.59	-0.90

a. 100% indicates that elasticity was calculated for the first two points along the trade-off curve starting at 100% of income without PES revenues.
b. 50% indicates that elasticity was calculated for the first two points along the trade-off curve starting at 50% of income without PES revenues.
c. 25% indicates that elasticity was calculated for the first two points along the trade-off curve starting at 25% of income without PES revenues.
d. Point refers to the point elasticity at a given point along the trade-off curve.
e. Arc refers to the arc elasticity at a given arc segment along the trade-off curve.

To address these potentially adverse trade-offs, two PES schemes were considered for biodiversity conservation and climate regulation. A survey of private forest owners with half being nudged and half receiving a 'neutral' text was administered. The average weighted management preferences for each group are shown in Table 5.

The results indicated that both groups would accept a loss in economic returns (i.e. there was a shift in the preferred levels of ES provisioning on the landscape that was higher than BAU management provisioning and below BAU provisioning service returns). The nudged text was administered in order to achieve a greater level of additional service provisioning above the BAU. The difference between the nudged and neutral groups was the the amount of traditionally-based economic returns (i.e. from provisioning service income) they were willing to forego. The shift towards income from participation in PES schemes was greater for the nudged group relative to the neutral group.

When the two PES schemes were compared, the climate PES scheme resulted in greater aggregated ES provisioning achievement for both nudged and neutral groups. The biodiversity conservation PES scheme had more equitable provisioning for all the regulating ES. This was especially apparent when the trade-offs between ES offerings were considered. The resulting losses or gains for each of the indicators, according to the biodiversity conservation PES scheme, are shown in Table 6. Choosing the correct ES offering to incentivize through the scheme and its associated indicators that demonstrate conditionality is important. Other ES offerings could, in many cases, be bundled together, but they may not always have the same requirements for achieving an optimal and equitable additional outcome relative to the BAU management scenario. ES that are most connected or interdependent within the cascade are more easily co-provisioned at socially efficient levels, and can be bundled or stacked within a singular PES scheme (Simonit and Perrings 2013; Turner et al. 2014). The full results for both schemes can be found in Article II.

Nudging ES providers could be an important tool for addressing some of the aforementioned PES design challenges. These include: connectivity of land use management units over the landscape for biodiversity conservation and targeting of geographical areas rather than individual service providers. Increased connectivity of a land area could be important for protecting certain species and reducing the distance between protected areas. These results are only the first step in exploring the role of nudging in PES scheme design. Still, the marginal environmental benefit per unit of income was always higher for the nudged group. This indicates social efficiency gains are potentially possible from including this tool in the design of PES schemes.

Table 5. Percentage of the forested landscape allocated to the alternative management regimes for both nudged and neutral (n = 10) forest owner groups (Adopted from Matthies et al. (2016)).

Forest Owner Group	BAU	ENR	CLI	BDI
Neutral	41.2	11.8	29.4	17.6
Nudge	25.9	15.6	32.5	26.0

Table 6. Normalized achievement of total economics returns, Biodiversity Index Value (BIV), carbon storage (CS), avoided radiative forcing from the albedo effect (RFA) relative to the baseline for nudged and neutral forest owners' preference constraints for the PES schemes for biodiversity conservation (Adapted from Matthies et al. (2016)). For economic returns, a value exceeding 1 represents an overpayment beyond the costs of conservation. For ES indicators, a value exceeding 1 represents increased achievement in provisioning additional to the BAU at the landscape level.

Ecosystem Service Indicators	Forest Owner Group	Economic Returns Scenarios			
		Excluding PES	Including Biodiversity PES (€ BIV^{-1})		
			Hartman 1^a	Hartman 2^b	Info. Rent Included
Economic Returns	Neutral	0.796	0.799	0.940	0.988
	Nudge	0.642	0.700	0.926	0.963
	Nudge Difference	-0.154	-0.099	-0.014	-0.025
Biodiversity (BVI ha^{-1})	Neutral	1.095	1.097	1.178	1.166
	Nudge	1.115	1.141	1.222	1.177
	Nudge Difference	0.020	0.044	0.044	0.011
Carbon storage (CS) (C kg ha^{-1})	Neutral	1.230	1.113	1.219	1.260
	Nudge	1.113	1.215	1.294	1.299
	Nudge Difference	-0.117	0.102	0.075	0.039
Albedo Effect (RFA) (W ha^{-1} 1E+10^{-1})	Neutral	1.012	1.007	1.010	1.012
	Nudge	1.007	1.012	1.013	1.015
	Nudge Difference	-0.005	0.005	0.003	0.003
Aggregated ES Indicators	Neutral	1.112	1.072	1.136	1.146
	Nudge	1.078	1.123	1.176	1.164
	Nudge Difference	-0.034	0.050	0.041	0.018

