LIÈGE université
Gembloux
Agro-Bio Tech

Forest, how should we manage your values ? A valuation of ecotourism ecosystem services of the Ardenne forests and its implications for current forest policies and practices.

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Dissertation originale présentée en vue de l'obtention du grade de docteur en sciences agronomiques et ingénierie biologique

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Année civile: 2021

Author: Johanna Breyne

Citation: Breyne J. 2021. Forest, how should we manage your values? A valuation of ecotourism ecosystem services of the Ardenne forests and its implications for current forest policies and practices. Thèse de doctorat, Gembloux Agro-Bio Tech – Université de Liège, Gembloux, 238 p.

Funding

The present research has been financed by the Interreg project AGRETA and was hosted by Gembloux Agro-Bio Tech at Liege University.

Abstract

The present research makes use of the Ecosystem Services (ES) conceptual framework to explore human-nature relationships by assessing how people value nature, taking the example of forest ecosystems through a case study approach. While multiple actors and studies stress the need for a transition towards more natural forests, forest governance is based on value judgements by different concerned actors, which evokes tension and conflict. While forest-multi-functionality is often proclaimed as a management strategy, production-oriented policies and practices remain the dominant orientation on the field, while other forest functions, such as socio-recreational forest aspects, remain in the margin. In order to allow for transparent decision-making, it is essential to underscore how the forest is valued by the wider public.

With the objective to contribute to reducing the existing knowledge gap on socio-recreational forest ES and to facilitate discussions and negotiations over envisioned and/or necessary changes in forest management, the present research performs a valuation of socio-recreational forest ES for the Ardenne forests through (i) estimating visitor frequencies as an indicator of recreational/ touristic ES; (ii) assessing wider public preferences for structural forest characteristics as an indicator of landscape attractiveness; (iii) and underscoring the socio-cultural (SC) forest values for a wide range of ES and other ways the forests are of importance to people as an indicator of the relative socio-cultural importance of forests. In addition, it uses SC values for (iv) addressing within-group heterogeneity in order to bypass stereotypic profiling.

Results demonstrate the importance of a wide range of forest values for the wider public and the prioritization of the role of forests for aesthetic appreciation, biodiversity conservation and for regulatory services; as well as a general preference for characteristics of natural forest ecosystems. The combination of these results reveals a mismatch between current forest governance on the one hand and societal forest values and preferences on the other hand. This mismatch is contextualized in the discussion by referring to the Multi-Level Perspective (MLP) and the potential influence of research results is then confronted with the prevalence of cognitive, regulatory and normative lock-ins. In the conclusion, we take a step back and reflect on the implications for research, policies and practices of employing the ES concept.

La présente recherche utilise le cadre conceptuel des services écosystémiques (SE) pour explorer les relations entre l'homme et la nature en évaluant la façon dont les gens apprécient la nature, en prenant l'exemple des écosystèmes forestiers à travers un cas d'étude. Alors que de nombreux acteurs et études soulignent la nécessité d'une transition vers des forêts plus naturelles, la gouvernance forestière repose sur le jugement de valeur de différents acteurs concernés, ce qui suscite des tensions et conflits. Alors que la multifonctionnalité de la forêt est souvent proclamée comme une stratégie de gestion, les politiques et pratiques axées sur la production restent l'orientation dominante sur le terrain, tandis que les autres fonctions de la forêt, comme les aspects socio-récréatifs de la forêt, restent marginalisées. Afin de permettre une prise de décision transparente, il est essentiel de souligner la manière dont la forêt est appréciée par le grand public.

Dans le but de contribuer à réduire le manque de connaissances sur les fonctions socio-récréatives de la forêt et de faciliter les discussions et les négociations sur les changements envisagés et/ou nécessaires dans la gestion forestière, la présente recherche effectue une évaluation des SE socio-récréatifs pour les forêts d'Ardenne (i) en estimant la fréquence des visiteurs comme indicateur des SE récréatifs/touristiques ; (ii) en évaluant les préférences du grand public pour des caractéristiques structurelles de la forêt comme indicateur de l'attractivité du paysage ; (iii) et en évaluant les valeurs socioculturelles (SC) pour une large gamme de SE et d'autres façons dont les forêts sont importantes pour les gens comme indicateur de l'importance socioculturelle relative des forêts. En outre, elle utilise les valeurs SC pour (iv) aborder l'hétérogénéité au sein des groupes afin de contourner le profilage stéréotypé.

Les résultats montrent l'importance d'un large éventail de valeurs des forêts pour le grand public et la priorité accordée au rôle des forêts dans l'appréciation esthétique, la conservation de la biodiversité et les services de régulation, ainsi qu'une préférence générale pour les caractéristiques des écosystèmes forestiers naturels. La combinaison de ces résultats révèle un décalage entre la gouvernance forestière actuelle, d'une part, et les valeurs et préférences sociétales, d'autre part. Ce décalage est contextualisé dans la discussion en utilisant la Perspective multi-niveaux (MLP) et l'influence potentielle des résultats de la recherche est confrontée à la prévalence des verrouillages cognitifs, réglementaires et normatifs. Dans la conclusion, nous prenons un peu de recul pour réfléchir aux implications de l'utilisation du cadre conceptuel de SE pour la recherche, les politiques et les pratiques.

I would like to take the opportunity to honor a long list of people who have played an important role along the voyage that has been this PhD thesis.

A huge and warm thanks to Kevin for having been an invested co-supervisor, having accepted to become head supervisor half the way, being available and steering every time needed and for entrusting one's autonomy and initiative the rest of the time, the constructive and human feedback and support, for enhancing conceptual reflections, the enthusiastic phone calls when an article passed, the numerous skype discussions over the wording of a text and for staying miles away from academic elitism.

Gregory for having accepted the co-promotion half the way, for the insightful discussions and the therapeutic gym sessions, the reminding of regulations I always forget and for adding a next level to interpreting sarcasm.

The members of my thesis committee, Tom and Hugues, for the constructive feedback, the advice on survey formats and the preselection of literature.

Jan as president of the jury to guide and structure the final steps, and external jury members Jens and Nicolas for their comments such to fine-tune the final manuscript.

The AGRETA team and especially Jens and the A-team PE, Noémie and Esmeralda for the many memorable moments, field trips, discussions, the running after survey respondents, the shared laughter and frustration and the amity that came about.

The DNF for the collaboration on the field and especially Thomas, Thierry, and François for the interest, support and motivation and the enjoyable souvenirs on wolves, fallen trees, black storks, strange tourists and missed leaps ...

The interns and TF'istes Esteban, Quentin, Maxime, Isabella, Soraya, Laëtitia and Juliette for the gain of time, the commitment, the coping with my endless requests for last modifications and for defying all weather conditions for surveys and images.

The many interviewees for their time, openness and insightful explanations.

The ADE team and especially Tatiana for the welcome and enriching break.

The (ex-)BP team and especially Thomas, Kathleen, Charly, Sophie and Axel for the sharing, the trust, the patience, the openheartedness, the jokes, the kicker and climbing sessions, the camera missions, Daverdisse, la Vendée… c'est parti mon kiki!

Laura for the listening, the advice, the support, the walks, the sharing, the sincerity, the hospitality, and so much more. And Will likewise. Time for sloes!

La Grange: Martin, Flo and Fran, Anais and Damien, Anthime, Marie and Steve, Wilburt for the time shared, the precious moments and the home-feeling.

Mario for the support, the love and the encouragements. My awesome family, for all of the road that took me to today, for the opportunity to pursue my studies, for enhancing a critical mindset, for the down-to-earth view, for being a solid home-base, I'm very grateful being able to share the finalization of this chapter all together. And my grandfather for the follow-up, being proud and the deadwood pile in the garden.

And last but not least Bast for this part of the road together, your love, patience and faith, for supporting my moody moments, for your critical regard and the fulfillment you bring along. Seb for hanging arround. Ulysse & Nino for asking if my thesis is still not finished. Galeos & Phenomène for those moments of peace in my head.

This PhD research forms part of a personal journey in search for narratives and tools that have the potential to effectively address current disruptive nature-human relationships. I therefore acknowledge some extent of normativity in the sense that I started from the idea that these relationships needed to be questioned or re-explored.

After having graduated as a biologist, I felt somehow frustrated on the lack of connections that had been made during those 5 years between ecological or environmental issues and the broader socio-cultural, economic and political context. This is why I opted for a second master in socio-political science, which enlarged my understanding of and shed another perspective on current environmental challenges. A consequent experience in project formulation and monitoring for a non-profit association aiming for the enhancement of sustainable development confronted me with a lack of data and insights on human-nature relationships related to the notion of ecosystem services. Because of this observation and my personal interest in socio-ecological systems, I seized the opportunity to work as a PhD student on the AGRETA project.

Evidently, as this PhD research was framed within a specific project with specific output demands, this strongly structured the type of research questions, methodologies and data employed. Nevertheless, and as will be demonstrated throughout this manuscript, the precise scope of the research has been influenced and adjusted by various events and encounters. The present work should thus rather be seen as resulting from an evolving trajectory during this 4.5 years of research. In addition, this field-driven nature of the questions dealt with throughout the PhD does not preclude having adopted a rigorous scientific approach when it came to performing the analysis serving to answer those questions. This broad dialogue between field considerations and academic requirements has been at the heart of my research process.

The evolutive nature of the path followed also applies to how the ecosystem services concept has been conceived throughout this research. Starting off from a pre-described ecosystem services orientation due to the original project framing, the angle shifted towards putting the focus on the notions of values, preferences and importance. This is also evident from the three consecutive papers making up this manuscript, with the first paper performing a classic ES valuation and the second paper exploring some limitations of the ES concept, and from the absence of the ES concept in the third and final paper. I will come back to this in the final conclusion of this manuscript.

For the sake of clarity, when using the personal noun ‘we’ in this manuscript, I refer to the ensemble of authors that contributed to the respective article or research aspect. Personal opinions or statements are denoted by using the first singular person.

I hope this work will provide its readers with new insights, points of view or questions that will contribute to the common search for more sustainable ways of interacting within the natural world.

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List of abbreviations

AGRETA	Ardenne Grande Région Ecotourisme et Attractivité
ANOVA	Analysis of variance
a.o.	among others
CAP	Common Agricultural Policy
Cfr.	*confer*
DCE	discrete choice experiments
DNF	Département de la Nature et des Forêts
e.g.	example given
ES	Ecosystem Services
EU	European Union
F	Feedback
GDP	Gross Domestic Product
GLM	General Linear Modelling
HFE	Hautes Fagnes-Eifel
HSFA	Haute Sûre forêt d'Anlier
i.e.	*id est*
IPBES Services	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem
Km	Kilometers
MCDA	Multi Criteria Decision Analysis
MLP	Multi-Level Perspective
NCP	Nature's Contributions to People
PES	Payments for Ecosystem/environmental Services
PhD	Doctor of Philosophy
PNDO	Parc Naturel des Deux Ourthes
SC	Socio-Cultural
SH	Saint Hubert

Chapter 1

Research context

1. Introduction

"Facts are facts, but perception is reality"- Albert Einstein

The omnipresent and profound impact of human activities on the natural environment has led to the formulation of the hypothesis that we are entering an *Anthropocene*, a term used to describe the most recent period in Earth's history in which human activity has a significant impact on the planet's climate and ecosystems (Haraway, 2015; Seddon et al., 2016). Without entering into the discussion of the pro's and the cons of this disputed wording, it calls upon a thorough reflection on current way earth's ecosystems are governed and managed. Despite human conservation and protection efforts, levels of biodiversity loss and ecosystem degradation continue to increase (Van Meerbeek et al., 2019). This in turn leads to a more and more impoverished natural world and a weakened resilience of ecosystems; outcomes which are further re-enforced by climate change. This poor planetary balance endangers existing live forms, both human and non-human (Raworth, 2017).

In the light of this urgency and in order to cease or reverse these evolutions, besides conservation and protection policies and practices, the concept of ecological restoration has received increasing attention. So did the United Nations designate the decade 2021-2030 as the "Decade of Ecosystem Restoration" (The United Nations General Assembly, 2019). If, what, why, where and how to protect, conserve and restore (degraded) ecosystems and their functioning represent questions to which the answers are outcomes of decision-making processes, including debates and negotiations on the perception, use and management of natural resources.

Decision-making is based on im- or explicit processes of 'value judgement' (Costanza et al., 1997; Jax et al., 2013) in which values act as mediators between beliefs or motivations on the one hand and behavior or concrete actions on the other hand (Hejnowicz and Rudd, 2017). Because of their pivotal role, the "value question" has received a significant amount of attention in literature on human-nature relationships. As values are multiple and plural, the term "value" can refer to a wide range of interpretations or meanings (Kenter et al., 2019; Kronenberg and Andersson, 2019; Spangenberg et al., 2014; Stalhammar, 2020). Values that shape decisions-making processes over ecosystem management can be regarded at as expressions of environmental narratives, to which a person or a group of persons, that directly or indirectly participate to these processes, adhere. People's perceptions of and interactions with nature, wilderness or specific landscapes are influenced by personal experiences and preferences, as well as by the cultural, social, political, economic and historic context they encounter themselves in (Andersson et al., 2015; Bennett, 2009; Cheng et al., 2010). Environmental narratives or discourses that arise around a specific case, are constructed storylines that reflect a shared vision to understand and take position on a certain environmental issue (Dryzek, 2005; Ernstson, 2013; Hajer et al., 2006). There exist multiple frames and ambivalent ways of interpreting nature, which in turn reflect more general differences and contradictions in people's conceptions of nature and the role of humans in relationship to it (Byg et al., 2017).

In this sense, debates around specific conservation and restoration approaches or concepts can be interpreted not as debates on the values inherent to these, but as articulatory practices that establish relations between those different approaches or concepts and their actors (Steinwall, 2015). Biodiversity conservation, for example, might be considered as a desirable goal, but how this goal is to be achieved can be subject to intense debate or oppositions (Ridder, 2007; Swart et al., 2001; Van Meerbeek et al., 2019). During processes and practices of articulation, arguments are constructed and meanings and values are assigned by actors or groups of actors. This allows for narratives to be affirmed, to be challenged or to develop and evolve. Different networks of value articulation can compete with each other over their influence in ecosystem management and policy regulations. In western societies, Nature is commonly presented as opposed to Culture and Society and has increasingly been secularized, institutionalized and instrumentalized to serve particular interests (Leroy and Arts, 2006). Within this duality frame, nature has mainly been understood as a resource provider (cfr. wood, food, construction) or as an object (cfr. biophilia, call of nature …) (Leroy, 2017). This externalization of nature from society has contributed to the devastating effects of human activities on the environment (IPBES, 2018; Johnson et al., 2017; McShane et al., 2011). In contrast, other non-dualistic narratives adopt a more holistic perspective on the place of humans and culture in relation to the non-human world, but they are often bypassed in scientific studies, public policies and practices (Christie et al., 2019; Díaz et al., 2014).

While the western conception largely dominates the policy area, it is also important to note that the nature-culture divide draws on a strongly debated opposition, that may only be rhetoric (Leroy, 2017). Hence, society and the environment are neither two separate entities, nor two opposite extreme ends of the same axis. But they are instead closely intertwined. This interdependent relationship is being expressed by what Serres (1990) refers to as the "resistance of reality", which refers to the occurrence of events or phenomena that by their existence challenge the nature versus culture rhetoric. Examples are innumerous: the enduring biodiversity crisis generating agricultural pollination deficits, fish stock depletion due to pollution practices threatening fishermen's livelihoods, but also the voluntary sabotaging of a dam-building project, a petition against the ineffectiveness of policies aimed at biodiversity protection, etc. (as in Jackson, 2011; Natagora et al., 2021; Potts et al., 2016; Teshale et al., 2002). These socio-ecological feedback systems remind human society that a given issue cannot be addressed purely as representing a *nature* or *culture* issue.

Nevertheless, policy mostly ignores the different ways of expressing socio-ecological dependencies, pointing the need for more explicit representation mechanisms (Latour, 2018). The existence of competing visions raises questions as to which one(s) should be used, which approach(es) should be employed, and which role should be reserved for science or other knowledge systems in the process of defining concepts and values (Martinez-Alier, 2003). However, these questions should not impede the use of multiple representation mechanisms that can give voice to the natural or non-human world (Daily et al., 2009). As aforementioned, for

something to be accounted for during decision-making processes means that it has to be given a meaning and thus be valued in some way. In this sense, in order to account for Nature and human environmental impacts in decision-making processes, several conceptual frameworks, as well as concrete mechanisms that give meaning and value, have been elaborated. On a conceptual stance, a reframing of human-nature relationships is for example proposed by the doughnut model for economics (Raworth, 2017), that centers society within ecological boundaries as defined by Rockström et al. (2009); the emergency of interdisciplinary research areas such as "environmental humanities" is another sign. On a practical stance, this integration could for example be envisioned by moral (e.g. traditional nature protection measures), financial (e.g. the polluter pays principle) or juridical (e.g. assigning legal personality to natural elements) mechanisms.

The present research makes use of the ecosystem services (ES) concept to explore these human-nature relationships by assessing how people value nature, taking the example of forests through a case study approach. It reflects on what the explicit revelation of the importance of various forest values for the wider public, as well as for particular groups, and its relation to concrete forest attributes or elements can indicate about current and future forest policies and management practices. Furthermore, it relates these observations to the wider movement of ecological transition.

a) Theoretical foregrounding of main concepts

Before getting to the core of this reflection based on the above outlined entry point, a review of key concepts and a theoretical foregrounding is necessary. This section includes the main concepts that will be touched upon throughout this manuscript.

A **conceptual framework** structures a certain issue at stake by providing descriptive storylines that define the issue and why it matters (Van Gorp, 2006). Framing thereby simplifies complex issues and provides a common way of understanding an issue between different stakeholders (e.g. between researchers, politicians, the media and the wider public) (Fisher and Brown, 2014; Van Gorp, 2006).

The **ecosystem services (ES) conceptual framework** has emerged in the nineteen eighties in response to concerns on continuous environmental degradation (Chaudhary et al., 2015). This conceptual framework explicitly points out the benefits people obtain from ecosystems (Millennium Ecosystem Valuation, 2005) and hereby emphasize the dependency of humans on ecosystems and their functioning. Ecosystem services are seen as the "direct and indirect contributions of nature to human wellbeing" (TEEB, 2010).

This conceptualization represented a novel way to enhance the protection, conservation and restoration of nature as it draws attention to the "interactions and interdependencies of nature, society and economy" (Dendoncker et al., 2018a). Whereas certain ecological functions are or were taken for granted, the ES concept allows for making them explicit to policy and economic reasoning. This is done by performing ES valuations, which are processes that assign value (e.g. a biophysical, economic or social value) to an ecosystem and/or its services (Millennium Ecosystem Valuation, 2005). The aim of these valuation processes is to provide support on environmental questions in order to enhance sustainable decision-making and ecosystem management (Potschin and Haines-Young, 2013).

The ES concept has found a broad uptake in environmental policy making and in research settings (Chaudhary et al., 2015; Olander et al., 2018). However, its use is also heavily criticized for several reasons. The major sources of criticism relate to 1) its normative, anthropocentric and utilitarian framing, where nature is a service producer, society the consumer (Plieninger, 2015; Winthrop, 2014) and where intrinsic values are largely ignored (Chaudhary et al., 2015); 2) its disputed suitability for biodiversity conservation objectives because of the shift from an intrinsic to an utilitarian argumentation and justification (Fisher and Brown, 2014); 3) its intertwining with a neoliberal market logic, said to incite a "commodity fetishism" (Brockington, 2011; Brondízio et al., 2010) and a consequent commodification of nature, a focus on marketable services, as well as an exclusion of non-economic values (Chaudhary et al., 2015; Plieninger, 2015); hence, the observed dominance of

monetary ES valuations have led to a discussion on whether this economic focus is inherent to the concept or solely related to its application (Barnaud and Antona, 2014; Fisher and Brown, 2014; Schröter et al., 2014); 4) its vagueness of definitions and classifications concerning services, contributions, benefits and values (Barnaud and Antona, 2014; Burkhard and Maes, 2017; Schröter et al., 2014); and 5) its neglecting of power, justice and equality related issues (Barnaud and Antona, 2014; Chaudhary et al., 2015), see box 1.

Bearing these shortcomings in mind, on the one hand ES and their valuations thus represent thus simplified representations of nature-human relationships; on the other hand they offer a tool to cope with the current externalization of the consequences of human choices and behavior (Brondízio et al., 2010). In this manuscript, I adopt a constructivist stance as outlined in Barnaud et al. (2018), which means that ES do not exist per se, but only if people acknowledge their existence.

It has become apparent that biodiversity and ecosystem degradation inevitably engender economic losses on the long term (e.g. the destruction of wetlands by transforming them into building areas, increase the risk for flooding, for which retention infrastructure needs to be build, as e.g. outlined in Depietri et al., 2012). Nevertheless, conservation and restoration activities often represent predominantly indirect gains (e.g. lower risk for flooding) instead of direct gains for private property owners (e.g. the selling of building areas). This discrepancy between public and private interests often counteract the will to modify ecosystem management (Fisher and Brown, 2014; Howe et al., 2014).

One way to address this issue is through **payments for ecosystem (or environmental) services** (PES), through which the beneficiaries of ecosystem services reward the ecosystem managers, those whose lands provide these ES with (non-)monetary contributions or incentives. This is a popular, albeit debated strategy and relates to one of the principal critics on the use of the ES valuation framework, namely that by the dominant focus on economic valuations, it promotes a marketization or commodification of nature, where investments are based upon ES returns (Fisher and Brown, 2014). The visualization of non-counted economic losses due to ecosystem degradation and non-sustainable practices in order to motivate a management change has somehow paved the way to the creation of PES systems where individuals or organizations are directly reattributed for not destroying the environment (Dendoncker et al., 2018a). This raises questions on the ethics and equity of PES systems as to who should pay, who should be rewarded, how does this impact social networks, what if inflation occurs, how are social and ecological values accounted for within PES mechanisms, etc. (Dendoncker et al., 2018b).

Box 1. Ecosystem services, to whose benefit?

The potential discrepancy between the ES benefits and interests of ecosystem managers on the one hand and ES beneficiaries on the other hand can be interpreted as a "contested geography of difference" (Ernstson, 2013), where spatial and temporal processes of generation and distribution create spatial and temporal inequities (Martín-López et al., 2019). Examples concern the geographical localization of urban parks and its relationship to the housing prices, or the time lag of climate change.

These processes are influenced by a socio-political context, e.g. the normativity of the ES under consideration, the human agency in the generation of ES, the regulation around ES access …, and by biophysical realities distributing benefits at different scales (Martín-López et al., 2014; Vallet et al., 2020).

Trade-offs in the generation and distribution of ES often mirror rivalry between the values and meanings of those ES for different actors or actor groups (Martín-López et al., 2014). Within this context, power has been defined as "the ability to influence or control the behavior of other people with respect to ecosystem service governance" (Berbes-Blazquez et al., 2016). The most vulnerable position regarding negotiations over ES provisioning is thus for actors with little power over ES management or access regulations, and who at the same time are highly dependent on ES delivery for their wellbeing (Martín-López et al., 2019). Addressing these procedural and distributional inequalities at different scales, resonates with notions of environmental and ecological justice as defined by Schlosberg (2013). For the ES framework to enhance a sustainable resource use, while contributing to human wellbeing through an adequate, equitable and reliable flow of ES, ES assessments should thus take into account not only how ecosystems are managed, but also why which ES are being prioritized and who benefits from the generated services (Ernstson, 2013; Vallet et al., 2020).

Despite its shortcomings, several authors point out the potential added value of the ES concept for research and policy-making (Barnaud et al., 2011; Dendoncker et al., 2018b; Turkelboom et al., 2018), and multiple propositions have been formulated to deal with the above listed concerns. For example, researchers have been calling for performing integrated and inclusive valuations, the first referring to an evaluation that articulates different value interpretations, the latter referring to the involvement of the actors concerned by the evaluation (Dendoncker et al., 2018a). Integrated and inclusive valuations strengthen the legitimacy and thus the applicability of the valuation outcomes for policy practices (Dendoncker et al., 2018a). Also, the normative framing of the concept has been underlined, in the sense that the very fact of assessing a service makes that this service is recognized as such. The valuation methods used to assess ES should thus themselves be recognized as "socio-cultural constructs that define the rules for eliciting or articulating values" (Brondízio et al.,

2010; Spangenberg et al., 2014). Hence, the choices that shape an ES valuation are not just a question of in- and excluding certain values from the valuation, but also of considering which valuation methods are suited for the valuation to be undertaken (Brondízio et al., 2010; Martín-López et al., 2014). The normativity of a framework should however not impede its use, as long as this normativity is acknowledged (Abson et al., 2014).

The ES conceptual framework represents one way to look at the interactions between nature and humans and more specifically at the interactions between ecosystems (the ecological realm) and human society (the social realm). Contrary to the original framing of the ES-cascade where both dimensions are separately represented (see Haines-Young and Potschin, 2012), the co-production of services, as well as disservices, by both non-human and human agents is increasingly being recognized (Blanco et al., 2019; Masterson et al., 2019; Spangenberg et al., 2014). ES can thus be seen as describing a socio-ecological system (SES), where ES emerge out of socio-ecological interactions (Masterson et al., 2019). This co-production is also the position I adopted regarding ES provisioning within this manuscript. The ES concept should thus be seen as an evolving environmental discourse or narrative wherein, besides ecological and economic mindsets, social sciences are also called upon to address issues of culture, justice, equality, wellbeing, etc. (Chaudhary et al., 2015; Stalhammar, 2021).

An output of this evolving discourse is the parallel conceptual framework that similarly addresses contributions of the natural world to the human world: the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) framework. This conceptual framework evolved from the ES framework and includes the following elements: nature; nature's contributions to people; anthropogenic assets; institutions and governance systems and other indirect drivers of change; direct drivers of change; and good quality of life. A main innovation, compared to the ES conceptual framework, withholds the replacement of the ES wording by **Nature's Contributions to People** (NCP), a shift that is not left undebated in the concerned literature (Neuteleers et al., 2020). In a similar vein to ES, NCP are defined as "all contributions, both positive and negative, of living nature to people's quality of life" (Díaz et al., 2015). The inclusion of the mentioned above additional elements into one overall framework underlines the aim of the IPBES framework to be more inclusive and interdisciplinary than the ES framework in the valuation of nature: it (1) emphasizes the socio-ecological co-production of ES (Bruley et al., 2021) thereby giving a central role to culture, (2) explicitly leaves room for other non-utilitarian worldviews on human-nature relationships, as well as for other (non-academic) knowledge systems, and (3) counters the intrinsic-instrumental dichotomy of values by including the relational value concept (Neuteleers et al., 2020; Pascual et al., 2017). Whilst the multiple adjustments and propositions made to improve the original ES conceptual framework address the same issues, notably through the promoted concept of 'integrated valuations'; this has not resulted in an

officially accepted and promoted revised framework, contrary to the institutionalized IPBES conceptual framework. Therefore, the use of the ES valuation framework, as originally formulated, could potentially still represent a purely scientific single-value single-service valuation of an uni-directional nature-human service provisioning; employing the IPBES valuation framework could hence be interpreted more as a statement explicitly acknowledging the existence of multiple visions, values and knowledge sources (Neuteleers et al., 2020). The IPBES framework has however in its turn been criticized for predisposing a "dualistic, anthropocentric and utilitarian representation of human-nature relationships" (Kenter, 2018; Muradian and Gómez-Baggethun, 2021), and for putting forward idealized management goals that do not lead to the concrete policy applications aimed for (Evans, 2019; Muradian and Gómez-Baggethun, 2021). Due to the broader policy uptake of the ES concept and valuation framework, compared to the use of the NCP concept within an IPBES valuation framework, it is the first that has been employed within this PhD research in its empirical design.

The use of the ES concept per se, while originated from an environmental concern, does not de facto lead to more nature nor to its sustainable management (Ernstson, 2013). A prioritization of one or a few ES, could on the contrary lead to impoverished and degraded ecosystems, e.g. plantation forests intended for carbon storage. Hence, the sustainability outcomes of ES valuations form part of negotiation processes between concerned actors with diverging interests. Moreover, a consensus outcome concerning ecosystem management that is considered legitimate by the majority of the concerned actors, is not per definition sustainable. Within the context of the ES valuation framework, I refer to concerned actors as "a(ny) group or individual who can affect or is affected by the ecosystem's services" (Hein et al., 2006). In this regard, Bosselmann (2008) argues for adopting a paramount legalized notion of sustainability that should not be negotiated, comparable to e.g. human rights. The notion of sustainable development is in this sense not about finding an equilibrium between economic, social and ecological interests, though reclaims a development within its environmental limits and the capacity of an ecosystem to maintain or restore its integrity (Bosselmann, 2008; Rockström et al., 2009). In addition, whilst the ES concept can be used for pointing out human dependency on ecosystems and their functioning, a negotiation over the prioritization of ES might obscure the ecological complexity behind those relationships and interdependencies, even more so as various processes and dynamics are still poorly understood (Hobbs and Cramer, 2008).

Compared to intensively managed systems, numerous studies find (near-)natural ecosystems to be more resilient (Hautier et al., 2015; Reif and Walentowski, 2008; Sabatini et al., 2018) and to support an enhanced delivery of a wider range of ES (Balvanera et al., 2006; Blewett, 2016). Within this manuscript, I employ the following original-ecological **resilience** definition: the ability of an ecosystem to absorb changes and still maintain its ecological functioning, underlining persistence, adaptive capacity, variability and unpredictability (Holling, 2013; Standish et al., 2014).

Ecological restoration or 'assisted recovery' aims to restore damaged, degraded or destroyed ecosystems. Increasing the degree of **naturalness** of an ecosystem (see box 2), by allowing natural dynamics and processes to occur, has by several authors been put forward as an ideal goal for the conservation and restoration of ecosystems and their functioning (Reif and Walentowski, 2008; Wallenius et al., 2010; Winter, 2012). (Ecological) naturalness has various definitions (McRoberts et al., 2012; Oliver et al., 2002; Siipi, 2004; Winter, 2012), though all relate to a continuum between entirely artificial and the 'original' state of the ecosystem, as uninfluenced by man (Burton and Macdonald, 2011; Laarmann et al., 2009; McRoberts et al., 2012; Reif and Walentowski, 2008; Winter, 2012). The concept of naturalness is closely linked with the concept of **hemeroby**, expressing the degree of human influence or artificiality on ecosystems (Reif and Walentowski, 2008; Winter, 2012). The exact relationships between both terms may vary, but overall these concepts tend towards opposite ends of the same scale. At the same time, their valuations accentuate or evaluate different aspects of an ecosystem, for which they are considered complementary, though not interchangeable, terms (McRoberts et al., 2012; Winter, 2012). In this manuscript, I will only refer to the concept of naturalness with regard to forest ecosystems, as will be outlined in the contextualization section.

It may be apparent that the naturalness and hemeroby concepts accentuate a nature-culture opposition by placing nature and human intervention at the extreme ends of the same axis. This nature-culture opposition therefore is the most common objection to naturalness as a nature conservation objective (Siipi, 2004). This formal opposition is for example demonstrated to be problematic for management practices aiming to enhance 'naturalness', thereby adopting specific intervention practices, e.g. close-to-nature forestry (Laarmann et al., 2009). Nevertheless, it is not the presence of culture per se that is put in opposition to a natural state of an ecosystem, but the degree of anthropogenic influence and dominance on its functioning, composition and structure. In practice however, as a valuation of ecosystem dynamics and processes can be a complex given, there exists a tendency to focus predominantly on the degree of human activities (i.e. on hemeroby concept) when assessing naturalness (McRoberts et al., 2012).

When performing or facilitating ecological restoration, historic, contemporary or future **reference ecosystems** are often employed to set the ecosystem on the *right* ecological track. It may be clear that the choice for a certain reference system is not solely based on ecological insights, but also reflects which elements or landscapes are mostly valued by the concerned actors, decision-makers and ecosystem managers.

Box 2. Naturalness, the sense of gradients

Regarding natural environments, it makes little sense to talk in dichotomist terms about what is truly natural and wat is not (Carver, 2016; Cózar-Escalante, 2019; Hettinger, 2014). In this respect, Taylor (1996) fairly wondered 'if there is no real purity, why be purist?'. Nevertheless, natural environments can vary in their *degree* of human influence, dominance and management (Bratman et al., 2012). It can thus be useful to talk about the degree of naturalness of an ecosystem, as opposed to a state of naturalness (Winter, 2012). In the aforementioned continuum from entirely natural to entirely artificial, the first refers to a hypothetical situation of an ecosystem that is zero percent modified by human activity (Winter, 2012), see figure 1.

With respect to forest ecosystems, this natural-artificial continuum ranges from pristine or primeval forests (which are distinct from virgin forests, the latter term referring to an inexistent state of "pure naturalness" (Hallé in Vidard, 2020; Winter, 2012) over near natural/intact and semi-natural forests to conventionally managed forests and finally to tree plantations (McRoberts et al., 2012). Historic or contemporary reference ecosystems are denoted in order to create this hypothetical construct of what a pristine forest would look like nowadays.

The concept of naturalness in a forest context has been proposed and used for several purposes. Firstly, in order to describe the ecological value of a forest; secondly, to use as a basis for the evaluation of management efforts aimed at maintaining or restoring forest biodiversity (Fischer and Wal, 2007; McRoberts et al., 2012; Winter et al., 2013); and third, as an indicator to identify old-growth forests as priority zones for establishing protected areas (McRoberts et al., 2012; Winter et al., 2013).

Even though a common approach for naturalness assessments of forests is lacking (Fischer and Wal, 2007), it has been identified as one of the seven sustainable forest management indicators by the Ministerial Conference on the Protection of Forests in Europe (MCPFE, 2003), which underpins the importance of this concept for forest management (Winter, 2012).

Figure 1. Gradients of naturalness (Winter et al., 2013)

Another concept that has recently gained in popularity amongst conservation scientists in order to tackle the biodiversity crisis and at the same time enhance ecosystem service delivery is **rewilding** (Jepson and Schepers, 2016; Jørgensen, 2015; Lorimer et al., 2015; Svenning et al., 2016). Again, a variety of definitions exist (see table 1 and box 3), but most often, rewilding, both as a concept and as a practice, is defined as aiming for restoring natural processes and dynamics of ecosystems such that they are functional without human intervention (Svenning, 2020). Regarding the discussion on a nature-culture dualism, some authors criticize the rewilding concept for further enhancing this duality by excluding culture and society from rewilding projects and ideals, thus withholding potential sources of conflict (Linnell et al., 2015; Swart et al., 2001).

Others on the contrary point out the recent explicit inclusion of the human dimension of the rewilding concept, in comparison to previous concepts such as naturalness and re-naturalization (Jepson and Schepers, 2016; Monbiot, 2014). This human dimension can be understood as pursuing a non-disruptive relationship respective to natural processes and dynamics, and thus proclaiming an acceptance of a non-control situation of humans over the non-human world (Tănăsescu, 2019). In this sense, rewilding is thus not a negation of the longstanding influence of humans on the structure and functioning of ecosystems (Ellis et al., 2021), but rather challenges the current hegemonic influence of human activities, which is how I interpreted the concept of rewilding within this manuscript.

As far as the supply of ES is concerned, Genes et al. (2019), point out a pitfall of explicitly using rewilding to enhance the delivery of ecosystem services. It might reorient the focus of rewilding on desired ES instead of on the original goal of biodiversity conservation, restoration and ecosystem resilience. Tensions around rewilding as a practical toolkit within an ES framework majorly relate to the main conceptual difference between these two popular strategies: ES as an anthropocentric approach, which focusses on the ES that are relevant for their human use, and rewilding as an eco-centric approach that focusses on restoring natural processes and dynamics, whilst including a focus on the reconciliation between humans and wild (read non-dominated) nature (Sandom et al., 2013).

Nonetheless, both the ES conceptual framework and the concept of rewilding have found a broad uptake in policy making and in public debate about ecosystem recovery (Pettorelli et al., 2018). While rewilding is by some understood as increasing the level of naturalness of an ecosystem (Jepson and Schepers, 2016), others point out the differences in interpretation of these concepts, which according to Ridder (2007) can be framed as "protecting biodiversity [increasing naturalness] versus respect for nature's autonomy [rewilding]". In this sense, the degree of naturalness is measured against a (historical) reference landscape, whilst the degree of wilderness is measured against the autonomy of natural processes and evolves towards an open-ended landscape instead (Peterson, 2008; Ridder, 2007).

Depending on the point of departure, this can result in so-called **novel ecosystems** (Corlett, 2016), also referred to as **feral** nature (Génot, 2017; Génot and Schnitzler, 2013). In practice however, there is a lot of overlap between both naturalness and rewilding concepts, with the overall common aims to minimize interventions and increase autonomy in order to restore natural processes in respect to, though not as a copy of, a reference ecosystem (Corlett, 2016; Jordan, 2020).

Both rewilding and increasing the degree of naturalness thus aim for the restoration of self-regulating ecosystems, which on a theoretical notion contrasts with the concept of **interventionism**, where human intervention is considered necessary to maintain and improve biodiversity (Van Meerbeek et al., 2019). Interventionism has traditionally been the principal modus operandi for nature conservation in Europe, while focusing on the conservation and restoration of specific species and habitats (Schenck, 2015).

In reality however, most ecological restoration projects, even if autonomy is the goal, rely on initial human intervention, such as the reintroduction of large herbivores (as part of an active rewilding approach) or the eradication of invasive species (to increase the degree of naturalness). Strategies aiming for an ecological restoration are by definition intentional activities (Gann et al., 2019), but address the whole range between entirely passive and entirely active restoration, depending on the level of human intervention. The natural recovery of an ecosystem falls therefore under ecological restoration as a passive approach if it is part of a deliberate plan to facilitate ecosystem recovery (Gann et al., 2019).

Box 3. Finding a way through the wilderness: about rewilding and the wild

Seen by some as a constraint (Jørgensen, 2015), by others as an opportunity (Prior and Ward, 2016), the plasticity of the term "rewilding" has triggered a series of publications on the definition of this concept. Table 1 summarizes the evolution and understanding of the term throughout the last decades. Rewilding, apart from a concept, also is a practice (Tanasescu, 2017) that aims to decrease human interventions and to increase ecosystem autonomy in order to (re-) obtain self-regulating and spontaneously developing ecosystems (Corlett, 2016).

Irrespective of the specific approach or definition employed, ecological functional restoration and autonomy are key principles to rewilding (Blewett, 2016). Rewilding is not synonymous to wilderness, as it is not a state, but a process aiming to increase the degree of wilderness. Its applied approaches concern a continuum ranging from high input restoration to entirely passive rewilding, with most field applications being situated at some distance from these ends (Corlett, 2016; Jepson and Schepers, 2016).

Wilderness is caricaturized by free functioning natural processes (such as stochastic disturbances, dispersal and trophic complexity), largeness and the absence of human interventions (Chapman, 2006; Corlett, 2016; Perino et al., 2019). This ideal state of wilderness, is often not feasible due to a variety of reasons, whether they are ecological, practical, social or political (Lorimer et al., 2015). Therefore, despite the goal of some rewilding projects to recreate a Pleistocene ecosystem, rewilding projects evolve towards some new ecosystem state (Lorimer et al., 2015), thus in other words an evolution towards self-regulating ecosystems, but not to an area devoid of human presence (Woods, 2005). This open-ended evolution is why some authors prefer the term wilding (Carver, 2016) and wildness.

It should be noted that invasive species represent an unsolved debate among rewilding advocates (Brackhane et al., 2019), since the invasion of exotic species can be regarded as a wilding event, but are at the same time harmful to local biodiversity. In this sense, it is often proposed that rewilding efforts should be aimed to improve ecosystem resilience, while controlling the level of invasive species in the meanwhile (Perino et al., 2019).

Remark also that wilderness, while increasingly being regarded as something worth full to promote, has a less positive history. At its first appearance in the German literature in the fifteenth century, it was synonymous to remoteness, deserted areas and the badlands, and indicated the absence of culture and humanity (Kirchhoff, 2019); wilderness, associated to wasteland, uselessness, ugliness and desolation, was therefore something to avoid (Schenck, 2015).

Table 1. Different rewilding approaches as described by the literature. Adapted from Corlett, 2016; Hayward et al., 2019; Jørgensen, 2015.

Rewilding approach	Definition and Key elements	References
Rewilding through three C's: Cores, Corridors, Carnivores	Rewilding as one essential element in efforts to restore fully functioning ecosystems through the reintroduction of keystone predators and ensuring that they have a sufficient interconnected space.	(Soulé and Noss, 1998)
Pleistocene rewilding	Also called Pleistocene mega-fauna replacement. Restoring ecological processes to a pre-human Pleistocene baseline via the translocation of extant, ecologically equivalent species.	(Donlan et al., 2006)
Island rewilding	Also called island taxon replacement. The translocation of substitute species to fill vacant ecological niches left by extinct species.	(Hansen et al., 2008)
Passive rewilding	A consequence of land abandonment when natural succession is allowed to follow its own course with the unaided colonization of wild species. Characterized by little or no human interference.	(Navarro and Pereira, 2015)
Trophic rewilding	The restoration of top-down trophic interactions and cascades via translocations or species (re-) introductions.	(Svenning et al., 2016)
Ecological rewilding	Allowing natural processes to regain dominance in order to restore ecological functioning.	(Corlett, 2016)
Rewilding	The re-organization of biota and ecosystem processes to set an identified social–ecological system on a preferred trajectory, leading to the self-sustaining provision of ecosystem services with minimal ongoing management.	(Pettorelli et al., 2018)

Bearing all these considerations in mind, the adopted management strategy for a certain ecosystem and the consequences of this governance for the ES delivery of the ecosystem, can neither only be seen as the outcome of (restored) biophysical processes, nor as the simple result of tradeoffs emerging from consensus-based decision-making within a socio-ecological system. Ecosystem management and the ES the ecosystem provides indeed also result from discourses, value-articulations and political struggle (Ernstson, 2013).

A **discourse** constitutes an ensemble of ideas and concepts that reflects a shared way of seeing things and of giving meaning to certain phenomena (Chaudhary et al., 2015; Hajer et al., 2006). Adherents of a certain discourse use a specific language when talking about events, which is based upon a common set of definitions, judgments, assumptions and opinions. These have been constructed to frame a discourse and allow for interpreting information in a specific way.

Narratives or story lines that build up a discourse are mobilized to promote a particular interest or point of view, to provide it with legitimacy, to enhance a certain view of reality, to suggest social positions and practices and to criticize or disempower alternative arrangements (Dryzek, 2005). Different discourses construct and interpret phenomena in different ways, but there is usually one institutionalized discourse with a particular claim of power, e.g. the dominance of democracy as the legitimate form of government.

Discourse institutionalization refers to the process by which certain ideas become accepted as 'commonsense' and crystalize in a particular institutional arrangement (Hajer et al., 2006). This does not necessarily happen within concrete institutions, but rather refers to the structuration of decision-making and the shaping of social behavior in such a way this occurs within the logic of one specific discourse, cfr. hegemonic thinking (Río and Ruiz-Ballesteros, 2019). The norms, guidelines, conventions and procedures that make up the institution enable or constrain particular ways of thinking or acting (Chaudhary et al., 2015). As a consequence, the institutionalized discourse becomes the dominant one, while alternative discourses are confronted by societal lock-ins that advantage the dominant reasoning. For example, dominant interests are reinforced by existing systems of law, education and media communication (Dryzek, 2005; Hajer et al., 2006). This makes it very hard to move outside of this dominant discourse and to induce changes to current policies and practices. Especially since discourses are not necessarily actively mobilized, but also "condition the perceptions and values of those subject to them" (Foucault in Dryzek, 2005).

Nevertheless, actors cannot be considered to be entirely controlled by discourses either (Uggla, 2017). Marginalized discourses potentially offer places where the truth-status of the dominant discourse can be contested and challenged (Goswami, 2014). This can be done by detecting flaws or internal divisions within the dominant discourse (Dryzek, 2005) and by processes of value-articulation (Ernstson, 2013). The contesting of hegemonic thinking is not a quest for some absolute truth, but rather a search for "detaching the power of truth from the forms of hegemony -social, economic, and cultural- within which it operates at the present time" (Foucault and Rabinow, 1991).

Hence, discourses can both represent power (as an instrument and as an effect, in the sense that discourses are shaped by actors and the other way around) and resistance (in the margin and as a starting point of potential new narratives) (Uggla, 2017).

With respect to nature conservation and ecosystem management, the ES concept can be regarded at as an environmental discourse that has acquired a dominant and hegemonic position to address human-nature relationships. Regarding the specific issue of ES management, environmental discourses shape the meaning that is given to a certain place or ecosystem. This results in certain meanings, and thus certain ES, being privileged over others. Dominant discourses on the management of specific ecosystems may have normalized certain socio-ecological processes and practices over time, such that alternative meanings and practices can be difficult to imagine (Masterson et al., 2019). Lock-ins create self-reinforcing dynamics, such as regulations or cultural norms that facilitate certain activities and meanings. Place-attachment has for example been identified as a potential barrier for inducing changes in ecosystem management in order to cease its degradation (Masterson et al., 2017a; Métris, 2019). Hence, place-attachment to a certain landscape results from the meanings this landscape embodies and it are those meanings which are sought to preserve (Masterson et al., 2019). People with a strong place-attachment may however seek to preserve distinct place-meanings than those aimed for by envisioned management changes. On the other hand, place-attachment has also been identified as a lever for change (Malmborg et al., 2021).

The interpretation of what is important or of meaning about a place is framed and self-reinforced by the dominant environmental narrative (Masterson et al., 2017a). While various place-meanings might co-exist, only dominant meanings are considered as legitimate. Actual land use and the prioritization of certain ES in the ecosystem management is contested within so called action arenas (Barnaud et al., 2018). This refers to "the social space where participants with diverse preferences interact, exchange goods and services, solve problems, dominate one another, or fight (among the many things that individuals do in action arenas)" (Ostrom, 2005). It follows from this aspect that if shared meanings are a condition for building consensus and to foster transformative collective action (Chapin et al., 2012), identifying the wider range of meanings is key. It could indeed lead to questioning dominant meanings, as well as the consequences of their practices, and form a starting point to escape these lock-ins (Masterson et al., 2019).

The use of the ES conceptual framework could address these **user-conflicts** and potentially facilitate the discussion by visualizing which meanings and functions are important to whom and which evoke debate (Barnaud et al., 2018). However, as aforementioned, the framework has also been criticized for neglecting power-relations between actors concerned with natural resource management and use. The socio-ecological co-production of ES results in trade-offs and synergies among ES, as well as among beneficiaries (Bruley et al., 2021; Howe et al., 2014), which can occur both spatially and temporally (Rodriguez et al., 2006). Ecosystem managers and regulatory institutions are therefore powerful players in the generation of potential trade-offs and synergies (Bennett, 2009), with ES beneficiaries dependent on their management, both for ES provisioning and for its distribution (Bruley et al.,

2021; Vallet et al., 2020), see also Box 1. It is therefore elementary for ES valuations to contribute to both ecologically and socially sustainable ES management and decision-making, to take into consideration the multitude of concerned actors and their mutual social positioning.

In this context, Fischer et al. (2017) call for more **multifunctional landscapes**, characterized by various functions in space and time (Haines-Young and Potschin, 2004), under the assumption that in multifunctional landscapes, "a more diverse set of ecosystem services is accessible to a broader range of beneficiaries". The focus in the last decades has on the contrary been put on the maximization of single production ES, e.g. intensive agriculture to maximize crop production. This resulted in a decrease of the diversity of ES provided by ecosystems (Duarte et al., 2020; Fagerholm et al., 2020). Multifunctional landscapes are seen as part of a *land-sharing* approach (Fischer et al., 2017), in opposite of *land-sparing* approaches, the latter proclaiming the maximization of certain ES in certain areas, while other areas are set aside for biodiversity conservation in space and time. The latter proposition in its extreme form is however based on a false dualism, since a.o. it ignores the multiple ES natural ecosystems provide (Felipe-Lucia et al., 2018), and presumes a non-detrimental effect of maximization areas to neighbor conservation areas.

(Re-)enhancing the multi-functionality of landscapes has been put forward as a way to manage trade-offs and synergies between different ES mutually and between the provisioning of ES and biodiversity conservation (Fagerholm et al., 2020). It could thus also be viewed as a way to enhance sustainable development and as well as minimize user-conflicts by providing multiple benefits to different user groups (Duarte et al., 2020; Fagerholm et al., 2019). Multifunctional landscapes are thus said to be prone to so-called win-win solutions, that produce positive outcomes both in terms of service production, biodiversity objectives and social acceptance. The concept of multifunctional landscapes has therefore found its uptake in diverse policy documents concerning spatial planning and ecosystem management (Fagerholm et al., 2020, 2019).

Despite the appeal of so-called 'win-win solutions', in reality, the win-win scenario rather seems to be the exception instead of the rule (Howe et al., 2014; Turkelboom et al., 2018). Instead, trade-offs between ES, nature conservation and various actor (groups), represent a more realistic picture of the situation on the field. Case-study analyses suggest that the main indicators for trade-offs to occur include the following: (1) at least one of the concerned actors has a private interest in an ES, with trade-off winners representing the private interest and trade-off losers representing the public interest in the same or in competing ES; (2) rivalry over production ES are more prone to trade-offs compared to other types of ES, with the winner benefitting from the specific production service and the loser having a broader ES user-profile (Howe et al., 2014).

In this sense, it has been suggested that taking a more realistic trade-off perspective as a starting point for negotiations and decision-making on ES policies and management might better allow for avoiding tensions and conflict than when starting off from a win-win perspective (Howe et al., 2014). In order to do so, ES valuations should focus on bundles of ES within a same socio-ecological system, rather than on single ES (Bennett et al., 2009). ES bundles are constituted by the different ES for which a –diverse- demand was identified and may serve to underline the fact that ideal bundles can vary and that the maximization of all ES simultaneously is utopic, due to biophysical, social and economic constraints (Howe et al., 2014). Hence, the proclaimed advantages of multifunctional landscapes, depend on the interpretation of multi-functionality by policy makers and site-managers, the bundle(s) of ES under question, the attended quality of those ES, the ruling power relations regulating the co-production and access to those ES, as well as the interdependencies of those ES with non-considered ES.

The generation (read co-production) and distribution (read accessibility) of a certain set of ES thus results from various intertwined political socio-cultural processes through the practices of actor-networks with a different level of influence (Ernstson, 2013).

b) Contextualization

During the last decade, forest ecosystems have received considerable attention, both in academic research as well as in policy making and during public debate (Primmer et al., 2020). This attention concerns their roles in mitigating climate change, their qualification as biodiversity hotspots and habitats for a wide variety of species, their forest products or the possibility of using them as sources of green energy, the benefits they bring to mental health, their touristic attractiveness, their patrimonial significance, their spiritual meaning, etc. In short, for the ecological interest they represent for nature conservation in se, as well as for the gamma of ecosystem services that forests provide to humanity, with the latter depending on the first. Nevertheless, a decrease in forest biodiversity has been observed worldwide, due the degradation and/or destruction of forest ecosystems (Foley et al., 2005), which in turn negatively impacts service provisioning (Felipe-Lucia et al., 2018).

European landscapes typically are highly fragmented and contain high population and infrastructural densities (Krumm et al., 2020). Once dominated by forests, the European continent underwent a gradual transformation from 'wild woodlands' towards so-called 'cultural landscapes' (Wallenius et al., 2010; Winter et al., 2013) to such an extent that hardly any primary forests remain (Welzholz and Johann, 2007). Today, forests make up 35 percent of Europe's land surface (FOREST EUROPE, 2021), ranging from Mediterranean broadleaved evergreen and thermophilic deciduous forests to the deciduous lowland and conifer-dominated mountain forests of Central Europe as well as to the boreal forests in Scandinavia (Larsson et al., 2008). Forests in Western and Central Europe have been subject to more intensive human interventions compared to forests in Northern and Eastern Europe (Burton and Macdonald, 2011). So have most of the forests in Western Europe been replaced by fields, pastures and moors by the end of the 19th century (Kandler, 1992; Kauppi et al., 2006).

Numerous studies indicate that natural forest ecosystems, compared to highly intervened forest plantations, are more resilient ecosystems, provide a wider range of ES and contain higher levels of biodiversity (Carnol et al., 2014; Sabatini et al., 2018; Winter et al., 2013). European forest cover has been expanding during the 20th and 21st century (Rudel et al., 2005), however, only about 0.7% of European forests, are left to develop without any human intervention (Bollmann et al., 2020; Sabatini et al., 2020; Winter et al., 2013) and only 14% of Europe's forests is in a favorable condition (FOREST EUROPE, 2021).

European forest management has traditionally been oriented towards timber production and this has remained the governing principle in most of Europe (Wallenius et al., 2010; Winter et al., 2013), with re- or afforestation actions in the Mediterranean region also targeting the ES erosion control and flood protections (Eekhout et al., 2020; Vallejo, 2005). The structure and composition of the European forests have been greatly altered by forestry practices aiming at a maximization of

majorly wood production as a single ES. This typically occurred through a focus on even-aged homogenous forest stands consisting of a few marketable tree species and the forests being subject to thinning and felling, well before their age of senescence (Felipe-Lucia et al., 2018; Wallenius et al., 2010). In general, this type of forest management causes a reduction in the supply of several other ES, such as carbon sequestration, water retention and aesthetic appreciation, affects the forest's resilience and generates biodiversity loss (Felipe-Lucia et al., 2018). Concerning the proportions of different types of forest stands (un-even aged, multiple/single-species …) and their type of management (intensively, semi-natural, primary) relative to the total surface of European forests, contradictory numbers can be found in different reports and studies (e.g. European Environment Agency, 2016; FAO and UNEP, 2020; FOREST EUROPE, 2021, 2015; Winter et al., 2013); this observation emphasizes the need for improved indicators on forest naturalness and/or measurements methodologies as also pointed out by Winter (2012).

In the recently published biodiversity strategy and forest strategy of the European Union for the period 2020-2030 (European Commission, 2021, 2020), a strong emphasis is placed on protecting existing natural areas, with a special focus on remaining European old growth forests, and, in second instance, on restoring degraded ecosystems, among which forest ecosystems. Therefore, the aim is set to mainstream biodiversity conservation into overall forest management practices in order to also restore biodiversity outside strictly protected areas by integrating structural attributes (e.g. habitat trees, standing deadwood, …), that enhance the ecological functionality of forest ecosystems (Bollmann et al., 2020).

Several authors (Cardoso et al., 2007; Trombulak et al., 2004; Winter, 2012) have been calling for more emphasis on maintaining and increasing the degree of naturalness of forests as a goal for their conservation, restoration and management (Landres et al., 1999). Hence, restoring natural characteristics of forests is by some seen as a potentially effective way to cease biodiversity loss and to alleviate the negative impacts of previous forest management on forest biodiversity and functioning (Kouki et al., 2001; Similä et al., 2002).

It is worth noting that there is thus no such thing as a natural forest or a non-natural forest. However, forests can be qualified as more and less natural forests, depending on their characteristics, land use history, the processes allowed, etc. More natural Eurasian forests typically contain high levels of deadwood, old trees, cavity trees, multilayered strata, a diversity of indigenous (tree) species, and show little signs of human intervention (e.g. selective thinning and cutting, clear-cut regimes, supplementary game feeding) (Wallenius et al., 2010). Although the vision of what European forests would have looked like without humans used to refer to a continuous and dense forest cover, this image has increasingly been challenged by a more open parklike landscape (Vera, 2000). While the discussion over the actual density of forest cover without human intervention appears somewhat endless, the image of a stable climax vegetation has made way for a more dynamic forest ecosystem that evolved under natural disturbance regimes (Bengtsson et al., 2000). In this sence, a more

natural forest contains spatial and temporal heterogeneity, including more open forest patches due to the natural dynamics and processes, such as e.g. flooding or browsing. Examples of these processes include fire, wind throws, pests, natural regeneration, grazing and browsing, predation, succession, etc. (Bengtsson et al., 2000; Kulakowski et al., 2017). In today's forests, a lot of these processes and dynamics are lacking, strongly restrained or altered (e.g. by tree plantation, tree species selection, fire control, pest control, hunting, feeding, etc.). At a European scale, the most natural reference system that still exist is the primeval Bialowieza forest located at the border of Poland and Belarus (Brzeziecki et al., 2020).

In addition, the majority of the megafauna once present on the European continent is today missing or gone extinct, such as the woolly mammoth (Mammuthus primigenius, extinct about 10,000 years ago), the straight-tusked elephant (Palaeoloxodon antiquus, extinct about 30,000 years ago) or the woolly rhinoceros (Coelodonta antiquitatis, extinct about 14,000 years ago) (Roca, 2020; Stuart, 2005), but others have survived until fairly recently such as the auroch (Bos primigenius, extinct in the 17th century) and the tarpan (Equus ferus ssp., extinct in the 19th century) (Cromsigt et al., 2018; Sommer et al., 2011). The European bison (Bison bonasus) now numbers a few thousand individuals scattered throughout Europe after having been on the verge of extinction at the beginning of the 20th century (Vasile, 2018).

Apart from these ecological insights on forest functioning, the importance of human values and preferences for nature and landscapes, more than ecology itself, has by several authors been put forward as being crucial for the success of nature conservation and for the acceptance of a changed management of ecosystems (Ernstson, 2013; Hayward et al., 2019; Meijaard and Sheil, 2011; Van Meerbeek et al., 2019).

Forest management is sometimes framed as withholding a management dilemma between production and nature conservation. However, this dualistic opposition oversimplifies public regards towards forests (Anderson et al., 2018). A whole wider range of values and functions shape current expectations regarding forest management (Sandström et al., 2011; Sing et al., 2018). Increasingly, expectations regarding forest functions and ES have shifted from a timber-production focus to a greater emphasis on forest protection and conservation and a wider variety of ES (Rametsteiner et al., 2009; Ranacher et al., 2020).

Multiple and often conflicting demands require different policies and management approaches taking into account this variety of demands (Lazdinis et al., 2019). In Europe, forest related conflicts have indeed been identified as being due to changing demands regarding (1) the intensification of forestry operations, (2) increasing recreational needs, and (3) the increased importance of the environmental movement (Niemelä et al., 2005). The increased concern of society about forests and their management implies the need for discussions on the values of underlying opposing demands as well as the need to seek consensus strategies that correspond to those

values; these strategies are not only technical but also political and cultural (Niemelä et al., 2005).

The acknowledgement of the increasing importance of ecological values and other forest functions, relative to timber production, has generated a shift in European forest policies since the 1970s and has promoted the concepts of sustainable forest management and multifunctional forests, including economic, but also social and environmental goals (Carnol et al., 2014; Uggla, 2017). This rhetorical multi-functionality, outlined in policy objectives, as well as the mainstreaming of biodiversity conservation in forestry practices, can however be easily watered down when examining its field implications (Krumm et al., 2020; Winter et al., 2013). For example, main pre-occupations of European forest owners, as demonstrated by Uggla (2017) still concern thinning and replantation practices, which, according to these forest owners, constitute well-managed forests and contribute to aesthetic appreciation, thus largely complying with a multi-functionality demand. Environmental responsibilities are acknowledged as something important by private forest owners, but are generally not put into practice (Uggla, 2017). Also Deuffic et al. (2018) point out that while European forest owners recognize multi-functionality as the dominant narrative for forest management, it is always considered possible to align their business-as-usual timber-oriented practices with this definition. The adoption of the term multi-functional forests in policy guidelines on forest management did thus not result in the preset win-win solution, that was aimed for.

Several studies have demonstrated that forest monocultures are less resilient and less performant in terms of service provisioning, compared to mixed forest stands (Cannell, 1999; Felton et al., 2016; Fleming and Freedman, 1998; Liang et al., 2016). However, while in general the wider public esteems that monocultures do indeed provide less cultural and regulating ES, they do not consider that this relation holds true for productive ES (Almeida et al., 2018). This belief is also shared by forest practitioners (Carnol et al., 2014). At the same time, European forest practitioners are increasingly concerned about the resilience of their monoculture forest stands and their current and future production capacities in the light of climate change and natural disturbances (Coll et al., 2018). These insights highlight a communication gap concerning the science-practice (and vice versa) interface (Almeida et al., 2018).

These brief examples, and their consequent outcomes in terms of the forest management being implemented effectively, remind of the power differences between managers and beneficiaries, leading to an unequal distribution of forest ES. Still, upstream environmental policies contribute to framing these on-the-ground misconceptions on forest multi-functionality. An analysis of the European institutional landscape of forest ES provisioning by Primmer et al. (2020) revealed that policy innovations focus on existing value chains of production ES, while other ES, such as non-wood products, recreation and various regulating ES receive fairly little attention, in contrast to the discursive sustainability and multi-functionality narrative. In this regard, an EU commissioner, entrusted that the proposition to use the term “close-to-nature forestry”, a forestry practice aiming for minimizing human

interventions and taking an exosystemic perspective, in the new EU strategy on forest management encountered a fierce opposition from the majority of commissioners, such that the vague term 'sustainable forest management' was retained in the official document, a term which does not put any emphasis on intervention restrictions (BirdLife Europe and Central Asia, 2020; European Commission, 2021).

c) Case study

As will be further detailed in the next section, this research takes place within the AGRETA - Ardenne Grande Région Ecotourisme et Attractivité - project (Interreg V GEIE - AGRETA (visitardenne.com)), which is a European-funded interregional project that aims to promote ecotourism ES in the Ardenne region.

The **Ardennes** are a forested area crosscutting the Belgian, Luxembourgian and French borders. The focus throughout this manuscript will be on the Belgian Ardenne, which is situated within the Walloon region[1]. Forests cover about 33% of Wallonia, which makes them an important element of the Walloon landscape. the forest cover in the Belgian Ardenne is even 58% (Blerot and Heyninck, 2017). Throughout this manuscript and unless specified otherwise, when using the word Ardenne, in the singular, I refer to the bio-geographical region of the Ardenne in Wallonia, plus the Walloon Jurassic region (Lorraine), which was added to the visual representation of the Ardenne to survey respondents (see below) because of the partner configuration in the AGRETA project.

From the middle ages and the early modern times onwards, three main practices related to human activities put pressure on the Walloon woodlands: the use of forests for the grazing of domestic livestock; cutting and coppicing for firewood and the use of wood for construction (Belayew, 2018). A pressure that accelerated during the 18th century due to the production of charcoal for local forges and other industrial puroposes, which caused a shift from coppice forests to high forests (Belayew, 2018). Since the 18th century, agricultural expansion, in combination with a significant demographic growth, also led to a decrease in forest cover. From the 19th century onwards, the industrial revolution caused an exponential timber demand, especially related to the mining industry and the associated construction of railroads (Blerot and Heyninck, 2017; Filot, 2005; Jacquemin et al., 2014). The ensuing reduction in forest cover reached its peak towards 1850.

In contrast, the 20th century has seen the intensification of agricultural practices and the liberation of less productive cultivated soils. These allowed for large plantation campaigns, promoted by the Belgian government (Jacquemin et al., 2014) and operationalized by the forestry administration, established in 1856. The forestry administration was mandated to protect and manage Belgian forests, while adopting interventionist techniques, such as draining systems, the introduction of exotic

[1] In Belgium, nature conservation and management falls under regional jurisdiction

species, monospecific plantations, etc. (Kervyn et al., 2018). These events contributed to a regain in Walloon forest cover, with an increase of 60% of forested land between 1850 and 2016 (Blerot and Heyninck, 2017).

However, while originally the Walloon forests were deciduous forests dominated by oak (*Quercus spp*.) and beech (*Fagus sylvatica*), the above events have led to the substantial presence of coniferous plantations, mainly consisting in pines (*Pinus sylvestris*) and later spruce (*Picea abies*), both exotic tree species to the Ardenne region. Nowadays, 43% of the Walloon forests consist out of coniferous forests, of which 30% concern spruce trees (Alderweireld et al., 2015; Jacquemin et al., 2014). Today, the Walloon forests are predominantly organized in regular forest stands (even-aged plantations), and 60% of the forests stands are mono- or bi-specific (one or two dominant tree species) (DGRNE, 2017).

Figure 2 shows a schematic representation of these briefly described alterations and composition of the Walloon forest cover since the 18th century (Kervyn, 2020).

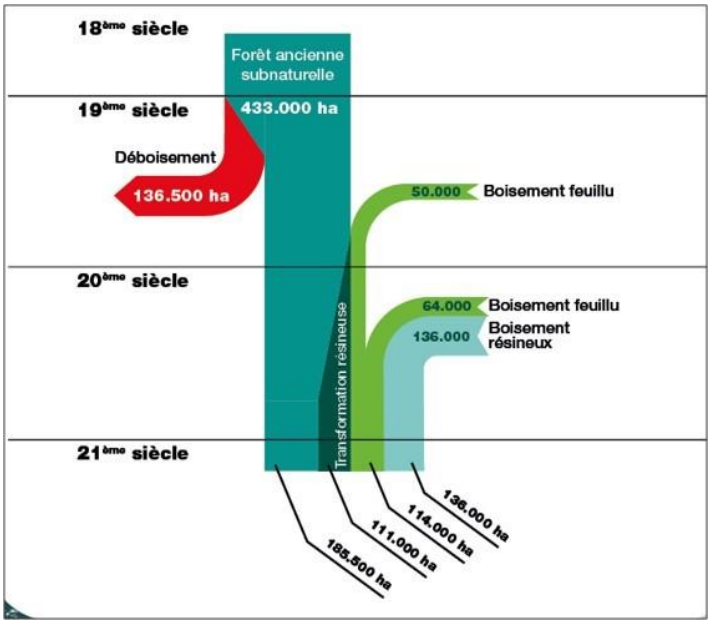

Figure 2. Evolution of the composition of the Walloon forest cover (Kervyn, 2020)

The overall ecological condition of the Walloon biodiversity shows a rather negative image as outlined in the last report on the condition of the Walloon environment (DGRNE, 2017) or as evident by the joint call of 270 Belgian scientists to urge decision-makers to take measures on the enduring erosion of biodiversity (VRT, 2018). This decline also concerns the forest ecosystem. As an example, the WWF claimed that, between 1990 and 2018, Belgian forest biodiversity declined by

about 26,6%; the Walloon forests more specifically show a decline of 1,8% per year (WWF, 2020). Among the larger fauna currently present in the Ardenne forests, we can find the beaver (*Castor fiber*) (with rising population densities since it has been illegally reintroduced in the late nineties) (Forêt & Naturalité, 2021a), the wolf (*Canis lupus*) and the lynx (*lynx lynx*) (the latter two which have made their recent return, but who are currently present in too low densities to perform an ecologically structuring role), and the game species wild boar (*Sus scrofa*), roe deer (*Capreolus capreolus*) and red deer (*Cervus elaphus*) (all three which populations are artificially regulated) (Bailly, 2018; Graitson et al., 2019).

Currently, 33% of the Walloon forests are considered as old growth forests, thus representing a specific ecological interest and 29% of the Walloon forests fall under the European Natura 2000 legislation, which implies certain management restrictions and obligations (Kervyn et al., 2018). Nevertheless, the evolution of habitat conservation in the N2000 network is said inadequate for 45 % and unfavourable for 55%. (Wibail and Farcy, 2018). While 20% of the Walloon forest area can be classified as representing fragile and marginal soils, where timber exploitation is not profitable and causes large ecological damage (Blerot and Heyninck, 2017), solely about 1% of the Walloon forests concern integral forest reserves, which means they are preserved from timber exploitation (SPW, 2019). Regarding the latter type of reserve, the obligation to dedicate 3% of the surface of the broadleaf forests owned by public entities to integral forest reserves was added to the revised forestry code in 2008. Nevertheless, these reserves do not have a strong legal protection status which weakens the presupposed positive ecological impact of this measure.

Regarding forest ownership, about half of the forests are owned by public bodies and managed by the Regional nature and forestry service (DNF - Département de la Nature et des Forêts); the other half is owned by private actors. The Forest Code outlines the management obligations and restrictions for both. Access to the forests for the wider public is guaranteed on public roadways, whether these are situated in private or public forests, in contrast with private roads where public access is not allowed. Also, it is mandatory for the public to stay on the forest roads and paths, trespassing is not allowed. Regarding forest visits, the Belgian Ardenne are a popular recreational and touristic destination, especially for the 6 million of people living in a buffer radius of 100km around this area (Colson et al., 2010a; De Valck et al., 2016). The mosaic of forests, villages and agricultural lands, the heterogeneously located tourism offer and the multiple entry and exit points to nature areas, make that the region may be recognized as a dispersed tourism hot spot (De Valck et al., 2016), which implies that visitor frequencies are dispersed over different zones of interest throughout the landscape.

While, especially at the communal level, revenues from timber and game remain important, eco-tourism is increasingly seen as an alternative strategy to stimulate the local economy in a way that aligns with biodiversity conservation objectives (Laurent and Lecomte, 2007). The contribution of overall touristic activities account for about 4 to 6% of the Walloon gross domestic product (GDP), which is up to ten times higher

than the overall contribution of the timber or hunting sector (Parlement de Wallonie, 2020; Région Wallonne, 2008). Moreover, the socio-recreational importance of the Walloon forests was inscribed in the Regional Policy Declaration after the regional elections of 2019 (Région Wallonne, 2019).

The different actors present within the Ardenne forests and concerned by its management can classically be divided into the following broad groups: private forest owners, public forest owners (the Walloon region and the municipalities mostly), forest managers (i.e. the DNF for public forests), forest loggers, hunters, forest visitors and naturalists (i.e. persons adhering to a nature association or with a specific interest in nature). Obviously, these actors hold different interests and expectations regarding the functions the Ardenne forests should comply with, which causes tensions and might induce conflict.

In addition to these different forest visions, the influence of forest actors on effective forest management policies and practices depends on their profile. Powerful actors own their influence to their official state mission, which is the case for the forest administration (DNF), or to their economic importance for the regional and/or municipal budget, whether in the form of wood sells or through the location of hunting licenses (Bodson, 2019a). This influence allows for nominating timber exploitation and hunting practices as *legitimate* forest usages. Nevertheless, changing societal demands, putting more emphasis on nature conservation and on forest recreation, accentuate tensions between different forests actors and challenge this proclaimed legitimacy (Bodson, 2019a; Filot, 2005).

The concept of multi-functionality was included in the revised forestry code in 2008 which proclaims by its regulations to "ensure the harmonious coexistence of their economic, ecologic and social functions" [translated from French] (Code Forestier, 2008). This inclusion was seen as a major progress as it represents an official and legal affirmation that forests have more roles to play than the sole production of wood. Still, while all forest ES contain ecological, social and economic aspects, this formulation seems predominantly interpreted as putting the economic function (note that this function was listed first) equal to wood and hunting revenues, the ecologic function equal to biodiversity conservation and, increasingly, carbon storage, and the social function equal to tourism and recreation (personal observation).

Interpreting the economic significance of a forest as being equivalent to the sole wood exploitation and hunting practices, bearing in mind the economic dependency of municipalities on forest revenues, further legitimizes the dominance of these functions over ecological and social functions of forests; the development of the latter functions being tolerated as long as they stay in the margin of the former (Bodson, 2019a). As such the adoption of the term "multifunctional" justifies a continued business as usual in (public) forest management. Thereby, it indirectly stresses the unequal power relations between actors typically considered as being more concerned by one of the three functions.

As outlined in the introduction, despite its shortcomings, employing the ES concept would allow to highlight the multiple roles and functions provided by the same landscape, as well as the interdependencies between them and thus to draw the attention to those ES and benefits that are otherwise ignored or minimalized in forest management decision making.

Considering the uptake of the ES concept in forest governance policies (e.g. as evident in the EU forest strategy, European Commission, 2021), I make use of the ES valuation framework to assess the socio-recreational function of the Ardenne forests in terms of visitor frequencies and landscape attractiveness. In parallel and in regard of the observed shortcomings of the ES concept, I underscore the importance of the Ardenne forests for the wider public by means of the socio-cultural value concept. By combining these both concepts, I operationalize an integrated ES valuation, which indeed allows for underlining the interdependencies between different forest functions and thus also between the various forest actors. This in turn allows for taking a critical look at current forest management policies and practices and their actuality within the current socio-ecological context, as well as at the use of the ES concept to frame human-nature relationships.

2. Research questions and general methodology

As aforementioned, the present PhD research takes place within the Interreg project AGRETA. This project includes eight different action groups around the topic of ecotourism in the Ardenne, working respectively on coordination, communication, marketing, sensitization, itinerary development, capacity building, mobilization and research. The latter research action group focuses on an evaluation of the attractiveness of the Ardenne landscape; it is within the context of this action group that data for the present manuscript have been gathered.

In total, the project counts eleven project partners among which several natural parks, tourism administration instances, a non-profit organization and two research institutes. During the implementation of the project, other instances (such as the forest administration service) also participated to the project. We have produced six outreach reports (five thematic reports and one summary report) based on the outcomes of the research action group, which we have presented to a large panel of actors (a.o. municipalities, nature organizations, tourism agencies, etc.) on four main occasions (see Figure 3).

Broad research objectives were defined at the start of the project, based on an observed knowledge gap concerning socio-recreational ES of the Ardenne forests. This knowledge gap will be further elaborated on and illustrated based on existing literature for each research question separately in the corresponding chapters of this manuscript. Due to the multitude of actors and profiles associated to and concerned by the project, as well as due to several contextual events that happened during the course of this research, the exact research orientations were modified during the course of the project. This format allowed to formulate new and parallel research questions in response to events, discussions or encounters, which contributed to shape the present PhD research.

In the next paragraphs, I will briefly outline how the five main research questions of this manuscript came about and how they have been structured within this manuscript into three chapters, each corresponding to one research article, and a discussion and conclusion section. This information is also schematized in figure 3. To illustrate the positioning of this research within the wider Ardenne context, I have also pictured 5 main contextual events on this figure, which occurred during the progress of the AGRETA project and which concern the Ardenne forests. These events all have a different relationship to my research questions or research outcomes as detailed below.

A significant part of the AGRETA project concerned the estimation of visitor frequencies in natural areas. This information was not available at forehand and its compilation by traditional monitoring techniques is strongly complicated by the diffuse character of the Ardenne nature areas. During the methodological implementation and the consequent analyses of the obtained frequency data, the results on visitor frequencies were frequently requested upon by different instances (the forest administration, research groups, project holders, etc.). Hence, visitor frequencies represent a crucial element in the argumentation on the importance of the socio-recreational functions of forest ecosystems. For example, the presence of visitors might represent a negligible or on the contrary might have a significant economic contribution to the local economy, compared to traditional municipal revenues.

The first contextual forest event relevant to socio-recreational forest ES concerns an outbreak of the African swine fever, which has been linked to controversial hunting practices that sustain over-densities of wild boar and which led to a lockdown of the affected zone, thereby impacting forestry and socio-recreational forest ES (Bailly, 2018). Monetary compensation mechanisms have been put in place by the Walloon government for pig farmers, tree nurseries and for private and public forest owners, though not for, for example, the tourism sector (De Schutter, 2021). Whilst this crisis will not specifically be dealt with within this manuscript, its occurrence underlines the dependency of recreational forest ES on how other forest uses (hunting in this case) are put into practice. It also stresses the need for supplementary data to assess the impact of this event on socio-recreational actors (e.g. tourism operators, forest visitors) in order to take these actors and the consequences of this event on their welfare and wellbeing into account. Altogether, this also confirms the interest of the methodology developed and the data produced within the context of the AGRETA project.

This afore missing objectivized data could thus challenge or reinforce certain discursive reasoning on the prioritization of various forest functions in the Ardenne forests and could therefore be extremely relevant with respect to the theorized discourse of multifunctional landscapes and within the context of user-conflicts between different forest actors. This need for data, as expressed by field actors, led to a search for adequate methodologies that could be applied within the Ardenne context. A scan of the existing literature showed us that there was also a need for adequate methodologies to monitor visitors and their behavior in diffuse nature areas. In response to this double data/methodological concern, a first methodological question thus imposed itself:

Research Question 1: "How to measure and monitor visitor frequencies and apprehend visitor behavior in diffuse nature areas?**"**

This first research question will be theorized, contextualized and analyzed in Chapter 2: Recreational forest ES.

Once visitor numbers and profiles were estimated, the next step of the analysis has been to explore whether visited forests also represent attractive forests to the wider public? The aesthetic appreciation of forests depends strongly on the adopted management practices. The major contextual forest event relevant for this issue is the major bark beetle outbreak, which has been linked to forestry practices aiming at the maximization of timber production ES and which resulted in various controversial propositions for future forest management (Forêt & Naturalité, 2021b).

Again, this crisis will not specifically be dealt with within this manuscript, but its occurrence highlighted the questionability of current dominant forest management policies and practices, especially in the case of public forests. In the light of the current overall poor ecological status of the Ardenne forests (see case study description), aiming for a higher degree of forest naturalness could lead to improved ecosystem resilience and forest biodiversity. This objective would also change the visual structure of the forest and thus potentially represent more or less attractive forests in the eye of forest visitors.

As mentioned above, forest visitors, as ES beneficiaries, have however little say over those matters, which are decided upon by the ES managers. In the absence of objectivized data, visitors are supposedly content with the actual offered forest landscapes. However, this does not need to be the case. Therefore, I aimed to objectivize the perspective of the wider public on forest management and assess the attractiveness of more natural forest ecosystems. This triggered the following question:

Research Question 2: "Which visual structural forest characteristics are preferred by the wider public?"

Once these forest preferences have been revealed, in addition to the gathered data on visitor numbers and profiles, and relative to the existing forest landscapes, this meant having gained better insights with respect to some of the supply (available landscapes), demand (preferences) and flow (rates of visits) aspects of the socio-recreational forest ES of the Ardenne. Nevertheless, while the original project focusses singularly on tourism and recreational ES, it quickly became obvious these are intertwined with other ES provided by the same ecosystem. The visual attractiveness of the Ardenne forests indeed depends on the implemented management practices, the latter being related to how economic and biodiversity objectives, among others, are put into practice. In the same vein, recreation is often not the only reason for which a certain area is of importance to a visitor who might also estimate other forest aspects of importance, such as carbon sequestration or air purification. The same holds true for other forest actors (e.g. forest loggers) who

might value a wider series of forest aspects than sole wood production. Based on the first two research questions we still lack information on how important these socio-recreational forest ES are to the wider public and how their importance is valued relative to other forest ES, as well as to other (non-instrumental) ways of how the ecosystem providing these ES, in this case the Ardenne forests, is of importance to people. These *forest values* can provide crucial information on the legitimacy and representativeness of current forest policies and practices and on potential future directions for forest governance.

As mentioned above, the type and quality of the diverse provided ES and the ways a forest can be of importance to people, strongly depends on the more global ecosystem management practices being adopted, thereby inducing a potential discrepancy between forest managers and non-managers. Therefore, the scope of the research analyses has been widened to cover the importance of a wider range of ways of valuing the Ardenne forests, which led to the following question:

Research Question 3: "For which aspects the Ardenne forests are of importance to people? And what is their relative importance?"

The ES valuation framework, that was employed to evaluate the socio-recreational forest ES within this research, makes use of values and value indicators in order to perform so-called "ES valuations". There exists a now well-established call to perform integrated evaluation valuations, which take into account the plural aspect that is inherent to the term "values". Looking at these issues and working out a concrete methodology to perform the envisioned ES valuations in an integrated way, led to the conceptual question of what is being understood by ES *values* and how this or these interpretation(s) relate(s) to the aforementioned notion of *importance* (the latter which will be assessed via the socio-cultural value concept). This induced the formulation of the following question:

Research Question 4: "How does the use of ES values within ES valuations relate to the notion of importance?"

These three research questions (research questions 2, 3 and 4) will be theorized, contextualized and analyzed in Chapter 3: Forests' attractiveness and importance.

New insights on the importance of various forest values (assessed via the notion of socio-cultural values for forest ecosystems, as will be specified in chapter 3), on the preferences of the wider public for visual structural forest characteristics and on actual visitation rates, might lead to proposed changes in forest management. Implementing changes requires discussions and negotiations over current practices between various forest actors concerned by forest management policies and practices and its consequences. These forest actors are classically divided into generic action group

categories which do not allow to address important within group heterogeneities. These generic actor groups withhold foresters, visitors, hunters and naturalists mainly. The use of these stereotyping classifications however, tends to reinforce tensions and nourish conflict. In this sense, it is interesting to investigate how to bypass these polarizations in order to facilitate discussions over potential management changes. We applied this question to the case of the wolf (*Canis Lupus*). Hence, the comeback of the wolf to the Ardenne territory as a third major contextual event offered an opportunity to apply the theorized notions of importance to a specific case that represented an (en)forced change in the forest ecosystem, evoking a diverging positioning from various forest actor groups. The (discursive) contradictions that became apparent in peoples positioning towards this event led to the incorporation of several questions on this topic in the planned survey. More specifically, it was investigated if the used notion of importance could more accurately deal with within-group heterogeneity of different actor profiles. Therefore, the following question was formulated:

Research Question 5: "What does the socio-cultural value concept reveal about the use of stereotypes and the heterogeneity within each actor group?"

This question will be theorized, contextualized and analyzed in Chapter 4: Actors' positioning on the return of the wolf.

The outcomes of this latter question, applied to the case of the wolf in the Ardenne, also triggered a reflection on the democratic character of institutional discourses related to forest management and consequently, on the potential discrepancy between institutional discourses on the one hand and personal visions of actors that (pre)supposedly adhere to those discourses on the other hand. Hence, even though they are constituted out of individuals, institutions are the bodies that decide on (public) forest management policies and practices. Thus, in order to alter current management practices in the search for obtaining more resilient forest ecosystems, certain changes at the institutional level are required. Apart from this potential personal-institutional discrepancy, various other blockages could be identified that complicate or impede required changes. One of those lock-ins is the absence of reliable data and documented insights to strengthen argumentations and counter misconceptions. Therefore, estimating visitor frequencies within nature areas, identifying preferences for certain structural forest characteristics, revealing for which ES and other aspects the forests are perceived most important by the wider public and explicitly addressing heterogeneity within actor groups, all represent elements that potentially could challenge current forest management policies and practices and thereby induce change. To what extent this theoretical logic also reflects real processes is reflected upon in the discussion based upon personal encounters with or indirect feedbacks from field actors.

The occurrence of the COVID19 pandemic, the fourth major contextual event, during the latest stages of the research and the resulted increased visitor frequencies in nature areas reinforced the attention for the socio-recreational aspects of nature areas (areas available for leisure activities, effect of visiting natural areas on human wellbeing, etc.). It somehow gave more weight to the research outputs, as it became difficult to ignore the importance of nature areas for recreation and more largely for human wellbeing. Nevertheless, at some moment, it also questioned the relevance of the obtained research results. Hence, the pandemic brought along a significant increase in visitor frequencies, as well as the presence of a new unfamiliar public frequenting nature areas. As the research outputs did not address this increase nor the behavior of this new public, they could be quickly considered as "outdated". Thus, while there is more attention for the results, at the same time, for a certain time, the specification "these results date from before the COVID19 outbreak" affected their perceived relevance, as noticed during the latest presentations of the AGRETA project outcomes to actors concerned by forest management.

In relation to the mobilization of the project outcomes, the Walloon government announced in the beginning of 2021 its intention to establish two National parks and to launch a project call on this topic to which a coalition of various actors can propose a certain area and project as candidate; this represents the fifth major contextual event. National parks have the double ambition of promoting nature conservation and restoration and improving the socio-recreational opportunities of nature areas. The establishment of a national park aims at changing actual management, abandoning the predominant focus on timber and game, and at enhancing the socio-economic benefits that a nature area could provide through alternative development scenarios, based on recreation and tourism. While searching feedback from various field actors relative to the potential impact of the provided data on management policies and practices, this call and the consequent processes of project formulation and negotiation, provided an opportunity to question concerned actors on the intended use and usefulness of the data and to identify other remaining blockages for adopting change.

These reflections on the potential impact of our research results on socio-recreational forest ES for current and future forest policies and practices, as well as on the limitations of providing new evidence-based data, will be elaborated on in Chapter 5: Discussion. Some new empirical data will be provided at the start of this section to illustrate some of these reflections. I conclude with Chapter 6: Conclusion and future perspectives.

This sequence of the formulation of research questions, of the implementation of methodologies, of the major contextual events and of main feedback moments is visualized in the following diagram (figure 3):

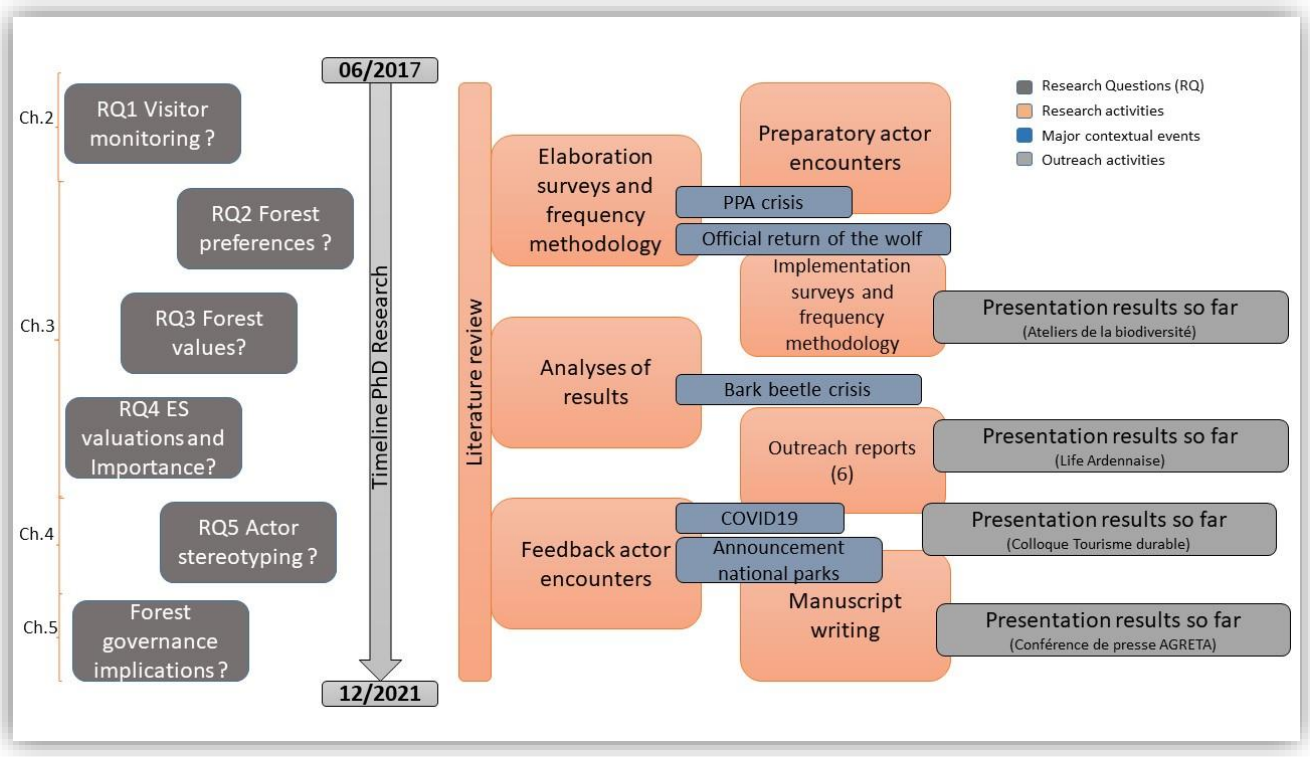

Figure 3. Timeline and key elements of the present PhD project

Chapter 2

Recreational forest ES

1. Framing of the article

In this first article, bearing in mind the aim to underscore socio-recreational ES of the Ardenne forests, I valuate the ES nature-based tourism/recreation. As aforementioned, a changing societal demand in terms of forest management is increasingly putting more emphasis on nature protection and conservation practices, which often conflict with traditional profit-oriented management practices. The ES nature-based tourism and recreation have often been put forward as an economic lever or argument for nature protection through its contribution to the local economy, thereby generating an alternative source of income (Budowski, 1976; Hall, 2019; Schägner et al., 2018; Schirpke et al., 2018). However, while direct and resource-based revenues, whether for private or public instances, are easily quantifiable, the indirect economic importance of forest visits is less straightforward.

The (mainly) indirect contributions to the local economy can concern increased economic activities, income, and employment, which are incentivized by tourism expenditures. In addition, nature visits also represent direct and indirect health benefits to humans, both physically and mentally (Bowler et al., 2010; Doimo et al., 2020; Karjalainen et al., 2010; Rajoo et al., 2020), and can thereby contribute to a reduction of public health costs (Saraev et al., 2020; Shanahan et al., 2016). The latter insights have for instance moved EUROPARC, the European federation of protected areas, to initiate the project "Healthy parks, healthy people", a theme that has recently gained even more in topicality due to the COVID19 pandemic.

During the pandemic the amount of nature visits has increased throughout Europe, which apart from potential benefits, also potentially creates or increases tensions between different user profiles, or can generate a detrimental environmental impact (McGinlay et al., 2020). Local environmental impacts most often associated to visitor frequencies are the trampling of vegetation, the erosion of soils and the disturbance of wildlife (Cole, 2004; Runnström et al., 2019; Salesa and Cerdà, 2020; Watson et al., 2014; Wolf et al., 2019). Broader environmental impacts are linked to transportation, water consumption and waste management among others (Wolf et al., 2019). Potential positive and negative environmental outcomes and impacts of nature visits depend on the spatial and temporal magnitude and density of visitor frequencies, on visitor behavior, and on the respective environment (Green et al., 2019).

In order to objectivize these impacts and adequately adapt both tourism and ecosystem management, a sound monitoring is essential. However, most European countries (Sievänen et al., 2008) do not have access to a standardized approach to monitor visitors to nature areas. Muhar et al. (2002) point out that the most important information to collect for visitor monitoring on a specific site are (i) the number of visits, (ii) the temporal variability of these visitor frequencies, (iii) the activity of visitors and (iv) the density of visitors. This information can be regarded at as flow indicators of the ES nature-based recreation and tourism, with flow describing the actual use of the ES (Baró et al., 2015).

i. The number of visits has been pointed out as the key indicator in visitor monitoring (Schägner et al., 2017). The main reasons being that this number a) can be put into relation with the (ecological and social) carrying capacity of the area, b) is essential to calculate economic contributions, and c) can be used to argument the need for new investments or infrastructure among others.

ii. The temporality of visitor frequencies can have important implications for local socio-economic dynamics due to, for example, a strong seasonality. Also, a same number of visitors can generate stronger or weaker environmental pressures, according to the specific season.

iii. Concerning the visitors' activities, information on how people are visiting a site allows site managers to adjust or intervene when necessary. For example, what is the proportion of hikers, bikers, horseman, etc., do they use the same trails at the same time? To what extent are the site rules respected, e.g. are dogs kept on the leash? This kind of information on visitor behaviour can give indications to avoid or ease conflicts between different user profiles.

iv. Large numbers of visitors do not necessarily lead to tensions, problems or conflict when they are adequately canalized and accompanied. However large visitor densities evoke the idea of mass-tourism, which in general does not align with the new search for authentic and locally embedded experiences (Ferrari and Gilli, 2016; Haukeland et al., 2021).

The diffuse geography of the multiple entry and exit points to the Ardenne forests, strongly complicates visitor monitoring (Cessford et al. in Arnberger et al., 2002). As is the case for many nature areas, the Ardenne are accessible without paying an entrance fee or without being registered. Current statistics on visitor frequencies for Wallonia are provided by the Walloon Observatory for Tourism (OTW). These data are based on two main inputs: (i) accommodation statistics (registered lodgings from hotels, bed and breakfasts, campsites, guesthouses, etc.) and (ii) paid entries for attractions (zoos, museums, attraction parks, etc.). The latter attractions include 3 thematic poles: nature, culture and sports. The "nature" pole concerns the following attractions with a paid entry: parks and gardens, caves, zoos and animal parks, and (two) nature reserves. As both data sources (accommodation statistics and paid entries to attractions) largely ignore visitor frequencies and behaviour within natural areas, the commonly available statistics on tourism and recreation thus does not allow to monitor nature-based tourism and recreation. Colson (2009) performed telephone surveys with Walloon and Brussel residents as well as one-to-one surveys in 40 forest plots and also used counted observations by forest guards. It was estimated that 45% of Brussel and Walloon residents go at least once a month into a Walloon forest and that approximately 130 million of people visit the Walloon forests yearly, based on

linear regression modelling. Bodson (2019) also surveyed residents from Wallonia and Brussels and similarly found that 49% of them visit a Walloon forest at least once a month.

These estimations are thus based on extrapolations of counting events or survey data at specific moments in time, and do not allow for identifying spatial-temporal patterns in visitor frequencies and behaviour (Cessford and Muhar, 2003; Muhar et al., 2002; Sievänen et al., 2008). Moreover, it is being recalled that these averaged findings are based on stated frequencies, and thus not on real data (Bodson, 2019b).

The absence of (spatial and temporal relevant) data on nature visits has two main consequences. First, it can result in largely ignoring the ES nature-based tourism and recreation in policy documents and management practices. Second, the argumentation based on visitor numbers and behavior used within debates around forest management is largely based on impressions, personal experiences and deductions. This can complicate the easing of tensions, the nuancing of conflicts and the objectivizing of the debate on the prioritization of forest functions and on the potential positive and negative impacts of visitor frequencies. Examples concern the perceived disturbance of wildlife by visitors, the perceived detrimental impact of mountain bikers on trails and the perceived over-frequentation impacting the flora of certain sites. Reliable data is thus missing to re-enforce reflections, to disentangle misconceptions or to counter unfounded argumentations. Based on the above outlined, this chapter concerns the following research question:

"How to measure and monitor visitor frequencies and apprehend visitor behavior in diffuse nature areas?"

Several monitoring techniques have been used to monitor visitors in natural areas, an overview of these methodologies is given in table 2. However, few methods allow for combining visitor frequencies with behavior, especially when a continuous monitoring is envisioned. Within the context of the AGRETA project (Interreg V GEIE - AGRETA (visitardenne.com)), of which one of the objectives was an estimation of visitor frequencies in the Ardenne forests, following methodologies were envisioned: (i) so-called "eco-compteurs", which are fixed counting devices, (ii) passive Wi-Fi tracking, (iii) social media (Flickr), (iv) passive mobile phone positioning data and (v) automatic cameras. Based on a feasibility check, the first option was quickly abandoned due to its high price, the limited amount of qualitative information and its fixed positioning; the second option was tested on the field, but abandoned after a couple of months due to problems with the hardware devices of the furnishing enterprise; the third option was explored but cancelled after the restriction on data access by Flickr; the latter two options were retained for the final experimental study design. The choice of the specific sites for experimenting both of the retained monitoring techniques within the Ardenne was constrained by the constitution of the AGRETA project.

Table 2. An overview of visitor monitoring techniques.
Adapted from (CEETO, 2018; Muhar et al., 2002).