a. Where Hartman rotations are those that exceed the optimal economic rotation (Faustmann) given a forest owner's preference for other objectives than monetary outcomes. Hartman rotation price levels were used to represent a range of forest owner's amenity values. Hartman 1 represents the lowest amenity value.
b. Hartman 2 represents a medium amenity value.
c. Info rents included represent the highest amenity value estimated by Juutinen et al. (2013).

3.4. Optimal forest species mixture with carbon storage and albedo effect for climate change mitigation (Article IV)

Objective and method: The objective of Article IV was to look both at the ES trade-offs between different boreal forest tree species, in the context of economically optimal mixed forest management, and the role of input parameter uncertainty in guiding PES design and implementation in boreal forestry. In this study only the climate regulation PES scheme was considered. Gibbard et al. (2005) and others have suggested that the prioritization of carbon storage over management for other climate regulating ES offerings (e.g. albedo effects) can lead to a net warming effect in boreal forest management. As a result, the idea of internalizing both the carbon storage and albedo effects have become increasingly supported in PES design literature (e.g. Betts 2000; Thompson et al. 2009). This is done by measuring all climate regulation ES offerings (e.g. albedo effect and carbon sequestration and storage) in carbon dioxide equivalent units. Still, within the current literature, considerations for the albedo effect in PES scheme design have demonstrated that there is a wide variation in the estimation of albedo input parameters. That uncertainty is extended to the differences in albedo effects for deciduous and coniferous species.

In Article IV the sensitivity of PES design was evaluated by incorporating this uncertainty using a JPGM for two boreal forest tree species: Norway spruce (*Picea Abies* Karsten) and silver birch (*Betula pendula* Roth.). The JPGM was created based on Valsta (1986; 1988), and the albedo effect was account for along with carbon storage in a mixed forest stand. Optimization of thinnings and rotations were derived by maximizing the mean annual increment (MAI) and ESEV

(€ ha^{-1}). By calculating the economically optimal solutions for different input parameters, it was possible to both determine the sensitivity of PES design to changes in input parameters and the economic diversification benefits of mixed forest management. The sensitivity in the absolute differences in the albedo effect between the two species was evaluated against changes in discount rates, PES price changes, and albedo saturation points.

Main Contribution: In Figure 9, the economically optimal level of birch in a stand was calculated for increasing absolute differences in albedo-related radiative forcing between the species, at differing climate regulating PES price levels. The full figure, including results for discount rates of 1 and 5%, can be found in Article IV. The optimal percentage of birch in a mixed boreal stand was found to be, on average over the rotation, ≈20% when no PES scheme was considered. This was the minimum economic diversification effect of mixed forestry, without consideration for unsystematic economic or ecological risks associated with mixed forest management.

Previously other similar optimization studies have found comparable results, with an optimal 5-50% mixture of deciduous species with coniferous species (e.g. Thomson 1991; Knoke et al. 2005; Rämö and Tahvonen 2015). Therefore, this research supports the view that the benefits of mixed forest management cover more than only intrinsic values and biodiversity. There are also economic diversification benefits, related to growth rates and prices, from planting mixed forest stands.

The albedo effect had a negative effect on ESEV, but, when coupled with rents for carbon storage and timber production, the economic trade-off between species resulted in an optimal mix of >20% deciduous species. This was a result of the differing albedo parameters between deciduous and coniferous species, along with the differing growth rates and ecological site demands (e.g. space, light). The results also contrast with previous findings by Thompson et al. (2009) who found that including the albedo effect in PES design led to an increase in the economically optimal rotation age for deciduous monocultures relative to coniferous monocultures. By using a mixed stand approach in Article IV, the optimal species mix did not lead to an increase in the rotation age relative to the Norway spruce monoculture.