		Visitor numbers	Direction of motion	Routes	Distribution in area	Group sizes	Visitor characteristics: age, gender …)	Visitor characteristics: origin, expectations …	Behavior
Interviews	Oral interviews			X	x	X	X	X	x
	Written interviews			X	x	X	X	x	x
Direct observation	Roaming observers	(x)	(x)	(x)	(x)	(x)	(x)		(x)
	Fixed counting points	X	X		X	X	X		X
Indirect observation	Counting devices (turnstiles, inductive loop sensors…)	x	(x)						
	Automatic cameras	X	X		X	X	X		X
	Time-lapse video	x	x		x	x	x		x
	Aerial satellite imagery	(x)	(x)	(x)	(x)	(x)			
Active Tracking	GPS		x	x	x				
Passive Tracking	Bluetooth tracking	X		x	x	(x)			
	Wi-Fi tracking	x		x	x	(x)			
	Social Media (Twitter, Flickr…)	X		(x)	x			(x)	(x)
	Mobile positioning data	X			x		x		
Counting of access permits	Tickets sold	x							
	Permits issued	x				x			

Self-registration	Trail registers	x		(x)		x			
	Summit books	x		x		x			
	Hut registers	x		x		x			

Mobile phone positioning data have been found relevant as a tool for monitoring tourist frequencies and behavior (Ahas et al., 2008; Raun et al., 2016). However, its use for specifically addressing nature-based tourism has remained under explored. The specific methodology and outcomes for monitoring forest visits in the Ardenne through mobile phone positioning data, are outlined in the AGRETA outreach paper by Breyne et al. (2021). Overall, while the large size of the cells of the mobile phone operator did not allow for selecting natural areas solely, the results did reveal the usefulness of the method for revealing large-scale spatial-temporal variations in frequencies, as well as variations according to the profile of origin of the visitor (local-regional-national-international).

Complementary, and as we will see in section 2, the automatic camera method proved effective for revealing small-scale spatial-temporal variations in frequencies, as well as promising for identifying proportions of user profiles linked to activities of the forest visitors. The combination of these different scales of frequency data, allows for gaining insights into visitor hot- and cold spots, that are relevant for different levels of decision making. Apart from a methodological interest, this pilot study addresses a knowledge gap concerning the frequencies, densities and user-profiles of forest visitors.

2. Article: How artificial intelligence facilitates the use of camera traps for monitoring visitor frequencies in diffuse natural areas. Lessons from a case study in the Belgian Ardenne

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Keywords:

Nature-based tourism, visitor monitoring, camera traps, automatized image analysis, ecosystem services, Convolutional Neural Network.

Abstract:

Visitor monitoring is an essential element for decision-making on ecosystem management and the evaluation of ecosystem services. However, in natural areas without entrance fees and with diffuse entry and exit points, this is a challenging task which can be very costly or time-consuming. Automatic cameras can provide both quantitative and qualitative data on visitor frequencies, profiles and activities. Nevertheless, to date, time-consuming image analyses have limited their use. This paper employs a convolutional neural network for the detection and identification of visitors in order to automatize this process. An analysis of the images issued from a year-round trail monitoring demonstrates that the use of a convolutional neural network provides accurate and promising results concerning the frequencies of persons and non-persons (e.g. dogs, bikes). The paper discusses the limitations and potential future improvements of the used methodology. It concludes with its added-value for the management of natural areas.

Reference:

Breyne, J., Guidosse, Q., Cioppa, A., Maréchal, K., Rubens, U., Van Droogenbroeck, M., Dufrêne, M., under review, How artificial intelligence facilitates the use of camera traps for monitoring visitor frequencies in diffuse natural areas. Lessons from a case study in the Belgian Ardenne, Journal of Outdoor Recreation and Tourism.

a) Introduction

Outdoor recreation and tourism can be considered as ecosystem services (ES) potentially benefiting human wellbeing and local economies. Indeed, these ES and their related benefits, such as aesthetic appreciation and stress relief are highly valued by nature visitors (Breyne et al., 2021a; Doimo et al., 2020; Smith and Ram, 2017). Therefore, they can represent an important political argument to conserve and restore natural areas (Budowski, 1976; Schirpke et al., 2018), especially when their financial contribution or spared-out costs are highlighted (Mayer et al., 2010; Schägner et al., 2017b; Shanahan et al., 2016). On the other hand, an over-frequentation of natural areas can also induce negative impacts on the environment, such as the trampling of vegetation, the erosion of soils, or the disturbance of wildlife. (Cole, 2004; Runnström et al., 2019; Salesa and Cerdà, 2020; Watson et al., 2014; Wolf et al., 2019). The COVID19 pandemic gave multiple site managers an appetizer of the diverse challenges that should be dealt within the context of the growth of nature-based tourism and at the same time stressed the need for qualitative natural areas for leisure activities (Derks et al., 2020; Korpilo et al., 2021; McGinlay et al., 2020; Rice and Pan, 2020; Venter et al., 2020). In order to manage visitor fluxes and to assure a sustainable management of natural areas, it is therefore crucial to assure a sound monitoring of visitors, in terms of frequencies and behavior (Eagles and Hornback, 1999; Sievänen et al., 2008; Wolf et al., 2012).

The number of visitors has been recognised as a principal indicator for the valuation of touristic and recreational ecosystem services (Schägner et al., 2018). Muhar et al. (2002) point out that the most important data to collect for visitor monitoring are (i) the number of visitors, (ii) the temporal variability of these visitor frequencies, (iii) the activity of visitors and (iv) the density of visitors. However, most natural areas are accessible without passing an entree gate or paying an entrance fee, which strongly complicates visitor monitoring and the consequent management of the area (Muhar et al., 2002). Therefore, technical solutions should be provided that facilitate this monitoring.

Currently, most information on outdoor recreation and tourism is based on extrapolations of counting events or survey data at specific moments in time, which does not allow for identifying spatial-temporal patterns in visitor frequencies and behaviour (Cessford and Muhar, 2003; Muhar et al., 2002; Sievänen et al., 2008). Traditional data such as accommodation statistics provide information on tourism frequencies in general, but do not allow to evaluate the number of visits to natural areas. While passive tracking systems with infrared sensors, such as eco-counters, have been used for several years in outdoor areas in order to estimate visitation rates, it remains difficult to discriminate persons from for example wildlife passages, as well as to obtain qualitative information on the nature of visitors' activities (Pettebone et al., 2010). Recently, innovative technologies, such as passive tracking based on social media or on mobile phone position data, or active tracking by GPS devices, have allowed providing more continuous and precise data while covering larger areas

(Heikinheimo et al., 2017; Kellner and Egger, 2016). A detailed overview of these different monitoring methodologies and their respective advantages and inconveniencies can be found in CEETO (2018), Cessford and Muhar (2003) and in Kajala (2007).

The present research investigates the potential of using camera traps combined with artificial intelligence (A.I.) for the monitoring of outdoor recreation and tourism. While camera traps and the analysis of images and videos have been widely used for the observation of wildlife (Arnberger and Hinterberger, 2003; Kammler and Schernewski, 2004; McGinlay et al., 2020; Watson et al., 2000), its use for the monitoring of outdoor recreation and tourism is rather recent (Arnberger et al., 2005; Campbell, 2006).

Cameras allow to monitor visitors in a continuous (all hours of the day and night and over longer periods of time) and cost-economic way (Roberts, 2011). Cameras can at the same time provide a large number of quantitative (i.e. numbers) and qualitative data (Arnberger et al., 2005; Campbell, 2006). Qualitative data allow for identifying visitor profiles (e.g. dog walkers, runners, hikers, bikers), to verify the group composition (e.g. alone, in group, with children), etc. Moreover, this technology can provide information on the revealed behavior of visitors (as opposed to the declared behavior) which makes it possible to identify potential infractions (e.g. dogs off leash, quads on hiker trails, nightly visits, etc.) This information can be used to generate quantitative and/or qualitative indicators, which allow for performing ES valuations relative to nature-based tourism and recreation. Nevertheless, for an effective use of camera traps for visitor monitoring, there are two main issues to cope with: (i) the enormous amount of data to be processed and (ii) privacy protection (Staab et al., 2021).

Regarding the amount of data to handle, large quantities of images, especially in case of long term monitoring, need to be stored and analyzed (Villa et al., 2017). While the storing of data depends on storage resources; data analysis, when performed manually, is extremely time-consuming. Previous studies making use of camera trapping for visitor monitoring mainly employed manual counting (Arnberger et al., 2005; Bambi and Iacobelli, 2017; Campbell, 2006; Conlon, 2014; Fairfax et al., 2014) or multiplied the number of pictures by a correction factor (Lupp et al., 2016) to estimate visitor frequencies over shorter periods of time. A solution that has been used to cope with the time demand of manually analyzing images is citizen science (Swanson et al., 2015). Here, volunteers have access to the image database and each manually identify a set of images in cooperation or under the supervision of professionals. Depending on the number and the expertise of the volunteers, this strongly reduces the time demand related to image analyses of the research team. Often used for the identification of wildlife, this solution does not lend itself for the monitoring of visitors, due to privacy protection issues, the latter being a major concern when employing new technologies. Previous studies placed the cameras at knee height (Bambi and Iacobelli, 2017), adjusted the settings to the lowest resolution possible (Arnberger et al., 2005) and/or blurred the lenses of the cameras (Campbell, 2006) in order to comply with privacy regulations.

Bearing in mind the above considerations, the present research mobilizes A.I. under the form of automatized image analysis to count and categorize visitors. Over the past decade, several machine learning and deep learning methods have emerged to detect persons alongside hundreds of different classes of objects in images and video sequences. Recent and fast deep learning networks such as YOLOv4 (Wang et al., 2021) and EfficientDet-D3 (Tan et al., 2020) allow for real-time accurate detections while much larger networks like Mask R-CNN (He et al., 2020) have excellent performances for the tasks of object detection and instance segmentation on a large variety of classes, but at the cost of a slower processing speed. The development of such innovative methods was made possible thanks to the availability of large datasets such as the Microsoft COCO dataset (Lin et al., 2014). The aforementioned methods were trained on this dataset and can now be used in many different real-world applications.

A parallel study by Staab et al. (2021) also combined A.I. with camera trapping for visitor monitoring in outdoor settings over a one-year period. They evaluated the performance of this methodology compared to conventional visitor monitoring approaches (more specifically to manual in-situ visitor counting, counting by an eco-counter pressure sensor, and counting based on manual image evaluation) for seven entrances to a protected forest area. In this study, we specifically address the following technical and analytical issues that need to be dealt with when employing this combined methodology: false trigger events, redundancy and non-detections. In addition, we evaluate the performance of the methodology for different objects of interest (see section 2.3.1) and, finally, results are used to gain insights on the spatial-temporal variability within and between different forest areas.

By combining methodologies through applying automatized image analysis to the monitoring of visitors by means of camera traps through a pilot study, we contribute to methodological advances in the field of outdoor visitor monitoring. These advances can improve ecosystem services valuations of nature-based tourism and recreational services, and thereby provide area managers with insightful information to foster a sustainable and transparent management of natural areas.

b) Material and methods

i. Case study area

The case study area concerns the forests of the Ardenne, located in the region of Wallonia in Southern Belgium. With 6 million of people living within a range of 100 km around those forests, there is a high demand for nature-based recreation and tourism (Colson et al., 2010b). Ardenne visitors gave “nature” as the main reason to visit the region (Breyne et al., 2020) and the majority of the Ardenne tourist operators name the natural environment as an essential aspect for their business (Breyne et al., 2018). The overall tourism sector currently makes up about 4 to 6% of the Walloon GDP (OwT, 2020). Nature-based tourism is increasingly regarded at as an economic

alternative for forestry and hunting activities, the latter strongly shaping the Ardenne landscape, while at the same time potentially favoring the conservation and restoration of the Ardenne ecosystems (Filot, 2005; Laurent and Lecomte, 2007). Current statistics on visitor frequencies for Wallonia are provided by the Walloon Observatory for Tourism (OwT). These data are based on two main inputs: (i) accommodation statistics (registered lodgings from hotels, bed and breakfasts, campsites, guesthouses, etc.) and (ii) paid entries for attractions (zoos, museums, attraction parks, etc.). Currently there is no standardized nor continuous approach to monitor visitors of natural areas in the Ardenne (Sievänen et al., 2008). The diffuse aspect of the multiple entry and exit points to the Ardenne forests, strongly complicate the monitoring of visitor frequencies and their behaviour (Cessford et al. in Arnberger et al., 2002). The only information on forest visits that is available for the Ardenne, is provided by two studies. Colson (2009) performed telephone surveys to Walloon and Brussel residents as well as one-to-one surveys in 40 forest plots and count observations by forest guards. He estimated that 45% of Brussel and Walloon residents go at least once a month into a Walloon forest and that approximately 130 million of people visit the Walloon forests yearly, based on linear regression modelling. Bodson (2019) also surveyed residents from Wallonia and Brussels and similarly found that 49% of them visit a Walloon forest at least once a month. Both these studies however, do not reveal spatial-temporal patterns of visitor frequencies, nor information of the profile of those visitors.

The present study examines the potential of combining camera traps with automatized image analysis to provide site managers with more continuous, detailed and site-specific information. The lack of information concerning forest attendance is a recurrent subject of discussion as well as a specific demand from policy makers and site managers of the Walloon region (author's observation). Four main forest massifs have been selected as a pilot site to test visitor monitoring the proposed methodology (see Figure 4). The Natural Park "Hautes Fagnes-Eifel" (HF-E) includes a large peatland reserve and is highly reputed as a tourist hotspot, this area has been recently closed down due to an estimated over-frequentation related to the COVID19 pandemic (Jebali and Van Oppens, 2020). The Natural Park "Haute Sûre forêt d'Anlier" (HSFA) represents the largest continuous broadleaf forest of Belgium, there are however few recreational infrastructures present and the forest is less known by the wider public. The Natural Park "deux Ourthes" (PNDO) concerns the valleys and plateaus around the Ourthe river and is situated around the two main touristic cities (La Roche-en-Ardenne and Houffalize). The forest of "Saint Hubert" (SH) lies at the heart of the Ardenne and is well known for its presence of game and for its majorly deciduous forests.

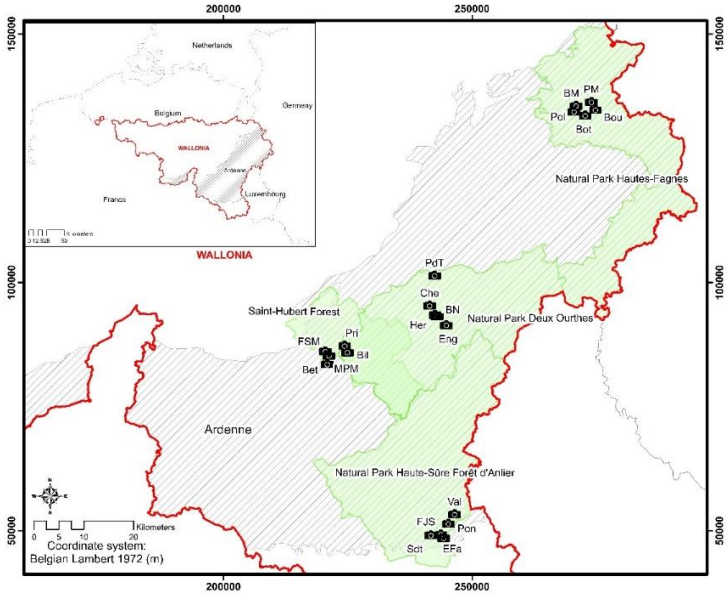

Figure 4. The area of case study and the emplacements of the twenty camera devices

ii. Experimental design

In the summer of 2018, twenty camera traps were placed in the four aforementioned forests massifs, with a partition of five per area. In coordination with the local forest agency 'Département de la Nature et des Forêts (DNF)' and the administrations of the concerned natural parks, the cameras were set up on some of the main trails of each of the four areas, such that a certain visitor flux was guaranteed. Some cameras were implemented on trails nearby specific points of interests, such as wildlife observation towers or reputed viewpoints. This sampling method allows for obtaining point-specific information on visitor frequencies and profiles, as well as for comparing outcomes between the four areas and between the specific camera positions; it cannot be used, however, to generalize this data for other hiking trails or areas. Nevertheless, the insights obtained from this data relative to visitor frequencies, densities and profiles, as well as the methodological insights obtained from this research, can be useful to overall tourism management in natural areas.

The camera model used is a Dörr Snapshot Limited Black 5.0 S, which costs 89 euros and runs on 8 alkaline AA batteries. Each camera was provided with a 16-gigabyte SD card. This model allows to detect objects in movement by infrared detection that works up to 15 to 20 meters of distance. The detection zone of this camera is equal to the field of view, with an angle of 52°. At each detection, the camera was set to take two images in a row, with an approximate reaction time between the detection and acquisition of the first image of about 0.9 seconds. Concerning the specific settings, two images were preferred over one, in order to allow objects to enter the field of sight after detection. The interval between two

detection events was set to a minimum of 10 seconds, to allow the objects to have sufficient time to move out of the capture area of the camera between two movement detection events. Cameras were placed at 3 to 5 meters above ground to discourage theft and an explicatory card was included in each objective in case someone would retrieve it. Vegetation that was obstructing the field of view or potentially triggering a movement detection, was removed on several occasions. The cameras took images for over one whole year with start dates varying between the 11th of June 2018 and the 21st of August 2018, depending on the area; end dates vary between the 12th of October 2019 and the 24th of October 2019. Images were collected and batteries were controlled once every one to three months. This resulted in a total of 757. 588 images for the 20 camera devices. The disposition of the cameras on the field is shown in Figure 4, their full name description is available in Table 3.

iii. Dataprocessing chain

(1) Detection and identification

In this paper, we made use of the Mask-RCNN algorithm (He et al., 2017) to detect and identify objects. This deep learning convolutional neural network is among the state-of-the-art ones for object detection in various environments. We leverage the implementation provided by the Facebook Research group (see https://github.com/facebookresearch/maskrcnn-benchmark for the used source code) which is implemented in Python, in the Pytorch deep learning framework, run with Linux (v. 3.7). The output of the algorithm is a set of predictions which are visualised as a processed image containing bounding boxes around each detected object as shown in Figure 5, and which are simultaneously saved in one text file per image providing the positions, the classes and the number of detected objects. Mask R-CNN has been trained with the Microsoft COCO dataset, which contains over 1.5 million of example objects (Lin et al., 2014) for 90 object classes. For this study three objects, corresponding to three classes annotated in the COCO dataset, have been selected for detection and identification by the model: persons, bikes, and dogs. These objects of interest correspond to the main user profiles of the monitored trails. After application of the Mask R-CNN network, we only keep objects corresponding to these classes if the confidence level is superior to 70%. The obtained text files are further processed with SAS software (9.4) in order to obtain aggregated visitor counts and for further analyses. It should be noted that the model was is programmed to detect individual objects and not the ensemble. For example, the model detects a bike and a person, but not a biker.

Figure 5. Example of a processed image with bounding boxes for each detected/identified object, in this case two persons (red) and two bikes (green)

Therefore, visitors refer to the number of persons detected, of which a certain proportion are bikers.

(2) Technical and analytical issues

In this section technical inaccuracies relevant to this study are addressed. The earlier these issues occur in the processing chain, the more impact they are likely to have on the rest of the system.

Missing data. Despite an overall continuity of the data, the data collection flawed on some occasions due to technical issues, moving vegetation, non-favourable weather conditions or theft on two occasions. This caused several time gaps ranging from a few days up to over a month for some cameras. All images issued from the camera Hérou (PNDO) were withdrawn from the analysis, due to a limited number of days for which images were registered. This was also one of the cameras that had been stolen. For the camera HF-Baraque Michel, images from the first autumn (before 29/11/2018) were removed due to the presence of a branch in the field of vision that revealed problematic for the model and the felling of the tree to which it had been attached. In general, due to the large number of devices and the total duration of the monitored period, missing data did not influence overall results.

Privacy Protection. In order to comply with the General Data Protection Regulation of the European Union, which has been reformulated in 2016 (GDPR 2016/679), several measurements were taken such that it was not possible to recognize individuals. Automatized data analysis was mobilised based on the contours of objects, hereby avoiding individual recognition. Also, initially, three layers of adhesive tape were attached to each camera lens in order to blur the images at the moment taken to meet privacy concerns of local authorities. However, after a couple months (see Table 1 for the specific dates), in accordance with the local site managers, these adhesives were removed because it resulted a source of non-detections by the model (see further). Nevertheless, the position of the cameras at a certain height (>3 meter) and the adjustment of the settings to the lowest resolution possible, contributed to avoid any individual recognition. The two phases of before and after the extra adhesive tape, imply that a part of the images had been blurred, while another part had not. While this difference did not affect the complying to privacy regulations, it could have had an impact on the performance of the algorithm. Therefore, this potential impact was tested though means of a bilateral paired t-test for each of the objects under study (i.e. persons, bikes and dogs).

False Trigger events. In order to demonstrate the added value of using atomized image analysis, compared to using an extrapolation of a control sample with the number of images as a proxy for visitor frequencies, the overall proportion of empty images (i.e. without object detection) and its variation over times was verified. This analysis occurred with the cleaned dataset, thus after deletion of erroneous images and of doubles.

Redundancy. One of the main problems to count visitors with an optimal accuracy rate was redundancy. Three main issues of redundancy had to be dealt with within this study.

First, according to the metadata, some detection events were triggered at less than 10 seconds after the previous one. This was most likely due to a bug while shooting the image or saving the metadata. These events have been suppressed.

A second issue concerns the series of two images at each detection event. Ideally, every object of interest is photographed a single time. Since cameras have been configured to take two pictures at each movement detection, the maximum number of objects for each class, counted over the two images, has been used. Thus over a sequence of two shots at the occasion of one movement detection, if the algorithm detected 2 persons on the 1st and 3 persons on the 2nd image, it was considered that 3 persons were present.

The third issue was related to the ten-second delay between two detection events, intended to allow sufficient time for objects to move out of the field of vision. This interval was constant for all twenty cameras. However, the position of each camera in relation to the trail was not constant. Hence, when the angle between the center of the image field and the trail is relatively small, the ten-second delay is not sufficient to

allow visitors to move out of the field of detection/view in time, before a second series of photos is taken. This could lead to multiple detections of the same visitor(s). These multiple detections also occur when persons stagnate under a camera. In some cases, this stagnating was induced by the placement of the camera and could have been avoided, as will be discussed in section 4.3. For the analysis of the images, whenever the detected number of visitors for a specific day and a specific camera was larger than 10 times the average of visitors per day for that same camera, the images were manually checked to verify if these extreme outliers were due to a special event (e.g. trail running) and represented thus true frequency rates, or if they were related to issues of redundancy (e.g. stagnating groups). If the latter was the case, the overall frequency for that day and that camera, was manually adjusted.

Model accuracy. Before being able to interpret the number of visitors, as well as the proportions of each user profile (i.e. hiker, biker or dog walker), apart from verifying outliers, it is essential to verify the accuracy ratio of the model. While the Mask R-CNN model has been trained with clear example images, it should be assessed to what extent this model performs properly for the images made by camera traps in field conditions and for the objects of interest to this study. To account for the potential impact of seasons on the performance of the model due to changes in leaf cover and luminosity, a control sample has been manually checked for each camera during each season. This control sample followed two criteria: (i) it concerned a sample of 100 images in a row, after randomly picking a date for each season and each of the 19 cameras and (ii) a minimum of 50 true positive objects belonging to one of the classes had to be counted. This resulted in a control sample of approx. 1% of the total image dataset. Next, based on these selected images, a confusion matrix was created for each camera, containing four categories: objects detected and correctly categorised (true positives - TP), mistakenly detected /identified objects (false positives - FP), mistakenly non-detected objects (false negatives - FN) and correctly non-detected objects (true negatives-TN). For the detection task in images whose acquisition is triggered by motion, the calculation of TN is problematic as we are unsure about the number of empty images that will be collected in the dataset. Therefore, practice favours the use of the sensitivity and specificity of the model calculated according to the following formulas:

$$Sensitivity(\%) = \frac{TP}{(TP + FN)} \quad (1)$$

$$Specificity(\%) = \frac{TP}{(TP + FP)} \quad (2)$$

Sensitivity gives the proportion of positives that is correctly identified, so for example a sensitivity of 90% for persons means that out of 100 persons, the model identified 90 persons correctly as persons. Specificity gives the proportion of negatives that is correctly identified, so for example a specificity of 90% for persons means that out of 100 predictions, the model correctly identified 90 as persons, but

also wrongly detected 10 other objects as being persons. To obtain an estimation that corrects for these errors, the following formula should be applied:

$$Estimation\ (no.)$$
$$= N - \left[\left(1 - Specificity(\%)\right) * 100\right] + \left[(1 - Sensitivity(\%) * 100\right]$$

The final visitor numbers and their resulting graphics that will be provided in the results section will be based on model outcomes and do thus not concern corrected estimates.

In addition, and as aforementioned, the potential impact of blurring the lenses with an adhesive tape during the first part of the monitoring period was evaluated for each profile through a bilateral t-test, paired per camera.

Camera positioning. The positioning of the camera is expected to play a role in the quality of the data (Campbell, 2006). The Mask R-CNN algorithm was trained on clear images, in good weather and in open environments. This is not always the case with photos taken on the field. The cameras implemented for this study display a varied positioning relative to the monitored trail. While we were aware that a standardize positioning would increase the stability of the results, this was not always possible due to spatial configuration of the field. Furthermore, this variation will allow for identifying the most suitable position of camera traps for future studies on visitor monitoring. Figure 6 provides an overview of the 20 sights of vision, with mentioning of the approximate horizontal angle of each camera relative to the monitored trail. Two specific issues related to camera positioning will be addressed: non-detections by the model, leading to a potential under-estimation of the number of visitors, and redundancy, leading to a potential over-estimation of the number of visitors.

Figure 6. Example images of the 20 cameras with indication of the horizontal angle relative to the trail. The first column concerns the natural park *Haute Sûre forêt d'Anlier* (HSFA), the second the natural park *Hautes Fagnes-Eifel* (HF-E), the third the natural park *Deux Ourthes* (PNDO) and the fourth the forest of *Saint Hubert* (SH)

Non-detections. This means that objects of interest are present on the images, but the model fails to detect them. To address this issue, a subsample of 3200 images was manually checked for the presence of non-detections. Where individuals were not detected/identified by the model, the assumed causes of these errors were recorded. This check was carried out during the first months of the field implementation and thus only concerned blurred images (see section 3.2).

(3) Visitor frequencies and their spatial-temporal variability

Following, overall visitor frequencies were calculated, as well as for each camera and for each forest area. Also the respective proportions of hikers, bikers and dogs were considered. The variability of visitor numbers and of the respective proportions of user profiles was evaluated over time. This time dimension concerns a potential effect of the seasons, weekends and holiday periods, as well as the distribution of visitors over a daily time-span. This information was visualized by means of descriptive graphs. Two general linear modelling (GLM) analysis were performed, the first assessed the relative influence of weekends, holidays periods and seasons on visitor frequencies per camera. The second included the specific location of the camera as an explanatory variable and underscored its influence, relative to those of weekends, holidays and seasons on frequency rates. In addition, local administrations were asked for an inventory of organised activities nearby the concerned camera spots for the time monitored. This information was crossed with the frequency data to potentially serve as an explanation for unusual high frequencies that had been observed. All analyses were performed with the statistical software SAS (9.4).

(4) Data section

Table 3 gives a detailed overview of the field functioning and of the overall results for each of the 20 implemented cameras. Taken into account that settings were such that each camera took two images in a row per detection event, this resulted in on average 45-46 movement detections per camera per day. The numbers in the column "after screening" refer to those images after deleting erroneous or empty images and after the deletion of the doubles. The total number of visitors presented is the number after correcting for outliers. The relative proportion of visitors refers to the proportion of each camera relative to the area and of each area relative to the overall total number of visitors. The images issued from the camera Hérou (PNDO), due its limited number of active days compared to other cameras, have been withdrawn from the analysis.

Table 3. An overview of the field functioning and overall results for each of the 20 cameras

Area	Camera	Camera code	Start Date	End Date	Start Date "non-blurred"	No. of active days	Total no. of images	No. of images /camera/ day	Total no. of images after screening	Total no. of visitors	Relative prop. of visitors	Avg. no. of visitors / image	Avg. no. of visitors / day	Total no. of bikers	Total no. of dogs
HSFA	Stand de tir	Sdt	21/08/2018	23/10/2019	01/04/2019	428	21 085	49	1 995	3 166	4.52	1.59	7	512	174
	Fagne Jean Simon	FJS	21/08/2018	23/10/2019	01/04/2019	428	10 137	24	3 082	5 977	8.65	1.94	14	1 098	176
	Etang	EFa	21/08/2018	23/07/2019	01/04/2019	389	50 920	131	20 671	34 479	58.88	1.67	89	2 263	1 040
	Pont	Pon	21/08/2018	22/10/2019	01/04/2019	427	25 060	59	5 022	8 520	9.97	1.70	20	761	148
	Vallée	Val	21/08/2018	23/10/2019	01/04/2019	428	18 691	44	2 640	3 118	5.64	1.18	7	923	120
	Total					**2 100**	**125 893**	**60**	**33 410**	**55 260**	**10.08**	**1.65**	**26**	**5 557**	**10.08**
HF-E	Polleur	Pol	11/07/2018	12/10/2019	12/02/2019	327	65 732	201	18 844	39 635	12.47	2.10	121	382	627
	Baraque Michel	BM	29/11/2018	18/10/2019	12/02/2019	449	121 734	271	30 192	108 748	33.69	3.60	242	492	593
	Pont Marie	PM	11/07/2018	05/08/2019	12/02/2019	383	65 926	172	23 408	72 326	21.93	3.09	189	439	192
	Bout	Bou	11/07/2018	24/10/2019	12/02/2019	470	41 344	88	13 380	33 015	10.39	2.47	70	634	200
	Botrange	Bot	11/07/2018	24/10/2019	02/08/2018	470	73 305	156	28 337	64 006	20.14	2.26	136	4 055	878
	Total					**2 099**	**368 041**	**175**	**114 161**	**317 730**	**57.98**	**2.78**	**151**	**6 002**	**57.98**
PNDO	Cheslé	Che	12/07/2018	23/10/2019	28/01/2019	469	7 998	17	3 174	7 644	7.62	2.41	16	28	95
	Hérou	Her	12/07/2018	16/06/2019	28/01/2019	222									
	Barrage Nisramont	BN	12/07/2018	23/10/2019	28/01/2019	405	40 180	99	18 289	35 577	35.49	1.95	88	75	1 435
	Engreux	Eng	12/07/2018	23/10/2019	28/01/2019	469	38 501	82	16 346	44 058	42.96	2.70	94	383	690
	Plateau des Tailles	PdT	12/07/2018	23/10/2019	28/01/2019	469	16 484	35	5 965	12 979	12.95	2.18	28	100	753
	Total					**2 034**	**103 163**	**51**	**43 774**	**100 258**	**18.29**	**2.29**	**49**	**586**	**18.29**
SH	Bilaude	Bil	13/07/2018	10/08/2019	21/03/2019	394	45 530	116	9 001	18 902	25.28	2.10	48	878	187
	Priesse	Pri	13/07/2018	23/10/2019	21/03/2019	468	46 603	100	12 300	23 727	29.79	1.93	51	571	158
	Pont Mauricy	MPM	13/07/2018	23/10/2019	21/03/2019	468	9 494	20	3 586	8 707	10.26	2.43	19	409	204
	Fourneau	FSM	08/08/2018	23/10/2019	21/03/2019	442	27 354	62	8 180	18 770	25.10	2.29	42	501	798
	Beyoli	Bey	08/08/2018	15/05/2019	21/03/2019	281	8 355	30	2 430	4 678	5.67	1.93	17	112	38
	Total					**2 053**	**137 336**	**67**	**35 497**	**74 784**	**13.65**	**2.11**	**36**	**2 471**	**13.65**
Total						**8 286**	**734 433**	**91**	**226 842**	**548 032**	**100**	**0.65**	**66**	**14 525**	**8 506**

b) Results

i. False trigger events

Table 4 indicates the proportion of false trigger events, i.e. "empty" images without any objects of interest as identified by the model. On average about 30% of the images is so-called empty, but this proportion varies between 0 and 100% according to the concerned camera and the specific point in time. Even though summed variances may cancel out, Figure 7 still demonstrates a very large overall variation in time. On average, the proportion of false trigger events is higher in late spring and early summer and it is lower during the winter season.

Table 4. The proportion of false trigger events per day.

Area	Avg. (%)	Median (%)	Min. (%)	Max. (%)
HSFA	40	35	6	96
HF	20	14	2	90
PNDO	20	15	0	100
SH	45	43	8	91
Total	31.25	26.75	4	94.25

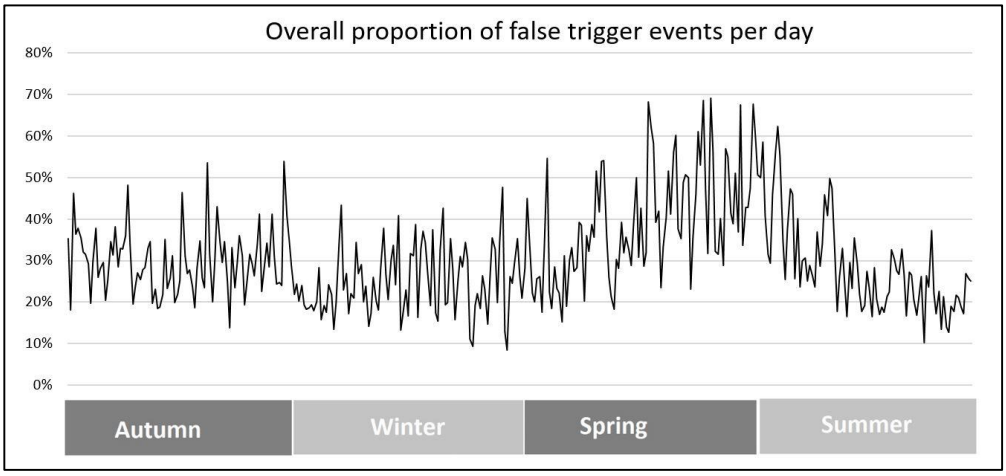

Figure 7. The overall proportion of empty images per day and its variation over a yearly timespan

ii. Redundancy

In Figure 8, the overall effect of considering different time intervals between two detection events on the number of monitored visitors has been visualized. It results from this graph that the chosen time interval has an impact on the accounted number of visitors. Large differences between intervals could be due to larger numbers of persons passing by over a short period of time (e.g. a group passing by), or to the stagnation of persons in front of the camera. Extreme outliers of more than 10 times the average number of visitors per day and per camera were therefore manually checked. In total, 34 days corresponding to this criterion were detected. Of these, 15 represented true counting events (due to e.g. organized trail running or the presence of snow during a weekend); the other 19 represented cases of redundancy (e.g. picnics or stagnating groups) for which the daily frequency has been adjusted accordingly.

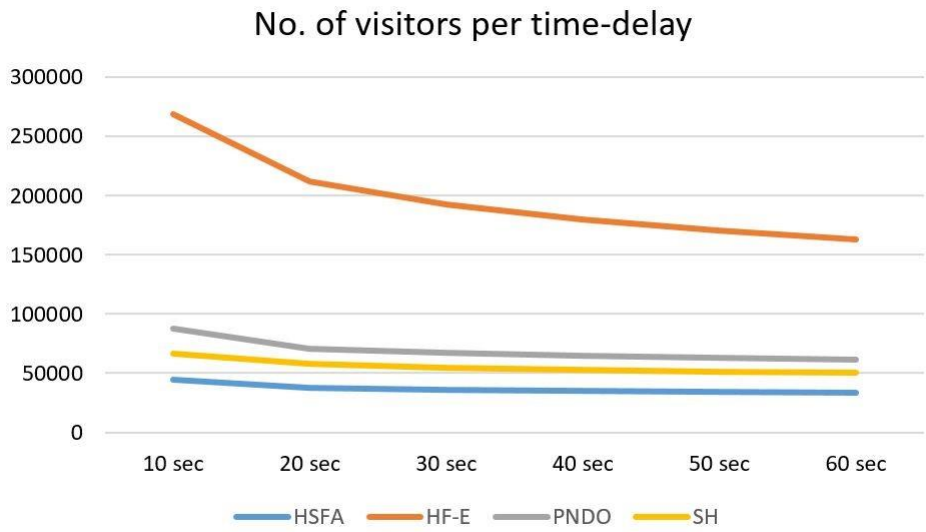

Figure 8. The effect of using different time intervals on the number of detected visitors

iii. Model accuracy

Table 5 gives the sensitivity and specificity ratios per object of interest. The results of the bilateral t-test, paired per camera, in order to compare the performance of the model for blurred and non-blurred images, does not indicate a significant difference for the specificity of the model for any of the profiles. However, it does indicate a significant difference for the sensitivity of the model for each object of interest. The additional blurring of the images thus indeed did impact the model's performance.

Overall, the model shows to be more performant for the detection and identification of persons, compared to the detection and identification of the objects “bike” and “dog”. Hence, the proportions of bikes and dogs are in reality higher than calculated by the model. Applying the correction formula, for bikes this means estimates are between 1.5 (non-blurred images) and 2 (blurred images) times higher; for dogs this means estimates are between tree (non-blurred images) and 4 (blurred images) times higher.

Table 5. Sensitivity and specificity ratios per object and the results of the bilateral paired sampled t-test. Note: ***p≤.001, **p≤.01; *p≤.05.

Object	Pairs	Sensitivity	Std. Deviation	Paired difference	Specificity	Std. Deviation	Paired difference
Person	blurred	0.92	0.05	0.05***	0.99	0.01	0.00
	non-blurred	0.97	0.02		0.99	0.01	
Bike	blurred	0.60	0.36	0.20*	1	0.00	0.31
	non-blurred	0.80	0.24		0.89	0.31	
Dog	blurred	0.33	0.34	0.26**	0.92	0.29	0.26
	non-blurred	0.59	0.17		0.99	0.03	

iv. Non-detections

Two major identifiable issues of non-detection events for blurred images were (i) the superposition of objects (21.7%) and (ii) a too important distance between the object and the camera (15.9%) (Figure 9a). Figure 6b provides an example image for each of the known sources of non-detection.

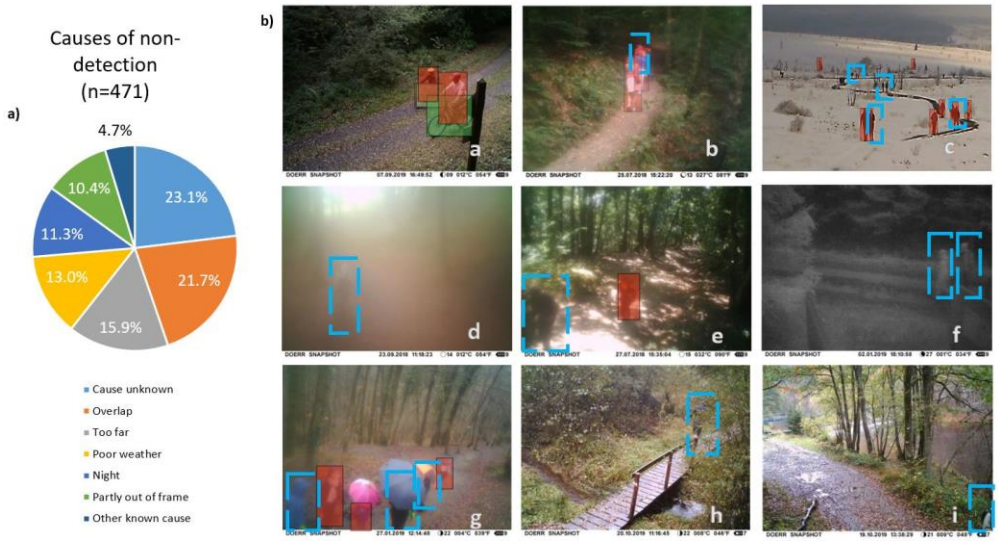

Figure 9. Causes of non-detection. a) The relative proportions of causes of a non-detection of objects. b) Examples of causes of (in)correct detection: (a) Ideal conditions, (b) Superposition, (c) Too distant objects (zoom x8), (d) Fog (weather conditions), (e) Poor light exposure, (f) Night, (g) Self-occlusion, (h) Occlusion due to context, (i) Object partly out of frame. Non-detected objects are marked by blue dotted lines

For cases b and c, the horizontal angle between the middle of the image and the direction of the trail is too small. This small angle has as a consequence that when the trail is too narrow and people have to follow each other, they are overlapping in the image (case b). Also, when combined with an open landscape, this angle does not allow persons to leave the frame within the 10 seconds delay, which means these persons are present on the image when a nearby object triggers the camera, but they are not counted since they are too far away (case c). On some occasions these far away objects are effectively counted (e.g. good light conditions), in this case representing an over-estimation of the amount of visitors, since these persons will be counted multiple times. Case d was caused by humidity that had installed between the lens and the adhesive, hereby completely blurring the image so silhouette recognition became impossible. Cases e and f were due to a poor contrast (due to a half-open canopy and the night-time respectively), which was enforced by the presence of the adhesive tape. In the case of items that block the view on the person, (e.g. the umbrella in case g), this is due to the height at which the cameras were placed. As the adhesive tape had an influence on the performance of the model, it was decided to remove after approval of local site managers, as outlined before. In the case of context-related occlusion (h), the camera detects movement behind a partial obstruction (e.g. bush), but the model does not recognize this partly hidden person. For the objects of interest that are partly out of frame (i), this is because they are moving in or out of the frame, in most case this concerns the first or second image of the sequence, and the object is correctly identifiable on the other image.

v. Visitor frequencies and their spatial-temporal variability

For the entire monitored period and the 19 cameras that were mobilized for the analysis, a total of about half a million of visitors were counted (Table 3). This number concerns the number of visitors passing on the monitored trails and thus not the number of unique visitors. Detected and identified hikers and bikers respectively represent 97.35% and 2.65%. Under the simplified assumption of 1 dog per person, about 1.55% of the visitors are dog walkers.

On average, 2 to 3 persons were detected per image (Table 3). While average group sizes were assessed for each camera, based on the number of persons on a same image, it was observed that these numbers, due to the differences in fields of view, depended principally on the respective camera positioning and did thus not reveal major insights in terms of group sizes.

Frequency results show a high spatial variation (see Table 3 and Figure 10). The area of the HF-E for example shows a frequency that lies 3 to 6 times higher than the other areas. The HSFA is the least visited area. Also, within a same area, there is a high spatial variation according to the geographical position of each camera. For HSFA, the camera Etang (EFa) accounts for 59% of the overall visitation rate. This camera is located on an easy walk around a pound, nearby one of the main villages of this forest, while the other cameras of HSFA are located on more remote trails. In the HF-E, proportions are more equally distributed. Baraque Michel (BM), near the starting point of the most famous trail of the peatland reserve, is the most visited spot and "Bout" (Bou) is the least visited spot; this latter camera is placed at the largest distance to any well-known starting point for an excursion in the reserve. In the PNDO, the cameras Barrage de Nisramont (BN) and Engreux (Eng), both located along a popular trail that crosses all of the Ardenne, show the highest frequencies; Cheslé (Che) with only 8% of the monitored visitors to the PNDO, the least. In the forest of SH, Priesse (Pri), located near a wildlife observation tower, records the highest frequency, Beyoli (Bey), located at the far end of the forest, accounted for only 5% of the monitored visitors to the SH forest.

Frequency numbers also show a high temporal variation (see Figure 10). High peaks in frequency were most often related to special events (trail running, mountain bike events, etc.) or, especially for the HF-E -the area with the highest altitude in Belgium- also to the presence of snow. The inventory of organised activities, provided by local administrations, indeed matched with unusual peaks in visitor frequencies. Figure 10 has some of these peaks indicated for illustration. The correlated activities often concern organised trail running. The effect of seasons, weekends and holiday periods is clearly visible, but is not equally pronounced for each site. These effects are demonstrated by the outcomes of the general linear modelling analysis of which the F-statistics (F) are given in Table 6. Weekends are on almost all occasions the main explanatory factor for visitor frequencies. The relative influence of holiday periods and seasonality on visitor frequencies however depended on the specific camera, with for example seasonality being an important factor for SH-Bilaude (were listening to

the deer roaring during autumn is an important event), while holiday periods are more important for PNDO-Plateau des Tailles.

When individual camera location was included as an explanatory variable to the general linear model, weekends were still the most important explanatory variable (F= 294.40), but the second factor was the specific camera location (F= 128.58), followed by holiday periods (F=17.14) and seasonality (F=13.20) respectively. When considering the differences in means of the number of visitors per day, weekends show 2.76 times higher frequencies than weekdays; holiday periods 1.38 times more. For all cameras confounded, compared to the winter season, spring accounts for 1.01 times more visitors, summer for 1.17 times more visitors and autumn for 1.3 times more visitors.

Table 6. An overview of the F values of the GLM for each of the explanatory variables per camera. Note: ***p≤.001, **p≤.01; *p≤.05

	Weekend	Holidays	Season	Weekend * Holidays	Weekend * Season	Season* Holidays	Weekend *Holidays*Season
Efa	**94.08 *****	2.59	0.46	1.17	2.11	0.92	2.7 *
FJS	**4.53 ***	0.45	1.15	1.63	0.69	1.42	1.01
Pon	**3.84 ***	0.16	2.19	3.10	0.16	0.71	1.08
Sdt	**9.85 *****	**11.56 *****	**5.49 *****	0.19	**6.19 *****	2.85 *	**4.00 ****
Val	**18.15 *****	2.01	**3.82 ****	2.50	2.20	0.58	1.21
BM	**26.75 *****	0.43	1.44	0.26	0.91	0.58	1.94
Bot	**49.20 *****	**9.50 *****	**7.07 *****	4.21 *	0.99	**10.52 *****	**9.29 *****
Bou	**67.93 *****	**6.06 ****	**9.95 *****	**8.63 *****	**3.44 ***	**4.69 *****	**4.66 *****
PM	**38.25 *****	3.64	**8.13 *****	**10.95 *****	2.14	2.30	1.51
Pol	**43.07 *****	**9.90 *****	**2.83 ***	1.67	2.40	**4.16 ***	**7.62 *****
BN	**56.53 *****	**18.16 *****	**15.59 *****	3.11	**4.20 ****	2.55	1.41
Che	**77.82 *****	**25.73 *****	**16.02 *****	0.15	**6.36 *****	**3.36 ***	2.88
Eng	**30.31 *****	2.70	**14.47 *****	0.03	**3.03 ***	0.37	1.33
PdT	**26.71 *****	**10.63 *****	2.24	0.04	1.84	0.97	1.62
Bey	**5.77 ***	0.05	0.28	**5.07 ***	0.14	1.80	0.52
Bil	**32.04 *****	0.03	**7.10 *****	**6.00 ****	2.35	**4.5 *****	0.81
Fou	**29.29 *****	1.95	1.97	1.35	1.67	0.99	0.35
MPM	**46.74 *****	**34.07 *****	**8.27 *****	1.00	**4.69 *****	**3.70 ****	**2.95 ***
Pri	**25.43 *****	0.74	**4.80 *****	**6.54 ****	**4.35 *****	2.45	0.48

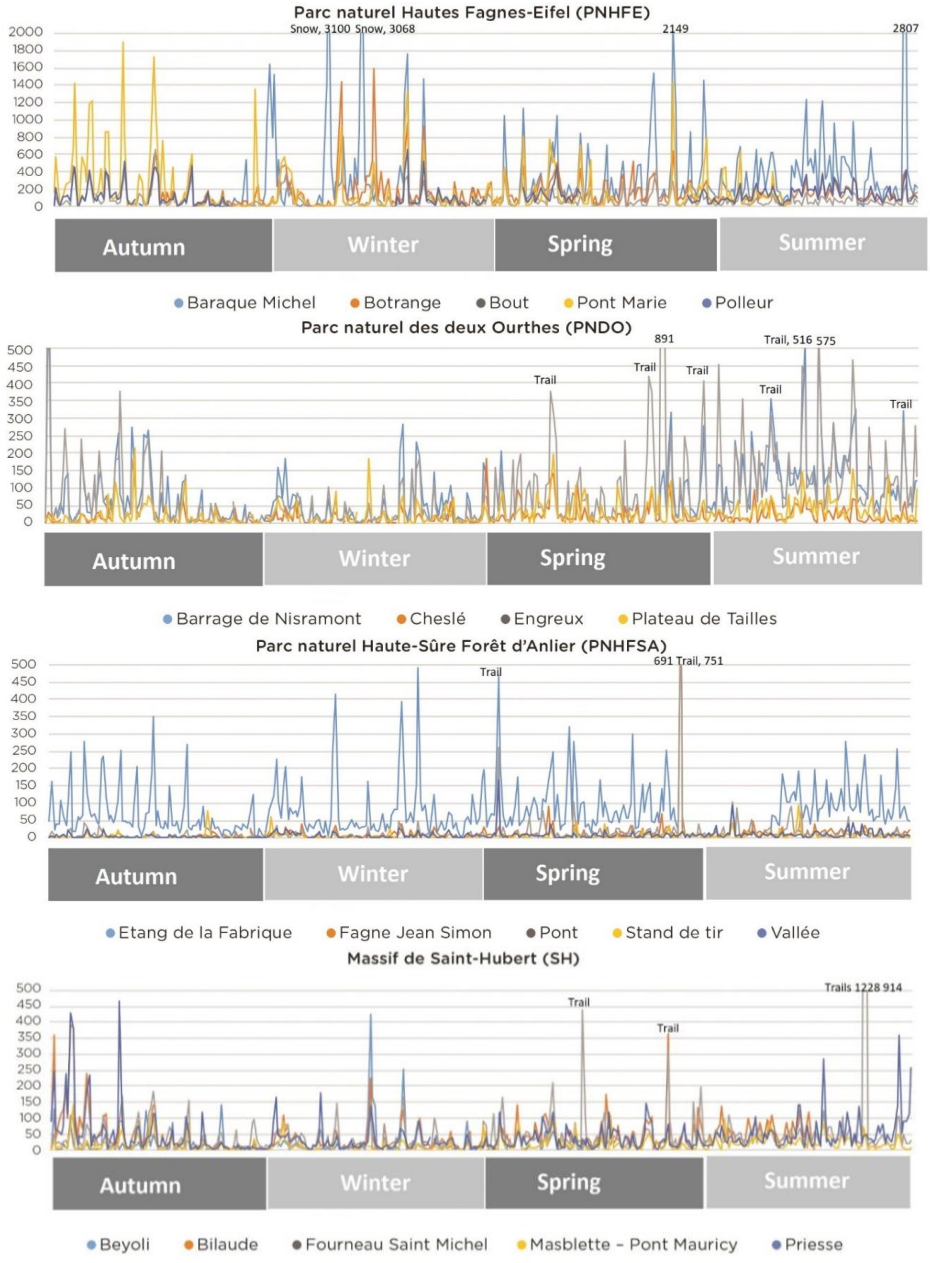

Figure 10. Spatial-temporal variation of the number of visitors for each area over a yearly timespan

When detailing the frequentation of visitors over the hours of the day (see Figure 11 - overall data), there are on average two peaks a day: a smaller one around 10-11 a.m., and a larger one between 14 and 16 a.m. This pattern is the same for all objects of interest to this study. The moment of the peaks varies along the season, with e.g. later peaks in summer than in winter.

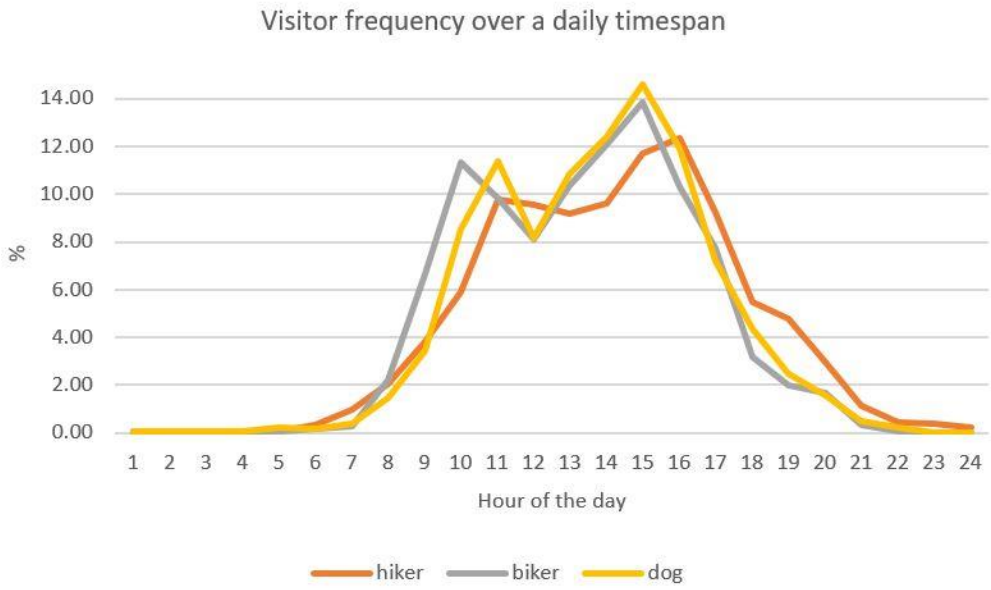

Figure 11. Visitor frequencies over a daily timespan (totals)

Not all sites are equally frequented by hikers, bikers or dog walkers (see Figure 12). Nevertheless, on the scale of the four different areas, differences in biker frequencies are less marked than for hikers. HSFA and HF for example show equal biker frequencies; only PNDO shows very low frequencies, compared to the other areas.

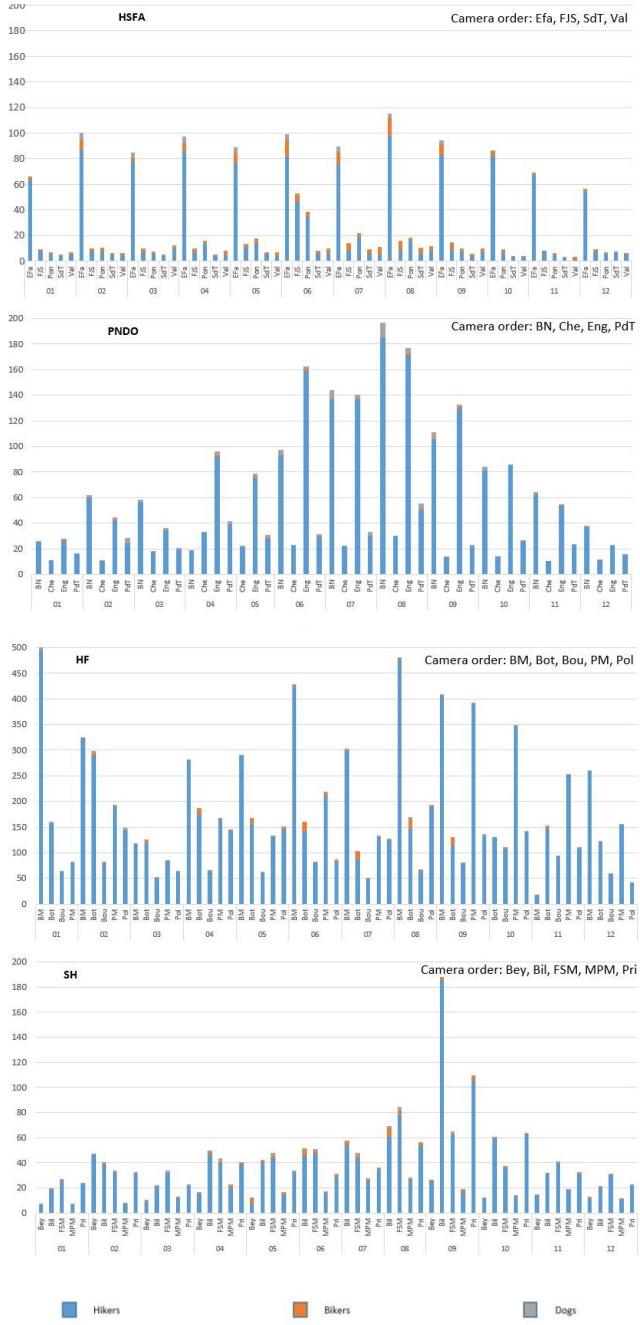

Figure 12. The average number of hikers, bikers and dogs per area and per camera (over a yearly timespan)

c) Discussion

i. The added-value of combining artificial intelligence with camera traps

Previous studies that used camera traps for visitor monitoring have predominantly either made use of manual counting (e.g. Fairfax et al., 2014) or of an extrapolation of the number of images based on the manual counting of a test sample (e.g. Lupp et al., 2016) to estimate visitor frequencies. While the first case allows to obtain qualitative information (e.g. on user profiles), due to its time demand, this method is not suited for continuous monitoring studies. In this study, this aspect was addressed by using artificial intelligence to detect, classify and count visitors. This allowed for performing a year-round monitoring on 20 different spots resulting in the examination of about 800.000 images. The second case, using the numbers of images in combination with a correction factor based on the manual counting of a test sample, bypasses partly the issue of time demand, though resulted problematic from our analysis. Hence, the number of empty images varied strongly depending on the specific camera and on the time of the year. This is also pointed out by Fairfax et al. (2014), who report 45% of false triggers due to environmental factors and 42% of images concerning confirmed users. In our study, the images used for the final analysis accounted only for 31% of all images taken. False triggers events were mainly due to moving vegetation or the passing by of wildlife within the detection field of the camera. In addition, this extrapolation method does not allow for identifying qualitative information (or assumes that qualitative results from the test sample are stable over space and time). Our results demonstrated that when employing an automatized counting method, it is possible to deal with the issue of empty images and at the same time gather qualitative information concerning visitor profiles (i.e. hikers, bikers, dog-walkers). Empty images are images without any object defined as an object of interest, i.e. persons, bikes and dogs in this case. Nevertheless, this does not mean an image is "empty". Hence, cameras were triggered on multiple events by wildlife passage. Contrary to when using infrared counting devices, these movement detection events do not lead to an over-counting of visitors.

While other automatized counters employed in natural areas can provide some limited qualitative information, such as the proportion of pedestrians versus bikers (e.g. the case for eco-counter devices), they do not allow for a verification of the data, in case of unusual observations. By relying on visual data, it is possible to manually check the images afterwards in order to verify observed anomalies in the data or to observe a specific behavior. Two examples from our case study can illustrate this. On several occasions the cameras from this study captured a significant peak in visitor frequencies, whether for persons, bikers or other users. In this case it was possible to manually check the images if for example a group accidently picnicked in front of the camera, causing repeated movement detections generating in its turn an over-counting, in which case the data have been corrected; or if these numbers were due to for example an organized trail running, leading to an effective increase in visitor frequencies. When combining dates from organized events, provided by the local administration, with our camera results, these dates indeed coincided with an increase

in visitor frequencies. This can provide useful information (i.e. number of participants) for event organizers in terms of organization, evaluation and communication. The second example concerns the camera Baraque Michel (HF-E) that monitors a duckboard in the peatland reserve; at some point, site managers contacted us to verify the images because they had found the duckboard broken and assumed acts of vandalism. After a manual check of the images, it showed that the duckboard broke down over a period of a week due to large numbers of persons passing by, while no acts of vandalism had been observed.

It should be noted that for the obtained information concerning visitor profiles (i.e. hikers, bikers and dog walkers), the model resulted very accurate for the detection and identification of persons, though gave more moderate results for the objects "bike" and "dog". In order to increase the sensitivity and specificity of the model for those latter classes, it is advisable for future studies that the model is trained on images taken on the field. For this paper we focussed on general visitor counting and included only a limited number of visitor profiles, namely hikers, bikers and dog walkers. With the Mask-RCNN technique, it is possible to include the detection of other profiles or items related to those profiles, such as horseman, joggers, backpackers, skis, wheelchairs, prams, children versus adults, etc. This would provide even more detailed insight into the profile of site users and their respective proportions over time. This in turn would allow site managers to objectivize needs, identify priorities and to adapt their management accordingly.

Finally, contrary to other counting methods, such as infrared automatic counters, cameras are clearly less costly and can easily be moved to a different place of interest. All above insights underline the potential of combining A.I. with camera trapping for visitor monitoring in natural areas, hereby confirming the methodological insights obtained by Staab et al. (2021).

ii. Spatial-temporal variability

Because of the automatized detection, identification and counting method used within this study, it was possible to handle large volumes of data and to assure a (quasi-)continuous monitoring over a one-year time period. In line with the expectations, there was a clear overall effect of the type of the day (week versus weekend) and of the specific period (holiday periods, the respective season). Overall, weekends recorded about 3 times higher frequencies than weekdays, and weekends resulted more important in explaining visitor frequencies than holiday periods or seasonality. This might hint at an overall higher influx of short-term excursions from persons residing at a relative moderate distance from the forest areas, compared to long-term holiday stays. Surprisingly when considering the seasonal effect, autumn seems slightly more attractive than the summer period, which could be due to a combination of the colours deciduous forests, the mushroom picking and the roaring of the deer at this time of the year in the monitored forests.

The results also demonstrate a strong spatial variability between and within sites, indicating differences in popularity and attractiveness. The area Hautes Fagnes-Eifel alone for example, accounts for more than half of the total amount of visitors. At the level of individual cameras, average daily frequencies range between 6 and 242

visitors. The cameras with the highest frequencies are located nearby specific points of interest, such as observation platforms/towers and hideouts for the cameras Botrange (HS), Bilaude (SH) and Priesse (SH), on a popular trail, such as the case for the cameras Pont Marie (HF) and Engreux (PNDO) or close by an easy access point, as for the cameras Etang (HSFA) and Barrage de Nisramont (BN). More remote cameras that are not located nearby a specific point of interest show relative lower frequencies, as is the case for the cameras Beyoli (SH), Pont (HSFA) and Bout (HF). For some trails, only the weekend effect results significant; this could refer to the trail being mainly used for local recreation, and thus not receiving an increased influx during more touristic periods. Other trails receive a significant higher frequency during holiday periods, which could indicate their attractiveness for more touristic purposes. This point-specific information can hint site managers on, for example, the pertinence of infrastructure on a specific location, the geographical designation of nature reserves or the potential for developing tourism activities.

As aforementioned, unusual peaks in frequencies for certain cameras resulted due to the organisation of specific events. Information obtained by camera traps (e.g. number of participants, profile of the participants) can be mobilized by event organizers or local authorities for the organization of similar future events, the evaluation of past events and the communication on the course of the event.

The frequentation of the different studied user profiles (hikers, bikers and dog walkers) over the hours of the day showed a similar peak in trail-use. For certain trails or during the high season(s) this might trigger tensions and conflict between users. Several incidents between bikers and hikers have already been reported for the Ardenne region (Newmedia, 2020; Sudinfo, 2020). Camera traps could be used to objectively examine this issue in problem-solving processes. The spatial variation of the presence of the different profiles seems largely due to access restrictions or to physically unsuited trails for specific types of use. For example, “HF-Baraque Michel”, the camera that recorded the highest overall frequency, accounts for 34% of the monitored hikers in the Hautes Fagnes, though only accounts for 8% of its bikers. Indeed, bikes are not allowed on this duckboard trail located in the peatland nature reserve. These results thus give an estimation of the frequency of infractions, which could hint site managers on the need of a revision of the signage or the need for an intensified field control at this place. The camera “PNDO-Barrage de Nisramont” shows 36% of hikers versus 12% of bikers, this difference in repartition is probably due to the fact this camera concerns a very steep and rocky trail.

Due to the observed impact of the camera positioning on the number or persons identified on a same image, it was not possible to draw conclusions from the observed group sizes. A standardisation of the camera positioning is advisable in order to address this issue (see section 4.3).

iii. Sources of unwanted variation

A first element that disturbed the quality of the obtained data within this study, was the initial supplementary blurring of the images. Hence, sharp images reinforce the differences between neighboring pixels; blurred images on the other hand complicate a correct class identification and significantly reduce the performance of neural

networks (Dodge and Karam, 2016). Overall, improving the sharpness of the photos does not significantly impact the specificity of the model. This means that the model does not mistakenly "visualize" objects when the images are blurred. On the other hand, the sensitivity of the model increases when the quality of the images improves. Therefore, using sharp images will increase the performance of the model for all the classes of objects studied.

A second element that affected the quality of the data was camera positioning. This aspect is discussed based on the identified causes of non-detection events. A first cause was the superposition of objects. Superposition occurred principally when cameras were positioned relatively frontal or with an angle of (nearly) 90° to the trail. Objects passing respectively behind or next to each other, are hence superposed on the image. This complicates a correct identification by the model.

The second major cause of non-detection concerned too-far-away objects. However, this issue should rather be considered as one of potential redundancy. Cameras positioned frontal to the trail allow objects for staying too long within the field of view. When the camera is activated due to a movement detection of a nearby object, objects situated at a greater distance are also captured on the same image. While a part of those remain undetected, it has been observed that the model does detect these objects on several occasions, especially in case of a good luminosity; this potential redundancy should be avoided.

Thus, even though Campbell (2006) proposes to place a camera such that trail users are moving towards or away from the camera in order to deal with fast moving cyclists, this frontal position does not lend itself for automatized detection methods due these issues of superposition and too-far-away objects. The best ratios of detection were found for cameras placed with an angle between 30 and 80° to the trail.

In addition, it is advisable not to place the cameras nearby landscape elements conducive to stopping objects of interest (as e.g. nearby bridges, tree stumps, intersections and hide-outs), since this increases the risk for redundancy.

A too great height of the camera, in combination with a low image resolution, complicates a correct identification of low to the ground objects, such as dogs in this study (author's observation). In addition, the Mask-RCNN model was trained on a dataset where objects were represented at about eye level (see https://cocodataset.org/#explore), giving a different perspective than a bird's eye view. The closer a camera is positioned to the trail, the more its height should be reduced in order to reduce this plunging view. A height of 2m at a distance of 3-5m seems ideal, though this also makes the cameras more visible to visitors, for which it is important to be able to protect them from theft, but also to camouflage them so as not to alter the behavior of the visitors.

Plant and light obstruction must also be taken into account when placing the cameras. It is advisable to verify the images taken during the first days to check for potential elements causing false triggering or obstruction. In addition, the vegetation at the edge of the detection field must regularly be trimmed.

iv. Future Perspectives

This study clearly demonstrates the potential of using camera traps in combination with artificial intelligence for outdoor visitor monitoring based on the amount of data handled, a continuous monitoring period, a correct identification of empty images and main objects of interest, the provision of qualitative data (i.e. visitors' profiles) on top of quantitative data and the possibility to verify manual data anomalies. Nevertheless, several possible improvements were identified for further research or field applications: (i) a standardized positioning of camera devices when comparison between cameras is envisioned, (ii) an improvement of the sensitivity of the model for objects of interest other than persons, possible through a scene-specific training of the method on images coming from cameras trap rather than from an external dataset (Cioppa et al., 2019) (iii) a clear policy regulation concerning privacy protection regarding the use of camera traps for visitor monitoring and the adopted analytical methodology, (iv) further research on how to compare or integrate different quantitative and qualitative monitoring techniques, such as mobile phone positioning data, visitor surveys, ecological impact valuations, etc. Note that the issue of privacy protection could be partly resolved by employing an algorithm that automatically detects the face of a person (e.g. Farfade et al., 2015) and blurs it on-the-fly before storing the data.

The quantification and reporting of visitor frequencies to natural areas, where afore no site-specific data was available apart from subjective observations, allows for highlighting the importance of these natural areas for the general public. An accurate estimation of visitor frequencies could facilitate a re-consideration of priorities in terms of the prioritised ecosystem services of a certain area as well as in terms of the budget released to sustain those respective services. While the cameras devices of this study were no longer in place during the COVID19 pandemic, the site of the Hautes Fagnes has temporarily been closed due to a reported over-frequentation (Jebali and Van Oppens, 2020). This event triggered a public discussion on how to sustainably combine nature conservation, access rights to nature for different user profiles, and diffuse and concentrated visitor frequencies (RTBF, 2021). The implementation of a flexible and continuous monitoring system, could facilitate decision making processes on this topic by providing reliable and objectivized information. Our results confirmed for example the general assumption that more remote trails receive lower frequencies than easy access or well-reputed or sign-posted trails (Marion and Leung, 2004; Zhai et al., 2018). An estimation of the order of magnitude of visitor frequencies to these different locations and its variation over time can guide site managers in the management and structuration of visitor fluxes through space and time, as well for existing as for future areas, prone to nature based tourism. Two brief concrete examples from our study-site can illustrate this point: (i) Apart from persons and person-related attributes, the detection of small and larger wildlife could also be envisioned, hereby completing existing wildlife monitoring systems (e.g. see Miller et al., 2017). This could indeed be useful for fostering an exchange on wildlife and visitor frequencies and cohabitation. So has for example one of the cameras of this study captured several images of the first official comeback of the wolf to the Ardenne territory. (ii) Within the context of the recurrent discussion on the cohabitation of

hikers and bikers in natural areas (Fontaine, 2020; Lamquin and Leprince, 2021), an idea of the proportion of each of these user profiles for different areas can help to identify problematic points, but also to nuance the media fuss that could arise around it.

This information on frequencies and visitor profiles in natural areas is, among others, to be combined with data on visitor preferences for landscape characteristics, as well as with indices of the ecological status of the landscape in question. For example, Baum et al. (2017) found that the ecological characteristics of a site explained for the largest share of its visiting frequencies, with specific location ranked secondly; and Simkin et al. (2020) found that the type of forest (old-growth, plantation, …) has an impact on the mental health effect on forest visitors. These data can inform site management strategies and provide arguments for a potential shift in management practices. As Eagles et al. (2000) pointed out when no information is available, there is the risk of being undervalued by management decisions, therefore a sound monitoring is needed to assure the sustainable management of natural areas.

d) Conclusions

The aim of this research was to contribute to field of visitor monitoring by testing the potential of the combination of camera traps with automatized image analysis. The innovative character of this study lies exactly in the further exploration of this combination and its related technical and analytical issues, hereby complementing the work done by Staab et al. (2021). The outlined methodology allows to alleviate one of the main constraints to the use of camera traps for visitor monitoring in a continuous way, namely the time-consuming demand in terms of manually verifying each image, without losing the level of detail of the available information. While this research concerned a pilot study and several points of improvement were identified, it also demonstrated the potential of this method. Camera traps in combination with artificial intelligence are able to provide insightful site-specific quantitative and qualitative information on visitor frequencies and profiles over a continuous time frame. This can complement information from more large-scale monitoring valuations if existent. Visitor frequency data should be combined with an understanding of the drivers behind those frequencies, such as specific landscape characteristics, with insights in the socio-cultural context, and with the ecological status of the area, among others. This research represents a contribution to the field of visitor monitoring and ecosystem services valuations. It provides an improved tool to visualize the importance of natural areas for recreation and tourism, which in turn can foster the sustainable management those areas.

Funding: This work was supported by the Interregional (Interreg) European program through the Ardenne Grande Région, Eco-Tourisme et Attractivité project (AGRETA) (2.336.460, 77€, 2017–2020).

Declarations: Conflict of interests - The authors declare no competing interests

Chapter 3

Forests' attractiveness and importance

1. Framing of the article

In respect to the objective of valuating socio-recreational ES of the Ardenne forests, after having evaluated the ES recreation/ecotourism via the flow indicators of visitor frequencies, the spatial temporal variability in these visitation rates and visitor's main profiles, I turn to the ES aestheticism of the Ardenne forests. In addition to the number of visitors, there indeed exists a well-documented research interest concerning the aesthetic preferences of visitors with respect to different types of nature or landscapes (e.g. Dramstad et al., 2006; Giergiczny et al., 2015; Gundersen and Frivold, 2011; Qiu et al., 2013; Shafer et al., 1969; Weller and Elsasser, 2018; Zoderer et al., 2019).

The estimation of the attractiveness or aesthetic appreciation of a landscape and its recreational potential may provide insights that are useful for developing nature-based tourism in accordance with societal aspirations (Eggers et al., 2018; Schirpke et al., 2018). Nevertheless, visually attractive landscapes may not be of ecological interest (Carvalho-Ribeiro and Lovett, 2011), thereby generating a trade-off between recreational and conservational objectives. Or, on the contrary, aesthetic preferences may correspond with ecologically interesting landscape features and thus reinforce one another, but conflict with current management practices. As the aestheticism of forests depends strongly on the adopted management practices, both are situations which might create tensions over the management of the landscape. Another possibility is that as long as access to nature areas is guaranteed, visitors might also not care at all about the specific landscape features. Therefore, a relevant question becomes: what type of forests do visitors prefer and what are the characteristics or more natural forests that (potential) visitors consider more attractive to visitors than characteristics of less natural or more intensively managed forests?

As aforementioned, the structure and composition of forest ecosystems is often greatly altered by management practices. The optimization of timber production on the short term has, relative to the structure and composition of forests, often led to a reduced number of tree species, to the introduction of exotic tree species, to a reduction of the average tree size, to an alteration of under storage diversity, to a reduction of the vertical and horizontal heterogeneity of forest stands, and to a reduced amount and diversity of remaining deadwood, all of these forest attributes which are likely to have an influence on the provisioning of various ES (Felipe-Lucia et al., 2018).

In this sense, forest preferences can be regarded as indicators of the social demand for the ES aestheticism of forests, of which the supply or the provisioning is strongly defined by forest management practices. Within the context of the aesthetic appreciation of forests, we use the definition of ES demand as proposed by Schröter et al. (2014), namely "the expression of the individual agents' preferences for specific attributes of the service, such as biophysical characteristics". Preferences are thus considered as indicators of future-oriented demand and express a desire of what *should be* (Frick et al., 2018). It should be noted however that this demand is limited by what is known by or familiar to the respondent (cfr. the shifting baseline syndrome, Monbiot, 2014). What should is thus conditioned by the existent. A comparison of the

characteristics of actual forest landscapes and expressed preferences can lead to the identification of mismatches in ES supply and demand regarding forests' aesthetics (Baró et al., 2015).

Dronova (2019) points out that, while aesthetic preferences may represent a means to enhance the delivery of other ES, the linkages between aestheticism and other benefits and ES remain understudied. As (i) the structure and composition of a forest gives an indication of its naturalness and therefore also of its conservation status and ecological interest, and (ii) natural ecosystems are said to provide a wider range of ES, to reveal aesthetic preferences related to forest structure and composition may provide useful insights for management practices, both in terms of potential trade-offs and synergies.

Previous research has indicated that a higher degree of perceived naturalness was linked to higher aesthetic values and a higher self-reported level of wellbeing for residents close to green spaces (Ode Sang et al., 2016). McMahan et al. (2016) show that respondents answered more negatively to human modified natural environments, compared to non-modified natural environments. Throughout Europe, several studies on public preferences for forest structure, indicate that people prefer stands with visual variation. Concretely this variation refers to stands with vertical layering, irregularly spaced trees and a greater number of tree species (Filyushkina et al., 2017; Giergiczny et al., 2015; Nielsen et al., 2007; Upton et al., 2012; Weller and Elsasser, 2018). Also older stands, as well as the presence of deadwood are favored (Giergiczny et al., 2015; Nielsen et al., 2007), the latter observation however being contested in other studies (e.g. Edwards et al., 2011). Visible signs of intensive forest management practices, such as clear-cuts, heavy machinery and the cultivation of exotic tree species are found to reduce the attractiveness of the forests (Mauser and European Forest Institute, 2021; Ranacher et al., 2020). Overall, people are found to be positive towards forest reserves and close-to-nature forestry practices, and negative towards decreasing the share of forest, as well as to intensive forestry practices (Edwards et al., 2012; Hemström et al., 2014; Ranacher et al., 2020; Weller and Elsasser, 2018).

Giergiczny et al. (2015) underline that while an intensive recreational use may negatively impact biodiversity and ecosystem functioning, forest visitors tend to prefer characteristics associated to more natural forests. This observation indicates that forests which are left to develop naturally, benefitting biodiversity objectives and regulatory ES, are also the forests which are most attractive to humans, thus representing a potential win-win strategy. However, this potential win-win strategy stands in sharp contrast with the observed mismatch between societal preferences regarding forest management and concrete forest management practices and thus reveals a discrepancy between the interests of ecosystem managers and non-managers (as also observed in Eggers et al., 2018; Nordén et al., 2017; Ranacher et al., 2020). Concerning the Ardenne forests, apart from a study by Colson et al. (2010), who found that broadleaved forests have a greater appeal to visitors than coniferous forests, no data on forest preferences has been encountered. Therefore, a first question, relative to the Ardenne forests, concerns:

"Which visual structural forest characteristics are preferred by the wider public?"

Therefore, preferences of the wider public of the Ardenne forests were addressed for several visual forest characteristics, that can be related to the degree of naturalness of a forest. The number of characteristics was restrained to five. This limitation is due to the restrictions on the number of variables used within discrete choice experiments, for which these characteristics have also been used within the same survey. A discrete choice experiments allows for determining an order of preference among the different characteristics chosen. The following characteristics were retained: tree species, age structure, the presence of deadwood and the openness of forest landscapes. Tree height was originally identified as a fifth characteristic as surrogate for tree age, the latter being often used as an indicator of the degree of naturalness of a forest system (McRoberts et al., 2012; Wallenius et al., 2010). Trees that are allowed to grow old indeed represent a specific ecological interest, a.o. as they often become so-called "habitat trees", which contain various "niches" that are used as habitats by other species (Vallauri et al., 2016). However, this characteristic was finally abandoned due to its limited relationship to tree age and the presence of habitat trees, two elements related to forest naturalness (McRoberts et al., 2012; Vallauri et al., 2016; Wallenius et al., 2010), and the observed difficulty of survey respondents to perceive the difference between medium and tall trees when presented in meters. Details on the methodology will be outlined in section 2, but below I elaborate on the choice for these specific characteristics.

i. **Tree species**. Tree species, and more specifically endogenic versus exogenic species compositions, is an often used indicator to assess forests' naturalness (McRoberts et al., 2012; Winter, 2012). In a first version of the survey (not mobilized for this manuscript), three options were available: coniferous, broadleaf and mixed forests. After analysis of the results, mixed forests were clearly preferred, an observation confirmed by various other studies and stresses the overall preference for heterogeneity (Filyushkina et al., 2017). However, since mixed forests are barely present in the Ardenne, this variable was adapted in order to force a trade-off between coniferous and broadleaf forests, which represent more accurately the field situation. As coniferous species are exogenous to the region and are most often in monoculture plantations with a clear-cut regime, the level of naturalness of these stands lies lower compared to broadleaf forests. Moreover, the current forestry code (Code Forestier, 2008) defends a so-called equilibrium between broadleaf and coniferous, often (mistakenly) interpreted as a 50-50 division and therefore commonly used to argument against proposals to increase the share of more natural broadleaf forests (Maebe et al., 2019). Currently, the proportions of coniferous and broadleaf forests within the Ardenne forests are 43% and 57% respectively (Kervyn et al., 2018). Evidently this binary distinction does not allow for distinguishing between endogenic and exogenic broadleaf tree species, which can also be found in the Ardenne, e.g. Northern Red Oak (*Quercus rubra*). However, while this is in important element to determine

the degree of naturalness of a forest, the survey was oriented towards the wider public and therefore simplified to broadleaf forests in general (with an assumption of being endogenic) versus coniferous forests.

ii. **Age structure**. The third variable concerns the age structure of the forest with two sub levels: even-aged and uneven-aged forests. Even-aged forest stands are a result of a forestry system based on clear-cuts and plantations. Even aged forests concern thus human-picked trees of the same age, planted at regular distances of one another, hereby representing a forestry regime that is easily recognizable in a visual manner. On the other hand, uneven-aged forests indicate non-exploited forests or more selective cutting-practices and/or natural regeneration processes. Uneven-aged forests represent thus vertically heterogeneous forests with trees of various ages issued from natural selection processes. Forest structure, including age structuring, is a commonly used indicator for assessing forests' naturalness (McRoberts et al., 2012; Winter, 2012), with uneven-forests containing higher degrees of naturalness than even-aged forests.

iii. **Deadwood.** The presence, type and amount of deadwood is an often used indicator for the degree of naturalness of a forest (Laarmann et al., 2009; McRoberts et al., 2012; Wallenius et al., 2010). In forests, about a quarter of the species are associated to deadwood (Vallauri et al., 2016). Deadwood is largely categorized into standing and laying deadwood, each with its specific biotic species associations. In European un-managed forests, average volumes of deadwood are situated around 160 m3/ha (Mergner and Kraus, 2020). However, average European forests contain less than 5% of their expected amount of deadwood in natural conditions (WWF, 2004). To enhance forest biodiversity it is proposed to increase the amount of deadwood in temperate forests to a threshold value of at least 20-30 m3/ha (Müller and Bütler, 2010; WWF, 2004). Currently, the average amount of deadwood in Walloon forests is situated around 9m3/ha (Alderweireld et al., 2015). Forests that have been classified under the Natura2000 network, have the legal obligation to contain at least 2 standing dead trees per hectare. Preferences within our study (see next chapter) are assessed only for a presence versus absence of deadwood. This binary representation is evidently a strong simplification of reality. However, the purpose is not to determine any preferred amount of deadwood by forest visitors, but to capture weather deadwood *in se* evokes a positive or negative reaction, which allows for replying to a main held conception that deadwood is perceived as untidy and thus disturbing (Edwards et al., 2011; personal communications).

iv. **Openness**. This variable concerns probably the most disputed characteristic concerning the degree of naturalness of a forest. As mentioned in the introduction, broadly there exist two opposing theories on the canopy cover of natural temperate forests before humans largely altered its structure and composition. One considers a closed and continuous canopy cover as the dominant situation (Mitchell, 2005); while its rivaling hypothesis considers a more park-like

landscape where the development of dense forests are impeded by large herbivores (Bakker et al., 2016). Without entering into the rather polarized debate on the "truthful hypothesis", natural forests contain undisputedly open spots of different scales due to natural disturbances, as for example in the case of (a) fallen tree(s) or increased water levels by beaver activities.

The assessed preferences within this study concern: dense/continuous forests, forests altered by open areas due to clear cuts and forests altered by natural open areas (e.g. peatland). While these options, contrary to the previous presented characteristics, do not necessarily represent a gradient of naturalness, forests altered by clear cuts clearly contain lower levels of naturalness. This visual sign of human intervention is characteristically linked to the hemeroby approach in the valuation of forests' naturalness (McRoberts et al., 2012). Both other options (continuous forests and forests altered with natural open areas) reflect possible forest management scenarios operating without a clear-cut regime, with their differences depending a.o. on the natural processes and dynamics that are allowed to take place (e.g. wind throws, senescence, natural grazing, flooding, etc.) and served to assess visitors' preferences relative to these both options.

As evident from the above description of visual forest characteristics, the visual attractiveness of the Ardenne forests will depend on the implemented management practices, the latter in turn depending on how, for example, objectives for biodiversity conservation or timber production are put into practice. As already mentioned, forest visitors might value the forest in various ways and not only for its recreational aspects. It is also worth recalling that also other forest actors, such as foresters or hunters, might consider the forests to be of importance for other aspects than for instance timber production or game availability.

Therefore, apart from assessing aesthetic preferences for visual forest characteristics linked to the degree of naturalness of a forest ecosystem to identify potential trade-offs or win-win strategies between aestheticism and biodiversity conservation, it is important to also assess how forests are of importance or of meaning to people. Preferences do not necessarily reflect the importance of something (i.e. one could prefer the color red in case of a forced trade-off but be equally satisfied with the color green). In order to identify potential trade-offs or win-win strategies in forest management, relative to socio-recreational forest ES, it is important to know for which aspects forests are considered most important and meaningful by the wider public. I prefer the wording aspects -although the term may seem more vague- over *functions* (as e.g. in Frick et al., 2018), since I consider the ecological role of a forest not so much as a function, but as a precondition for other forest aspects (including functions) to take place, as well as because of the utilitarian connotation of the word *functions*.

While public preferences for forest features might favor characteristics of natural forests, which could be aligned with a forest management strategy aimed at biodiversity protection, nature conservation might be considered less primordial than the timber production service of the forest ecosystem when asked directly. According to the Eurobarometer, the European public highly values forest ecosystems for

biodiversity conservation and for its regulating ES (a.o. climate mitigation, air and water quality etc.), while economic forest functions (a.o. timber products, biofuel, employment in forestry sector etc.) are considered of lesser importance (Mauser and European Forest Institute, 2021; Ranacher et al., 2020). Anderson et al. (2018) and Frick et al. (2018) underline that an understanding of the perceived importance of various forest aspects, by the wider public is essential to establish publicly accepted forest policies and practices. Therefore, for the Ardenne forests, a second sub-question concerned:

"For which aspects the Ardenne forests are of importance to people? And what is their relative importance?"

In order for being able to answer these questions, it needs to be cleared out which valuation methods are considered suitable and what is the understanding of those forest values that are being assessed. As aforementioned, the term *values* can be used under various meanings and a significant amount of literature has been devoted to this value question (e.g. Hejnowicz and Rudd, 2017; Kenter et al., 2019, 2015; Kronenberg and Andersson, 2019; Stålhammar and Pedersen, 2017; Tadaki et al., 2017).

First, within the context of ES valuations, employed to evaluate the socio-recreational forest ES within this research, values have been differentiated into dimensions, types, areas, realms, categories, lenses, etc.; into economic, monetary, social, cultural, socio-cultural, ecological, biophysical, etc.; or further into use and non-use, future, potential, market and non-market, existence, etc.; or more broadly into intrinsic, relational, shared, communal, instrumental, assigned, held, transcendental, contextual, etc. The exact differences between all these wordings are often not clear and moreover, frequently overlap. At the same time a variety of conceptual frameworks with each their particular adaptations try to align a certain set of value-meanings in a coherent and comprehensive ensemble. Which framework is thus employed and which are the values under valuation?

Second, as different actors have different backgrounds and interests, they are associated with different (sets of) values that are of importance (see previously). These values may vary across space, time and social groups (Tadaki et al., 2017), with certain values being more prone to change than others. Concerned actors can represent individuals or (institutionalized) groups. In relation, differences have been found when performing individual or deliberated valuations (Kenter et al., 2015a, 2016) or when underscoring personal or perceived institutional values (Primmer et al., 2017). Moreover, actors' values are framed by discourses within a specific socio-cultural and political context. Thus, whose values are actually being assessed when performing ES valuations?

Third, as the choice for a value elicitation method determines to some extent the ES and values that will be assessed, the retained method is in itself a product of a valuation process (Martín-López et al., 2014). The researcher(s) performing an ES valuation can therefore also be concerned as (a) concerned actor(s) and should acknowledge that the valuation outcomes do not produce some true version of given

facts, but rather an interpretation of a certain situation, within a specific methodological framing (Jacobs et al., 2018). For example, Tadaki et al. (2017) argument that valuations operated from a specific methodological viewpoint can mask societal choices as "technical judgements".

In addition, as seen before, there exists a now well-established call to perform integrated and inclusive evaluations that take into account different value interpretations as well as a diversity of concerned actors (Dendoncker et al., 2018b). Needless to say that the value landscape relative to ES and their valuations represent quite of a challenge. Still, values are crucial elements in decision-making processes and play a pivotal role in the ES framework, the latter which is increasingly used in environmental decision-making on ecosystem policies and practices. Therefore, in order to deal with the various ways an ecosystem, the Ardenne forests in this case, is "of value" and to mobilize the socio-recreational ES valuation outcomes in a transparent manner, that is considered legitimate by the concerned actors, a third sub-question seemed crucial:

"How does the use of ES values within ES valuations relate to the notion of importance?"

ES valuations, which involve looking at the state or trends of supply, flow (actual use) and demand of a certain (set of) ES or at the potential mismatches between the supply and demand sides of those ES, can be interpreted as describing the *performance* of a certain (set of) ES. At a conceptual level, it is crucial to distinguish thus from the notion of *importance* used within this research, and which denotes the various ways in which he wider ecosystem providing those ES is deemed of importance. This will be underscored via the concept of socio-cultural (SC) values for an ecosystem as detailed in the next section.

In this sense, the notion of importance can also be considered as expressing a social demand, not for the a specific attribute of a services, nor as "the amount of a service required or desired by society" (Villamagna et al., 2013), which is another frequently used definition of demand within the ES conceptual framework, but as a demand for the policy and management orientations regarding a certain ecosystem as a whole to center their priorities on certain ecosystem aspects or values of that same ecosystem.

This notion of importance is also present within Multi Criteria Decision Analysis (MCDA), a method commonly used within integrated nature and ES valuation frameworks. While a large number of MCDA methods have been developed, most MCDA methods consist of the following six steps: (i) Problem definition, (ii) stakeholder analysis and engagement, (iii) definition of policy/planning alternatives, (iv) definition and assessment of (ES) criteria and their corresponding indicators, (v) selection and weighting of (ES) criteria, and (vi) prioritization of alternatives (Langemeyer et al., 2016).

This method notably allows for combining information on the *performance* of alternative scenarios (e.g. different types of forest management) based on a series of performance indictors with the subjective judgement of different concerned actors

about the relative *importance* of the broader evaluation criteria (e.g. carbon capture, biodiversity) (Saarikoski et al., 2016).

Hence, this abstraction of values at these two levels of interpretation (as ES valuation outcomes describing performance, and as the values reflecting the importance of various ecosystem aspects or criteria) aligns the proposed method of using socio-cultural values (i.e. importance) complementary to ES valuation outcomes (i.e. performance) as will be outlined in the next section.

Nevertheless, there are some main differences between the use of MCDA and SC values. Firstly, MCDA methods are said to be suited for eliciting the judgements of a relatively small group of concerned actors, not for capturing individual judgements across the wider population, thereby potentially compromising representativeness and democracy (Saarikoski et al., 2016). Conversely, SC values can be used for underscoring values for the wider public (see next section). Secondly, MCDA outcomes are strongly dependent on the selection of representative indicators. However, not all criteria/aspects of an ecosystem that are of importance can adequately be measured by indicators (e.g. sense of place) (Scolobig and Lilliestam, 2016), leading to an exclusion of those values in the scoring of alternatives. SC values do specifically identify indicators for representing each value and therefore allow for including a wider range of values in the scoring of their (relative) importance. Nevertheless, it should be acknowledged that the scoring of SC values is also constrained by the choice for the specific SC values represented to the respondents.

Thirdly, the finality of MCDA is to inform decision-making processes relative to the selection of specific future alternative scenarios. SC values on the other hand aim to gain insight on the relationship between performance indicators and the various ways in which an ecosystem is of importance. Apprehending SC values is intended to understand the reasoning behind the acceptance or rejection of certain management scenarios, which allows to challenge the legitimacy of current policies and practices, to disentangle misconceptions on the relationship between e.g. ecological indicators and broader ES or ecosystem values and to create common ground between difference concerned actors on the basis of common values or interests. In this sense, the SC concept can be useful in complement to MCDA by creating space for the expression of a wide range values that are difficult to apprehend by specific value indicators.

In addition, the future performance of an ecosystem under a certain scenario strongly depends on how the governance around the future scenario is organised, which is often difficult to apprehend beforehand based on specific (ES) indicators. While the SC value concept allows to open the discussion on future scenarios by challenging existing policies and practices, MCDA on the other hand potentially fringes the future potential of an ecosystem by relying too strongly on certain indicators, esteemed relevant in the current context, which leaves little room for imagination in the construction of those future scenarios.

These notions of ES performance and the importance of the various aspects of the wider ecosystem providing the ES will be further conceptualized, theorized and illustrated via the concept of socio-cultural values for ecosystems in the next section.

Finally, once preferences and priorities have been identified and once it has been defined how ES values, as well as the broader forest values (via the broader concept of socio-cultural values), are understood and how they relate to each other, one can start to answer the question of what these revealed data tell us about or imply for actual and future forest management? For example, aesthetics, biodiversity and life-support (e.g. filtering of water and air, mitigation of climate change, etc.) are highly valued forest aspects by the European public (Baranzini et al., 2015; Horne et al., 2005; Rametsteiner et al., 2009). These ES do not necessarily represent a mutual trade-off in terms of forest management, but rather a potential win-win opportunity.

Hence, with natural forests demonstrated to provide a wider range of ES (Burton and Macdonald, 2011; Keesstra et al., 2018; Navarro and Pereira, 2015; Winter et al., 2013), natural forests that are managed (or left unmanaged) for biodiversity purposes, are also the ones that are preferred by the wider public (Giergiczny et al., 2015). Nature conservation efforts, based on ecological indicators, could thus generate an increase in certain ES benefits (Bryce et al., 2016) and thereby generate an increased well-being.

In order for the ES approach to support environmental and social sustainable decision-making, an increased focus on this well-being component is essential (Bryce et al., 2016). These insights can nourish the reflections and negotiations around forest management and represent important arguments to shift a timber-maximization oriented management towards close-to-nature forestry practices or lead to the creation of hands-off forest ecosystems, that are left to develop naturally.

2. Article: How integrating 'socio-cultural values' into ecosystem services valuations can give meaning to value indicators

Authors:

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Keywords:

Ecosystem services; Socio-cultural Values; Stakeholders' perceptions; Forest management; Value Pluralism; Subjective indicators.

Abstract:

As an attempt to clarify the meaning of 'values' within nature valuations, this paper proposes the complement and fine-tuning of the concept of 'socio-cultural values' relative to ecosystem services (ES) concept. Firstly, it makes a conceptual clarification between biophysical, social or monetary value indicators describing the performance of a service, and socio-cultural values reflecting opinions on the importance of the various valued aspects of the concerned ecosystem. Secondly, it provides a practical application to illustrate how to interpret 'social value indicators' through their interactions with 'socio-cultural values'. An adequate use of these 'socio-cultural values' combined with subjective social value indicators' makes it possible to take the opinion of a wide range of actors into account and to give meaning to their expressed preferences instead of blindfolding on caricaturized profiles. The case study in this paper deals with the Ardenne forests (Belgium). Wider public preferences for different structural forest characteristics (as performance-oriented ES value indicators) actually relate to different 'socio-cultural values'. The study results reveal a mismatch between current forest management strategies and wider public preferences. This paper clearly demonstrates the potential of 'socio-cultural values' to improve legitimacy and to foster consensus-building or consent of decision-making in natural resource management.

Reference :

Breyne, J., Dufrêne, M., Maréchal, K., 2021. How integrating 'socio-cultural values' into ecosystem services valuations can give meaning to value indicators. Ecosystem Services 49, 101278. https://doi.org/10.1016/j.ecoser.2021.101278

a) Introduction

Despite the popularity of the Ecosystem Services (ES) approach to guide the study and operationalization of human-nature dependencies (Costanza et al., 2017), it has been criticized for its strong normative framing (Robertson, 2006). The term "normative" refers to the ES conceptual framework assuming that nature is a service provider, whereas this is only one way of seeing nature. Moreover, which ecosystem services are then being provided strongly depends on who is judging. In reply, ES have been redefined as 'the benefits that humans *recognize* as obtained from ecosystems that support, directly or indirectly, their survival and quality of life' (Harrington et al., 2010). The addition of the verb 'to recognize' does indeed make the anthropocentric framing of the ES concept more evident since it underlines the point that ES need to be identified by humans in order to exist (Barnaud et al., 2018). It is this definition of ES that has been adopted in this paper. Moreover, since different people recognize different ES, this definition also highlights the importance of accounting for diverse sets of values and evaluations when applying the concept to policy and decision-making (Barnaud et al., 2011; Davies et al., 2015; Hauck et al., 2013; Jacobs et al., 2016; Jax et al., 2013; Martín-López et al., 2014).