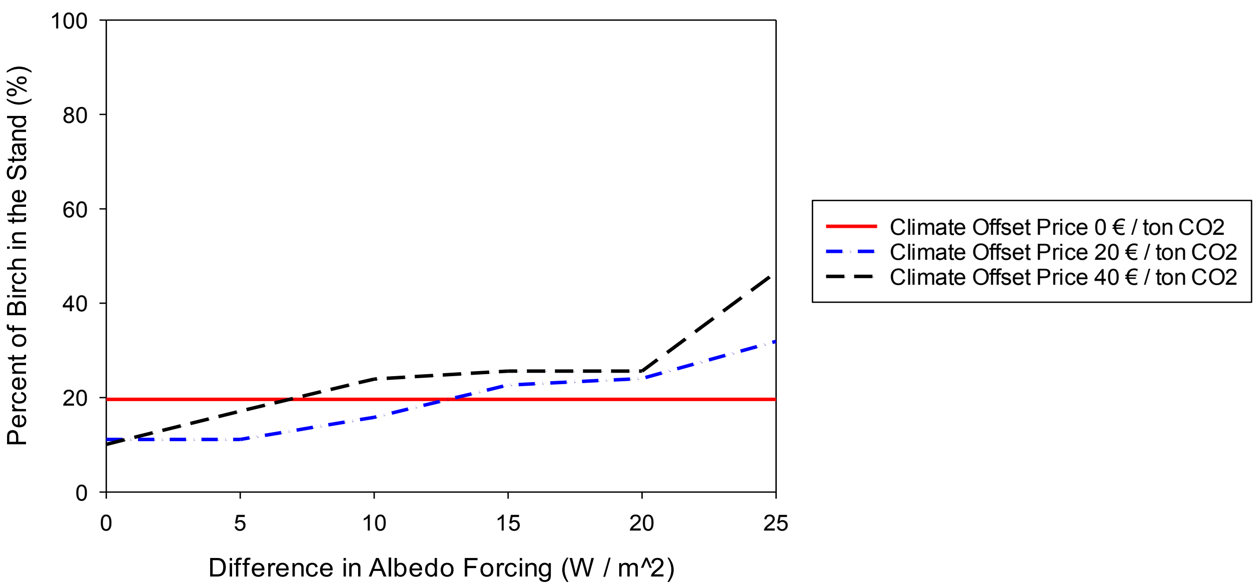

Figure 9. Average percent of silver birch over the entire rotation for increasing climate offset prices (€ ton $CO_2{}^{-1}$) and increasing differences in albedo forcing (W m^{-2}) between Norway spruce and silver birch (Adapted from Matthies and Valsta, (2016)).