Values should be understood as an umbrella concept covering a broad range of different interpretations of what the word 'value' stands for (Spangenberg and Settele, 2016). There are thus various ways to define, classify, assess and express them. However, the way values are conceptualized and measured is subject to ambiguity (Anderson et al., 2018; Kenter et al., 2019) in the sense that certain sets of values are either easily ignored, downplayed or conflated. First, the issue of certain sets of values being ignored has triggered a call for an integration of multiple sets of values into ecosystem service valuations (Boeraeve et al., 2015; Jacobs et al., 2016; Kenter et al., 2016; Martín-López et al., 2014). The recent revision of some main ES frameworks has indeed included multiple values in the amended versions (CICES, 2018; Díaz et al., 2015; Fish et al., 2016; Pascual et al., 2017). Second, a socio-cultural interpretation of values is often downplayed to the benefit of economic interpretations in ES valuations and applications (A. Byg et al., 2017; Chan et al., 2012; Pröpper and Haupts, 2014; Scholte et al., 2015). Thus, even when multiple value sets are assessed, the question of how to integrate, combine or use them for decision-making processes remains a challenge (Dendoncker et al., 2018b; Kronenberg and Andersson, 2019). Third, and related to the previous point, is the tendency to conflate the performance of a service with its importance. With performance we refer to the assessed state or trend of (an) ES; with importance we refer to what extent and how this service or its associated benefits matter (in non-monetary terms) for someone or for a group of persons. This is a fundamental aspect since not assessing the various opinions on importance can cause to overlook crucial interdependencies between services, benefits and concerned actors and thus hamper an inclusive valuation. For example, the performance of timber provisioning (i.e. an ES under consideration when assessing forest ecosystems) could be assessed by biophysical indicators (e.g. the total area under forestry or the volume of annual round wood removals), by economic indicators (e.g. the market price per m3) as well as by social indicators (addressing non-monetary social aspects of the ES). These latter could either be objective (e.g. the

number of employments in the timber value chain) or subjective (e.g. the preference for a certain wood type). However, these valuation outcomes do not address the multitude of meanings or ways in which the ecosystem matters for different groups or persons. These latter notions of importance and meaning-making are strongly shaped by the socio-cultural context of the concerned actors (Berbés-Blázquez et al., 2016; Brondízio et al., 2010; Tadaki et al., 2017).

Bearing these considerations in mind, this paper operationalizes a socio-cultural valuation approach, acknowledging that values are shaped by the broader social context, worldviews and social perceptions (Díaz et al., 2014). Within this paper it does so through assessing both indicators of ES performance and indicators of ecosystem importance. By means of an empirical case study, it explicitly addresses the relationship between both aspects through linking preferences for management options, as indicators of performance, with expressed opinions on the importance of various valued aspects of a same ecosystem. Our aim is to assess how this socio-cultural approach can provide relevant insights for the management of natural resources by explicitly adding opinions on importance to ecosystem services valuations.

b) Theoretical background

i. The relationship between performance and importance

Substantial work has been undertaken to address the different ways of approaching values in environmental valuations (e.g. Arias-Arévalo et al., 2017; Chan et al., 2012; Christie et al., 2019; Gould et al., 2019; Irvine et al., 2016; Ishihara, 2018; Kendal and Raymond, 2019; Kronenberg and Andersson, 2019; Maynard et al., 2015; O'Connor and Kenter, 2019; Peltola and Arpin, 2017; Rawluk et al., 2019; Stålhammar and Thorén, 2019; Van Riper and Kyle, 2014). According to Kenter et al. (2019, 2015), three main concepts of values can be identified: (1) transcendental values as broader core values covering ethic principles or desired end states; (2) contextual values that address the worth or importance of something; and (3) quantitative or qualitative value indicators as outputs of some form of evaluation. Broad transcendental values are said to influence the more tangible contextual values, which, in turn, influence the choice for concrete value indicators (Kronenberg and Andersson, 2019). For values to be explicitly considered in a decision-making processes, they need to be visualized or translated into commonly understood units and communicated. For instance, the category of performance indicators can be expressed through amounts of money, maps and indices (Kenter et al., 2016), while the expression of the meaning and importance of a service (including its emotional, affective and symbolic aspects) can for example take place through rankings or testimonials.

Within an ES valuation framework, values fulfill a mediation function between benefits and processes of governance, which, in turn, can give rise to concrete actions regarding the management of natural resources and ecosystems (Díaz et al., 2015;

Haines-Young and Potschin, 2010). It has been pointed out that broader categories of values, such as transcendental or contextual values, are limited in their expression in terms of actions, which render them less applicable for applied research (Kollmuss and Agyeman, 2002). It should be underlined, however, that the use of performance indicators at best only partially reveal underlying aspects of importance. A focus on mere performance indicators could therefore aggravate mismatches between environmental management and societal expectations and, in turn, lead to social tensions and conflict (Anderson et al., 2018). Explicitly assessing both indicators of ES performance and indicators of opinions on the importance of various valued aspects of the same ecosystem and linking these directly or indirectly to one another, allows for partially addressing this issue.

To this respect, Aretano et al. (2013) call for both using objective and subjective indicators to perform ES valuations. Subjective indicators are understood as self-reported (individually or collectively) preferences (Bryce et al., 2016; Harrington et al., 2010). While preferences in themselves do not necessarily reflect a notion of importance or meaning, they can more easily be linked to expressed opinions of importance than other performance-oriented indicators. In that respect, preferences appear well-suited to bridge the gap between objective measures of performance and the meaning attached to the measured elements, thereby facilitating an integrated nature valuation.

For example, residents close to a forest could strongly dislike the presence of deadwood within it, but at the same time find the biodiversity aspect of the forest very important. This could indicate discrepancies between preferences and the ecological status of the same natural resource (Scholte et al., 2015) and provide an incentive for the government to make efforts towards awareness-raising regarding the positive effects of deadwood on biodiversity. While preferences for a specific aspect (e.g. the presence of deadwood) might be diverging, overarching meanings (e.g. biodiversity conservation) might be shared, thus generating a common basis for discussion or communication. Conversely, preferences for that specific aspect might be similar, while underlying meanings might be different or differently prioritized (e.g. biodiversity conservation and aesthetic appreciation) and thus be differently affected when landscape elements change (e.g. when a bark beetle outbreak causes large die-offs). Hence, while broader categories of values are less easily applicable to nature management, it is possible to address them by gaining insights into their relationships with the category of performance indicators. It is important to note, however, that the choice for certain indicators (whether they are objective or subjective) is also framed by the socio-cultural context and thus not a neutral element. This should be acknowledged and explicitly taken into account (Breslow et al., 2017; Martín-López et al., 2014).

ii. What are socio-cultural values within nature valuations?

Within the ES framework, values and valuation methods have been commonly divided into three domains/dimensions (with terminology depending on the author), which are: ecological/biophysical, social/socio-cultural and economic/monetary

(Kronenberg and Andersson, 2019; Martín-López et al., 2014; Stålhammar and Thorén, 2019). This categorization, however, does not leave any room for introducing the notion of importance in a way that does not cause conflation.

Therefore, we consider these three domains as referring to the ES value indicators used to describe the performance of a service, which is to be distinguished from opinions on the importance of that same service. In a socio-cultural valuation approach when combined with ES valuations, valuation is thus performed on two levels: (i) the evaluation of the performance of a service through objective and subjective non-monetary indicators, to which we refer to as 'social value indicators' and (ii) the evaluation of opinions on the non-monetary importance of the various valued aspects of the same ecosystem through 'socio-cultural value indicators'. As (Kenter et al., 2015b) pointed out, the term "social values" can refer to different usages. The word "social" can be used to indicate a societal or shared interpretation of the aspect at stake, as in social process, social problem, social scale, etc. Shared values, which are to be distinguished from individual values since they refer to values expressed by a set of people who belong to a same group (Kenter et al., 2019), also belong to this type of use. In addition, the term social can also be used to refer to one of the three above-mentioned value domains, next to the ecological and economic value domains. This latter use has often been linked to the original category of cultural ES, thereby representing non-monetary values to describe cultural ES (Sherrouse et al., 2011). Social value indicators thus do not measure a specific socio-cultural value. They instead measure an aspect of the *performance* of a certain service for/to which a person holds/assigns a certain *importance*, the latter being what we call a socio-cultural value. Since the objective and/or subjective social values indicators that will be used to asses a given ES performance ultimately depend upon the socio-cultural (including institutional) context within which the valuation takes place, we acknowledge that social value indicators are not completely independent from socio-cultural values. However, since social value indicators do not necessarily entail notions of importance, we propose to explicitly look at the interaction of performance and importance through assessing the interactions between social value indicators and socio-cultural value indicators.

As a matter of illustration, let us consider, for instance, the case of landscape attractiveness for tourism activities as an ES. Its performance could be described by a set of biophysical value indicators (e.g., hectares of accessible forest), economic value indicators (e.g., the willingness to pay to visit certain landscapes) and social value indicators (e.g., tourist preferences for certain landscape characteristics). Socio-cultural (SC) values, in turn, could point out the importance of therapeutic, patrimonial, economic and other values related to a variety of aspects of that same landscape. It must be noted that socio-cultural values may encompass negative repercussions (e.g., a negative feeling related to mass tourism). SC values represent a process of giving meaning/ assigning importance to an ecosystem by different actors (Munda, 2004). An ES demand may thus entail a concrete demand for the service *in se* (e.g., grasped by a performance indicator such as the number of accessible hectares) in order to modify the indicator outcome in future evaluations (e.g., to increase the

number of hectares), or result from a will to give more weight to a service (e.g., perceived through SC values that reflect the importance of forests as a leisure area).

In this paper, the term 'social value indicators' is used to qualify those indicators belonging to the social value domain. The term socio-cultural values is of a distinct nature and is used to denote 'an opinion on the non-monetary importance people, as individuals or as a group, assign to the various aspects of an ecosystem (based on Scholte et al., 2015). SC values can thus be either individual or shared values and may or may not concern a service with a social intention. Within this definition, the term "cultural" thus adds a process of meaning-making (Fish et al., 2016; Propper and Haupts, 2014). As far as debate on environmental values is concerned, SC values can be deemed as touching upon instrumental, intrinsic, as well as relational values (Arias-Arévalo et al., 2017; Small et al., 2017). Whether values exist as inherent to nature, or whether valuation is, by definition, an outcome of human activity, is a matter of debate. However, human valuation is surely not limited to instrumental values only (Jax et al., 2013). Socio-cultural values provide a space to express relational values as well, and intrinsic values, which are inevitably intertwined with people's interpretations of ES (Chan et al., 2012; O'Connor and Kenter, 2019). SC values echo the aforementioned broader literature on values in which we situate SC values as being contextual and place-based (Tadaki et al., 2017). However, while SC values are framed as place-based since they address the importance of ES and benefits within a same ecosystem, this does not necessarily mean that the specific SC value is expressed as place-based. For instance, while patrimonial values are likely to be interpreted as place-based, biodiversity values are likely to represent an overall concern.

As an illustration, let us consider the ecosystem service of a natural area as a place where people can experience nature, such as the Abruzzo National Park in Italy. To evaluate this service and how it performs, a value indicator is decided on, measured and represented by a specific unit. In this case, a biophysical value indicator could be the number of brown bears (*Ursus arctos marsicanus*), the emblematic species of the Abruzzo National Park; an objective social indicator could be the number of local institutions that use the image of the bear in their communication; and an economic indicator could be the cost associated to the distance people are willing to travel to observe this species. Once an evaluation methodology is agreed upon, the factual outcome (e.g., the bear population size) is a given. However, what this number means depends on who is interpreting it and in which context. It can thus be subject to discussion. For example, a high number of bears could be interpreted as positive by tourists wanting to observe this species, but as negative by local shepherds concerned with the security of their livestock (although interpretations are not necessarily one-to-one dependent on users' profiles). These groups of stakeholders thus hold different preferences (subjective social indicator) for the bear population size (objective biophysical indicator). Divergent interpretations of the same indicator can result in conflicting usages and practices when not properly addressed. Once an outcome is produced, it still needs to be given a meaning, which is what socio-cultural values are about. Through explicitly linking the preferences for a management option (here, on bear population sizes) with how the ecosystem matters for different actors, it is

possible to address which notions of importance and meaning play a role in the choice for management scenarios and thus take them into account during management decision making. The process of giving meaning can differ for different stakeholders and according to the contextual setting of the evaluation. It can also relate to different ES. By confusing performance with importance or by only assessing one of both, these observations would be lost in the blender of "values". This could be quite problematic given that they withhold important information for making decisions and communicating about the eventual bear population policy and what roles and functions of the area (the national park in this case) are being prioritized.

To summarize, performance-oriented value indicators and SC values are strongly intertwined with one another, with the first being dependent on the latter. This does not preclude that they also are of a distinct nature and should thus not be confused in nature or in ES valuations. Therefore, indicators should (1) be assessed at these two levels (performance and importance) to (2) enable a proper accounting of the connection between performance indicators and meanings. As a result, while performance-oriented value indicators and SC values both provide relevant information, the most interesting aspect of addressing both aspects of performance and importance, is that it allows for a better understanding of how these distinct indications regarding the 'value' of a given ecosystem interact. Another important notion about the way SC values are assessed in this study concerns the idea of relative importance. By this we refer to how much a certain ecosystem aspect matters relative to other aspects, as well as to how this differs according to different stakeholders, which reflects the idea of certain meanings being prioritized over others (Masterson et al., 2019). This relativity was enforced through the methodology (see Section 3.4), and while it does not imply that some values necessarily have to be more important than others, it does make it possible, on an aggregated level, to identify priority values for the overall public as well as for specific stakeholder groups (though the latter has not been dealt with in this study). Once SC values have been assessed, the aim is to explore the links between these contextual values and the connections with performance-oriented ES value indicators. Within this study, the latter are subjective social indicators and assessed through concrete preferences (see Section 3.3).

The following diagram (Fig. 13) mainly draws on the ES cascade- model by Haines-Young and Potschin (2010) and on the framework for conceptualizing cultural ES by Fish et al. (2016). It provides a schematic overview of the concepts and their linkages as outlined above. ES and their resulting (dis)benefits are interpreted as outcomes of the interactions between ecosystems and human agency (Ernstson, 2013), the latter encompassing both 'socio-cultural practices' and 'contextual values' as pictured in Fig. 1. Nature valuation outcomes can both concern performance-oriented indicators (i.e. assessed in this study through preferences as social value indicators) as well as indicators reflecting an opinion of importance (i.e. are assessed through the use of socio-cultural value indicators).

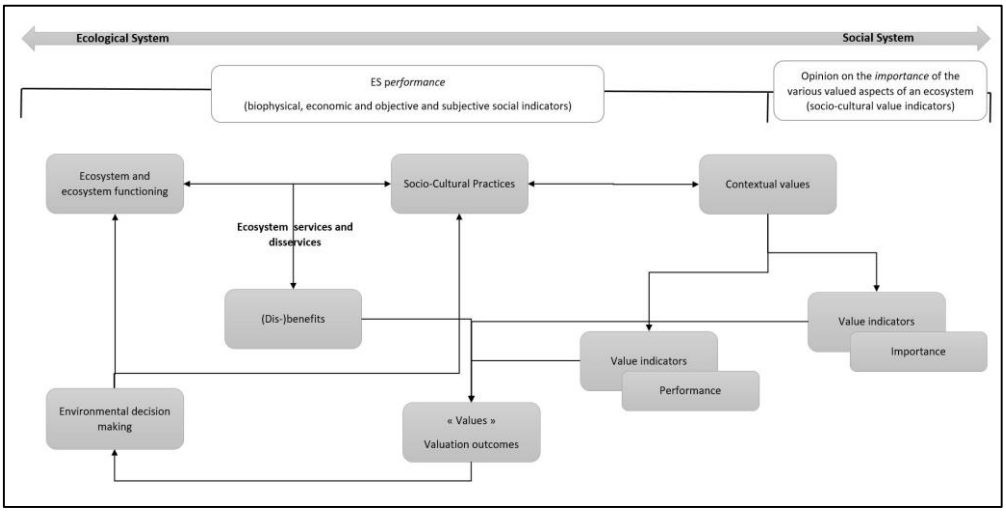

Figure 13. A schematic overview of the concepts used within this study

iii. The added value of a socio-cultural importance-performance approach

Rather than a fixed set, the set of socio-cultural values that can be taken into account should be flexible and depends on both the specific situational context and on the research settings (Barnaud et al., 2018; Reyers et al., 2013). Its meaning-making can vary for different stakeholders since it assesses the criticality of variable social interpretations of ecosystems including their ES (see the issue "Critical for whom?" in de Groot et al., 2010). By differentiating between performance and importance, a SC value approach represents an elegant way to cope with the current conflation between value meanings. By a SC value approach, we refer to (1) the double valuation of subjective social indicators and of SC values that assess the opinions on the importance of the concerned ecosystem; (2) a valuation of the correlation between these two forms of indications; and (3) an interpretation of those correlations. By contextualizing subjective performance-oriented indicators through highlighting their interactions with SC values, the SC value approach could foster consensus-building and improve the legitimacy of compromises. Through a case study we will demonstrate its potential to bring both transparency and legitimacy to decision-making processes, e. g., by identifying common ground between stakeholders as well as by recalling the (inter)dependencies between stakeholders and the ecosystem functioning.

c) Materials and methods

i. Concretizing SC values: The attractiveness of natural landscapes

To demonstrate the relevance of distinguishing performance from importance in order to address the meaning making behind subjective social value indicators within nature valuations, we focus on the ES, "attractiveness of natural landscapes".

The "attractiveness of natural landscapes" is traditionally evaluated within the category of cultural ecosystem services (Haines-Young and Potschin, 2012; Millennium Ecosystem Valuation, 2005). The purpose of most of these evaluations is to estimate the recreational and touristic potential, monetary value or the potential number of visitors of a certain area. This is done either indirectly by testing certain indicators such as trail density, the number of red list species, the presence of water bodies, etc. (e.g. Nahuelhual et al., 2013; Schägner et al., 2018), or directly through expressed preferences or count data (e.g. Chhetri and Arrowsmith, 2008). These evaluations describe the situation of the service by means of evaluation indicators and rarely assess the relative importance of this service with respect to other ES. As a consequence, they also ignore the interdependencies between for example ecotourism or recreation and other ecosystem-dependent benefits, values or stakeholders. For instance, when focusing on the ES, "attractiveness of landscapes", a specific interest (e.g. tourism) is linked to a specific profile (e.g. a tourist), which might obscure a multitude of reasons why the visitor cares about the landscape; these reasons may form part of the motivation for tourism but are ignored during the valuation. By assessing both subjective social value indicators and SC values, this could allow for the inclusion of other aspects into the ecosystem valuation, even if this is not the main objective of the specific study.

The ES, "attractiveness of natural landscapes", is extremely well suited to demonstrate the relevance of distinguishing and combining performance-oriented subjective value indicators and socio-cultural values. This is because of the above-mentioned usual framing as a single cultural ES, as well as because of the multiplicity of stakeholders related to this ES, whether they be (potential) users or managers. This multiplicity can lead to diverging preferences on (specific elements of) management options and consequently give rise to potential conflicts. For a given case-study we will evaluate landscape preferences (as indicators of performance), as well as opinions on the (relative) importance of ES provided by the same landscape in order to demonstrate the added-value of this approach.

ii. Case study area

The area of our case study, the **Ardennes forests**, is a geographical unit of 11,200 km2 that stretches over parts of Belgium, Luxembourg and France (see Fig. 14). Our focus concerns the Belgian (Walloon) part. These forests include large open areas such as prairies, peatlands, clearings, etc. Its specific location, with 6 million people living within a buffer radius of 100 km, gives the Ardenne a peri-urban character,

implying a high existing and potential demand for tourism and recreational activities (Colson et al., 2010). While traditional focuses on wood production and hunting activities remain important, eco-tourism is increasingly being seen as an economic alternative with the potential to stimulate the local economy and diversify activities in a way that is consistent with the protection and promotion of biodiversity (Filot, 2005; Laurent and Lecomte, 2007). Moreover, recent findings have emphasized the demand for a more explicit integration of social and ecological forest dimensions (Rametsteiner et al., 2009), with an observed shift in societal values away from predominantly instrumental and towards multifunctional values (Kendal and Raymond, 2019; Uggla, 2017).

Conflicts related to forest management have recently increased at the European and worldwide scale (Mormont, 2006). In the case of the Ardenne forests, indicators of potential conflicts include: citizen demonstrations against possible sales of public forests (mpOC, n.d.), a petition against current hunting practices (Stop Dérives Chasse, 2021), the return of the wolf to the Ardenne (Denayer and Bréda, 2020), management of the african swine fever (Baily, 2018) and management of the bark beetle (*Ips typographus*) outbreak in spruce plantations (Forêt & Naturalité, 2021b). These elements concerning Ardenne forest management render this study area very suitable for assessing the interest of evaluating interactions between subjective social value indicators and SC values.

Figure 14. The geographical localization of the case study area. The trans-border Ardenne forests are indicated in green, Belgian borders are highlighted in red.

iii. Survey

An online survey was outsourced to the private company Kantar ("Global Data Insights," n.d.) in order to obtain a sample of 1516 respondents (after elimination of speedsters), of which 286 were French, 686 Belgian, 278 Dutch and 266 German. Country proportions were defined by the authors of this study, based on the main visiting nations of the Ardenne forests[2]. The representativeness of each country sample was verified for the following socio-economic variables: gender, age, income level and education. Even though the fact that outsourcing the survey to a private company might induce some bias regarding the profiles of the respondents in their panel, the company was responsible for guaranteeing a country-wise representativeness for the gender and age variables. Three versions of the survey were used: Dutch, French and German. Respondents were contacted by mail. The survey was conducted in April 2019 and took an average of 17 min. to complete. It consisted of five main parts: (A) introduction; (B) respondent profiling and scoring of SC values; (C) frequency and nature of visits to natural areas in the Ardenne; (D) preference questions and discrete choice experiments (DCE) on structural forest characteristics and on touristic infrastructure; and (E) socio-economic variables. Parts B and D are of major importance within this paper since they deal with performance-oriented indicators (preferences) and SC values; they thus serve to illustrate the conceptual reflection outlined above.

The orientation towards the wider public as a sampling group is relevant since it is a concerned actor in various ways: in terms of its tax contribution to the management of public forests (Byg et al., 2017), as residents of the area, as potential visitors (Turkelboom et al., 2018), and in terms of gaging public opinion about the importance and meaning of natural areas in contrast to local interest groups. Following this reasoning, we evaluate whether or not responses differ between residents and non-residents of the Ardenne region in all of the analyses. When relevant, we divide non-residents into effective visitors (who visited the Ardenne forests at least once during the last 12 months), occasional visitors (who have already visited the Ardenne forests, but not during the last 12 months) and potential visitors (who have not yet visited the Ardenne forests).

While this information was available via the survey, respondents were intentionally not further classified into user categories for this research (e.g., naturalist, hunter, forest owner, tourist, etc.). The aim of this study was to focus on common or opposing values within the wider public in general, without relying on a categorization of actors, which could mask within group heterogeneity (Turkelboom et al., 2018). Moreover, since a single person can belong to several categories at once (Barnaud et al., 2018). This implies a superposition of categories, which is not the case when using SC values. Also, the majority of the categories was poorly represented due to our focus on the general public. Although it might have been interesting to look at

[2] Due to confidentiality issues, it was not possible to include respondents from Luxembourg, who are also frequent Ardenne visitors.

differences based on socio-demographic variables as well, this was outside the scope of this research (a part from assessing the sample's representativeness).

A preliminary version of the survey, using the same methodology, was implemented in November 2018. It served as a test for improving questions in terms of formulation, content and representation, which ensures the high quality of the final results of April 2019, used for this paper.az

iv. Subjective social value indicators

To reflect the performance of the ecosystem service, "attractiveness of natural landscapes", we evaluated the preferences of the wider public for structural forest attributes as subjective social value indicators. Four attributes were retained after reviewing the literature (Giergiczny et al., 2015; Hoyos, 2010; Nordén et al., 2017) and checking for their relevance for forest management options and for the Ardenne territory. These attributes are: species composition (coniferous vs. broadleaf), even vs. uneven aged forests, presence or absence of deadwood, and openness of the landscape (whether they be closed forests or forests that include open areas due to clear-cuts, or that include semi-natural open areas such as peatlands or pastures). Respondents were asked to indicate their preference for each attribute, represented using simplified black and white images, as can be seen in Fig. 15. The choice for these basic illustrations instead of images, for example, was to avoid the unintentional influencing of respondents by light, colors, season, weather, etc., that would have been presented on the images. The attribute 'openness' was then split into two variables: one dummy variable describing the continuity of forests (closed (0) or open (1)), and one variable describing the type of openness of the forests (clear-cuts (0) or semi- natural open areas (1)). We checked for differences in preferences (represented as binary variables) between residents and non-residents using non-parametric chi-square tests.

We then regrouped preferences for forest attributes according to three management schemes: 'natural forests', 'artificial forests' (more intensively managed and more production-oriented forests) and 'other' forests. In total, there are 24 possible combinations of attributes or scenarios. 'Species composition' was not included to define the management models. Even though Ardenne 'artificial forests' are mainly dominated by coniferous species, this is not an exclusive given. We defined 'natural forests' by: the presence of deadwood, semi-natural open areas within the forests and uneven aged forests. This combination regroups two scenarios out of 24. 'Artificial forests' were defined through the combination of: the absence of deadwood, even aged forests and continuous forests or open areas due to clear-cuts, representing four scenarios out of 24. All other combinations were grouped into the 'other' group representing the remaining 18 scenarios. We used R Studio statistical software (version 1.2.1335) for all of the analyses.

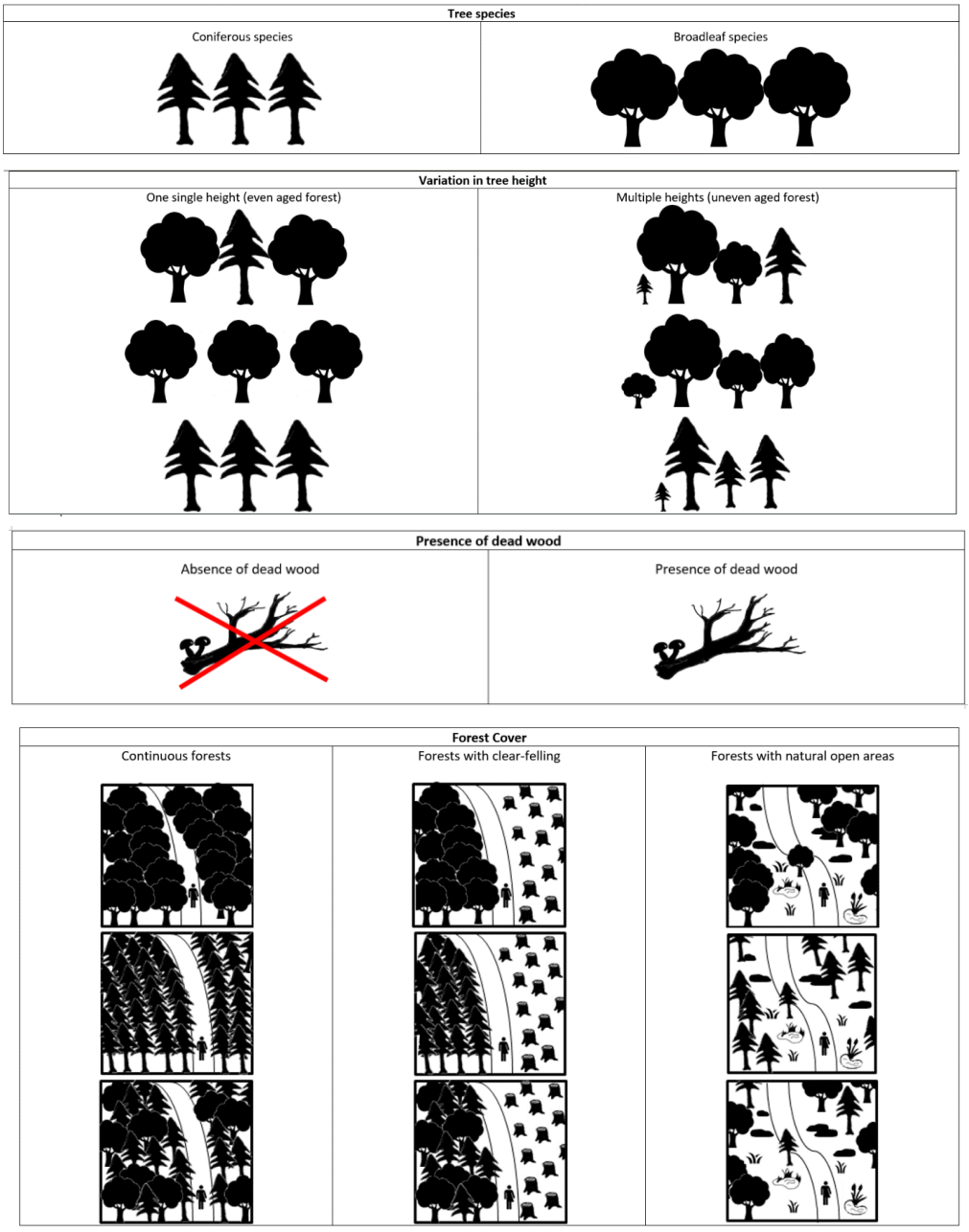

Figure 15. The attributes used for the preference questions on structural forest attributes

v. Socio-cultural values (SC values)

The relative importance of the SC values attributed to the Ardenne forests by the wider public was evaluated on the basis of scoring. Table 7 below specifies the typology of SC values used for this survey. This typology is based on a literature review (Bagstad et al., 2016; Brown and Reed, 2000; De Vreese et al., 2016; Raymond et al., 2009; Sherrouse et al., 2017, 2014; Smith and Ram, 2017b; van Riper et al., 2012). It has thereafter been adapted to the local context based on the recurrent mention of certain values during several informal encounters with a variety of local stakeholders (forest guards, hunters, tourism operators, private forest owners, institutions active on natural resource management, etc.). These encounters took place during autumn 2017 in the context of the preparatory phase of the overall funding project. Participatory observation to several local events on the topic of the (management of the) Ardenne forests (conferences, round-tables, excursions, expositions, etc.) also contributed to the selection. Retained SC values were selected when considered relevant for both locals and tourists, and some specific subdivisions were made to account for the ecotourism-oriented setting of the overall project. The SC values mentioned in Table 7 all refer to the importance of various ecosystem aspects, including ES or a set of ES. Since these aspects can also have important negative repercussions (Blanco et al., 2019), two SC values for disservices have been included. A preliminary version (sample of 775 respondents) of the survey had an 'other value' option in the event that an important value was overlooked. However, since this option was rarely used, this was left out of the final version. Also, for this final version, the order of the SC values presented to respondents was randomized in order to control for this influence.

Respondents were asked to score SC values by distributing a total of 100 'votes' over 13 SC values, consequently enforcing an indication of their relative importance. It was not obligatory to include all the mentioned SC values in the scoring; an automatic counter was used for this question to avoid miscalculations.

The overall scoring of SC values and the variance of the sample was visualized by using a violin plot, for which values underwent a log + 1 transformation, commonly used to minimize the effect of outliers (Garson, 2012). ANOVA tests (R package 'ggplot' v. 2.21) and Tukey's post hoc tests were used to check if residents and visitors (effective, occasional and potential) differed in their scoring. Where assumptions of normality or equal variances were not met, non-parametrical Kruskal Wallis and Dune's tests (R package 'FSA' v. 0.8.25) were used. Dune's tests made use of the p-adjustment method, as defined by Benjamini and Hochberg (BH) (1995).

Table 7. The socio-cultural (SC) values presented to the respondents. Respondents could only see the explicative phrase (second column) and had 100 points to divide up between these SC values

Socio-cultural values and their explanation	
Socio-cultural value	**Explicative phrase showed to the respondent**
	The Ardenne forests are important to me because …
Aesthetic value	… I can enjoy the views, sounds, smells, etc.
Biodiversity value	… they provide a habitat for wild animals, plants and microorganisms.
Direct economic value	… they provide economic products such as timber, mushrooms, game, etc.
Indirect economic value	… they create jobs because of their touristic attractiveness, of which I can make use as a user or operator from the touristic sector.
Extensive recreational value	… they provide a space for my outdoor activities such as hiking, biking, observation of fauna and flora, etc.
Intensive recreational value	… they provide a space for my outdoor activities such as quad, 4x4, MTB circuits, mass events, etc.
Bequest value	… they allow future generations to know and experience these forests.
Patrimonial value	… they are part of the cultural patrimony in the same way as villages, abbeys, castles, etc., and they are part of the history of the region.
Relational value	… they provide a place to create or reinforce social relationships (outings with family or friends, working environment, etc.)
Mistrust value	… one could feel ill at ease in those forests because they create fears (of getting lost, they are dark and gloomy, etc.)
Life Support value	… in the battle against climate change and the maintenance of a healthy living environment through the renewal of soil, air, water, etc.
Inspirational/Therapeutic value	… they are inspiring places and make one feel better, physically as well as mentally.
Disservice value	… they can also have a negative impact on daily life (less room for urbanization or agriculture, pests or damage by wildlife, etc.)

vi. Detailing the used social value indicators and socio-cultural values

Table 8 outlines how SC values have been interpreted for this paper by borrowing from the notions of value lenses and dimensions described by Kenter (2019).

While the specific categories of the dimensions 'intention' and 'justification' are inherent to the concept of SC values, the specific categories regarding the other dimensions result from the methodological framing of the study. Since SC values should cover a range of ways an ecosystem is of importance, the intentions of SC values are both self- and other-regarding, depending on which specific ecosystem aspect is being valued. SC values should concern all three ways of justification to allow for a broad range of meanings. For this case study, respondents in were individually asked to indicate how important a SC value for the study area is for them personally. The dimensions of provider and scale thus both concerned the individual level. As far as the valuation method is concerned, the chosen elicitation process was non-deliberative and resorted to the use of stated values; each SC value was then aggregated from individual levels to represent the wider public's opinion.

The subjective social value indicators used for this study assess public preferences for visual forest characteristics and thus entail an instrumental justification. Respondents were individually asked to state their personal preferences, which were then aggregated.

Table 8. An overview of the addressed value dimensions and categories, borrowing from Kenter et al. (2019)

Lenses	Dimensions	Key question	Categories	SC values (Case study)	Social value indicators (Case study)
Value lens	Concept	What does one mean by 'values'?	Transcendental values Contextual values Value indicators	Contextual values	Value indicators
	Provider	At what scale are values being expressed?	Individual scale (Pre)-aggregated social scales	Individual	Individual
	Scale	What is the scale of the values being expressed?	Individual scale Social scales	Individual	Individual
	Intention	Who is being regarded with the expression of values?	Self-regarding Other-regarding	Both	Self-regarding

	Justification	How are values justified?	Instrumental Intrinsic Relational	All three ways	Instrumental
Procedural lens	Elicitation	What process is used to elicit values?	Stated Deliberated Revealed	Stated	Stated
	Aggregation	How are values aggregated?	Aggregated from individuals Pre-aggregated	Aggregated from individuals	Aggregated from individuals

vii. Linking social value indicators with socio-cultural values

To examine the correlation between social value indicators and socio-cultural values, we assessed for correlations between the three predefined management models ('natural', 'other' and 'artificial' forests) and the SC values. One approach could have been to test the correlations between all SC values and each structural forest characteristic separately. Nevertheless, the choice was made to adopt a three-way management approach since, in the opinion of the authors, it better reflects the adopted management practices in the Ardenne forests and thus facilitates the interpretation of results. We made use of one-way ANOVA (analysis of variance) and t-Tukey's tests of means on the logged SC values. Equal variances were assessed using Bartlett's test. Where assumptions of normality or equal variances were not met, non-parametrical alternatives were used, i.e., a Kruskal Wallis and Dune's test. The BH p-adjustment method was used for Dune's tests. The purpose of the above analyses was to evaluate whether SC values can offer an interpretation the outcomes of the preference valuation.

d) Results

The survey sample was representative (verified per country) in terms of gender. Concerning age, there were slightly less people representing the youngest age class. The sample was overrepresented for the highest income class as well as for the highest educational level, which is a common issue for Internet-based surveys (Menegaki et al., 2016). These demographical characteristics only served for verifying the representativeness of the sample respective to the general population. They will thus not be further dealt with within this paper.

i. Preferences

Table 9 summarizes expressed preferences in percentages. On average, we observe a strong preference for characteristics of 'natural forests', such as the presence of deadwood, uneven aged forest layers and semi-natural open areas within the forests, over characteristics of plantation or highly managed forests, further referred to as 'artificial forests'. Continuous forests are slightly preferred over forests with clear-cut areas, but semi-natural open areas within forests are clearly identified as being the most attractive. On average, broadleaf species are preferred over coniferous species. Residents, when compared to non-residents, had a less strong preference for the following characteristics: uneven aged forests ($p < 0.001$), presence of deadwood ($p < 0.001$), discontinuous forests ($p < 0.05$) and semi-natural open areas ($p < 0.001$).

Table 9. Overall preferences (rounded off) for forest attributes

Structural forest attributes		
Attribute	**Level**	**Percentage (%)**
Species	Coniferous	35.75
	Broadleaf	64.25
Deadwood	Absent	20.32
	Present	79.68
Evenness	Even	12.34
	Uneven	87.66
Forest cover	Continuous	16.82
	Clear-cut	13.32
	Natural	69.85

ii. Socio-cultural values

Fig. 16 represents the average scoring of the SC values selected in this study, ordered by importance, from highest scored to least scored. All SC values were selected by the whole set of the respondents to explain why the Ardenne forests are important to them, although some SC values appear more important than others. The overall top three contain SC values for the aesthetic services of the forests, for

biodiversity conservation and for the renewal of air, water and soil (life support). Negative aspects, such as mistrust and disservices appear at the end of the ranking, but their importance is stronger for residents than for non-residents (both $p < 0.001$). Moreover, residents have higher SC values for intensive recreational services ($p < 0.001$) and effective visitors have higher SC values for therapeutic services compared to occasional or potential visitors (both $p < 0.01$).

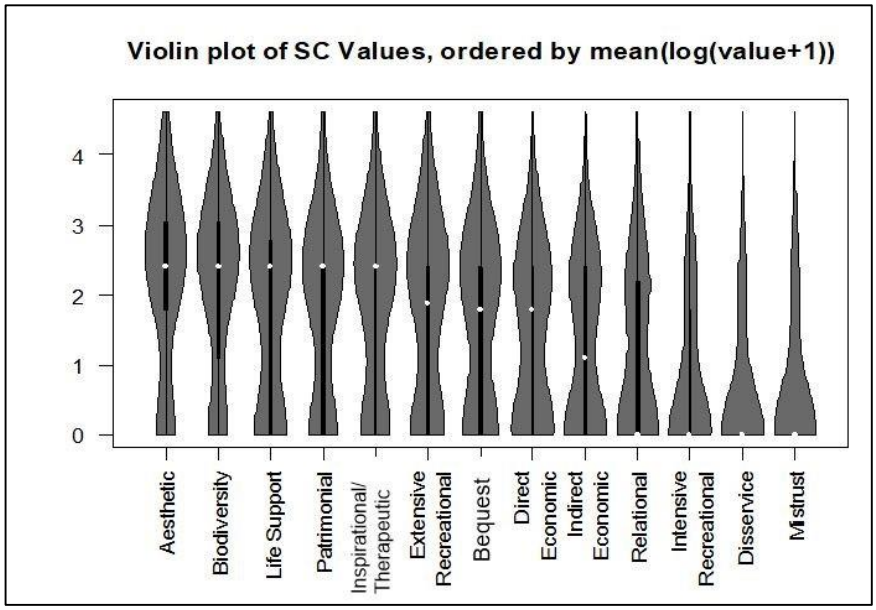

Figure 16. Violin plot representation of the 13 scored SC values, ordered by mean (log(value+1))

2. Linking social value indicators with socio-cultural values

We evaluated whether or not SC values significantly differ between the three predefined management models by using one-way ANOVA tests and the post-hoc Tukey test of means. A total of 874 people chose the combination that was identified as a 'natural' forest, 79 people opted for the combination classified as 'artificial' forest, and the remaining 563 people chose combinations that were referred to as 'other'. The results are summarized in Table 10. Respondents who prefer 'natural forests' scored 'aesthetic' and 'biodiversity' values higher; while respondents who prefer 'artificial forests' scored 'mistrust', 'intensive recreational', 'indirect' and 'direct economy', 'relational' and 'disservice' values higher. SC values for 'bequest', 'patrimonial', 'therapeutic/ inspirational' and 'extensive recreational' do not

significantly differ between management models. Note that the SC value for 'Life support' is not scored significantly different between 'natural' and 'artificial' forests.

Table 10. ANOVA or Kruskal Wallis and t-Tukey's tests of means or Dune's test, comparing the scoring of SC values between the preference groups for three predefined management models ('natural', 'other' and 'artificial')

Results of the scoring of SC values according to forest preferences					
SC VALUE	**ANOVA/Kruskal Wallis Pr(>F)**	**Bartlett's test for equal variances**	**Tukey's test of means/Dune's test**		
			Natural	**Other**	**Artificial**
Aesthetic	p < 0.001	yes	A +	A +	B
Biodiversity	p < 0.001	yes	A +	B	B
Bequest	p = 0.693	yes	A	A	A
Life Support	p < 0.001	yes	A +	B	AB
Direct economic	p < 0.05	yes	A	AB	B +
Inspirational/Therapeutic	p = 0.715	yes	A	A	A
Mistrust	p < 0.001	**no**	A	B +	C +
Patrimonial	p = 0.336	yes	A	A	A
Intensive recreational	p < 0.001	**no**	A	B +	C +
Extensive recreational	p = 0.293	yes	A	A	A
Indirect economic	p < 0.01	yes	A	A	B+
Relational	p < 0.001	yes	A	B+	B+
Disservice	p < 0.001	**no**	A	B +	C +
+ = significantly higher values compared to the other groups.					
A,B,C = groups that are significantly different from each other for a certain SC value.					

e) Discussion

The wider public concerned with the Ardenne forests, including residents and non-residents, has the overall tendency to prefer characteristics of 'natural forests' over 'artificial forests' (plantations or highly managed forests). Clearly, the presence of deadwood, natural open areas and uneven aged forests are preferred over the absence of deadwood, continuous forests or the presence of clear-cut areas and even aged forests. Moreover, broadleaf species are preferred almost twice as much over (non-indigenous) coniferous species. These findings are consistent with previous studies of forest perceptions (Colson, 2007; Edwards et al., 2012; Horne et al., 2005). Overall preferences coincide with features of forest management that favor biodiversity (du Bus de Warnaffe and Lebrun, 2004; Felipe-Lucia et al., 2018; Verheyen et al., 2006).

While certain ES are objectively important for society, irrespective of where they may rank in valuations based on subjective preferences (Gómez-Baggethun and de Groot, 2010), preferences here seem to match a management system that would also benefit from a variety of ES (Lewis et al., 2019; Maebe et al., 2018; Radu, 2006a).

As mentioned before, respondents were not classified into user categories (e.g., hunters, foresters, etc.). For this study, we instead focused on the opinions of the wider public (including residents and non-residents). Extra attention should be paid to residents who resulted more moderate in their 'natural forests' choice and could thus show reluctance when management changes are envisioned. This could be due to the socio-economic dependency of the region on timber and hunting revenues (Carnol et al., 2014).

More recently, researchers have called for mainstreaming integrated ecosystem service valuations. This means that ES valuations should multiple value dimensions into account and that the relationships between these indicators, as well as between stakeholders and ES, should be dealt with (Boeraeve et al., 2015; Jacobs et al., 2016; Kenter et al., 2016; Martín-López et al., 2014). While we follow Kronenberg and Andersson (2019) in that a fully integrated valuation (including all relevant values/dimensions/stakeholders) is not always possible, nor desirable, SC values can complement this integration by underlining the various ways in which an ecosystem matters. Hence, other important ecosystem aspects or services (i.e. than the ones that are the scope of the research) are made explicit and their relative importance can be assessed for different types of stakeholders. Bearing this in mind, this paper considered the interactions between preferences (as subjective value indicators of the performance of the ES landscape attractiveness) and socio-cultural values (as an expression of the relative importance of the various valued aspects of an ecosystem), in order to properly interpret the outcomes of a nature or ES valuation. The following main insights are discussed in more detail in the next paragraphs: (1) SC values can help to remind dependencies between ES; (2) addressing SC values can facilitate the interpretation and integration of objective and subjective value indicators; and (3) addressing SC values can be useful for processes of negotiation, legitimization and communication of natural resource practices.

First, even though the survey was framed around the ES landscape attractiveness, results reveal that respondents take a variety of ecosystem values into account when

scoring SC values. This observation implies paying attention to dependencies and trade-offs between these various aspects of a same ecosystem, which are often ignored (Martín-López et al., 2014). For instance, aesthetic ES, to which people attributed the most importance, depend heavily on the way economic ES are carried out through forest management practices, meaning that the first is subordinate to the latter. Addressing SC values can help to remind us of these dependencies during ES valuations since (1) both aesthetic and economic interests are valued; (2) aesthetic interests were deemed more important than economic interests; and (3) preferences for forest characteristics correlated with aesthetic importance differ from those correlated with economic importance.

Second, certain preferences are correlated with specific SC values. SC values offer a way to interpret the expressed preferences (Gómez-Baggethun et al., 2014) and thus to give meaning to objective indicators assessing an ES. For example, SC values for 'aestheticism', and 'biodiversity' are correlated with preferences for characteristics of 'natural forests'. This correlation could imply a consistency in the concrete visualization of theoretic concepts by the wider public. This does not amount to saying that people necessarily include these theoretic concepts in a fully conscious manner. Indeed, the quantitative approach pursued in this survey does not suffice for comprehending this sort of finer information. Ideally, quantitative and qualitative methods should thus be combined (S. Stålhammar and Pedersen, 2017). While this research constitutes an exploratory application of the SC value approach as described in this paper, the intention is to deepen the meaning-making aspect by integrating qualitative methods in future research. The inclusion of qualitative information would generate further insights, notably on whether people associate SC values and performance-oriented indicators when taking a survey such as the one presented in this paper. In addition, a qualitative approach would more directly allow for assessing how people make meaning, either individually or collectively, of ES performances in relation to a specific place (Klain et al., 2017; Tadaki et al., 2017).

In the same vein, 'artificial forests' that are generally less appreciated, are preferred by people who attributed a higher score to the SC values for 'disservices', 'mistrust', 'direct economic, 'intensive recreational', and 'relational'. On the one hand, this might indicate that these 'artificial forests' are associated with certain negative perceptions through their structural characteristics. On the other hand, they are perceived as being important for their economic contribution, the ease with which they can be used for intensive recreational activities or for supervising the territory, and their role in creating or maintaining social structures, the latter probably being related to the timber industry and/or hunting activities (Carnol et al., 2014). The association between 'artificial forests' and the SC value for direct economic contributions seems to indicate that people perceive intensively managed forests as having a higher productivity and cost efficiency than 'natural forests', while this is not necessarily always true (Dieler et al., 2017; Liang et al., 2016).

Along a similar line of reasoning, the SC value for 'life support' is not scored differently between 'natural' and 'artificial' management models. This could indicate that the wider public perceives these regulatory services as being equally well performed by highly managed or by more 'natural' forests. However, research reveals

that 'natural' forests are more effective in terms of life support services than forest plantations (Lewis et al., 2019). These findings underpin the importance of combining subjective social value indicators of forest preferences with biophysical value indicators of, for example, forest productivity or a forest's capacity for carbon removal to check for perceived associations. In this way, visualizing SC values can facilitate the interpretation and integration of both objective and subjective indicators during nature or ES valuations. Again, to further interpret this correlation, it would be advisable to combine it with qualitative research methodologies.

Third, an understanding of which values are favored through the choice of a specific management scheme can lead to the questioning of the consistency and legitimacy of dominant discourses (Mormont, 2006). The SC value "biodiversity", for example, is cited as the second most important for the Ardenne forests by the wider public, while 'direct economic' revenues are ranked eighth out of thirteen. However, this relative importance does not seem to be satisfactorily accounted for, neither in the observed situation on the field nor in the general policies or local management plans.

The Walloon forestry code (Code Forestier, 2008) incorporated the general concept of 'multi-functionality' of the forest, generally conceived and interpreted as an integrated sustainability scheme with the simultaneous achievement of social, environmental and economic goals (Scohy, 2017). However, this has not yet proved its efficiency to significantly trigger general forest management practices towards satisfactory results in terms of biodiversity conservation (Maebe et al., 2019; Wibail and Farcy, 2018). Dead wood, for example, as a key indicator of forest biodiversity (Radu, 2006b), is highly preferred by the wider public in our study. Despite this, the average volume of dead wood for the Walloon forests is estimated at 8.2 m3/ha (Alderweireld et al., 2015), largely below the 336 to 555 m3/ha found in natural forests (Bobiec, 2002)[3]. Moreover, societal expectations for more 'natural forests' contrast with the actual landscape of Walloon forests, where intensively planted and managed (mostly non-indigenous species) forests occupy more than the half of the forested area (Alderweireld et al., 2015).

Furthermore, numerous incentive policies (e.g., public subsidies for high-density coniferous plantations) and/or actual practices (e.g., conversion of ancient broadleaf forest into planted coniferous forests on the public domain) appear to be contradictory to the declared increased attention paid to biodiversity and life support services (Wibail and Farcy, 2018). As expressed elsewhere, this might well be a form of a 'lock-in' process (Maréchal, 2010; Vanloqueren and Baret, 2008). Among the elements that contribute to locking-in 'artificial forest' practices are the false associations on which policies sometimes rest (such as the above example of perceived exclusivity between economic productivity and intensive forest management—see Drouet (2018).

In order to achieve a forest policy that is accepted and supported by the public and that thus diminishes the risk of conflicts, a thorough understanding of the diverse values associated with those forests is essential (Anderson et al., 2018). Kenter et al.,

[3] The 'critical threshold value' for volumes of deadwood in 'natural' low-land oak-beech forests is estimated at 30–50 m3/ha (Müller and Bütler, 2010).

(2016) point out that even though a democratization of values could enhance a more sustainable and equitable decision-making process in terms of natural resource management, democratic deficits often persist. The observations in this study hint at a certain mismatch between societal values, preferences and actual forest management. This mismatch has also been observed in other studies (Buijs et al., 2011; Deuffic et al., 2018; Edwards et al., 2016; Uggla, 2017), where forest managers seem to have focused mainly on (productive or ecological) performance, while residents focus on a variety of forest meanings (e.g. aestheticism, sense of place, …).

This observation calls for rethinking the way forest policies and practices are decided on and put into practice. As an illustration, we briefly reflect on the example of the bark beetle outbreak mentioned in the case study description. Although they are often assumed to be less productive, natural forests have been proven to be more resilient to pest outbreaks, compared to spruce plantations (Faccoli and Bernardinelli, 2014). Our results show that turning to a more nature-based management would thus account for the overall preferences and SC values that predominantly appear in the wider public's opinion. This observation could serve as an argument to defend a potential change in actual forest management policies.

This reflection shows that SC values could reveal flaws in certain discourses, as well as promoting a renewed management of forests that would correspond to changing societal needs and values. Addressing SC values can lead to new perspectives concerning established discourses and practices. It must be noted, however, that the selection of addressed SC values plays an important role for the interpretation of the results. SC values that were not included in this survey (e.g. educational values, sense of place) may represent important issues that were overlooked and therefore limit the insights that can be retained from this study.

f) Conclusions

This study indicates that we should distinguish the various ways an ecosystem is of importance from the performance of the services it provides. The results indeed show that socio-cultural values offer a useful complement to interpret outcomes of subjective valuations of performance. SC values offer a simple and practical way to add affective valuation in nature or ES valuations and to assist their integrated evaluation. This is because (1) SC values can help to remind us of the dependencies between various forest aspects or services; (2) addressing SC values can facilitate the interpretation and integration of objective and subjective value indicators; and (3) visualizing SC values can help stimulate debate concerning forest management, legitimize (or contest) future decision-making processes, improve communication between stakeholders, and offer possible insights into consensus-building based on common values.

As outlined in Section 3.3, we purposely addressed the wider public instead of looking for extreme viewpoints correlated with existing conflicting discourses. This approach allows us to contextualize subjective performance-oriented indicators, to look for common ground between stakeholders, and to question the legitimacy of actual management and dominant discourses. However, in order to further analyze

the policy potential of this approach, it is advisable to repeat the methodology while addressing specific stakeholder groups and with a more qualitative, place-based approach to understand how people make meaning. This would make it possible to determine whether or not the discourses proponed by the representatives of these groups are coherent with their manifested SC values, and if their preferences and relative importance significantly differs from the wider public.

Finally, even though the aim is to account for multiple sets of values in nature or ecosystem services valuations, this study is a contribution to research on Western studies. However, as mentioned earlier, the list of SC values depends on the contextual settings and can be modified accordingly. Therefore, the use of the SC value concept in nature valuations could provide an added-value in a non-Western context as well.

To conclude, relevant forest management undoubtedly requires the valuation of its performance. Our results also show that socio-cultural values should not be neglected since touching upon importance and meaning-making (and the ensuing possibility to adequately interpret subjective performance-oriented indicators) is crucial for a sound nature or ecosystem service valuation and for adopting socially accepted management strategies.

Declaration of Competing Interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements: Our thanks go to Dr. Nicolas Dendoncker for his helpful comments on the manuscript. We also thank Dr. Jens Abildtrup for evaluating the representativeness of the survey sample.

Funding: This work was supported by the Interreg Europe program under the AGRETA (**Ardenne G**rande **R**égion, **E**co-**T**ourisme et **A**ttractivité) project (2.336.460,77€, 2017-2020).

Chapter 4

Actors' positioning on the return of the wolf

1. Framing of the article

Taking into account the wider socio-ecological context outlined in the introduction as well as the socio-cultural values, the forest preferences and the estimate visitation rates for the Ardenne context specifically, might motivate certain changes in forest management. To decide on these modifications will require discussions and negotiations over current and future forest policies and practices between different forest actors in order to ensure a certain adhesion to the adopted strategy and avoid conflict. At the same time, changes in forest policies and practices require a repositioning of forest actors on the matter and towards one another, which might disturb existing power relations.

Up until now, we only considered the wider public and did not distinguish between different actor profiles. Nevertheless, actors concerned with forest management are classically divided into actor groups based on their respective profiles (foresters, visitors, hunters, …). However, the use of such generic classifications - which associate each individual actor to an overarching general discourse- tends to reinforce oppositions between actor groups and mask the heterogeneity of values and opinions present within a same actor group, hence nourishing conflict (Van Herzele and Aarts, 2019). An approach based on actors' profiles might in this sense not be an adequate starting point for discussions on required changes in forest management.

It has been underlined that the acknowledgement of the diversity of values strengthens the overall legitimacy of valuation processes and the decision-making based on these valuations (Cash et al., 2003). Nevertheless, values are often grouped by actor group and within-group heterogeneity is an issue which can easily be overlooked in valuation processes (Turkelboom et al., 2018). In this sense, it is interesting to investigate how to account for within-group heterogeneity in order avoid polarizations based on actor profiles and to facilitate discussions over eventual management changes. Within this context, I investigated how the use of the SC values concept as theorized in the previous chapter helps doing so by providing insights into the positioning of actors, without relying on their profile. Therefore, the following question was formulated:

"What does the socio-cultural value concept reveal about the use of stereotypes and the heterogeneity within each actor group?"

It can be insightful to address this question for a (en)forced change in the forest ecosystem, notably by the spontaneous return of a key-stone wildlife species. The arrival of a new player on a territory, especially if it concerns a key-stone species, which can have a substantial impact on the entire ecosystem it lives in by for example modulating the resource availability for other species, can alter existing co-habitation modes and thereby give rise to so-called human-wildlife conflicts. Nevertheless, these human-wildlife conflicts can often be interpreted as "human–human dimensions of conservation conflicts arising from the interaction between humans and other species"

(Redpath et al., 2013). Hence, the arrival of a key-stone species can expose and increase existing tensions between different human actors operating within the same space and would thus need a certain concertation regarding decisions on wildlife management.

We applied this question to the case of the wolf (*Canis lupus*). The recent return of the wolf to the Ardenne territory, which occurred during the course of the present PhD research, can be regarded as an example of a spontaneous rewilding event, hereby potentially increasing the degree of naturalness of the forest ecosystem. The wolf, as a large predator, is a keystone species, which potentially has a strong positive influence on the delivery of multiple ES (e.g. riparian restoration, disease regulation, etc.) (Ripple et al., 2014). Nevertheless, these positive outcomes may be dampened or erased by human interventions and thus depend on the adopted management strategy (Ripple et al., 2014). Previous research has demonstrated that threatened or formerly extinct animals, such as is the case for the wolf in the Ardenne, are now increasingly accepted by the wider public (Rametsteiner et al., 2009). This change in public opinion might influence decision-making over wildlife management. Within this context, we first examine overall public positioning regarding the return of the wolf to the Ardenne:

"What positioning does the wider public adopt towards the return of the wolf to the Ardenne?"

The questioning of this positioning will be organized around four recurrent issues relative to the potential polarization around wildlife comebacks based on Van Herzele et al. (2015) (see the next section) and coupled with the expressed relative importance of the ES delivered by the landscape under question. Inspired by the linkages between values, attitudes and behavior (Kollmuss and Agyeman, 2002), the explanatory power of SC values for an actors' positioning is evaluated. Subsequently, we zoom in on the positioning of hunters (i.e. as a concerned actor group) regarding the topic.

Despite the fact that a human substitution does not lead to the same functional consequences for the respective ecosystem (Ripple et al., 2014), the lack of large predators is often mobilized in hunting discourses as a justification for their hunting activities (e.g. Peterson et al., 2020). This discourse is also employed by Ardenne hunters (i.e. hunting as a substitute for the impact of predators on the ecosystem), according to which they ensure a regulatory role concerning game densities in order to maintain a healthy ecosystem functioning (Goethals, 2017). A return of large predators to a territory might affect the public legitimacy of this mobilized discourse and hence lead to a questioning of the related hunting policies and practices. In this sense, hunters and hunting associations are often linked to a strong negative positioning towards wolves (Arbieu et al., 2020; Dressel et al., 2015).

This point of view was also confirmed during several of the preparatory actor encounters, which were undertaken at the initial stages of this research (mentioned upon in the introduction and detailed in the discussion section). Examples of this negative positioning towards the comeback of the wolf to the Ardenne include (see the discussion section for an overview of the encounters): "the natural areas are far

too small for large predators, the wolf does not belong here, neither does it generate any added value, on the contrary, it only generates stress and it will come too close to housings" [translated from French] (Encounter P8); "it prevents the hunter from exercising its hunting right" [translated from French] (Encounter P10); or more straightforward "the wolf is a competitor to hunters, that [its return] will not happen, we will kill it [translated from French] (Encounter P10).

On the other hand, evidently, these points of view are not representative for all hunters on the Ardenne territory (Goethals, 2017, author's observation). The consistent reference to hunters as representing one coherent ensemble during public debate, including within research settings (e.g. Rutten et al., 2021), masks this heterogeneity and re-enforces polarization dynamics (Van Herzele and Aarts, 2019). By making use of SC values concept, we argue it is possible to address this heterogeneity through looking at which values are important for whom. This would allow for bypassing a fixation on actor profiles and to focus the debate on the common or diverging issues of importance and how to address these issues.

In addition, by accounting for the heterogeneity present within actor groups, it would allow for questioning the representativeness and thus the legitimacy of the dominant discourse of the overall actor group.

Finally, for a certain adopted policy, addressing SC values would enable to be transparent on the consequences (positive and negative) of the policy on the forest values that were deemed of importance by the concerned actors, instead of depicting a policy as favoring or disfavoring a certain actor group. Hence, to empirically underscore this argumentation, the following sub questions were formulated:

"Do hunters show a different positioning towards the return of the wolf compared to the public in general?"

"Do SC values provide a better explanatory factor to explain hunters' positioning compared to their profile?"

It does not lie within the scope of this research to go into detail regarding wolf management in the Ardenne, nor regarding the different actors' positioning on behalf of the return of the wolf to the Ardenne territory, which is exhaustively documented elsewhere (Schockert et al., 2020). Rather, this event is used as an example to investigate the added value of using SC values for the overall ecosystem, relative to the sole use of actors' profiles for interpreting actors' positioning regarding a specific topic. More precisely, it is assessed how SC values can address the issue of the stereotyping of actor groups, while acknowledging within-group heterogeneity within the context of a specific debated subject. Hence, the findings can be insightful for future negotiations over changes in actual forest management policies and practices.

2. Article: The wolves are coming: understanding human controversies on the return of the wolf through the use of socio-cultural values

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Keywords: Socio-cultural values · Human–wildlife conflict · Carnivore re-establishment · Public debate · Conservation conflict.

Abstract: Wildlife comebacks are often subject to public debate. Recurring controversies dominate the discussion, while the frequent use of stereotypes to describe concerned actors reinforces polarizations. This is not any different for the return of the wolf. In order to assist in the interpretation of the human dimensions of the wolf debate, we propose the use of the socio-cultural (SC) value concept. This concept allows address the various way an ecosystem is of importance to people and to give meaning to indicators of a specific issue without blindfolding on caricaturized profiles. The methodology is applied to the case study of the Ardenne (southern Belgium), where the wolf has recently made its comeback. An online survey, based on main points of controversy in human–wildlife debates, was presented to a large sample (N = 1461) of local residents and (potential) visitors, representative for age classes and gender. The answer options were modeled as a function of socio-demographic and profile variables, as well as SC value variables. Overall, a positive positioning was observed. The example of the hunter profile is used to demonstrate how SC values address heterogeneity within and overlap of profiles between groups. Our results show that the use of SC values, complementary to the sole use of standard profile variables, is an interesting tool to overcome preconceptions and to understand underlying reasons behind peoples stated position on points of controversy. These insights can, among others, lead to question the legitimacy of existing discourses and to transparency in terms of which values are accounted for by an actual or proposed management.

Reference:

Breyne, J., Abildtrup, J., Maréchal K., 2021. The wolves are coming: understanding human controversies on the return of the wolf through the use of socio-cultural values. European Journal for Wildlife Research 67, 90. https://doi.org/10.1007/s10344-021-01527-w

a) Introduction

Across Europe, the wolf's range is expanding, and it is reclaiming its original territory (Chapron et al., 2014). This comeback does not occur without controversy (Boitani and Linnell, 2015; Linnell and Cretois, 2018; Salvatori et al., 2020). The return of this predator could potentially benefit the restoration and maintenance of ecosystem functioning (Ripple et al., 2014), but it also challenges the current uses of a certain territory, as well as the current discourses and actor positioning in relation to the management of this same space (Drenthen, 2015). Hence, the return of the wolf is as much an ecological question as a socio-political one (Benhammou, 2019; Enck et al., 2006; Geerts, 2018). When human concerns, perceptions, and attitudes are not properly taken into account through management policies, this potentially gives rise to human–wildlife conflicts, which often prove difficult to solve. Van Herzele et al. (2015) describe three recurrent points of controversy in public debates concerning wildlife comebacks. These are (i) whether the species in question belongs to the reclaimed territory or not; (ii) whether the animals represent an opportunity or a threat; and (iii) whether it is preferable to keep population sizes under control through human interventions or through natural processes. The way the question is brought to public debate through various forums (such as media channels, parliament, specialist magazines) by as well the general public as adherents of particular groups, such as hunters, conservationists, or farmers, often reinforces polarizations instead of contributing to solutions (Van Herzele and Aarts, 2019). One dynamic that was identified as contributing to this polarization is the frequent use of stereotypes and the stigmatization of those particular groups. In order to obtain a more constructive way of establishing relationships between the concerned actors, it is essential to avoid this kind of conflict-reinforcing dynamic (see also Van Herzele and Aarts 2019). Therefore, a key element is to understand the support base of and the meaning behind those controversial positions within the general public, as well as within the actor groups that are subject of the aforementioned stereotyping.

Surveys and interviews are commonly employed methodologies to study the human dimension of wildlife debates or conflicts, either at a specific point in time (Ericsson et al., 2008; Hermann and Menzel, 2013; Majić and Bath, 2010) or over a larger time span (Dressel et al., 2015; Killion et al., 2019; Treves et al., 2013). This human dimension may concern values, beliefs, attitudes, or (intentional) behavior towards (the management of) a wildlife species (Enck et al., 2006). Drivers to explain or interpret the human dimension mainly include socio-demographic variables (such as age, gender, education, distance from wolf populations) (Arbieu et al., 2019; Frank and Sjöström, 2007; Glikman et al., 2011), as well as other profile variables such as place of residency or profession/activity (being a hunter, a farmer, a tourist, etc.) (Bath et al., 2008; Heel et al., 2017; Naughton-Treves et al., 2003; Røskaft et al., 2007). In addition to those socio-demographic and economic variables, several studies corroborate the interest of adopting a more value-oriented approach for studying human–wildlife aspects (Dietsch et al., 2016; Grilli et al., 2018; Kaltenborn and Bjerke, 2002; Teel et al., 2010; Vaske and Donnelly, 1999). The cognitive hierarchy model (Fulton et al., 1996) is one often used conceptual framework that addresses the

values–attitudes–behavior chain in human–wildlife interactions (Johansson et al., 2016). Within this framework, values are understood as fundamental values, which are few in numbers, slow to change, central to beliefs, and transcend to situations; they are accompanied by value orientations, which are less abstract basic beliefs towards a specific domain of interest (Grilli et al., 2018; Kaltenborn and Bjerke, 2002; Manfredo and Dayer, 2004; Vaske and Donnelly, 1999). There are however multiple ways to address the value concept (Kenter, 2019; Spangenberg and Settele, 2016). Contrary to previous studies that address values or value orientations towards wildlife specifically in order to explain or predict attitudes or behavior on wildlife and its management, this study focuses on contextual values for the various aspects of the broader ecosystem to which wildlife is returning in order to interpret the positing of both the general public and particular actor groups on the aforementioned points of controversy concerning wildlife comebacks.

Kenter et al. (2019) identify three main concepts of values: (1) transcendental values, which correspond to the aforementioned fundamental values from the cognitive hierarchy model; (2) contextual values, which give meaning to the broader transcendental values; and (3) quantitative or qualitative value indicators as outcomes of an evaluation process. Breyne et al. (2021b) further propose to operationalize socio-cultural (SC) values, reflecting the relative importance that an actor attributes to the various aspects of the concerned ecosystem. As such, SC values offer a way to interpret and give meaning to the outcomes delivered by certain indicator-based valuations. SC values are contextual and place-based (Tadaki et al. 2017) and can withhold intrinsic and instrumental, as well as relational values (Arias-Arévalo et al., 2017; Small et al., 2017). The set of SC values used for a given study is flexible depending on the context and research settings.

By adopting the SC value concept, our aim is to contribute to the interpretation of the heterogeneity within certain subgroups (Sponarski et al., 2013) that are commonly used for classifying and explaining the attitudes of concerned actors (for example, residents vs. non-residents, farmers vs. non-farmers). First, we assess the positioning of people on the three aforementioned points of controversy formulated by Van Herzele et al. (2015), after which we evaluate the relationship between this positioning and standard sociodemographic and profile variables. We then evaluate the interest of using the SC value concept for a deeper understanding of people's position depending on which view they have of the territory and what they consider to be its functions or roles. In this sense, SC values offer a way to operationalize the "sense of place" concept, as described by Cheng et al. (2003) and Masterson et al. (2017, 2019).

This approach is all the more important given that people's concerns, beliefs, attitudes, or behavior towards wolves do not necessarily represent an actors' opinion about the species per se but are instead a reaction to how this species impacts (or is thought to impact) the territory it claims. The return of the wolf to a certain territory challenges the actual use of this same space by humans and may reinforce existing competing interests between actors (Redpath et al., 2013). By providing insight into people's positioning on some main points of controversy concerning the return of the wolf, the aim of this paper is to contribute to the construction of a positive dialogue

in the public debate by visualizing and understanding (1) the positioning of the general public on the outlined points of controversy and (2) the heterogeneity of the positing of the adherents of particular stakeholder groups on those same points. To illustrate the latter aim, the example of hunters as a particular group has been used. The insights based on why a landscape is important to whom, can assist policy makers in taking legitimate and transparent decisions concerning existing and potential human–wildlife conflicts (Everaert et al., 2018).

b) Methodology

i. Case study

The case study concerns the Belgian (cf. Walloon) Ardenne. The Ardenne is a highly forested region that represents a geographical unit of 11,200 km2 that extends beyond Belgium, into Luxembourg, Germany, and France. The structural characteristics of these forests have been highly shaped by wood production and hunting activities. Its specific location, however, with six million people living within a buffer radius of 100 km, gives the Ardenne a peri-urban character, implying a high existing and potential demand for tourism and recreational activities (Colson et al. 2010). The revised forestry code from 2008 promotes a multifunctional landscape and aims to ease tensions between different users of the same space (Code Forestier 2008). These users include not only residents, farmers, hunters, forest owners, and loggers, but also tourist operators and tourists themselves. Tensions between different user profiles exist around a range of topics (Filot 2005), among which the presence and management of wildlife species. Recently, these tensions also concern the wolf species (Denayer and Bréda 2020).

The wolf had disappeared from Belgian territory during the nineteenth century due to hunting activities (Everaert et al. 2018). During the twentieth century, there were occasional stories about killed livestock or spottings (Everaert et al. 2018), but its presence remained unconfirmed. In 2018, a female wolf, descended from East German populations, was reported in Flanders (HLN, 2018) (see Fig. 17). Shortly after, another male was photographed in the Hautes Fagnes, signaling the first official comeback of wolves in the Ardenne. At the time of this writing, five male wolves have been identified on Ardenne territory, of which at least one is sedentary (LeSoir, 2019). The Ardenne are a major corridor for reconnecting wolf populations from southern Europe with those from Eastern Europe (De Standaard, 2020).

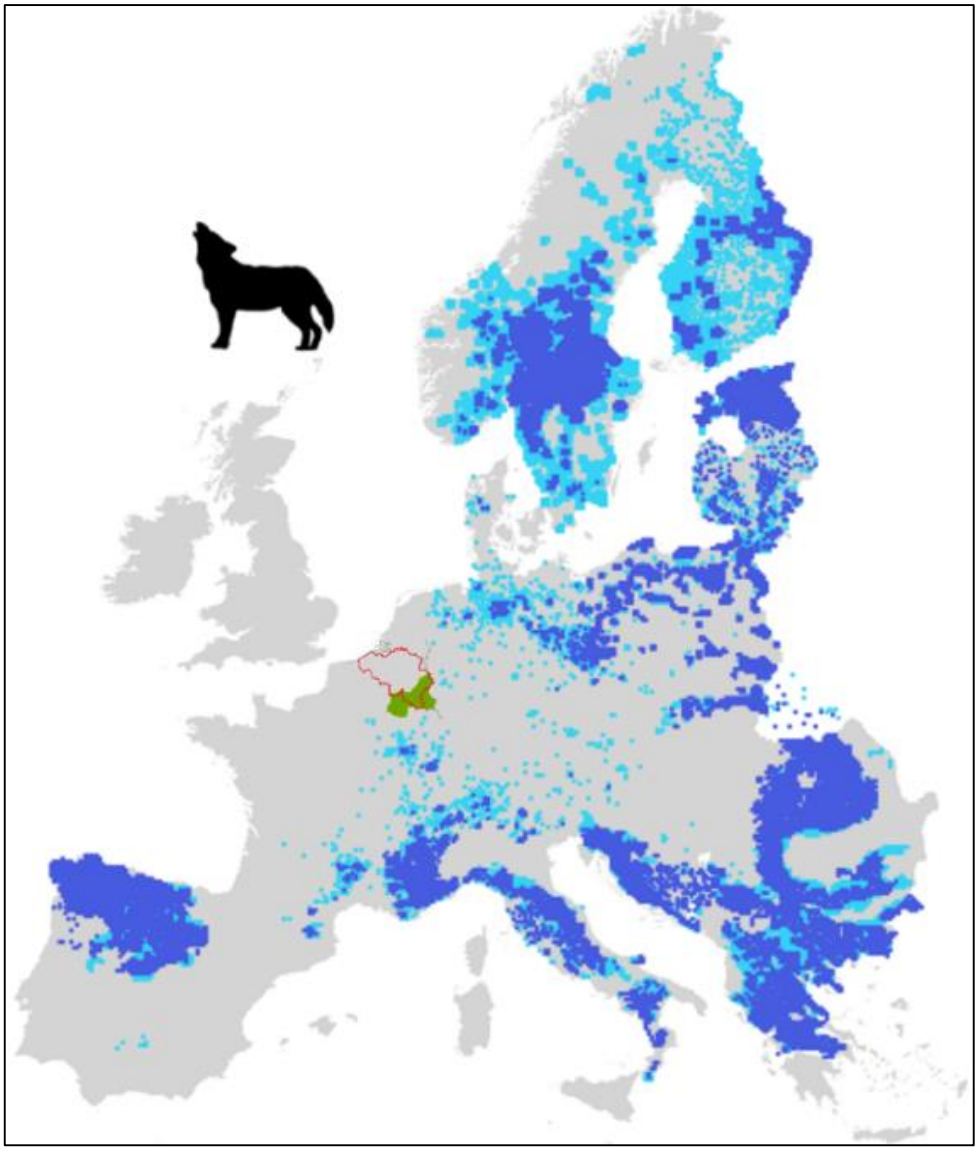

Figure 17. The distribution of wolf populations in Europe. Trans-border Ardenne forests are indicated in green; Belgian contours are highlighted in red. Adapted from Icie (2020)

The wolf has been legally protected since 1992 by the European Union Habitats Directive (92/43/EEC). To anticipate the wolf's arrival and manage its comeback, both Flemish and Walloon "wolf-networks," including diverse stakeholders, have been established[4] (Denayer and Bréda, 2020; Everaert et al., 2018). These stakeholders include representatives from the public administration, from the hunting sector, from naturalist associations, from the livestock sector, from the academic sector, and from non-profit associations ("Réseau Loup," n.d.). As a result, a Walloon wolf management plan was released by the ministry at the start of this year (Schockert et al., 2020). The return of the wolf is a heavily mediatized topic, with frequent reporting on the number and the behavior of every wolf present on the territory. Nevertheless, this event is not completely without conflict. A major event was the illegal killing of a female wolf with cubs in Flanders in the spring of 2019. Hunters are suspected to be responsible for this act (Mariotti, 2019), which was framed as "murder" in several media communications (Buitenlandredactie, 2019; Somers, 2019). Because of their conflicting position regarding wolves and their management (Denayer and Bréda, 2020; Filot, 2005), hunters are one of the main profiles addressed through this study. Even though this was not specifically asked in the survey, it is known that hunters in the Ardenne region mainly concern big game hunters (Goethals, 2017). Also the position of farmers, forest owners, forest loggers, and tourist operators was evaluated. Since the survey did not allow for a profound profiling, we did not expect any influence from a broad farming profile. Being a forest owner or a forest logger could potentially have an influence on the respondents' positioning, due to the overpopulation of ungulates and wild boar in the region (Delvaux, 2015), on which the presence of wolves could have a regulating effect. However, the overlap with a hunting profile is recurrent for these two categories. Tour operators finally could think of the wolves in the Ardenne in terms of either an opportunity or a threat for their business, depending on how they estimate the reaction of the visitors to the region. Since the return of the wolf is inevitable and public policy leans towards cohabitation, it will be of major importance for policy makers to oversee and ensure an inclusive implementation of the wolf management plan in order to avoid conflicts (Van Winckel, 2019).

ii. Survey

An extensive web-based survey targeting residents and (potential) visitors to the Ardenne was drawn up using Limesurvey software, with the objective to assess people's preferences, expectations, concerns, behavior etc. of, for, and in the Ardenne' natural environment. The survey could be filled out either in Dutch, French, or German. The survey sampling was carried out by Kantar ("Global Data Insights" n.d.), based on their double-opt-in panel[5] representing the general public. The sampling group consisted of (i) residents, (ii) visitors, and (iii) potential visitors, the

[4] In Belgium, due to the decentralization of official authorities concerned with nature protection and conservation, the regions of Wallonia and Flanders each have their own "wolf-regulation plan.".

[5] In double-opt-in panels, the panelists, after having voluntary opted to be part of the panel, confirm their contact email, authorize receiving invitations to surveys, and provide background data.

latter two being inhabitants of the neighboring regions of the Ardenne. This targeting was due to the focus of the overall survey on nature-based tourism in the Ardenne region. Therefore, in France, only inhabitants of the Grand Est and Haut-de-France regions (northern France) were sampled, and in Germany, only the Länder Nordrhein-Westfalen, Rheinland-Pfalz, and Saarland (eastern Germany) were sampled. In all of these specific regions, the wolf has recently made or is making its return. It must be noted, however, that the wolf has been present for a longer time in other regions of both Germany and France. Kantar was responsible for guaranteeing the representativeness of the sample according to age class (only adults were allowed to participate) and gender. Nevertheless, the representativeness of the sample in terms of age, gender, and education level was verified for each country with Eurostat data (Eurostat 2020a, b). The survey was conducted in April 2019 and took an average of 17 min. A total of 1667 questionnaires were received. After deleting 151 questionnaires to which respondents replied too quickly (identified as speedsters[6]), as well as 55 others for which not all of the wolf questions had been answered, the final sample included 1461 useable records (Flanders- Brussels, 297; Wallonia[7], 372; France, 276; Germany, 244; the Netherlands, 272)[8], to which we will henceforth refer to as the wider public. In respect to the current legislation on privacy regulations, respondents agreed on a consent to participate, and all data was treated anonymously.

iii. Questions on the return of the wolf

The survey included four questions focusing on the return of the wolf (Table 11). Questions 1 to 3 each address one of the controversies concerning wildlife returnees, as described by Van Herzele et al. (2015). More specifically, Question 1 deals with people's belief on the question of belonging; Question 2 (wolf regarded as an opportunity or a threat) refers to people's behavioral intention regarding recreational ES; and Question 3 assesses people's opinion on the financing of management strategies. Questions 4a and 4b serve to complement Question 3 and assess people's opinions on tax contributions since the Walloon wolf plan proposes certain measures that will have to be paid for, such as the implementation of electric fences to protect livestock from wolf attacks. The relationship between taxation and wolf tolerance is therefore of specific interest for decision-makers on wolf management (Linnell and Cretois 2018).

[6] Respondents replying faster than 40% of the median interview time.

[7] The Belgian regions, Flanders, Brussels, and Wallonia, were based on the ZIP codes of respondents' residencies. Flanders and Brussels
were combined for the analysis since neither is concerned by the Walloon regulations on wolf management.

[8] Due to confidentiality issues, it was not possible to include respondents from Luxembourg, who are also frequent visitors to the Ardenne.

Table 11. Questions on the return of the wolf in the Ardenne as presented to the survey respondents

Survey questions on the return of the wolf in the Ardenne	
Questions	Answer options
1. To what extent do you agree with the following statement: "An animal such as the wolf belongs to the Ardenne' natural environment"?	5-point Likert items: strongly disagree, disagree, neutral, agree, strongly agree.
2. Has the return of the wolf had or will have an influence on your forest visiting behavior?	a) I would go less often into the forests. b) I would not change the frequency of my visits, but I would feel less at ease. c) No influence. d) I would not change the frequency of my visits, but it would render my forest visits more exciting. e) I would go more often into the forests.
3. Since the wolf is back in the Ardenne, what measures should be financed in order to manage its expansion and interactions with human activities?	a) Measures to eradicate the wolf populations in order to obtain zero interaction with human activities. b) Limit the effects of the wolves and constrain their territory so that wolf-human interactions remain rare. c) Indifferent. d) Promote cohabitation between wolves and human activities without restraining them (knowing that on some occasions, these interactions can cause damages).
4. a) To what extent do you agree with the following statement: "It is normal for a small part of the taxes to be earmarked to manage the expansion of the wolf and its interactions with human activities? "	5-point Likert items: strongly disagree, disagree, neutral, agree, strongly agree.
b) (Only asked when disagreeing with Question 4) – For what reason did you disagree with the statement that "It is normal for a small part of the taxes to be earmarked to manage the expansion of the wolf and its interactions with human activities?" Chose the most pertinent response.	a) I am not in favor of the return of the wolf, so I don't wish that a part of my taxes be earmarked to manage its expansion. b) I don't think all citizens should pay for this, only those who are in favor of the wolf's return. c) I think this topic is too specific for it to be included in our taxes. d) I don't live in a country where the wolf has returned/will return.

iv. The scoring of SC values

Respondents were asked to score SC values by distributing a total of 100 votes over 13 SC values, thereby enforcing an indication of their relative importance. It was not mandatory to include all the listed SC values in the scoring; an automatic counter was used to avoid miscalculations. Respondents were only able to see the explicative phrase (second column). In addition, the order of the SC values was randomized for the survey to avoid the introduction of a bias related to a fixed order of SC values. For a more detailed description concerning the concept of SC values, the objectives of the overall survey, and the choice of the SC values listed in Table 12, interested readers can refer to Breyne et al. (2021).

Table 12. The socio-cultural (SC) values presented to the respondents. Respondents were only able to see the explicative phrase (second column). In addition, the order of the SC values was randomized for the survey to avoid the introduction of a bias related to a fixed order of SC values

The socio-cultural (SC) values presented to the respondents	
Socio-cultural value	**Explicative phrase showed to the respondent**
	The Ardenne forests are important to me because …
Aesthetic value	… I can enjoy the views, sounds, smells, etc.
Biodiversity value	… they provide a habitat for wild animals, plants and microorganisms.
Direct economic value	… they provide economic products such as timber, mushrooms, game, etc.
Indirect economic value	… they create jobs because of their touristic attractiveness, of which I can make use of as a user or operator from the touristic sector.
Extensive recreational value	… they provide a space for my outdoor activities such as hiking, biking, observation of fauna and flora, etc.
Intensive recreational value	… they provide a space for my outdoor activities such as quad, 4x4, MTB circuits, mass events, etc.
Bequest value	… they allow future generations to know and experience these forests.
Patrimonial value	… they are part of the cultural patrimony in the same way as villages, abbeys and castles, and they are part of the history of the region.
Relational value	… they provide a place to create or reinforce social relationships (outings with family or friends, working environment, etc.).
Mistrust value	… one could feel ill at ease in those forests because they create fears (of getting lost, they are dark and gloomy, etc.).

Life Support value	… in the battle against climate change and the maintenance of a healthy living environment through the renewal of soil, air, water, etc.
Inspirational/Therapeutic value	… they are inspiring places and make one feel better, physically as well as mentally.
Disservice value	… they can also have a negative impact on daily life (less room for urbanization or agriculture, pests or damage by wildlife, etc.).

v. Modeling people's positioning on points of controversy regarding the comeback of wolves in the Ardenne

Answer options were modeled as a function of all three sets of variables (see Date overview section), applying an ordered logit model (Greene and Hensher 2010). All SC values underwent an ln (SC value + 1) transformation, commonly used to minimize the effect of outliners (Garson 2012). Interaction terms were defined between the variable country/region - with Wallonia (WL) as the reference[9] - and each socio-demographic variable. The answer options to the four questions were either 5-point Likert items (Questions 1 and 4) or represented a natural ordering (Questions 2 and 3). Question 3 had only four 4 answer possibilities while the other questions had five. While this could potentially have influenced the respondent's way of answering, the number of response possibilities does not change the ordered logit estimation conceptually as long as each question is analyzed separately. Assuming a latent variable regression model where y_n^*n is a latent continuous measure:

$$y_n^* = \sum_{i=1}^{I} \alpha_i x_{in} + \sum_{j=1}^{J} \beta_j z_{jn} + \sum_{l=1}^{L} \gamma_l v_{ln} + \sum_{c}^{C} \sum_{i=1}^{I} \delta_{ic} x_{in} D_c + \varepsilon_n \, , n = 1, \dots, N \quad (1)$$

In this function, x_{in} are socio-demographic variables, z_{jn} are profile variables, and v_{ln} are SC value variables describing the respondent n. D_c=1 if the respondent is from region c, and 0 otherwise (c={Flanders, France, Germany, Netherlands}). $\alpha_i, \beta_j, \gamma_l, \delta_{ic}$ are the parameters to be estimated. ε_n is an error term distributed randomly according to a logistic distribution. The latent variable y_n^* is not observed but is assumed to be linked to the stated ordinal answer options with discrete values 1,…,H by the censoring mechanism in Equation (2) where τ_h are the observed thresholds defining the boundaries between the different answer options, which are estimated freely, together with the parameters in Equation (1), by maximization of the log likelihood function in Equation (3):

[9] The Walloon region is taken as a reference since this region is the administrative unit responsible for wolf management in the Belgian Ardenne.

$$y_n = \begin{cases} 1 \;\; if \; -\infty < y_n^* \leq \tau_1 \\ \quad\quad ... \\ h \;\; if \;\; \tau_{h-1} < y_n^* \leq \tau_h \\ \quad\quad ... \\ H \;\; if \;\; \tau_h < y_n^* < \infty \end{cases} \quad (2)$$

$$\text{Ln}L \; = \sum_{n=1}^{N} \sum_{h=1}^{H} I_{nh} \log[F(\tau_h - V_n) - F(\tau_{h-1} - V_n)] \quad (3)$$

In (3), the index variable I_{nh}=1 if $y_n = h$, and 0 otherwise, $F(\cdot)$ is the cumulative probability function for the logistic distribution, and $V_n = \sum_{i=1}^{I} \alpha_i x_{in} + \sum_{j=1}^{J} \beta_j z_{jn} + \sum_{l=1}^{L} \gamma_l v_{ln} + \sum_{c}^{C} \sum_{i=1}^{I} \delta_{ic} x_{in} D_c$ is the deterministic part of (1).

The likelihood function is maximized by applying an ologit procedure in STATA 2015 (StataCorp, 2017). We estimated the model using inverse sample probability weights with respect to gender, age and level of education. A particular reason for this was the necessity to account for the sample, displaying both higher levels of education and a lower representation of the youngest and oldest age classes than those prevailing in the overall population (see below).

We have also carried out the estimation assuming a normal distribution of the error term (ordered probit model); the results were fairly robust to the assumptions of the distribution of the error term. A stepwise selection procedure was used to select significant explanatory variables in the final model for each of the four questions. The procedure operated from general to specific and the cut-off significance level was set at 0.1 percent. However, before applying this procedure, we tested the general model (*unrestricted model*) to see if the SC values as a group had a significant effect on the responses, applying a likelihood ratio test:

$$LR = -2LnL(restricted\ model) - LnL(unrestricted\ model)$$

where the *restricted model* is the model without the SC values, and *LR* is X^2 distributed with the degrees of freedom corresponding to the difference in number of the estimated parameters in the two models. Finally, in order to assess the significance of observed differences in SC value scoring for certain subgroups within the standard profession/activity groups, based on their divergent answers to the wolf questions, we used independent sample t-tests. Again, since the answers to the wolf questions were ordered, a Spearman rank correlation test was used to verify the coherence between the four questions.

c) Results

i. Sample representativeness

It appears that the youngest and oldest age classes of the sampling group are slightly underrepresented (see Table 13), even though the survey company targeted a representative sample with respect to age classes. However, chi-squared independence tests were rejected for each country using conventional significance levels. The level of education is significantly higher (except for the German regions) in the sample relative to the population. This bias for the variable education is a recurrent issue when employing internet-based surveys (Olsen 2009).

Table 13. Distribution (in percentages) of the sample and the population for the following variables: gender, age and education class, for each of the four countries

Representativeness of the sample in comparison to the general population								
	Belgium		France[10]		Germany[11]		The Netherlands	
	Population	Sample	Population	Sample	Population	Sample	Population	Sample
18-24 yr.	10.2	9.4	10.8	7.2	9.6	7.8	10.8	5.1
25-34 yr.	16.2	16.7	15.4	18.1	15.0	15.6	15.7	16.2
35-44 yr.	16.3	19.1	16.0	19.6	14.0	14.3	15.0	18.8
45-54 yr.	17.6	22.6	17.3	22.8	18.9	32.8	18.5	23.2
55-70 yr.	24.3	28.6	25.2	29.7	25.1	26.6	25.4	30.5
> 70 yr.	15.4	3.6	15.3	2.5	17.4	2.9	14.7	6.3
χ^2 -test	$\chi^2(5)=79.00^{***}$	P=0.000	$\chi^2(5)=43.12^{***}$	P=0.000	$\chi^2(5)=55.47^{***}$	P=0.000	$\chi^2(5)=30.03^{***}$	P=0.000
Education-low[12]	21.7	13.5	23.4	13.0	17.1	26.6	21.0	14.7
Education-medium	37.7	40.5	46.3	35.9	56.8	35.2	40.7	49.6
Education-high	40.6	46.0	30.4	51.1	26.1	38.1	38.3	35.7
	$\chi^2(2)=27.34^{***}$	P=0.000	$\chi^2(2)=57.93^{***}$	P=0.000	$\chi^2(2)=46.55^{***}$	P=0.000	$\chi^2(2)=10.96^{***}$	P=0.000
Women	51.2	49.6	52.1	54.0	51.4	44.3	50.8	50.7
	$\chi^2(1)=0.69$	P=0.41	$\chi^2(1)=0.39$	P=0.53	$\chi^2(1)=4.93^{**}$	P=0.026	$\chi^2(1)=0,00$	P=0.995

[10] France : Grand Est region (Alsace, Champagne-Ardenne and Lorraine) and Hauts-de-France region.

[11] Germany: Länder Nordrhein-Westfalen, Rheinland-Pfalz and Saarland.

[12] Education-low: Less than primary, primary and lower secondary education, International Standard Classification of Education 2011 (ISCED11) =0-2; Education-medium: Upper secondary and post-secondary non-tertiary education, ISCED11=3-4; Education-high: Tertiary education, ISCED11= 5-8

ii. Data overview

This section contains three overview tables (Tables 14, 15 and 16) presenting all of the variables used for the modeling. Note that the number of respondents for each country/region was defined by the survey design (Table 14), and that in Table 16, gross values are given, whereas for the analysis, logged values were used.

Table 14. An overview of the socio-demographic variables

An overview of the socio-demographic variables used for the modeling exercise					
Variables	**Definition of the variable**	**Mean**	**Std. Dev.**	**Min**	**Max**
Age	• Categorical, treated as numeric • Age classes and the averages used: 18-24: 21.5; 25-34: 30; 35-44: 40; 45-54: 50; 55-70: 62.5; > 70: 75	47.11	14.49	22	75
Education	• Categorical, treated as numeric • Education classes: Primary education: 1; Lower secondary education: 2; Upper secondary education: 3; Post-secondary non-tertiary education: 4; Short-cycle tertiary education or Bachelor: 5; Master or doctoral education: 6	3.93	1.39	1	6
Income	• Categorical, treated as numeric • Income classes and the averages used for each class: <1500: 750; 1501-2000: 1750; 2001-3000: 2500; 3001-4500: 3750; 4501-6000: 5250; >6000: 7000; for NA, the overall average was used: 2489	2475.49	1308.04	750	7000
Gender	• Equal to 1 if female; 0 otherwise	0.50	0.50	0	1
City size	• The size of the city or village of residence • Categorical, treated as numeric • City size classes used: Rural or village < 500 inhabitants: 1; 500-20,000 inhabitants: 2; 20,000-100,000 inhabitants: 3; > 100,000 inhabitants: 4	2.48	1.00	1	4
Country/Region	• Creation of binary dummy variables for each country/region • Included independently and in interaction with the other socio-demographic variables • Included Wallonia (WALL), Flanders-Brussels (FL-BXL), France (FR), Germany (GR) and the Netherlands (NL)	/			

Table 15. An overview of the profile variables

An overview of the profile variables used for the modeling exercise		
Variables	**Definition of the variable**	**Share of the sample**
Resident	• Equal to 1 if a resident of the Ardenne region and if farmer and hunter and forest owner and forest logger and tour operator; equal to 0 otherwise	12%
Farmer	• Equal to 1 if a farmer in the Ardenne region; 0 otherwise	4%
Hunter	• Equal to 1 if a hunter in the Ardenne region; 0 otherwise	4%
Forest owner	• Equal to 1 if a forest owner in the Ardenne region; 0 otherwise	5%
Forest logger	• Equal to 1 if a forest logger in the Ardenne region; 0 otherwise	4%
Tour operator	• Equal to 1 if a tour operator in the Ardenne region; 0 otherwise	6%
Non-nature visitor	• Equal to 1 for residents not having visited the Ardenne natural environment AND for tourists having visited the Ardenne, but not its natural environment; 0 otherwise	17%
Ardenne visitor	• Equal to 1 for non-residents having visited the Ardenne; 0 otherwise (residents also equal to 0)	76%

Table 16. An overview of the socio-cultural value variables

An overview of the socio-cultural value variables used for the modeling exercise				
Variables	**Mean**	**Std. Dev.**	**Min**	**Max**
Esthetic value	15.37	17.68	0	100
Biodiversity value	12.96	14.02	0	100
Life Support value	10.65	13.92	0	100
Mystical/Therapeutic value	10.35	13.93	0	100
Extensive recreational value	10.19	14.50	0	100
Patrimonial value	9.51	11.27	0	100
Future value	7.98	10.85	0	100
Direct economic value	6.12	9.14	0	100
Indirect economic value	5.63	9.36	0	100
Relational value	4.63	9.22	0	100

Intensive recreational value	2.87	7.20	0	100
Disservice value	1.91	5.33	0	100
Mistrust value	1.84	5.33	0	100

iii. Overall positioning on points of controversy regarding the comeback of wolves in the Ardenne

Concerning the wider public, a large majority of people agree that the wolf belongs to the Ardenne' natural environment (Q1, Fig. 18). The presence of wolves appears to potentially have a positive impact on the frequency of forest visits in the Ardenne (Q2), with 17% reporting an intentional increase (Fig. 18). For 43% of the respondents, the frequency of visits would remain unchanged, with 28% for whom it would increase the level of excitement of their visit and 15% for whom the presence of wolves would make them feel less at ease. Regarding the management of wolves (Q3), 45% of the respondents favor the financing of a cohabitation strategy, while 36% would like to see measures to limit the possibility of human–wolf interactions, and 6% would want to see measures to have the wolves eradicated (Fig. 18). Note that for reason of simplification, the strategy promoted by the Walloon ministry is the only option visualized on the positive side. About taxes (Q4a), 15% opposed the idea that a small part is earmarked for the management of wolf populations, while 55% agreed and 30% remained indifferent (Fig. 18). Of the 15% who were opposed to a taxation (Q4b), those who expressed being against the return of the wolf in response to Q1 gave this as the main reason. Other explanations mainly indicate that the subject is too specific to be included in a general tax and that not all people should pay, only those favoring the return of the wolf. Table 17 provides the Spearman rank correlations, which are all positive and highly statistically significant.