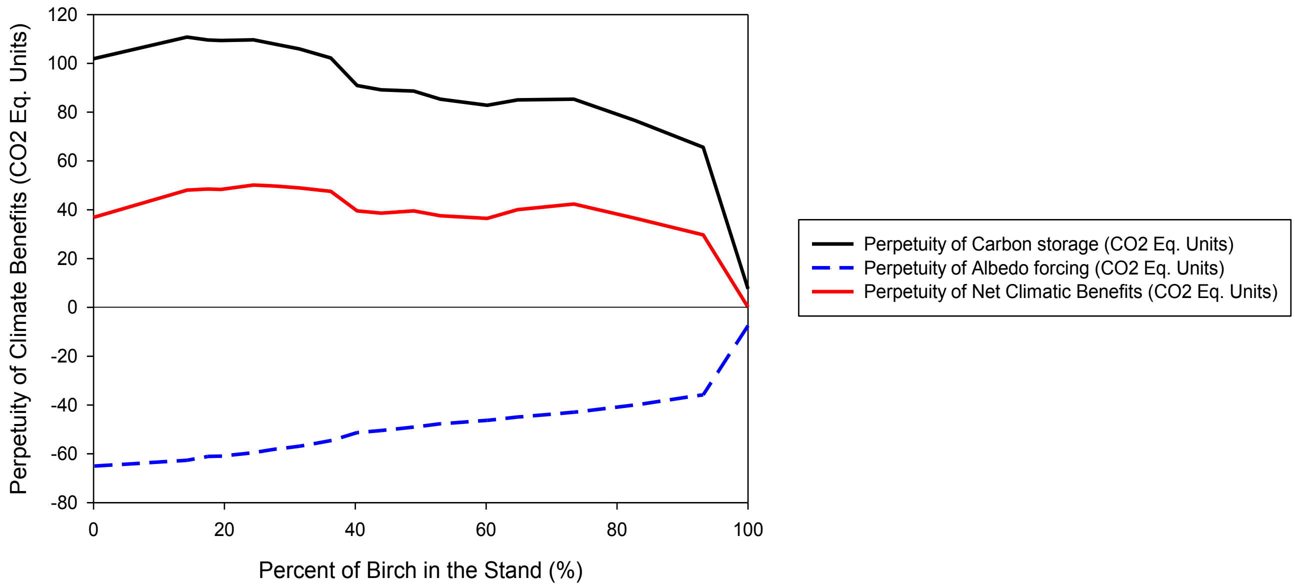

Figure 10. Perpetuity of carbon storage and albedo forcing, separate and net, for an increasing average percentage of silver birch in optimal rotation (Adopted from Matthies and Valsta, (2016)). Climate benefits are reported as the discounted perpetuity of carbon dioxide equivalent units of carbon storage and radiative forcing from albedo, at a 3% discount rate, stand albedo saturation point of 60 $\mathrm{m^3 ha^{-1}}$, and a baseline climate offset price of 20€ $\mathrm{ton\ CO_2}^{-1}$.

In this article, the ES offering trade-offs between species showed the benefits of species diversity in natural ecosystem management. The importance of these benefits, specifically related to the climate regulation benefits, were strengthened by more accurately accounting for them in the design of a PES scheme. In Figure 10, the present value of the discounted environmental benefits and costs, from carbon storage (benefit) and albedo effect (cost), are accounted for separately and the net of the two effects is also given. The x-axis corresponds to an increasing average percentage of silver birch over the rotation of the optimal mixed stand. The trade-off curve demonstrates the economic and environmental diversification benefit of mixed forest structures over the alternative monoculture stands, where the far left of the x-axis is a Norway spruce monoculture and the far right is a monoculture silver birch stand. The optimal mixture for net environmental benefits was 24% silver birch and 76% Norway spruce.

Finally, Thompson et al. (2009) noted that there is a potential overpayment that can occur when all of the ES functions and processes that pertain to a given service offering are not fully accounted for in the PES scheme. In this case, the exclusion of the albedo effect in many previous studies means a socially inefficient overpayment and suboptimal levels of ES provisioning for society. This article's results, along with those of Articles II and III, support a number of studies that demonstrate the importance including all of these functions and processes when designing efficient and effective PES schemes.

4. DISCUSSION AND CONCLUSIONS

4.1. Contributions of this research

This research contributed towards filling two knowledge gaps, which have emerged in the peer-reviewed ES literature. First, a lack of a fully service-centric language within the ES value creation discussion has led to a proliferation of 'production' and 'goods' oriented concepts and language in reference to an inherently service-based concept. A broader and harmonized lexicon around ES value creation has been provided in Articles I and II through the introduction of service and environmental-focused terms (e.g. Ecosystem Service Expectation Value (ESEV), *value-in-impact*). As a result, the existing terms were shifted away from the GD logic towards describing the role of ES offerings. This was a step towards creating a service-centric approach to ES offerings that are continuously being employed and described in environmental and economic research.

Until now, ES-based research has largely ignored the numerous, valid, and helpful research outcomes from other fields of study (e.g. service sciences). This means that new terms are often created (see Spangenburg et al. 2014) in a way that conflicts with the existing service lexicon. Therefore, this research moves more towards harmonizing the existing service terms rather than creating totally new terms. A set of harmonized terms and concepts offer a common communication platform between business and natural science approaches that could be helpful in driving more interdisciplinary ES research discussions.

The four articles addressed previously unexplored questions relating to the internalization of value-in-exchange into ES decision-making processes. In Articles II, III, and IV, various design aspects of PES schemes were evaluated to determine their suitability in assessing PES schemes. These include: (1) the sensitivity of PES design to parameter inputs, (2) price volatility impacts on service providers, and (3) the potential for behavioural economic approaches to policy design. Consideration was also made for trade-offs within the ES cascade and between ES and economic objectives. All of these aspects were analyzed by co-currently using multiple different methods.

Internalization of various externalities (e.g. climate regulation) will affect forestland investments by private forest owners, who are both investors and land managers. As a result of these inquiries, a further understanding about how risk aversion, financial risks and PES schemes interact was determined to be an important research question. Article II addressed these questions from the PES or ES exchange value perspective regarding private forestland investment at the landscape and stand levels. The results of that article indicate that the financial diversification benefits are limited to PES schemes that are highly uncorrelated with other revenue streams from the same stand. These results contrast with previous findings (e.g. Engel et al. 2015) that suggest that socially efficient PES schemes are also highly correlated with the opportunity costs of conservation. Thus, the research outcomes presented in Article II help to further the complex discussion about the trade-offs within PES scheme design.

Further exploration of related research questions was accomplished through Articles III and IV. They addressed the social inefficiency and spatially continuity in PES design. Article III looked at the role of nudging and behavioural approaches to PES scheme design. These outcomes were coupled with an evaluation of the trade-offs between ES offerings. This study contributes to the growing number of articles looking at behavioural approaches to PES scheme design. It is one of the first to use nudging in the context of a PES scheme, and demonstrates the potential importance of nudging to address social inefficiencies and geographic targeting challenges. It also draws on non-monetary valuation of different ES provisioning outcomes (i.e. ranking forest management preferences) from forest management, in conjunction with monetary valuation of the same service outcomes, and demonstrates the role of a blended approach to ES value creation in PES design.

In the case of Article IV, a JPGM approach was employed to evaluate the role of inter-species trade-offs for different climate regulating ES offerings. This was important for establishing a clearer understanding of the role of mixed forest management in addressing ES provisioning challenges and PES scheme design. The results demonstrated that there is an opportunity for greater consideration of mixed forests in addressing the challenges associated with meeting multiple ES management objectives.

The results of Articles II, III, and IV all demonstrate the importance of making a full account of the functions and processes that contribute to a given service offering when designing efficient and effective PES schemes. For example, the inclusion of albedo effects in all three empirical articles contributed to more robust policy recommendations. Those results helped to better articulate the role of boreal forests in climate change regulating. Comparison between biodiversity and ES offerings also provided an important contrast with competing ES provisioning outcomes from forest management. The articles also demonstrate the challenge, and potential impossibility, in designing PES schemes that bring together an accounting of all ecosystem functions and processes in an efficient, effective, and equitable manner. In developing schemes to address environmental externalities, decision-makers should therefore also take the uncertainty of imperfect ES accounting into consideration as a political coping strategy when designing these policies.

The last three articles also represent a step towards both a normative behavioural approach to decision-making and a portfolio approach in applying multiple different methods to improve the policy prescription in PES research. This reflects the warnings by Berg (2003) and Polasky and Segerson (2009), that decision-making without regard for trade-offs or stakeholder input can lead to sub-optimal decision outcomes. Inclusion of these different elements of the decision process highlighted the ecological and financial diversification benefits between service offerings and between a service and other objectives (e.g. economic). As a result, these four contributions raise new questions about the ecological and financial diversification benefits for service offerings to society and how to address them in a socially efficient manner.

4.2. Limitations and future research themes

The articles that form this dissertation were not a singular and cohesive project with a set starting aim to answer a singular research question. As a result, some of the language and concepts are used inconsistently throughout the four articles. A good example is the use of the term 'service' and the plural form 'service offering' in comparison to the more widely accepted term 'services' in reference to ES offerings. This stems from the fact that Articles II, III, and IV were all written and accepted prior to the acceptance of Article I. Although the first article forms the main theoretical argument behind this dissertation, a progression towards the use of the service-centric language is evident when reading the papers in the order they were written (III, II, IV, I). This demonstrates the incremental evolution of understanding and formulation of concepts that occurred throughout the PhD research process. It also demonstrates the lack of a congruent service-based approach within the ES literature, which the authors used to guide their ideas in writing the first three articles. Proliferation of theoretically incorrect and non-service oriented ideas act to create a lack of clarity for researchers and practitioners unfamiliar with the ES terms and concepts. That lack of clarity provided the impetus for writing Article I, which should be viewed as the culmination of that process and not as a conflicting argument.

That evolution or process is still ongoing, and there are a few examples of shifts in language or concepts, in some of the articles, that still require further critical evaluation. One example of a terminology shift is the use of 'intra-service trade-offs' in Article II. This was meant to demonstrate those trade-offs that occur between service offerings within the service cascade, and away from trade-offs that occur with other non-ES service offerings (i.e. related to service offerings that are the result of resource integration processes by the firm, or the transfer of exchange value – money). An example of a conceptual shift is the placement of the SVC Framework within the context of sustainable development in Article I. While this conceptualization is still incomplete from the ecological viewpoint, it is even more so from the perspective of social impacts and their role in value creation. The omission of social impacts was intentional to help focus the audience of Article I on the harmonization challenges in context of ES provisioning impacts. Nevertheless, it is acknowledged that ecological and social impacts have differing roles within the proposed SVC Framework that will need to be addressed in the future. The evolving service-centric lexicon will also continue to require further critical evaluation within the ES discussion, and it is accepted that this process is incremental and ongoing.