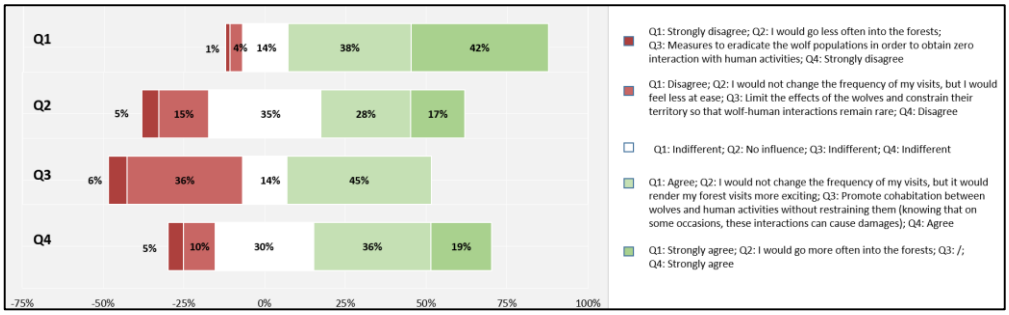

Figure 18. A visualization of the descriptive results of the answers to Question 1 (**Q1**), Question 2 (**Q2**), Question 3 (**Q3**), and Question 4 (**Q5**). Percentages are rounded off to two digits, leading to a total of 99% instead of 100%; *N* = 1461

Table 17. Pairwise Spearman rank correlations between the answers to the four wolf questions

Correlations between the wolf questions			
	Q1	Q2	Q3
Q2 – correlation	0.314	-	-
(p-value)	0.000	-	-
Q3 – correlation	0.388	0.179	-
(p-value)	0.000	0.000	-
Q4a – correlation	0.432	0.286	0.231
(p-value)	0.000	0.000	0.000

iv. Outcomes of modeling people's positioning on points of controversy regarding the comeback of wolves in the Ardenne

For Question 1, concerning the perceived belonging of the wolf to the natural environment of the Ardenne, 7 independent variables out of 27 were significant (Table 18). For the socio-demographic variables, the older the people were and the higher their level of education was, the less they thought the wolf belongs to the Ardenne. The country/ region variables indicate that respondents from Flanders- Brussels and the Netherlands are significantly more negative on the question of belonging than the rest of the sample. For the profile variables, non-nature visitors thought less often that the wolf belongs to the Ardenne, and for the SC value variables, the higher people scored biodiversity and life support values, the more they thought the wolf belongs to the Ardenne. Four interaction variables were significant. The negative effect of age on the question of belonging was stronger for the inhabitants of France; education was significantly less negatively correlated in Flanders-Brussels and the Netherlands compared to the rest of the sample; and the size of the town of residence was positively correlated with the question of belonging for French citizens.

For Question 2 concerning the influence of the return of the wolf on forest visiting behavior, 7 independent variables were significant. Older people, women, people with a higher education, and Flemish people were more likely to consider that the wolf would have a negative impact on forest visits. One profile variable, being a farmer, had a positive impact on forest visits. The higher people scored esthetic, mistrust, and mystical/therapeutic values, the more positive they considered the effect of wolves on their forest visits. Two interaction variables were retained, namely, a positive effect of being female in Germany and a negative effect of education in the Netherlands.

For Question 3 concerning the positioning of respondents along a simplified gradient of financing wolf–human interaction modes, 3 independent variables were significant, of which none were socio-demographic. For the profile variables, tour operators seemed less inclined to favor the financing of a cohabitation. The higher people scored the SC value biodiversity, the more they chose the cohabitation option, whereas the higher people scored the SC value disservices, the less they chose this option. One interaction variable was retained by the model: education was positively correlated in Flanders-Brussels.

For Question 4 concerning whether it was considered normal that a part of general taxes is earmarked for wolf management, 12 independent variables turned out to be significant. The older the person was, the less willing he or she was to accept this idea; French and Germans, as well as Ardenne residents, were more willing to accept this idea than the rest of the sample, whereas the Dutch and people who do not visit nature in general were less willing to accept it; tour operators were more favorable towards this idea than non-tour operators, and people who had already visited the Ardenne were more favorable than people who had not. For the SC values, people who attributed higher scores of life support and disservice values were more favorable, while people who attributed higher scores to extensive recreational and relational values were less favorable. Four more interaction variables were significant. The negative effect of age was stronger for French citizens; in Flanders-Brussels, the larger the size of the town of residence was, the more inhabitants that were favorable; and in the Netherlands, people with a higher income and a higher level of education were also more favorable.

Crossing the country/region row with the FL, FR, GR, and NL columns gives the significance of the respective independent country/region variable. Crossing the other rows containing socio-demographic variables with the FL, FR, GR, and NL columns indicates relevant interaction terms.

All tested socio-demographic variables were significant for at least one of the questions, whether in interaction with the country/region of residence or as an independent variable. However, other variables were included in the initial model but turned out not to be significant in any of the models: these included the hunter, forest owner and forest logger profile variables, and the indirect or direct economic, intensive recreational, future, and patrimonial SC values. Still, we found that SC values are important variables to explain the answers to the four questions. Using a LR test, we tested whether we could exclude the 13 SC values in a general model where we had included all of the socio-demographic and profile variables. This was rejected with a probability $p < 0.000$ for all four questions.

Table 18. The symbol ° indicates a negative correlation, the symbol * a positive correlation, the number of symbols indicates the level of significance. Significance codes are: ***/°°° p<0.01, **/°° p<0.05, */° p<0.1, with three symbols representing the highest level of significance. Crossing the country/region row with the FL, FR, GR and NL columns gives the significance of the respective independent country/region variable. Crossing the other rows containing socio-demographic variables with the FL, FR, GR and NL columns indicates relevant interaction terms.

A summary of the significance of the tested variables for each of the four questions.																				
Questions	**Q1 Acceptance**					**Q2 Forest visits**					**Q3 Measures**					**Q4a Taxes**				
Variables\ regions	**WL**	**FL-BXL**	**FR**	**GR**	**NL**	**WL**	**FL-BXL**	**FR**	**GR**	**NL**	**WL**	**FL-BXL**	**FR**	**GR**	**NL**	**WL**	**FL-BXL**	**FR**	**GR**	**NL**
Socio-demographic variables																				
Age	°°°		°°°			°°°										°°°		°°		
Gender						°°°			**											
Income																				**
Education	°°°	**			*					°°		***								**
Country/Region		°°°			°°°													**	***	°°
City size			*														**			
Profile variables																				
Resident																*				
Farmer						**														
Hunter																				
Forest owner																				
Forest logger																				

Tour operator			*		°°°		***	
Non-nature visitor	°°°						°°°	
Ardenne visitor							*	
Socio-cultural values								
Esthetic			*					
Biodiversity	***				***			
Direct economic								
Indirect economic								
Extensive recreational							°	
Intensive recreational								
Future								
Patrimonial								
Relational							°°	
Mistrust			**					
Life Support	*						**	
Mystical / Therapeutic			**					
Disservice					°°°		**	

d) Discussion

In this section, we first discuss the overall results. We then focus briefly on the observed influence of commonly used explanatory variables, before addressing the added-value of SC values. For the sake of conciseness, only the most insightful correlations with respect to our object of analysis will be discussed.

i. Overall positioning on points of controversy regarding the comeback of wolves in the Ardenne

A first observation is that even though the specific ways of how to deal with the presence of wolves (Questions 2, 3, and 4) are subject to a diverse set of opinions, the question of belonging (Question 1) reached a high level of positive unanimity within the surveyed population. Whether this could have been influenced by the greater availability of natural areas in Walloon Ardenne than in Flanders (Van Herzele and Aarts 2019) should be verified. The evidence of this high level of unanimity is blurred by the over-representation of stereotypic discourses in the public debate. When, for example, the spokesman for the most important hunting association in the Belgian Ardenne states that "the wolf does not belong to this industrialized world. It is up to the population to give its view on this topic" [translated from French] (Schoune, 2020), he clearly overstates the discourse of non-belonging. The case of hunters is further discussed in the "What do the SC value variables tell us?" section. All wolf-related events (livestock attacks, new observations, road accidents, etc.) are widely portrayed through diverse media channels. Naturalist associations welcome its comeback, which is expressed through a big "finally!" (Natagora, 2017); the public nature administration officially favors and emphasizes its "natural" return (Libre.be, 2020), while some papers and magazines opt for sensitizing titles such as "seven sheep throat cut" (L'Avenir, 2016). Within the scope of this study, it has not been underscored what the influence of these mediatized information was on the matter.

Second, the general public addressed through the sampling group is divided on the question of the financing of certain management strategies for coping with human–wolf interactions. Since a cohabitation is envisioned by Walloon policy makers (Schoune 2020), even though the proposed strategies within this study were simplified for methodological reasons, this point will be of major concern for establishing a strategy that can count on public support.

The third wolf-related issue explored in this study is whether its return/presence instead represents an opportunity or a threat (i.e., for this survey oriented towards the frequency and nature of forest visiting behavior). In this instance, the overall effect is positive, though for some people, the presence of the wolf in the forests they frequent seems to generate some fear and precaution. This observation indicates an important point in the communication concerning wolf behavior and wolf–human interactions (Arbieu et al. 2019). Moreover, there seems to be a group of people (about 14% of the respondents) who apparently do not feel concerned to any extent by the content of this survey, expressing indifference through their answers. As could be expected, respondents not having visited a natural environment during the last 5 years seem

more likely to be indifferent with respect to Q1 and Q2, though this was not significant on a conventionally statistical level.

Positive and significant correlations between the answers to the four questions indicate a coherence in the way people replied to the questions and clarify possible interactions between questions. Respondents who are positive on the question of belonging are (i) more likely to believe that the wolf will increase the benefit they receive from their forest visits, (ii) prefer the financing a type of management that favors cohabitation, and (iii) are more likely to accept that a part of general taxes be earmarked for wolf management.

Thus, to give an example, the positive correlation between the answers to the question on human–wolf interaction strategies and the acceptance of a tax indicates that respondents are willing to pay for a cohabitation strategy and are opposed to the eradication of wolf populations, which could also have been a possibility. Since there are mixed scientific results on the tendency of public support for wolves over time and on the influence of closer-by living populations (Broberg and Brännlund, 2006; Dressel et al., 2015; Frank and Sjöström, 2007; Killion et al., 2019; Lute et al., 2014), it remains to see if the positive correlation between the question of belonging and financing a cohabitation strategy will endure, once wolf population sizes go up and human–wolf interactions increase (in terms of physical encounters, observed presence, livestock kills or other damages, etc.). Arbieu et al. (2020) underline the importance of positive interactions for an improved coexistence over time, which will be a point of attention for managers and policy makers. Another important point concerns the observation that financial compensation mechanisms for livestock losses, even though these are positively received, do not improve the tolerance levels of the recompensed actors (Naughton-Treves et al. 2003). This remind us that the above described observations concern correlations and not causality. Complementary, the willingness to pay (WTP) for securing the wolf's survival does not increase with increasing wolf population sizes (Boman and Bostedt, 1999), which could be a point of discussion for the revision of budget attributions in the case of increased compensational costs.

ii. Tendencies regarding socio-demographic and profile variables

The observed results regarding socio-demographic variables largely correspond to what has already been demonstrated elsewhere. For instance, the older the respondents are, the more negative they are in their positioning on the points of controversy (e.g. Majić, 2007; Piédallu et al., 2016; Røskaft et al., 2007). According to Majić and Bath (2010), the gender effect observed for the question on forest visits (Q2) can be linked to a matter of fear, where women are observed to have a greater fear or safety concern about going to places were wolves are present. Note that fear is not necessarily acceptance-related (Zimmermann et al., 2001). We did not find a statistically significant effect of the level of income, which also confirms previous findings (Broberg and Brännlund 2006; Naughton-Treves et al. 2003). Some studies (Majić 2007; Naughton-Treves et al. 2003; Roskaft et al. 2007) found that higher levels of education correspond to more positive positions towards wolves. The

negative correlation observed in this study is somehow surprising and needs further investigation to be correctly interpreted. Note that the bias in representativeness for the education variable is a recurrent issue when using Internet-based surveys (Olsen 2009).

We also observed an influence of the country/region of residence on the stated positioning regarding the questioned points of controversy concerning wolves. Flemish and Dutch citizens are more negative than Walloon citizens, an observation already underlined by Drenthen (2015). This correlation could be due to the lack of cohabitation for the inhabitants of these two regions where the wolf has been absent for a longer time span (Houston et al., 2010; Zimmermann et al., 2001), though not all studies confirm this hypothesis (Treves et al., 2013). Otherwise, a lower disposition of suitable habitat could offer an explanation for more negative responses when respondents (unintentionally) transpose the question to their own area of residence. French and German residents seem to be more positive about the acceptance of a tax. This could be explained by the fact that both are countries where the wolf has been present for a longer time (Houston et al. 2010) and where compensation mechanisms are in place.

We tested five professions/activities (being a hunter, a farmer, a forest owner, a forest logger, and a tour operator) for their significance in explaining the positioning of respondents along the questioned points of controversy, of which tour operator turned out to be strongly correlated. For example, tour operators were more in favor of a general tax for wolf management than non-tour operators. Since the Ardenne is a major tourism destination due to its natural richness, tour operators may be concerned about tourists' reactions to the presence of wolves. The observed disapproval of a cohabitation strategy could thus be a reaction of precaution against the anticipated reaction of tourists, but this should be verified. In this case though, the concern of tour operators could be alleviated with the results to the question about forest visit frequency regarding the presence of wolves, with more people intending to increase than decrease their visits to forests. As a result, the presence of wolves in the Ardenne may also represent an opportunity for ecotourism (Thulin et al., 2015; Vega and Garrido, 2016).

Overall, professions/activities[13] were less significant than expected to explain responses. One reason could be that the proportion of each category was rather small (around 5%), which is due to the orientation of the study towards the general public without oversampling particular profiles. Furthermore, profiles may overlap since, for instance, 2.74% of the sample consists of people reporting to be both hunter and forest owner, while these two categories represent 4.4% and 4.0% of the overall sample, respectively. A second explanation is the potential heterogeneity that can be found within common classifications (Killion et al., 2019; Lute et al., 2014; Sponarski et al., 2013). Regarding this heterogeneity, we briefly zoom in on the case of hunters. As aforementioned, this profile mainly concerns big game hunters. This category is often linked to a negative positioning towards wolves (Arbieu et al. 2020; Dressel et al. 2015; Sponarski et al. 2013), whereas no such correlation appeared in our results.

[13] Note that professions/activities were only considered if they were carried out within the Ardenne territory.

Although this could potentially be due to the low size of the sub-sample of hunters (representing 4% of the sample group), we could still expect to detect an effect in the model used if a strong positioning was present for this group as a whole. For instance, for Question 3 on interaction strategies, 24% of the hunters in our sample preferred an eradication of wolf populations, which is much higher than the 6% of the overall sample. However, there are also 24% of the hunters who favor a complete cohabitation (vs. 45% for the overall population). This may explain why the model could not detect any statistically significant correlation since being a hunter does not imply a pronounced and consistent positioning towards the wolf. The official discourses of specific interest groups are often strongly polarized, sometimes having more of a function of enhancing group cohesion than representing the opinions of the organization's members (Van Herzele et al. 2015).

iii. What do the SC value variables tell us?

Several authors have underlined the importance of value orientations compared to demographics or profession-based variables in order to interpret the human dimension of human–wildlife interactions (Grilli et al., 2018; Lischka et al., 2010). In this study, this issue was addressed by linking SC values to the main points of controversy regarding the return of the wolf.

iv. Tendencies regarding SC value variables

In general, respondents considered the Ardenne forests highly important in terms of their role for biodiversity conservation, as seen by the fact that the SC value biodiversity had the second highest score of all 13 of the SC values presented. The SC value for biodiversity is also strongly correlated to the question of belonging (Q1) and to the preferred answer option for the interaction modes (Q3). Taken together, these two results seem to indicate that the return of the wolf is part of a larger aspiration for biodiversity protection. More precisely, the wolf belongs to the Ardenne, and financing of a cohabitation strategy should be favored according to those people who associate the Ardenne forests with biodiversity values. People for whom the biodiversity concern is of lesser importance are more inclined to think the wolf does not belong to the Ardenne and chose less often the option of cohabitation.

Another important SC value for forest ES (with the third highest score) is life support. The perceived importance of an ecosystem, in this case, the Ardenne forests, in maintaining a healthy environment and in contributing to the mitigation of climate change, is strongly correlated to the positioning of respondents on the questioned points of controversy. This could indicate that the wolf, as well as other species, is seen as being a part of this ecosystem, with its own role to play in maintaining and improving the ecosystem's functioning. We found that esthetic, mistrust, and mystical/therapeutic values relate positively to forest visiting experiences with a wolf presence. Mistrust could either be interpreted as something negative or could refer to a fascination for the wild and the unknown (Drenthen 2015), hence explaining its positive correlation to forest visits. This is in keeping with the observation by Arbieu

et al. (2020) that "the excitement to see [have seen] a wolf could be a strong driver of positive attitudes."

People who see the Ardenne forests as representing something negative (SC value "disservices") favor the financing of an eradication or limitation of wolf populations. These people are also in favor of a general tax system for wolf management. Disservices, however, are not related to the question of belonging. Thus, these people are not opposed to the idea that the wolf is a part of the natural environment of the Ardenne but are concerned about minimizing the risks of its presence in terms of potential human–wolf interactions as well as in terms of financial implications. These are important insights for policy makers who are responsible for the implementation of the wolf management plan.

v. The added-value of using SC value variables

A more thorough understanding of people's concerns, beliefs, and opinions based on SC values could indeed help to develop more detailed and nuanced policy regarding wildlife, including wolf management, by avoiding a stereotypic classification of the actors. With the use of SC values, people are positioned on a gradient of the varying importance allotted to several SC values, which excludes potential problems of overlap between standard profile variables (i.e., multi-collinearity in statistical terms). The use of SC values can also help to deal with the issue of heterogeneity within groups, as can be illustrated by the aforementioned example of hunters' positioning on Q3 (i.e., with 24% of the hunters being in favor of eradication and 24% being in favor of cohabitation). When evaluating the differences in value scoring between those two subgroups of hunters, a significant difference[14] can be observed for the SC value biodiversity, which is much higher for the hunters in favor of financing cohabitation (an average of 15.53 votes) than for those in favor of financing eradication (an average of 5.07 votes). It should be noted that biodiversity turned out to be significant for the entire sample for this question (Table 4), so people who consider biodiversity to be an important aspect of the Ardenne, whether they are hunters or not, are more likely to favor the financing of a cohabitation strategy.

The use of standard variables can therefore lead to discussions driven by stereotypes and preconceptions, which reinforce debate and conflict (Van Herzele et al. 2015). Von Essen and Allen (2020) criticize the use of stakeholder participation models that divide the debate on wolf management on the basis of preconceived interest positions for each particular actor group and from which it is difficult to develop new perspectives. The analysis of the position of the general public and the brief exploratory analysis of the case of hunters in this study illustrates how SC values can nuance both the stereotyping of a particular group, such as hunters, as the stereotyping of the public opinion by the institutional discourse of a particular group. Von Essen and Allen (2020) advocate models of deliberation that begin with a common starting point rather than with polarizing differences. Individual SC values could assist in

[14] The *p* value for the independent sample *t* tests used was 0.04.

bringing legitimacy and transparency to the negotiation table, which could potentially offer a potential starting point to help build shared values (Kenter et al. 2016) in order to reach consensus.

The use of SC values for ES allows to identify which concrete aspects of a territory are of importance to different persons. These persons can both refer to the general public, as well as to adherents of a particular interest group who might occupy controversial positions on the questions of belonging, opportunity or threat, or management strategy regarding the comeback of the wolf. SC values address landscapes and are thus context-specific and dependent on the situation at stake. They do not represent specific values for wildlife or for a certain species. This makes their use less suited for generalized conclusions on wildlife valuations and for a comparison over territories. Therefore, the concept should be seen as complementary to the use of wildlife value orientations.

e) Conclusions

Overall, the results of our study tend to reveal a positive positioning on the points of controversy addressed and a general preference to finance a cohabitation between humans and wolves in the case study area. This positioning is positively associated with a consideration of the role of forests for biodiversity and life support. Although there exists a small minority of people who are against the return of wolves, a great majority of the people surveyed see the return of the wolves as a positive asset. The stated negative positions towards wolves have been observed for people not physically concerned by their presence (e.g., non-nature visitors); for people concerned about the potential negative impacts of forests in general (e.g., people with high scores for the SC value *disservices*); and for people for whom nature per se is not that important (e.g., people with low scores for the SC values *biodiversity*, *life support*, or *therapeutic*). Moreover, older people seem to be more negative. The geographical context is important, revealed by significant regional differences in positioning that may be due to the history of human–wolf cohabitation in the different regions.

The aim of this article was to illustrate how the use of SC values for ES valuations helps to overcome preconceptions and to better understand the underlying reasons behind stated positions on common points of controversy concerning wildlife and wildlife returns. Socio-demographic or profile variables can still be good predictors, but they can also mask heterogeneity within groups. By illustrating the case of hunters, we demonstrated that the SC value biodiversity has proven to be a significant variable not only for hunters, but for the entire sample as well. Without the use of the SC value framework, it would have led to a misinterpretation of the results.

The results of this research point out that careful attention should be paid to the unintended caricaturizing of actors in the public debate. By asking people which SC values, associated with the ES provided by the concerned territory, they consider most important for the territory that the wolf is reclaiming, it is possible to better identify which values are at stake in the case of diverging opinions. These insights can lead to questions about the legitimacy of existing discourses, to transparency in terms of

which values are accounted for by an actual or proposed management, as well as to the identification of a common ground to, for example, improve information campaigns.

Acknowledgements: Our thanks go to Ann Van Herzele for her helpful comments on the manuscript. We would also like to thank Soraya Chaer for her help with the descriptive graphics.

Funding: This work was supported by the Interregional (Interreg) European program through the Ardenne Grande Région, Eco-Tourisme et Attractivité project (AGRETA) (2.336.460, 77€, 2017–2020). The UMR BETA is supported by a grant overseen by the French National Research Agency (ANR) as part of the "Investissements d'Avenir" program (ANR-11-LABX-0002–01, Lab of Excellence ARBRE).

Declarations: Conflict of interests - The authors declare no competing interests.

Chapter 5

Discussion

As outlined in the introduction and despite the rhetorical discourse of forest multi-functionality, actual European and Ardenne forest management predominantly focusses on the maximization of timber production through implementing intensive management practices. Nevertheless, this strategy is increasingly being contested, especially in the light of the wider context of biodiversity erosion and of changing societal aspirations, the latter putting more emphasis on the role of forests for biodiversity conservation, regulatory ES and socio-recreational ES. Hence, new forest policies should acknowledge the variety of ES potentially delivered by forest ecosystems and the role natural forests play in their effective and sustainable delivery, as well as promote and facilitate practices that sustain and translate this acknowledgement to concrete changes in the field (Savilaakso and Guariguata, 2017).

Socio-recreational and ecotourism forest ES are frequently put forward as an opportunity for developing a so-called experience-based economy instead of a forest economy based on resource extraction, thereby representing a lever for nature conservation and restauration objectives. In order to account for socio-recreational forest ES in forest governance decision-making, and in view of the current knowledge gap on the socio-recreational ES of the Ardenne forests, a valuation of these ES was required.

The present research made use of the ES framework to underscore the ES nature-based recreation and tourism (via visitor frequencies, the spatial-temporal variation of these visitation rates and visitors' profiles) and aestheticism (via forest preferences). I also underscored the importance of various forest aspects for the wider public, through the notion of socio-cultural values. This latter notion was also employed to underscore within-group heterogeneity of actors groups relative to actors' positioning on the recent return of the wolf to the Ardenne. I briefly discussed how these valuation outcomes relate to forest naturalness and how they challenge current forest policies, practices and discourses.

Improved decision-making regarding sustainable ecosystem management has been proclaimed as an outcome of ES valuation valuations (Sing et al., 2018); however, whilst the ES perspective has widened up the scope of the debate on a conceptual level, whether these valuations actually lead to improved landscape management is less clear (Dendoncker et al., 2018a; Savilaakso and Guariguata, 2017; Stalhammar, 2021). Therefore, the following sections reflect on the potential of the research results for effectively modifying forest policies and practices. To do so we will lean on supplementary material, which will be detailed in the next section.

1. Methodological Note

More specifically, two supplementary sources of empirical data will be employed. The first concerns the aforementioned actor encounters (see section 4.1), both at the start of the AGRETA project (preparatory encounters) and at the end of the project (feedback encounters). It is worth noting that these encounters did not aim at a statistically sound sample, but rather at gathering diverse interests and viewpoints on forest management and its related topics (e.g. ecotourism, hunting, multi-functionality, etc.).

The preparatory encounters concern a limited list of interviewees representing a broad spectrum of viewpoints, which was identified during the early stages of document review. I made sure to include the main actor profiles concerned by forest management (hunters, naturalists, foresters, tourism sector, decision-makers). The feedback encounters concern a limited sample of concerned actors with different profiles, familiar to some extent with the AGRETA project and its outcomes to be able to discuss the results. Some encounters were organized as semi-structured interviews. Other encounters took the form of open discussions around some aspects of forest governance or the research results. Indoor semi-structured interviews were recorded, while notes were taken during outdoor interviews or open discussions. The choice of the format for the interview depended on the occasion, as the interviews were principally meant to gain personal insights into Ardenne forest governance, no standardized methodology was adopted. An overview of the formal actor encounters can be found in Table 19 below, where the actors' profiles have been listed. The information gathered from these discussions are completed by insights on forest governance issues obtained during other informal actor encounters or impressions gathered during events related to forest governance (e.g. two hunting events, an exhibition of wood logging machinery, an excursion on Pro Silva management techniques, conferences on forest governance, organized forest walks, etc.).

The information obtained through the preparatory actor encounters helped to gain a deeper insight in Ardenne forest governance issues and in different actor perceptions and the relations between various actor groups related to these issues, as well as to shape the questions posed in the employed survey. For this discussion, they serve as a kind of reference baseline to reflect on the potential impact of the research outcomes on forest governance. The information obtained through the feedback actor encounters served to concretize this potential impact of the research results and to identify potential barriers for translating research outcomes into specific adaptations of forest policies or practices.

Table 19. An overview of the preparatory and feedback actor encounters at the start and the end of the research project

Date	Profile(s)	Format	Encounter no.
Preparatory encounters			
08/08/2017	Non-profit association (Royal Forestry Society)	Semi-structured interview	P1

19/08/2017	Tourist operator (ecotourism)	Discussion	P2
24/08/2017	Forest agent (forest administration)	Discussion	P3
24/08/2017	Nature organization	Discussion	P4
30/08/2017	Non-profit association (hiking paths)	Semi-structured interview	P5
31/08/2017	Private forest owner	Discussion	P6
1/09/2017	Private forest owner	Discussion	P7
27/09/2017	Hunter (council member of the main hunting association)	Semi-structured interview	P8
28/09/2017	Head of the cantonment (forest administration)	Semi-structured interview	P9
12/11/2017	Hunters (various members of the main hunting association)	Discussion	P10
22/01/2018	Representative of the Ministry of Nature	Semi-structured interview	P11
Feedback encounters			
25/05/2021	Municipal mayor	Discussion	F1
19/06/2021	Director of a Natural Park	Discussion	F2
23/06/2021	Project managers at different natural parks (3)	Semi-structured interview	F3
29/06/2021	Municipal mayors (2)	Discussion	F4
30/06/2021	Researcher	Discussion	F5
02/07/2021	Forest agent	Semi-structured interview	F6
04/07/2021	Forest agent	Discussion	F7

The second supplementary source of empirical data concerns the outcomes of a student group work, that was organized within the context of the course “Ecosystem Services and Landscapes” for the students of agro-engineering at the University of Liège (supervisor Kevin Maréchal). There were six groups, with each group consisting out of four to six persons. The students were asked to organize encounters with actors concerned by forest management to discuss socio-cultural values for forest ES and the perceived impact of proposed management changes on a range of ES. These encounters took place in the spring of 2020. The following profiles were allowed: persons working for the forest administration, for a forestry company or for a nature association, hunters and farmers. To ease these discussions, a semi-structured interview format was proposed and pre-prepared tables were provided. As far as the socio-cultural value question is concerned, the exact same format as the scoring exposed within the articles of chapters 3 and 4 was used. However, in addition to the afore explained methodology, this time the actors were asked to score the values a first time in a personal way and a second time as representative of their overarching institution or federation. For the present research from the overall group work, only the results from the value discussions with four forestry agents will be employed.

2. Research implications for the Ardenne forest governance

It can be insightful to frame this reflection on the potential of the present research results for facilitating a potential sustainability transition for forest governance by employing the Multi-Level Perspective (MLP). This perspective distinguished three analytical levels: niche innovations at the micro level, socio-technical regimes at the meso level and socio-technical landscapes at the macro level (Geels, 2002). Transitions occur through interactions between processes taking place at these three levels (Geels and Schot, 2007). When applying the MLP, a transition, from production oriented plantation forests towards a natural forest paradigm, can arise from interactions within and between macro, meso and micro levels concerned with forest governance.

The macro level withholds the broader context of climate change and the worldwide decline of biodiversity, but also evolving societal values and aspirations, as well as the different more acute crises mentioned in the introduction, relevant to the Ardenne (i.e. the African swine fever outbreak, the bark beetle outbreak and the COVID pandemic), which all raise questions upon current forest management policies and practices. These events hence put pressure on the meso level, which consists out of the institutional structuring of the existing forest governance system. Pressure is also exercised by the micro level, within *niches* where innovations concerning forest management are conceived in a selective environment that is shielded from eminent practices. Established systems at the meso level tend to be self-protective and show path-dependency which can lead to the presence of so-called lock-ins which complicate or impede the uptake of innovative developments and thus hinder a sustainability transition (De Herde et al., 2019).

At the start of the overarching funding project, a **knowledge-gap regarding socio-recreational forest ES** had been identified, which oriented the project's research focus. A lack of founded data can impede the countering of misconceptions and weaken an argumentation when challenging dominant discourses regarding the socio-recreational aspects of current forest governance. However, this absence of information is not addressed by current governing instances at the meso level. In addition, it resulted quite complicated to obtain the scarce existing information on the topic due to the multitude of administrative layers and actors, the vagueness of their missions, the dispersion of the information, the incompatible data formats, the confidentiality regulations, etc. The identified lack of information and the absence of a structural response can be regarded at as representing an informational lock-in.

In this context, newly gathered data can represent a powerful artifact to (dis)arm certain discourses and its monitoring and communication can be seen as a first step to legitimize alternative management scenarios (Bodson, 2019a), being experimented within niches. More specifically, the previously inexistent data on socio-cultural forest values, visitor frequencies and the wider public's preferences could now be mobilized to better take into account the socio-recreational aspect of the Ardenne

forests in forest policies and practices. This could be done by pinpointing synergies between nature-based recreation, societal aspirations, biodiversity objectives and the provisioning of multiple ES, and would thus enable the proposition of alternative socio-economic development pathways based on more natural forest ecosystems.

In a nutshell, the main insights arising from the AGRETA project, to which this PhD research is linked, are: 1) visitor frequencies of the Ardenne forests, which are ignored in the traditional statistics on recreation and tourism, are significant and can be monitored and visitor fluxes can be channeled, 2) aestheticism, biodiversity and life support are the forest aspects considered most important by the wider public and are ranked well before more direct economic forest functions, 3) the attractiveness of the forests increases with a higher degree of forest naturalness, 4) public preferences correspond to a management strategy that also favors biodiversity objectives and the supply a wide range of forest ES; 6) nature-based tourism and recreation represent an important economic opportunity to be developed, 7) there exists a mismatch between current forest management strategies and societal socio-cultural forest values and preferences. These key insights, which were communicated by means of a summary outreach report and multiple presentations, are by several actors, those which aspire a sustainability transition, perceived as allowing for advocating and legitimizing a shift in forest management policies and practices towards more natural forests.

ES nature-based recreation and tourism

Visitor frequencies often represent a point of controversy among different Ardenne forest actors. Hence, as long as frequency numbers are left upon interpretations, it results difficult to engage in a constructive discussion on for example visitor access, flows and its impact on biodiversity (Encounters F2, F3, F4).

This demand for data, formulated by field actors within the context of the AGRETA project was followed by the identification of the current lack of an adequate methodology to meet this demand within the context of diffuse nature areas, such as the Ardenne. Hence, a first research question (RQ1) was formulated in chapter 2:

"How to measure and monitor visitor frequencies and apprehend visitor behavior in diffuse nature areas?"

A novel methodology for visitor monitoring was tested, based on the combination camera trapping, frequently used for wildlife monitoring, and artificial intelligence software, namely automatized image analysis. This combined method allowed for analyzing close to 800 000 images taken over a one-year period on twenty sites in four main forest areas. On a methodological level, the employed methodology resulted successful for handling large amounts of data and thus for ensuring a continuous monitoring, for providing stable results over all seasons and weather conditions, for correctly identifying persons and (to a lesser extent) bikes. This potential to identify different user profiles (i.e. hikers and bikers) is useful for e.g.

being able to relate trail use to environmental degradation or to anticipate or relax user-conflicts by objectivizing user proportions. The method also represents a flexible and cost-beneficial way to deal with visitor monitoring in diffuse nature areas. Several future improvements have been identified among which: to train the model on field images to improve its performance for non-human objects, to adopt a standardized camera positioning and provide clear guidelines on privacy regulations. On an applied level, results allowed for estimating point-specific visitation rates, spatial-temporal variations in visitation rates and proportions of visitor profiles; for comparing frequency rates between sites and forest areas; and for pre-identifying ways to channel visitor fluxes relative to certain points of interests.

As theorized in chapter 2, the effectuated estimation of visitor numbers and the obtained insights in the spatial-temporal variation of visitor fluxes provided evidence based knowledge that was indeed judged to have the potential to 1) objectivize discussions on perceived over-frequentations (Encounters F3, F6), 2) to guide site managers in the structuring of visitor fluxes (Encounters F1, F3, F4, F6) and 3) to construct realistic economic scenarios based on extrapolations, which can challenge the economic hegemony of timber and game revenues (Encounters F1, F3, F4). Illustrative of the perceived utopic and unrealistic aspect of an economic development based on an ecotourism strategy is the comment “revenues from tourism that replace those [hunting and game] revenues? Impossible! As we are not going to pay an entrance fee …” (Encounter P8).

A side-note to make on the objectivizing of visitor frequencies is the lack of information on the impact of visitors on the natural environment. For example, trampling of the soil is often mentioned as a negative effect of visitor numbers. Whether an objectivized number of visitors is perceived as an over-frequentation or not depends on their respective impact. Information of visitor frequencies should thus be further accompanied with research/data on the adverse impacts of visiting rates on the natural environment in order to allow for reaching consensus on the carrying capacity of the ecosystem under attention. In this sense, some consulted actors regarded the provided frequency data as a reference baseline and expressed a demand for a recurrent monitoring system (Encounter F3, F4). Based on our research outcomes, the proposed and tested methodology for visitor monitoring could be implemented on some strategic points and accompanied by a regular feedback report in reply to this demand. Moreover, compared to existing methodologies, such as e.g. eco-counters, the proposed method has the potential to offer more precise data, while at the same time being more economically interesting and flexible in its field implementation. Nevertheless, the present research only concerned a pilot system. The data analysis and the production of results would need to be further automatized and optimized for it to be of direct interest for site managers. Also, in regard of the demand from some forest agents for the images related to (potential) infractions, it should be safeguarded that a monitor system is not used as a control system. While visitor monitoring can allow for gaining insights in the proportion of infractions or misbehavior, I believe that implementing a steering and control of visitor behavior can better be accounted for by for instance the employment of forest stewards.

Within the context of the AGRETA project, an extrapolation of the (potential) economic revenues from nature-based tourism was performed based on the estimated frequency rates. The problematic issue of accounting for indirect economic benefits was indeed often underlined when talking about the provisioning of multiple ES, (Encounters F1, F3, F4, F6). Hence, production ES (such as timber production and increasingly carbon storage) do indeed result in direct revenues for the (private or public) landowners, whereas ES benefitting the public good, such as water retention, erosion control or landscape attractiveness withhold little direct incentives for potential providers to engage for their provision. In this context, while estimations on saved-out costs can represent a rather abstract concept (e.g. reduced public health spending due to physical and mental health benefits people obtain from visiting forests), indirect revenues from tourism and recreational activities are more tangible and their estimations are perceived as a convincing element to persuade decision-makers to modify forest management strategies (Encounters F1, F3, F5).

ES aestheticism

Following the first research steps dealing with how much forests are visited, we move to understanding more deeply the attractiveness of those forests. Recalling that the visual aspect of a forest ecosystem strongly depends on the type of forest management, which is often predominantly oriented towards timber production, the following second research question (RQ2) was formulated in chapter 3:

"Which visual structural forest characteristics are preferred by the wider public?"

The visual forest features that were presented to the survey respondents were selected along a natural-artificial gradient. Results show that the wider public has a strong preference for characteristics that align with natural forest ecosystems, i.e. endogenic tree species, vertical heterogeneity, the presence of deadwood and of natural open areas. Intensive management practices on the contrary are indirectly disfavored viewed the aversion of monocultures, single-age plantations and clear-cuts. This objectivized information allows for disentangling held misconceptions on the preferences of the wider public regarding forests visual characteristics and therefore also on the type of forest management. Interestingly, we could observe multiple surprised reactions in response to the manifested preference for deadwood, which is the visual element most commonly used by various agents as disliked by visitors and thus in legitimization of intensive management techniques keeping the forests "clean" (Encounters F3, F6, F7). This demonstrated preference for the presence of deadwood should not be confused with an interpretation of deadwood as waste wood. For example, some forest managers claim visitors disliked deadwood, because of the disapproving reactions from visitors on the waste wood left behind after logging interventions (Encounter 6).

Socio-cultural forest values

Because of the dependency of socio-recreational forest ES on the type of forest management, which in turn depends on the set priorities by forest policies and management strategies (e.g. biodiversity protection, timber production, hunting facilities, etc.), I considered it important to contextualize these ES valuation outcomes within the wider ecosystem, notably by underscoring the various ways the forest is valued by the wider public. Therefore, a third research question (RQ3) was formulated in chapter 3:

"For which aspects the Ardenne forests are of importance to people?
And what is their relative importance"

These forest values were identified through the scoring of socio-cultural values for the forest ecosystem. A wide range of diverse forest values are shown to be of importance to the wider public. Among this range of values, some are judged relatively more important than others. For instance, the importance of the forests for biodiversity conservation, regulatory ES and extensive recreational opportunities, are consistently higher ranked than the direct and indirect economic benefits obtained through forest ES.

Because of the importance of natural ecosystems for nature conservation and for ensuring a sustainable and diversified ES provisioning, this observation thus supports a shift towards more natural forest ecosystems, but contradicts with current dominant forest policies and management practices, which remain largely production oriented. Evolving societal values, which now put a greater emphasis on a wide range of forest ES and especially on non-production ES, thus supports nature conservation interests and challenge traditional forestry practices (Sténs and Mårald, 2020). While production ES (e.g. timber production) remain of importance, the way the delivery of these ES is conceived in forest policies and practices at the meso level should therefore acknowledge the changing wider environmental and socio-cultural context (Sing et al., 2018) at the macro level.

It has to be noted that the choice for eliciting socio-cultural values to represent the wider public's opinion by aggregating individual values undoubtedly influences the valuation outcomes. As already mentioned,, differences in valuation outcomes have been observed when comparing the outcomes of the aggregation of individual values with those of value deliberations within participatory actor groups (e.g. Eriksson et al., 2019). At the same time, the outcomes of group-based value deliberations depend on the individuals present within the group and can thus be challenged for its representativeness (e.g. Kenter et al., 2016). While ideally both methods should be combined, the scope of this thesis was to probe wider public's values with respect to the overall Ardenne forests. Therefore, the choice for aggregating individual values was retained.

Following, and in view of the plural dimensions inherent to the word *values*, I wondered how the use of ES values obtained through ES valuations stand in relation to the scoring of the socio-cultural values for the forest ecosystem. This led, in chapter 3, to the following fourth research question (RQ4):

"How does the use of ES values within ES valuations relate to the notion of importance?"

This question was dealt with by building on a conceptual distinction between the notions of the performance of ES, described by ES value indicators, and the notion of importance of the various aspects of the wider ecosystem providing those services, described by socio-cultural value indicators. In this regard, socio-cultural values for an ecosystem could be considered as an application of broader values-for-nature conceptual frameworks, such as the Life conceptual framework (O'Connor and Kenter, 2019), the latter which intends to accommodate for different value-dimensions. The use if SC, such as done in this research, can indeed serve for bringing together instrumental values (the ES considered of importance), relational values (as conceptualized by the NCP concept, Stålhammar and Thorén, 2019) and intrinsic values (the importance of nature in se) (Small et al., 2017).

Subsequently, we underscored the correlations between these elicited SC forest values and the indicated forest preferences, the latter reflecting the social demand relative to the ES aestheticism. This exercise showed that certain SC values are correlated with the expressed preferences for certain forest characteristics. Moreover, these correlations show a certain cohereny between forest values and preferences. SC values for aestheticism and biodiversity services resulted correlated with preferences for characteristics of more natural forests, while characteristics of more intensively managed forests, that are generally less appreciated, are preferred by people who attributed a higher score to the SC values for disservices, mistrust, direct economy, intensive recreation, and relational aspects. It was worth noting that according to the expressed preferences, such as the SC values bequest, patrimonial, therapeutic/ inspirational and extensive recreation. All these results about existing and non-existing correlations between SC values and preferences allow for identifying potential misconceptions (e.g. the SC value for 'life support' services are not scored differently between 'natural' and 'artificial' management models), for identifying common values between actors with different preferences or the other way around, for identifying non-obvious or unexpected linkages or non-linkages (e.g. the patrimonial SC value not being related to a specific management regime) and thus to challenge existing discourses over peoples preferences for a certain type of ecosystem management.

Obviously, these observations concern correlations and not causal relationships, and should thus be accompanied by qualitative research techniques to reinforce this meaning-making aspect of SC values in relation to ES valuation outcomes and for gaining major insight in the reasoning underlying the observed associations.

SC values, within actor group heterogeneity and the return of the wolf

The above results could lead to proposed changes in forest management regimes. Implemented changes are a result of decision-making processes, which requires a re-positioning of concerned actor groups. These latter are often classified into stereotypic groups based on actor profiling, which triggers polarization and nourishes tension and conflict. Within actor group heterogeneity is often ignored when presenting valuation outcomes per concerned actor group. This observation led to the formulation of the fifth research question in chapter 4:

"What does the socio-cultural value concept reveal about the use of stereotypes and the heterogeneity within each actor group?"

This question was applied to the case of the return of the wolf to the Ardenne, representing an (en)forced spontaneous rewilding event, which is known to provoke a strong opposition from hunters, as a concerned actor group. Therefore, following sub-questions were formulated:

"What positioning does the wider public adopt towards the return of the wolf to the Ardenne?"
"Do hunters show a different positioning towards the return of the wolf compared to the public in general?"
"Do SC values provide a better explanatory factor to explain hunters' positioning compared to their profile?"

Results showed an overall positive positioning on the return of the wolf, more precisely a general agreement on the the wolf having its place in the Ardenne nature, a general positive stated influence of the presence of the wolf on nature-based recreation and a general acceptance of dedicating tax revenues to this issue. Nevertheless, there were more mixed opinions regarded the preferred management strategy of wolf populations. This will be a future point of attention in order to increase the adhesion of the general population to a cohabitation strategy. In this sense, the rewilding movement can offer an opportunity to frame the return of large predators in a broader story on wild nature, biodiversity protection and restauration and human wellbeing.

The fact of being a hunter on the Ardenne territory, did not result significant for explaining people's positioning on those matters. Nevertheless, when taking a closer look to the question on wolf management strategies, a strong within-actor group heterogeneity was detected among the hunter group. At the same time, the SC value biodiversity resulted significant as an explicative factor, both for respondents in general as for the hunter group on this question. This indicates that peoples individual positioning does, in addition to other contextual variables, not necessarily depend on one's user profile, but rather on one's broader SC values for the concerned ecosystem.

Hence, SC values allow both for recognizing that actors, regardless of their user profile, express multiple values (including instrumental, relational and intrinsic values) and for finding shared values as a starting point for discussions over changes in ecosystem management. Looking at the associations between the various elicited SC values of a specific ecosystem and people's positioning regarding a specific event occurring within this ecosystem, allows for gaining insights in the nature values influencing a certain position or attitude.

The outcomes of the latter paper on the return of the wolf have not yet been communicated via an outreach activity and will thus not specifically further be discussed relative to the feedback actor encounters on our research results.

In terms of their field implications, all consulted actors during the feedback encounters underline the utility of being able to rely on evidence-based knowledge on socio-recreational forest aspects in discussions with other actors concerned by forest governance. More specifically, the results are perceived as useful for 1) comforting a premonition on visitors' preferences (Encounter F3), 2) demonstrating the potential alignment between tourism and nature development (Encounter F3), 3) providing reasoned feedback on forest management plans as proposed by the forest administration (Encounter F3), and 4) facilitating collaborations between different agents, for example by relying on economic extrapolations to convince councils or by countering claims from the tourist administration, generally reluctant in collaborating on nature projects, on a non-interest for more naturalness by the wider public (Encounter F3, F4).

Lock-ins and transition pathways

In the context of the forthcoming project call for Walloon national parks and the coincident timing of the publication of the outcomes of the AGRETA project, on the one hand the results were considered relevant for the elaboration of a project candidature and to legitimize decision proposals, on the other hand the project call provided an extra structural and financial incentive to concretize actions in line with the presented research outcomes (Encounters F2, F3, F6). Also the usefulness of disposing of a documented outreach report to back-up a discussion was underlined (Encounter F3). Nevertheless, it came also forth that research outcomes do not reach enough decision-makers, which have the influence to alter forest governance policies and practices (Encounter F4).

In addition, while the summary report was considered useful, most of the partners of the AGRETA project did not (fully) read the report. Most project partners conceived their responsibility on the topic as forwarding the information to the decision-makers present on their respective territory, without a specific intention or without an intended follow up (Encounter F3). This stresses the need for agents engaging in an active interaction with other actors on the provided research results, which often depends on personal motivation and contacts.

Thus, addressing the knowledge gap on visitor frequencies, values and preferences by generating evidence-based knowledge on socio-recreation forest aspects, is confirmed by diverse concerned actors as having the potential to facilitate a management transition towards more natural forest ecosystems and for taking better into account socio-recreational forest functions. The generation of this evidence-based knowledge can in this sense be regarded at as sustaining the innovation development within niches and as well as the aim of destabilizing the dominant regime.

Nevertheless, the effective impact of this information on forest decision-making at the meso-level remains to be confirmed, as research outcomes have only recently been published and diffused and since further mobilization will depend on the awareness, interest, agreement, concern and means of concerned decision-makers (Waeber et al., 2021) regarding the societal advantages of a transition towards more natural forests.

Three generic mechanisms of impact generation related to knowledge production have been conceived, including: i) improving the access to and the promotion of (new) knowledge to facilitate its up taking by decision makers; ii) encouraging joint social learning that creates shared understandings which can foster collective action; and iii) enhancing competences of potential change agents which will enable them to better respond to sustainability challenges (Schneider et al., 2019).

Regarding the first mechanism, indeed, Waeber et al, (2021) have shown that despite the existence of evidence-based knowledge, decision-makers do not necessarily respond accordingly, due to 1) unawareness of the knowledge, 2) a rejection of the knowledge content, 3) not sharing the concern and 4) the incapability to respond. In order to enable change upon the provisioning of certain knowledge, so-called *architects* are needed, which are aware of the information, accept its reality, think it is important to act upon and have the capability to do so (Waeber et al., 2021).

The second mechanism on joint learning underlines the importance of social learning, both as a process and an outcome, in deliberative processes for sustainability transformations (Eriksson et al., 2019). The co-production of new knowledge and understandings within social action-arenas where multiple actors confront and share their ideas, values and opinions on a given issue (Barnaud et al., 2018), can facilitate the taking of collective action for change.

The third mechanism pinpoints the need for capacity building for potential agents in order for these agents to become of so-called change agents or architects. These change agents do not have the power to create transformative change on their own, but they can enable the transition by facilitating the conditions for collective action to take place (Schneider et al., 2019; Waeber et al., 2021).

For transformative change to take place, a combination of these mechanisms at different scales and institutional levels, whilst involving a variety of actors, is often needed. Hence, various types of lock-ins (see further) can be encountered that could slow down or impede change; and to tackle the various types of lock-ins that can be present, will need a variety of strategies to be undertaken. Below, I will briefly address some of the encountered lock-ins for forest management in the Ardenne forests.

Based on further analytical reflections and the exchanges with concerned actors during the feedback encounters, several difficulties were identified that (could) impede an application of the research results. Still borrowing from the terminology used within transition studies, these difficulties can be labeled as lock-ins. These lock-ins can be categorized in cognitive, regulatory, normative and technical driven lock-ins, which will further be detailed below. Category definitions are borrowed from De Herde et al., 2019 and Ningsih et al., 2020. Whilst it lies not within the scope of the present research to point to detail existing or potential lock-ins related to forest governance, some main examples mentioned by concerned actors within the context of the feedback encounters will briefly be outlined. This helps to place this research within the broader socio-cultural and institutional context that frames the potential uptake of research outcomes. Thereby it can hint on where, apart from the production of evidence-based knowledge, complementary approaches are needed to facilitate sustainability transitions within forest governance settings.

Cognitive lock ins refer to dominant routines of knowledge transmission which orient future developments and which hinder alternative knowledge transmission systems. The above discussed knowledge gap forms part of these cognitive lock-ins, but also other cognitive lock-ins were identified. An example concerns the competences of the forest administration relative to socio-recreational forest ES. While the forest administration is responsible for the elaboration of management plans for the public forests and their implementation, several forest agents manifested they were formed and employed to manage forests and not visitors nor their aspirations (Encounters F4, F7). In this context, it is interesting to note that a recent official statement from the administration hierarchy that the socio-recreational forest aspect is part of their mission (Encounter F7) evoked a fierce internal opposition among multiple forest agents, who are not all convinced of the added value of developing the socio-recreational aspect of "their forests" and this regardless of their possible ecological concerns (Encounter F7). Indeed, various forest administrators convinced of a shift towards more natural forest ecosystems perceive an opposition between developing socio-recreational forest aspects and conservation interests (Encounters F4, F7). Moreover, language employed by forest agents shows a mental privatization of public forests, whether these concern forest reserves or production forests, hereby denoting visitors as external elements, which are only limitedly welcome and which should have no say over forest governance practices. This can be nicely illustrated by the following quote: "But to say that public forests are not private, that no!" [translated from French] (Encounter F7). This single focus on technical forest management competences, moreover often reduced to timber production techniques, limits the ability of foresters to adopt a broader ES perspective in their management practices. A forest owner for examples states that "biodiversity is very important, but when we are planting species like spruce and douglas firs, that already increases the biodiversity of the forest plot"; another owner states: "our forests are well protected, because here we don't deforest, but we replant" (Encounters P6, P7).

Technical lock ins refer to technological or infrastructural standards which orient future and hinder alternative technologies. A major obstacle for adapting forest

management in accordance with the presented research outcomes concerns the lobbying and the actual structuring of the timber sector in Wallonia. Currently, the majority of the Walloon timber-processing enterprises are equipped with machinery that solely handle coniferous trees of a certain limited circumference. Thus, apart from some small-scale exceptions, large broadleaf trees are consequently being shipped abroad, thereby leaving the territory without generating any added-value (VEDIA, 2021). Moreover, enterprises are specialized in only a limited number of tree species. These market norms favor the maintenance of monoculture coniferous tree stands for the local timber sector and impede a shift towards diversified broadleaf and old-growth forests.

Regulatory lock ins refer to existing regulations, standards and laws which orient future and hinder alternative regulatory pathways. Relative to the mentioned above dependency of the timber sector on coniferous forests, the aimed "equilibrium" between broadleaf and coniferous forests mentioned in the forest code, can be identified as a regulatory lock-in. This equilibrium is often interpreted as a 50-50 standard, thus also representing a cognitive lock-in, which would be "threatened" by a larger focus on broadleaf forests, with thus the "legal obligation" to keep at least half of the surface with a coniferous cover (Rogeau, 2021; Sillon Belge, 2017), even though the relative share of each forest type has officially not been specified. Another example concerns the short term accountability obligations of institutions and the related turn-over of electoral decision-makers. Diversifying economic revenues through ecotourism activities and even more improving ES provisioning and forest resilience by shifting to natural forests span over a larger timeframe, which often results incompatible with decision-makers' ambitions operating in short-term legislatures. These issues point out only some of the regulatory difficulties of initiating a sustainability transition in forest governance institutions.

Evidently, there exists a broad overlap as well as important interactions and feedback mechanisms between these categories. The following example illustrates some of the interactions between the mentioned above types of lock ins and shows how pathway dependency can be reinforced at different governance levels. Due to remaining misconceptions on natural forests and production forests relative to ES provisioning, e.g. carbon storage potentials (cognitive aspect) and short term international obligations e.g. national emission reduction goals (regulatory aspect), easy available solutions, e.g. intensive tree planting of fast growing species (technical aspect), are promptly underscored with existing methodologies (technical aspect) and proposed by mandated research institutes (cognitive, normative and regulatory aspect) (Encounter F5). This leaves little room for alternative innovative pathways to be developed (Waeber et al., 2021).

A last category of lock-ins appears crucial within the context of Ardenne forest governance and concerns the category of normative lock-ins. **Normative** lock ins refer to established relationships and behavioral norms and values which orient future pathways and hinder the establishment of new relationships and the evolution of current norms and values. While a democratization of values for ES, thus wider public values being represented in ES valuations, is said to lead to more sustainable, legitimate and fair decision-making, Kenter et al. (2016) highlight the persisting democratic deficit in ecosystem management policies and practices. This means that wider public values, even when they are assessed, do not translate into a decision-making that is representative of these values.

For the Ardenne, a mismatch between societal expectations and actual ecosystem management has been observed. This mismatch can be related to the normative context at the institutional meso level, where forest governance takes place. A societal perspective should in principle be adopted by governmental decision-making to ensure collective interests (Dendoncker et al., 2018b; Vatn, 2005). Nevertheless, actual forest management rather prioritizes ES that benefit individual interests. During the progress of the research and through the interactions with agents from the forest administration, a certain discrepancy was noticed between individual discourses concerning forest management and effective management practices. To address this presentiment, the double socio-cultural value scoring exercise was included in the abovementioned student group work (see methodological note in this section).

Hence, for the ES valuations performed within the present research, to obtain overall values, an aggregation of individual values has been employed as methodology. Nevertheless, public spaces are managed by institutions. While institutions are made up of individuals which hold certain values, institutions also represent a self-regulating body which represents institutional norms and values. Primmer et al. (2017) pointed out a potential difference between personal values of decision-makers and the institutional values these same persons perceive to dominate in the context where they operate. In this sense, normative institutional settings represent a potential lock-in situation for a democratization of socio-cultural values relative to ecosystem management.

To illustrate this potential discrepancy between personal and institutional values in a preliminary way, Figure 19, summarizing the outcome of the student group work on SC values mentioned in the methodological note of this section, is rather insightful. This figure results from the comparison between the scoring of socio-cultural values from a personal perspective and the same scoring from an institutional perspective. Positive and negative bars indicate how much more or less a certain (set of) service(s)/benefit(s) was judged of importance according to a forest manager responding as a person, compared to the very same forest manager responding from the standpoint if its position, i.e. representing the forest administration. What the figure shows is that the differences are more salient for some categories than for others. More precisely the trend seems to be that life-support, biodiversity, future and inspirational values were higher scored on a personal basis, whereas direct and indirect economic values and patrimonial values were more highly scored on an

institutional level. Even though these outputs concern a very small test sample and the forester grouping is evidently heterogeneous, still they hint at the existence of a personal value – institutional value discrepancy in at least some cases.

According to the ES framework and following the values-beliefs-norms theory, values translate into decisions and actions that have an effect on ecosystems and their functioning (Stern, 2000; see also chapter 1). Nevertheless, the influence of people's values on their environmental behavior and decision-making is not direct and is constrained by the wider social and institutional context (Harmáčková et al., 2021). This is even more obvious when the same person, a forest manager in our example, expresses different valorization priorities when asked personally and as a representative of their institution.

Thus, whilst a forest agent might consider a shift to more natural forests important because of their importance for biodiversity conservation and for regulatory ES, this might not translate into a shift in management practices, due to the institutional value context, which proclaims other priorities. This case corresponds with the situation of a lack of capacity, impeding decision makers to act upon evidence-based knowledge as described by Waeber et al. (2021). This is problematic as it are the institutional bodies that on a structural level decide on forest management policies and practices.

The existence of this situation was confirmed by various forest agents during the feedback encounters (Encounters F4, F6), who complained about the hierarchical pressure they receive to comply with timber production objectives and to employ intensive management techniques, which do not align with their personal insights, their field observations and the forest they aim to conserve or restore towards a more natural state.

This personal-institutional discrepancy also relates to the common use of classical actor profiles to describe certain actor groups; both by the specific actor group itself as by other actor groups. This creates thereby a certain stereotypic image of the actor group as a whole, hereby deepening the differences between actor groups, masking the resemblances between those groups, and neglecting within-group heterogeneity as demonstrated for the case study on the return of the wolf to the Ardenne in chapter 4. Individuals adhering or supposedly adhering to a certain group and thus to a certain discourse with its associated values and norms, often do not match with this simplified image.

Therefore, a focus on common socio-cultural values could be a more fruitful starting point for exchanges on forest policies and practices based on the concretization of those values and the consequent implications for dependent ES and service beneficiaries (Anderson et al., 2018; Buijs et al., 2011; Pelenc et al., 2015). In addition, Hejnowicz and Rudd (2017) point out that "shared values do not necessarily exist a priori", such that this interaction could also trigger a mutual interest and understanding of other socio-cultural values that had not been pre-identified as common values.

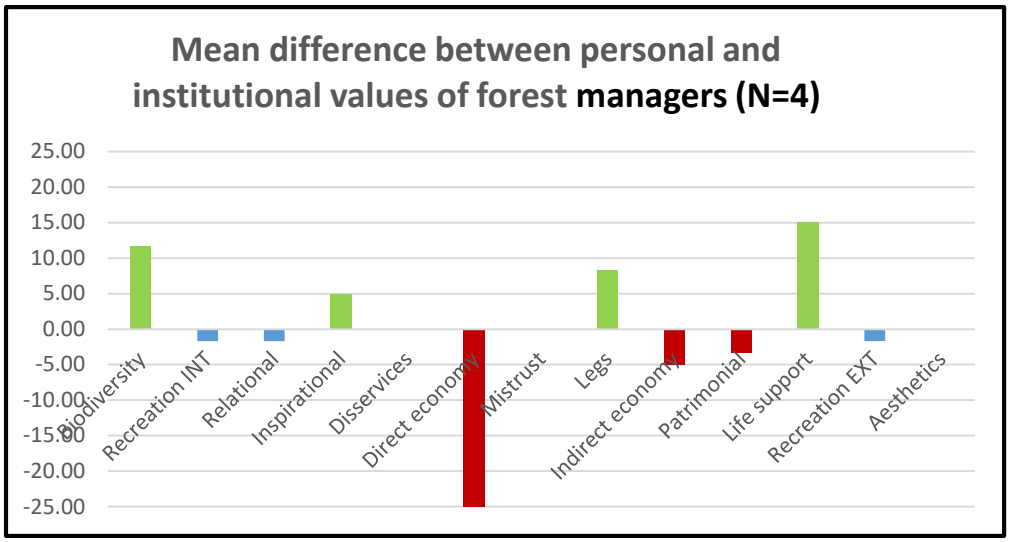

Figure 19. The difference in scoring of socio-cultural values by forest agents personally and in position

In sum, improved evidence-based knowledge is necessary and may help to assess and highlight the consequences of certain decisions (Blicharska et al., 2020). Nevertheless, the actual management decisions largely "depend on different actors' worldviews, which are rooted in their personal situations, their power and professional identities, and the political and legal realities" (Blicharska et al., 2020). Several authors indeed underline the presence of various barriers or lock-ins which might restrain the operationalization of new ES knowledge in decision-making or the obtaining of sustainability transitions (Langemeyer and Connolly, 2020; Sing et al., 2018).

In order to obtain a sustainability transition, these lock-ins need to be addressed. In line with the insights presented above, this will need as well cognitive (e.g. capacity building of the forest administration), technical (e.g. market transformations), regulatory (e.g. legal adjustments) and normative (e.g. a democratization of forest governance) innovations (Niemelä et al., 2005) to generate successful transition pathways.

3. An ecological transition of European forests management

Whilst the presented case-study focuses on the Ardenne forests, research outcomes align with existing research elsewhere in Europe. Moreover, pressures exercised at the macro-level, such as the context of climate change, biodiversity crisis and evolving societal values, remain valid at a European scale. Insights obtained from the present research can thus also be applied outside the case study context.

Several studies have pointed out the need to protect remaining forests with a high level of naturalness, as well as the need to restore degraded forest ecosystems by inducing a shift in management regimes to allow for a higher degree of forest naturalness (Chiarucci and Piovesan, 2020; Krumm et al., 2020; Wallenius et al., 2010; Winter et al., 2013). This proposed shift would largely correspond to evolving societal values putting more emphasis on biodiversity, regulatory ES and socio-recreational forest aspects, as well as to expressed visual preferences for the forest landscape. To date, there exists no overarching and binding policy regime at the European Union level concerning forest governance. Nevertheless, I mentioned the new EU Forestry Strategy in the introduction, which is a non-binding proposal to frame EU forestry activities; connected to the recently published Green Deal, which is a EU strategic plan proposed by the EU Commission that aims for climate neutrality by 2050 and which emphasis the importance of natural forest ecosystems in a climate mitigation context.

The rhetorical aspect of a multi-functional forest governance approach has already been underlined, as well as the overall mismatch between general policy documents and societal aspirations on the one hand and actual forest management on the other hand. It has been put forward that in order to enhance sustainable ecosystem management, eliciting values for nature and performing ES valuations can generate evidence-based knowledge that in turn can rise awareness on the ecological, socio-cultural economic impacts and consequences of different management regimes and thus support sustainable decision-making. These new insights can represent a first step to potentially lift certain cognitive lock-ins and as such put pressure on established forest governance regimes by developing alternative forest governance pathways. The valuation of ecosystem services, if perceived relevant, legitimate and credible (Potschin and Haines-Young, 2013), can thus create incentives for a change in management practices, as it has been documented in the case of an agro ecological transition (Mattos et al., 2011). However, few counter tendencies have so far been observed regarding forestry management practices (Helseth, 2021). Alternative forest management practices have been advocated, researched and put into practice to some extent. Nevertheless, it has been pointed out that these concepts such as close-to-nature forestry, continuous-cover forestry or pro silva forestry, are often loosely defined, which leaves the quality of their implementation strongly dependent on the good will and competences of local forest managers (Krumm et al., 2020; Uggla, 2017).

Moreover, whilst it has been estimated that the total economic value of a (semi-)natural forest ecosystem consists for 10% out of timber production, with 90% representing the provisioning other ecosystem services (Vallauri et al., 2016), dominant management approaches largely stick with timber production as their main objective whilst employing interventionist strategies. Alternative propositions of forest governance at the other edge of the hemeroby axis prioritize biodiversity conservation, as well as the provisioning of ES over longer time-frames, and therefore advocate for large forest ecosystems to be released from management interventions (Krumm et al., 2020). An example that received quite some media-footage concerns the French ecologist Francis Hallé who recently launched the project of (re)creating a primary forest in Western-Europe of at least seventy thousand hectares ("Association Francis Hallé pour la forêt primaire," n.d.). These hands-off propositions correspond to a rewilding approach, which focusses on the restoration of natural dynamics and processes. In this sense, the abandonment of large agricultural areas in eastern and southern Europe has been put forward as an opportunity for a passive rewilding strategy through natural recolonization and successional processes (Navarro and Pereira, 2015). Similarly and in complement, the re-introduction of missing megafaua has been promoted in order to stimulate landscape heterogeneity and maintain or create natural open areas within a forest mosaic system (Pereira and Navarro, 2015), sometimes specifically with an ES objective such as e.g. fire suppression (Johnson et al., 2018).

The evaluation of the attractiveness of differently managed forests, showed that preferences are compatible with this proposed shift to more natural forest systems. Nevertheless, in this study a limited number of visual characteristics of natural forests were represented in a simplified and static way. In order to restore naturalness in forest ecosystems, Burton and Macdonald (2011) indicate that "the biggest challenge is the social and political will required to undertake restoration efforts that seriously embrace the stochasticity and the temporal and spatial heterogeneity of natural forests". Hence, the restoration of natural processes and dynamics and the choice for open-ended ecosystems, in line with a rewilding approach, inevitably alters the forest landscape, on some occasions in a rather impressive way, as for instance the case for the flooding of alluvial forests plains, for whole forest stands affected by insect pests, for a large number of fallen trees after the passage of a storm, etc. The managers of Bavarian National Park for example decided not to intervene when a storm caused large tree felling and a consequent bark beetle outbreak generated wide landscapes filled with dead standing and fallen trees (Müller and Job, 2009).

Although forest ecosystem's health and vitality, which includes issues such as resilience to climate change, tree diseases, insect pests, forest fires or storms, is an often addressed topic by public bodies, literature on the public opinion related to this issue remains rare (Rametsteiner et al., 2009). Eriksson et al. (2018) found that opinions regarding how those events should be coped with are mainly based on concerns other than the specific management practices, they were for instance based on ecological forest values. Since larger parts of the public are not highly involved in forest management, they do not necessarily have a strong opinion on such change-inducing events or the precise technical management practices that should be

implemented (Rametsteiner et al., 2009). However, what people want the forest to be used for indirectly defines the type of forest risk management people prefer (Eriksson et al., 2018). Müller and Job (2009) for instance found public support for a policy of non-intervention in the case of natural disturbances. Thus, strategies in line with the values of the general public are likely to be accepted, but, in case of more pervasive or controversial forest management, the potential resistance of the public cannot be ignored (Eriksson et al., 2018). Forest management strategies should therefore address how they influence these general values (Eriksson et al., 2018). In the case that values and preferences result not being coherent, providing specific information on for instance the biodiversity interest of a certain strategy to the public could alter preferences (Brahic and Rambonilaza, 2015). This implies that the acceptance for the landscape consequences of a chosen strategy, such as for example when having to do with post-disturbance landscapes, can be positively influenced by communicating on the ecological benefits of these forest elements (Gundersen and Frivold, 2011; Müller and Job, 2009; Qiu et al., 2013).

The altering of a certain place, whether by management interventions or by a non-intervention approach, inevitably provokes a reaction from people, independent from them being familiar with the area or not (Cheng et al., 2003). Their response will relate to the group of actors they will identify with (Cheng et al., 2003). As mentioned in the introduction, forest conflicts in Europe predominantly relate to changing demands on (1) the intensification of forestry operations, (2) increasing recreational needs, and (3) the increased importance of the environmental movement (Niemelä et al., 2005). Whether conflicts lead to governance changes will depend on the ability of individual or collective agents to influence the uptake of alternative pathways by decision-makers. Dominant interest groups have developed a rather narrow set of ways of how a certain landscape is of importance (i.e. the relative importance of certain socio-cultural values), which are used as a legitimization of existing power regimes (Cheng et al., 2003). Nevertheless, the use of these groupings reinforces prejudices of the actors belonging to those groupings, which can further aggravate conflicts (Niemelä et al., 2005). From our case study, and as demonstrated elsewhere (Cheng et al., 2003; Turkelboom et al., 2018), it was evident that there exists a large heterogeneity within and overlap between these artificial groupings and their pre-supposed value oppositions, thereby challenging dominantly held discourses.

In addition, research indicates that forestry actors and forest managers focus more on productivity, with a much more positive attitude towards interventionist management practices including even aged stands and clear felling, while the wider public seems more concerned by biodiversity conservation, regulatory ES and socio-recreational forest aspects (see Buijs et al., 2011; Edwards et al., 2011; Nordén et al., 2017). However, based on the present research outcomes, this observation does not necessarily reflect an inherent value difference between forest managers as persons and the wider public, but a potential disconnection between institutional and personal values, with different value prioritizations present within a same actor, which are expressed differently according to the context. This issue, its magnitude, its underlying explanations, its implications and how to deal with it, deserves to be further explored in future research.

Today, forests are also at the center of the attention of new "bio-economy" development issues, which are seeing the revival of certain forms of exploitation such as the use of local wood for construction, or the development of the use of woody biomass for the manufacture of pellets or wood chips. Despite the advantages that these uses may provide with regard to the use of energy-intensive or non-recyclable materials, or relative to the required substitution of fossil fuel energy (Karvonen et al., 2017), these developments may have a significant impact on future forest management choices (e.g. plantations of fast growing tree species) or their ecology (e.g. a reduction of dead wood material).

A focus on common socio-cultural values by concerned (not necessarily local) actors could therefore represent a constructive starting point for acknowledging the current and potential future mismatch between ecological and societal values and preferences on the one hand and actual institutionalized forest management on the other hand and for facilitating the revision of current forest policies and practices accordingly. Hereby, it is the responsibility of the government to provide a good living environment for its inhabitants (and thus to ensure a secure provisioning of a wide range of ES) which, on top of the mentioned concerns on the institutional management of public forests, raises the question on the degree of freedom that private owners have in their management decisions (Eggers et al., 2018). While forest policies aim to orientate forest owners' behaviors, some gaps may remain between policy makers' objectives and forest owners' final decision (Deuffic et al., 2018).

Private forest owners are at the same time urged to take their responsibility in social and environmental forest aspects (e.g. complying with environmental legislations as for example Natura2000 obligations), but are also pushed towards production outcomes to ensure a continuous provisioning of the timber sector (Uggla, 2017) (e.g. governmental plantation subsidies after calamitous events or clear-cuts to regain a tree cover within a short time-frame). This generates tensions as regulatory pathways to guide forest owners do not necessarily align or even oppose, which hinder sustainability transitions. The social and environmental responsabilization of forest owners is not necessarily performed by the government, but can also be proclaimed by the associative world to put pressure on established forest governance practices (Uggla, 2017). Moreover, if a production logic is still an important driver for action, the respect of societal demands (such as a non-interventionist management strategy) gives less-profit-oriented forest owners a new legitimacy for action that did not exist before (Deuffic et al., 2018). In this sense, forest owners are not fully subjected to discourses, but can actively resist pressure in one sense or the other and develop pathways of resistance (Uggla, 2017).

Various levers to facilitate a sustainability transition and to promote and strengthen a forest governance approach that takes a societal stance could be envisioned. Examples may include legal adjustments, financial mechanisms, information campaigns, etc. For example, Höltermann (in Krumm et al., 2020) proposes that forest owners having bet on risky investments aimed at maximizing a single ES, such as the case for monoculture and eve-aged spruce plantations, should no longer qualify to receive public support after calamitous events; exogenic tree species could be removed from the list of allowed tree species; economic incentives

for forest owners to ensure the delivery of non-production ES could be envisioned (Savilaakso and Guariguata, 2017); filing a law suit to hold the government accountable for not complying restoration goals, as currently trending within the context of emission reduction goals (e.g. klimaatzaak.eu), could be a possibility to exercises pressure on current forest governance regimes; etc.

These and other examples of small and big forest governance innovations, whether or not already implemented on the ground, represent an evolving effort to engage in sustainability transitions. Simplistic solutions should however be avoided for allowing structural changes and not reinforcing current path dependencies. Finally, improved forest management does not necessarily require changes in land-use nor in land-tenure in order to be implemented and by consequence, in theory, represents a rather simple transition with straightforward biodiversity and ecosystem services gains (Griscom et al., 2017). Therefore however, forest management actors need to consider how the choice for a certain management strategy will be perceived by the general public and need to proactively and continuously strive towards a trustful relationship (Eriksson et al., 2018).

4. Broader nature management shifts

Swart et al. (2001) identify three broad nature conservation approaches: the *wilderness* approach, which takes an eco-centric stance and focusses on self-willed natural landscapes; the *functional* approach, which takes an anthropocentric stance and implies intensively managed landscapes; and the *arcadian* approach, which advocates stewardship within semi-natural landscapes. Stewardship, within the context of nature conservation, can be defined as taking care of nature, thereby representing an interventionist approach in which cultural and historic nature management practices take an important place (Riechers et al., 2021; Swart et al., 2001). This arcadian approach (coming from the Greek Arcadia, representing an idyllic and bucolic landscape) is the most practiced nature conservation approach in (Western) Europe, but is increasingly challenged by the trending rewilding discourse. Van Meerbeek et al. (2019) state that, relative to nature conservation, "these paradigms are not conflicting but complementary" and advocate for "rewilding where possible, human intervention where needed." Also several other authors (e.g. Jepson and Schepers, 2016; Winter et al., 2013) reason that there is a need to sustain both legacies of intervention and non-intervention nature conservation approaches.

In this sense, Cózar-Escalante, 2019 and Fernández et al., 2017 propose to adopt a pragmatic approach of rewilding. While, in terms of nature conservation, societal choices can lead to conserve certain cultural landscapes that need ongoing human intervention, other landscapes can be considered more fit to re-install or re-authorize natural dynamics and processes. What we would find are thus 'hybrid landscapes' (Cózar-Escalante, 2019) that contain several layers of natural and human elements, with intertwined natural and cultural histories (Hourdequin and Havlick, 2014). Landscapes can be seen as dynamic and historic spatial units representing an arena of human activity and cultural negotiations (Ingold, 2002). Cózar-Escalante (2019)

proposes to acknowledge that there are different modes and degrees of authenticity and to avoid adopting essentialist positions on what nature should look like and on how it should be conserved and restored. Hence, rewilding can raise issues when there is a fear that rewilding could cause the loss of the cultural value of landscapes, and a feeling of estrangement from a new nature (Drenthen, 2009), given that many rural residents associate nature with cultivated pastoral landscapes and not necessarily with wilderness. As Miller (2006) explains, people tend to take their childhood reference as a baseline for what an ideal state of restoration should look like, which refers, in most places in (Western) Europe to a landscape shaped by agriculture or production forestry, also referred to as the *shifting baseline syndrome* (Monbiot, 2014). Nevertheless, due to the broader alarming context of o.a. climate change and biodiversity decline, transformative changes are needed towards sustainable trajectories; for which purpose the potential of nature-based solutions has been underlined (Palomo et al., 2021).

The present study focused on forest ecosystems and demonstrated that a management shift towards more natural forests lies in line with societal expectations. These expectations were a.o. assessed through the scoring of socio-cultural values and the preferences for forest characteristics. Similar reflections can be undertaken for other ecosystems. For example, on the public appreciation relative to the adopted management practices of wetlands, grasslands, peatlands, rivers, etc. and on the perceived relative importance of the variety of values of these ecosystems; as well as on the degree of naturalness and its impact on ES supply of these ecosystems under their current and potential future state.

Within this context, the increasing abandoning of European agricultural lands has been pointed out as an opportunity for rewilding large areas (Navarro and Pereira, 2015). This abandonment mainly the result of wider socio-economic trends (e.g. the structuring of global agricultural markets, rural-urban migrations in search for new economic opportunities, etc.) as well as of, in second instance, environmental drivers (e.g. drought, erosion, etc.) (Leal Filho et al., 2017; Rey Benayas, 2007). Evidence-based information on the ES supply of these rewilded lands could represent convincing elements to inform, persuade and motivate actors concerned with ecosystem governance. This rewilding proposition does not withhold a land-sparing approach, but has to be interpreted as the pragmatic rewilding approach is outlined by Cózar-Escalante (2019).

There exist, for instance different models of (very) extensive agricultural systems in Europe, where wild nature is more integrated. The Iberian Dehesas, populated by of large populations of wild mammals and birds, is regularly cited as an example. Although not completely free of criticism or pitfalls (notably in terms of the potential development of mature forest ecosystems), the results in terms of biodiversity remain remarkable, particularly for the conservation of many rare species (Mansoura et al., 2009; Ramírez-Hernández et al., 2014). New systems probably also need to be invented or refined, such as Knepp's 'wildland farm' in Great Britain, where several species of wild and domestic mammals graze in semi-liberty within a more global project combining extensive agriculture and tourism activities.

The movement of rewilding, representing a potential transition in nature conservation, does thus not happen in a vacuum, but should be contextualized within the broader context of the needed ecological transition and thus be aligned with transitions in other fields or sectors, such as, for instance, the transition towards agro-ecology (which notably includes the adoption of ecology-sound agricultural practices, the relocation and shortening of food chains, a pea for more transdisciplinary modes of research, etc.) (Wezel et al., 2020).

However, current agricultural regulations can also counteract the adoption of a rewilding approach. The European Common Agricultural Policy (CAP) for instance, currently under revision, subsidizes farmers to "avoid the encroachment of unwanted vegetation on agricultural land" through the so called Pilar 1 subsidies (EC-LNV, 2004). This means that in order to apply for certain subsidies, farmers must prevent the establishment of shrubs and trees on their lands. At the same time Pilar 2 subsidies pay farmers to "undo some of the damage inflicted by this system" (Monbiot, 2014), as for example through hedgerow planting. In addition, agri-environmental regulations aiming at improving biodiversity rely often on costly interventional management practices, such as subsidized grazing or mowing (Schou et al., 2021). Schou et al. (2021) demonstrated that even if rewilding approaches with for instance large herbivores could result more beneficial than certain agri-environmental schemes, as well in ecological and ES terms as in terms of cost-efficiency, the CAP artificially renders agro-environmental schemes economically more advantageous.

Moreover, existing conservation schemes such as the Natura 2000 network and its corresponding regulations are conceived as static schemes, while natural ecosystems are dynamic and can evolve into other systems. In this sense, also existing nature conservation mechanisms can represent a regulatory lock-in that freezes ecosystems in time and impedes the development of natural processes and dynamics.

Devoting research to socio-cultural values, relative to different ecosystems and landscapes, could help identify which aspects of the ecosystem are most of importance to people, irrespective of the actor group they could be classified in (e.g. farmers, fisherman, entrepreneurs, hunters, decision-makers, etc.). Linking these values to concrete management policies and practices could, as demonstrated through the Ardenne case study, help identify matches and mismatches between societal expectations and effective ecosystem management. This identification could thereby foster transparent and legitimate decision-making. In addition, discrepancies between socio-cultural values at different levels of governance could shed light on potential lock-in situations that could impede future transitions. In this sense, for sustainability transitions to take place, the integration of socio-cultural values in valuation frameworks and decision-making processes could represent one leverage point in the discussion on envisioned human-nature relationships (Riechers et al., 2021). This could further open up a reflection about the moving away from the idea of human control over ecosystem functioning, also within current nature conservation approaches.

Chapter 6

Conclusion and future perspectives

The current environmental crisis and its human origins urge the need for response and require a reconsideration of actual human-nature relationships. These latter are predominantly based on a resource-flow model, where the extraction, use and consumption of natural resources for human wants result in a disruption of the ecological functioning of ecosystems. This observation has prompted a call for ecological restoration actions and for a reframing of the interactions between the human and the non-human world.

The present research made use of the commonly employed Ecosystem Services (ES) framework to explore human-nature relationships, taking the example of forest ecosystems through a case study approach. Forest ecosystems have recently received increasing attention, especially regarding their regulatory capacities and as potential biodiversity hotspots. In addition, the COVID19 crisis has underlined the need for qualitative public natural areas for recreation and leisure activities and has recalled the linkages between public health, the biodiversity crises and the ecological functioning of ecosystems. Within this context, multiple actors and studies stress the need for a transition towards more natural and resilient forest ecosystems. However, decision-making over the hence required changes in forest management policies and practices is based on value judgement by different concerned actors at different levels of power, influence and interests, which is prone to evoking tension and conflict. In order to allow for transparent decision-making processes that take into account societal expectations, it is essential to underscore how the forest ecosystem is valued by the wider public.

The overarching AGRETA project underscored the ecotourism value and potential of the Ardenne forests in view of proposing alternative socio-economic development schemes to (public) forest authorities. Within this context, the present research addressed the valuation of the Ardenne forests by the wider public through (i) estimating visitor frequencies as an indicator of recreational and touristic forest ES; (ii) assessing wider public preferences for structural forest characteristics as an indicator of the ES aestheticism or landscape attractiveness; (iii) and underscoring socio-cultural (SC) forest values as an indicator of the relative socio-cultural importance of various forest aspects. In addition, it made use of SC values for (iv) addressing within-group heterogeneity in order to bypass the stereotypic profiling of concerned forest actor groups.

Results demonstrated the importance of a wide range of forest values for the wider public and the prioritization of the role of forests for aesthetic appreciation, biodiversity conservation and for regulatory ES; as well as a general preference for characteristics of more natural forest ecosystems. The combination of these results revealed a mismatch between current forest management governance on the one hand and societal values and preferences on the other hand. This mismatch has been contextualized in the discussion section by employing the Multi-Level Perspective (MLP) and the potential influence of research results has been confronted with the prevalence of cognitive, regulatory and normative lock-ins, based on insights obtained through discussions and interactions with concerned forest actors.

On a conceptual stance, results demonstrated the potential of using SC values for the overall ecosystem in combination with specific indicators of people's positioning on a precise aspect of the ecosystem (e.g. on an ES). This combination indeed allows for (i) contextualizing the importance of an ES under evaluation within the wider ecosystem relative to other valued aspects of the same ecosystem, (ii) identifying misconceptions over perceived linkages between the provisioning of certain ES and their functioning, (iii) identifying mismatches between societal expectations and adopted governance policies and practices, and (iv) accounting for within-group heterogeneity, which in turn might lead to question hegemonic discourses present within certain actor groups. Conceptually differentiating the intertwined *importance* of the wider ecosystem from the *performance* of ES supplied by this same ecosystem and looking at the association between both elements can thus provide information or insights that can be mobilized within areas of resistance in order to reinforce certain transition movements towards more sustainable ecosystem management.

In this sense, complementing performance-oriented ES valuations with broader nature-valuations, as is done with the use of SC values, can enlarge the diversity of values taken into account in the valuation process, compared to a sole use of the ES concept. More particularly, it allows for gaining insights in the meaning-making of expressed social demands for ES provisioning. Integrated nature or ES evaluations can thus make use of the SC concept to broaden the scope of value dimensions (including instrumental, relational and intrinsic values). The interpretation of a social demand on two levels of abstraction (for the performance of an ES and for the importance to be put on various ecosystem values within ecosystem governance) allows for characterizing the ES under value within a wider socio-ecological context. Looking at the associations between SC values and specific indicators can enhance the meaning-making of revealed preferences and, by doing so, increase the transparency and legitimacy of an adopted ecosystem management approach.

I started the present research by using the ES concept for a valuation of socio-recreational forest ES. However, the compelling notions of values, preferences and importance relative to ecosystem governance, increasingly collided with the instrumental and anthropocentric framing of the ES concept. This led us towards the above-mentioned conceptual distinction between the interwoven notions of *importance* and *performance* and to complementing the socio-recreational ES valuations with the scoring of SC values for ecosystems. SC values were then used for contextualizing and interpreting not only the obtained ES valuation outcomes, but also for gaining insights about the positioning of people towards nature specific events. While, originally, I searched for adapting the ES framework for it to include broader ways of valuing nature, it eventually was the combination of complementary concepts that led to a more integrative and satisfying valuation frame. Since the path followed is of crucial importance for the research outputs, the insights from this PhD research would most likely have been much different, had I started off directly outside of the ES conceptual frames.

In this sense, as Malmborg (2021) rightly notices, instead of wanting to extend the ES concept to encompass all forms of human-nature interactions, we rather should

acknowledge its limitations and expanding nature-valuations with other concepts or tools. Indeed, adaptations of existing frameworks and the potential of these revised frameworks remain largely framed within the limits of the original framework. As mentioned in the introduction, frames provide a common way of approaching a topic which allows people to give a shared meaning to reality (Van Gorp, 2006). The ES framework offered a novel way for framing human-nature relationships by calling upon the dependency of human society on ecosystem functioning. The objective of the ES framework is essentially to internalize environmental costs into the economic functioning of human society based on ES valuations, with the underlying idea this will improve the ecological status of ecosystems and their functioning (Muradian and Gómez-Baggethun, 2021). Nevertheless, frames also inherently encompass a reductionist vision of the ecological functioning of ecosystems. A clear example concerns the carbon capture function of forests. The sequential reasoning made by many is the following: climate change should be tackled as it puts human society at risk, this issue is to a great deal due to rising levels of carbon emissions, trees stock this carbon, so let us all -individuals, enterprises, governments- plant trees to tackle this problem. Despite its non-nuanced logic, this clear and simple message is reproduced at various levels of societal organization, e.g. by researchers (Encounter F5, Bastin et al., 2019), the media (ex. Ysebaert, 2021), politicians or foresters (ex. in Rogeau, 2021; Uggla, 2017).

In addition, while integrated ES valuations -taking into account a variety of ES, indicators and actors- indeed offer a more nuanced story, we have touched upon the limited potential of evidence-based knowledge alone, relative to the importance of several lock-ins that impede required changes (Blicharska et al., 2020). The AGRETA project provides forest decision makers and managers with concrete indices allowing for arguing a change in forest management and to consider the development of an ecotourism strategy for public forests. As outlined in the discussion section, for this information to induce change, it needs human agency and advocacy in combination with other impulses directed at overcoming certain barriers or lock-ins. The concept of agency refers to the capacity to act in an independent way and to make free choices (Waeber et al., 2021); advocacy refers to activities that aim to influence decision-making processes. Hence, decision-making is framed within a certain socio-political and institutional context with its own logic, power plays, discourses, vested interests, communication channels, etc. Recent ES literature searches to integrate environmental justice within ES valuations so that methodological choices as well as the valuation outcomes are also just and fair (Langemeyer and Connolly, 2020). Without agency, advocacy or supplementary triggers that induce shifts in mindsets, policies or practices, this does not mean however that the policies and practices relying on these outcomes will result in an ecologically and socially just and democratic change in view of the afore mentioned barriers and lock-ins.

In this sense, integrated ES research can create openings in seemingly fringed situations by shedding a novel view on them. In our case-study, diverse actors underlined the utility of being able to dispose over the provided data that highlighted forest ES other than timber supply and hunting facilities, in order to mobilize this information for arguing changes in forest management. However, most actors said

that they were not going to take up this agency role themselves, leaving the provided information to await a "right agents – right timing" momentum. For the Ardenne context, some actors identified the combination of the increasing urgency of the climate and the biodiversity crises, the European obligations on the matter, the project call for the creation of National Parks by the Walloon region, the incrementing questioning of dominant discourses by researchers as well as by actors on the ground due to field observations, and the presence and gathering of engaged persons with certain abilities on a specific territory as representing this potential momentum cocktail, with its ingredients representing triggers for change on all levels of the MLP. Apart from providing a piece of the puzzle of change, the ES framework is also useful as a communication tool for ordering all those elements into a comprehensive and clear story line, which in combination to the already embedded use of this frame, facilitates the take-up of the proposed story line.

Nevertheless, when it comes to translating ES valuations outcomes into concrete policies and practices, the discussion often fringes on financial retribution schemes. An ES logic follows the reasoning that the highlighting of the (monetary and non-monetary) benefits for human society and the economy in general is the most effective strategy to propagate environmental protection. The governance of natural areas - including forest- should take into account societal challenges, before serving particular or individual interests (Jacobs et al., 2013). Setting apart for a moment the previously discussed difficulties with inducing change in public institutions, private landowners do not have a direct (financial) interest in adapting their management for the public wellbeing, which induced the implementation of compensation schemes and of payments for ecosystem/environmental services (PES) systems on the one hand, and a reluctance of public authorities to undertake actions on private properties on the other hand. Recent catastrophic flooding in the Walloon region for example call upon a revision of previously rectified rivers and to restore the natural riverbed (note: rivers are public property). However, the public authority responsible for these restauration works feels reluctant to take action since this would concern private land, for which they are not mandated and which would generate potential conflict with e.g. the farming community (personal communication). In this sense, the voluntary bases of potential compensation schemes and PES modalities as well as the repetitive financial input needed for their implementation do not offer a satisfactory alternative.

During the concluding conference of two European funded projects (i.e. the SINCERE and the NOBEL projects[15]) on payment systems for forest ES and including a multitude of project partners, it was put forward that the implementation focus of recently adopted EU forest strategy lays on biodiversity, ecotourism and the forest as a carbon sink, while neglecting the economic role of the forests (Langue in SINCERE project, 2021), as if those mentioned forest aspects did not have an economic importance and as if forest ES were not interdependent on one another; it was put forward that "people want more recreation, they want a nice place to walk, this cannot happen in a forest that is left unmanaged" (Langue in SINCERE project,

[15] The Sincere (Spurring INnovations for forest eCosystem SERvices in Europe, sincereforests.eu) and the Nobel-payments for forest ecosystem services (boku.ac.at) projects are funded by the Horizon 2020 program and aim to develop novel policies and new business models for forest ecosystem services.

2021), which is clearly an un-nuanced and at least doubtful argument considering the insights from the present research; and undertaken research that was exposed mainly focused on the modelling of forest ES, the creation of business models and the combination with public policies allowing for a quantification and a recompensation of the underscored ES; key words included profitability, growing stock, supply and demand curves, etc.; its conclusion could be summarized by "most of the income from forests comes from timber and there is a lack of alternative valorization schemes" (Lovric in SINCERE project, 2021). While other PES schemes exist which do not rely on the marketization of ES, as for example the development of an experience economy (Weiss in SINCERE project, 2021), where the marketing of experiential ES is based on a high quality nature, which aligns with the ecotourism strategy envisioned by the National Parks project of Wallonia, this example of two notorious research projects illustrates the mainstream setting of how an application of ES valuations is envisioned.

While the ES framework merits credit for recalling effectively the dependencies of humans on the natural world, it does not fundamentally change the dominant human-nature relationships, but it stays within and reinforces the dominant existing frames of human-nature relationships that organize western societies. Hence, even a public good is still perceived (and thus managed) as a good.

This poses question of the role of scientific researchers on the conception of influential metaphors such as is the case of the ES cognitive framework. Whilst scientific knowledge exists among other forms of knowledge systems, such as local experiences, beliefs, art-based approaches, etc. (Riechers et al., 2021), it has a dominant position in terms of the production of legitimate knowledge within the organization of Western societies (Cobern and Loving, 2001). However, the construction of scientific concepts, methodologies and explanations concerning ecosystem functioning rely on and re-produce the social, political and cultural frames in which the researcher is operating (Stalhammar, 2021; Vatn, 2005).

The interpretation of ES value valuations for their application in policy and governance should therefore not overshadow a potential need for more fundamental changes concerning human-nature relationships and interactions (Stalhammar, 2021). Scientific researchers should therefore actively interact with alternative knowledge systems (Muradian and Gómez-Baggethun, 2021) and engage in transformational research that goes beyond the borders of existing frames (Larson et al., 2021). Coming back to our case study, we do thus not agree with to the recent words from a Walloon forestry expert according to which forestry should be left up to the experts and that the response to the current challenges relative to forest management "ought to be technical and not philosophical" (Rogeau, 2021). Technical solutions do indeed inherently reflect a philosophical choice of complying with the dominantly adopted cognitive framework.

The present research provides some preliminary arguments that identify a certain openness and public support for adopting an alternative discourse. Indeed, in the top three of forest aspects deemed of most importance, biodiversity protection figures among two complementary anthropocentric motivations. In addition, we also

observed that actor groups host an internal heterogeneity questioning the hegemony of current dominant discourses.

To this regard, the insightful paper by Muradian and Gómez-Baggethun (2021) places three elements that frame current human-nature relationships at the foundation of the environmental crisis: the society-nature divide, anthropocentrism and utilitarianism. The authors propose to center the solutions specifically on these elements and hence identify a need for "a shift from a morality of utility to a morality of care, a reallocation of property rights, and the extension of the community of justice to non-human entities". In other words, they see the need to reframe human-nature relationships within an ethical system, where the expression of power by humans on the environment is restrained by the legal rights accorded to natural entities, which by consequence of their recognition as moral entities cannot be owned by human individuals nor institutions.

When the representative of the European confederation of forest owners thus states that European carbon storage has increased since the 1950s due to forest management and that these forest owners have not been financially compensated for this function, neither for other provided regulatory ES (Langue in SINCERE project, 2021), setting aside the simplistic logic that an increase of tree cover is tantamount to a likewise increment of forest functioning, this reasoning evidently depends on how one defines property rights.

Setting aside all other interrogations that could generate this proposition, it nevertheless raises questions on the proposed system of care, where human representatives are ought to speak on the behalf of natural entities (Muradian and Gómez-Baggethun, 2021). Hence, as discussed above, appropriate management for nature areas differs according to the narrator (Cheng et al., 2010), so who will speak for nature and more specifically, for which nature? For example, current forest owners and managers might consider adopting a new communication strategy based on story telling while framing foresters as caretakers (SINCERE project, 2021). In this sense, *caring for* should be differentiated from *taking care of*, which recalls the tensions between rewilding approaches and stewardship approaches towards nature and its (non-)management, but which could be enriched by re-approaching the concepts outside of their Western realm (Swart et al., 2001).

In summary, the ES conceptual framework provides a useful communicative tool to recall the multiple dependencies of human society on the natural world, as well as dependencies between human agents mutually regarding their positions as managers and beneficiaries. Integrated ES outcomes can be mobilized to pave the way for more transformative change to follow. Evidently, the sense of momentum felt by different forest actors to induce change stands apart of how this change should be framed. For instance, the changing societal demands and needs are also seen to represent a starting point for institutional innovations concerning payment schemes for forest ES (Weiss in SINCERE project, 2021). Thus while innovations are more likely to be proposed in the near future, different agents with different visions are eager to use this window of opportunities to propose different alternative systems. In view of the needed

transformative change, it would be wise not to bet on the very same frame for providing all innovative solutions.

Despite the merits of the ES framework, it is esteemed that the integration of this framework into policies and practices has not led so far to transformative changes of human-nature relationships (Muradian and Gómez-Baggethun, 2021). This observation could be linked to the fact that this framework operates within the existing frames and regimes of societal organization, as it is visible, for example, through the taking-for-granted of current property rights. The application of the ES concept therefore tends to reinforce these existing frames and do not fundamentally question current human-nature relationships in view of the required changes. In consequence, while the ES concept can open up space for inducing transformative change, it does not lend itself to being translated into concrete policies and practices. Hence, there is a need for new frames which would allow to address certain lock-ins, due to existing governance regimes, and which allow for transformative changes regarding the place of humans within the natural world to take place. While new frames evidently bring along their own contradictions, complexities and constraints, this should not impede their very conception.

"The secret of change is to focus all of your energy, not on fighting the old, but on building the new" - *Socrates*

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