It is also important to note that the four articles do not provide a comprehensive or definitive set of recommendations for policy- and decision-makers. Rather, they demonstrate that certain methods or combinations of methods can lead to specific recommendations. Therefore, the recommendations given in each article should be viewed in tandem with those in comparable literature when determining the appropriate approach to PES scheme design. Those recommendations are also highly dependent on the input data. For example, the data for nudging private forest owners in Article III was conditional on the participants who were part of the survey and scientists who designed the survey. Similarly, the JPGM in Article IV was based on field measurements, and the species mixture effect noted by the model may be biased by imprecise or inaccurate input data. Lastly, the application of some of the methods (e.g. MPT, nudging) used were experimental, and require further critical evaluation and replication.

Most of the specific limitations of the research has been covered in the articles, and is not reiterated here. There are however two points, that pertain to Article III, that were not mentioned in the article itself. First, that there are important ethical questions for policy-makers about the boundaries of information used to impact individual's 'rational' decisions in regard to the use of nudging in environmental policy design. Additionally, in the article non-nudged individuals were referred to as 'neutral'. This was a potentially misleading identifier, as the neutrality of information is highly subjective. Therefore, readers should be aware of that when gauging the outcomes of that article.

Despite these limitations and discrepancies, the four articles represent an important step towards a clear and cohesive set of terms and concepts that can be easily transferred between many different disciplines. This is a vital step if researchers and decision-makers are serious about the development of interdisciplinary research on sustainable development challenges. Without a cohesive understanding of how value creation and flows occur between the various service systems that are researched, often in secluded silos, there is a great challenge to bring all of the outcomes together. It also demonstrates the opportunities for evaluating PES policies with multiple and new methods. The blended methodological approach, that incorporates monetary and non-monetary valuation, demonstrates that a more holistic realization of value within the policy instrument can lead to new perspectives on old recommendations.

Future research should focus on additional harmonization of the ES and service science terms, and aim to create more meaningful inter- and multidisciplinary service-centric research. Natural ecosystems are already subjected to high levels of human intervention and management. It would be beneficial, both from the perspectives of the firm and natural sciences, to facilitate more harmonized and co-operative research and research goals. This starts with being able to understand each other. Beyond harmonization of the terms and concepts, this could be extended to integrating existing approaches of assessing value flows and ES flows.

The recognition of the total value of a given ES throughout the business ecosystem, that includes both monetary and non-monetary values (value-in-use and exchange), will also require more concerted efforts. A combination of existing methods, exploration of the application of old methods to new research questions, and the development of totally new approaches will be necessary and beneficial. All of these are essential to better integrate both exchange and use values associated with environmental externalities into the economic and social macro service systems. This process is still nascent and consideration for monetary or exchange value has so-far gained more attention (e.g. Gómez-Baggethun et al. 2010).

For PES, further recognition of use value could, for example, potentially improve the equity of schemes. This could be realized by better communicating the value-in-use of forest access for indigenous communities to those who are purchasing PES credits (e.g. REDD+), and, thereby, giving an opportunity for greater value co-creation between buyers and service providers. Recognition of the importance of use value in value determination has been slow to be recognized within the ES literature, which has limited the opportunity to research and test how these value co-creation opportunities could be realized. Articles II, III, and IV make little mention of this or these opportunities, which is a result of the order of article publication. This could form a major research theme, both within the wider ES literature and, more specifically, the PES literature, in the future.

Finally, all of this research excluded ecological risks and the insurance value that resilient ecosystems have in hedging against these risks. This is a major aspect of risk diversification modeling, but was beyond the scope of each of the articles. There are currently some examples of how these aspects of risk have been accounted for (e.g. Knoke et al. 2008). Still, the amount of literature is limited relative to the importance of this aspect of modeling. Numerous frameworks (e.g. the EU Green Infrastructure Strategy and the Sendai Framework for Disaster Risk Reduction) mention the importance of natural ecosystems in providing this service, and efforts have been made within the financial sector to recognize the potential outcomes of further research on this issue (IFC, 2012; NCC, 2015). Therefore, further study should aim to incorporate these ecological risks and natural ecosystems' ability to reduce the severity of damages into financial modeling of this nature.

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