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When we cannot have it all: Ecosystem services trade-offs in the context of spatial planning

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ABSTRACT

Spatial planning has to deal with trade-offs between various stakeholders' wishes and needs as part of planning and management of landscapes, natural resources and/or biodiversity. To make ecosystem services (ES) trade-off research more relevant for spatial planning, we propose an analytical framework, which puts stakeholders, their land-use/management choices, their impact on ES and responses at the centre. Based on 24 cases from around the world, we used this framing to analyse the appearance and diversity of real-world ES trade-offs. They cover a wide range of trade-offs related to ecosystem use,

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including: land-use change, management regimes, technical versus nature-based solutions, natural resource use, and management of species. The ES trade-offs studied featured a complexity that was far greater than what is often described in the ES literature. Influential users and context setters are at the core of the trade-off decision-making, but most of the impact is felt by non-influential users. Provisioning and cultural ES were the most targeted in the studied trade-offs, but regulating ES were the most impacted. Stakeholders' characteristics, such as influence, impact faced, and concerns can partially explain their position and response in relation to trade-offs. Based on the research findings, we formulate recommendations for spatial planning.

1. Introduction

Despite the popularity and desirability of so-called 'win–win solutions' in spatial planning, they seem to be rare in real-world situations, where managers need to cope with trade-offs and hard choices tend to be the rule (Vane-Wright et al., 1991; Kooiman and Jentoft, 2005; Tallis et al., 2008; McShane et al., 2011; Muradian et al., 2013). Spatial planners face the challenge of finding ways to organize landscapes, land-use, natural resources, wildlife and other issues in such a way that they can better fulfil the diverse requirements of society, such as needs of local residents, viability of local economic activities, requirements of visiting tourists, maintaining environmental quality, safeguarding biodiversity. The ecosystem services (ES) concept is considered useful for addressing this challenge, as it is a broad and inclusive concept that stimulates reflection upon landscape multifunctionality (Grêt-Regamey et al., 2008; Niemelä et al., 2010; Wu, 2013). Many ES assessments at the local scale provide an overview of potential delivery, actual delivery and/or values of ES for a certain area. In many cases, such assessments have limited value for planning, as they are not very 'actionable' for planners and decision-makers (Eigenbrod et al., 2010; Laurans et al. 2013; Ruckelshaus et al., 2015). One problem is that lists of ES give the impression that provisioning, regulating and cultural ES can be met at the same time, while in most situations it is impossible to manage ecosystems in such a way that all these ES are simultaneously utilized at desired levels (Swallow et al., 2009; Raudsepp-Hearne et al., 2010).

The term 'trade-off' has become very popular in the ES literature to deal with ES interactions, but it has predominantly been used to point to a negative correlation between spatial (or temporal) co-occurrences of ES supplies (e.g. Rodriguez et al., 2006; Nelson et al., 2009; Mouchet et al., 2014; Castro et al., 2014, 2015). To operationalize trade-offs for spatial planning purposes, we propose to return to its original meaning as applied in economics, where trade-offs are usually explained in terms of society's production-possibility frontier. Trade-offs arise due to "*the basic economic fact that limitation of the total resources capable of producing different commodities necessitates a choice between relatively scarce commodities*" (Samuelson 1970, p. 17). Key elements of this definition are: (1) there is only a <u>finite</u> amount of human and natural resources, (2) humans need to make <u>choices</u> about how to utilise resources, and (3) choices involve a '<u>sacrifice</u>' represented by the foregone production of goods and services each choice entails.

In the context of spatial planning and ES, trade-offs can be translated as '<u>land-use or management choices</u> that increase the delivery of one (or more) <u>ecosystem service</u>(s) <u>at the expense</u> of the delivery of other ecosystem services' (derived from TEEB (2010), UKNEA (2011) and Felipe-Lucia et al. (2015)). This definition corresponds with similar approaches, such as 'beneficiaries trade-offs' (TEEB, 2010) and 'demand-demand associations' (Mouchet et al., 2014). In practice, this relates for example to situations where co-use seems to be impossible (e.g. housing development vs. nature conservation), when two or more desired ES either cannot be delivered at the desired magnitude or strongly inhibit each other (e.g. agriculture vs. flood control), or when the burdens and benefits of ES are unequally distributed over different stakeholders (e.g. maintaining traditional landscapes vs. rural tourism) (Quintas-Soriano et al., 2016). ES trade-offs often reflect rivalry between well-being components (Iniesta-Arandia et al., 2014) or value dimensions (Martín-López et al., 2014).

This way of framing of ES trade-offs puts stakeholders (with their different values, interests, needs, power and choices) and their actual use of ecosystems at the centre of the ES trade-off analysis. This is justified if we consider that stakeholders are not only the prime actors that cause ES trade-offs (Hicks et al., 2013; McShane et al., 2011), but are also the key players in finding solutions to alleviate these trade-offs. When ES trade-offs result in 'winners' and 'losers' (Daw et al., 2011; Howe et al., 2014), they can become a source of friction between stakeholders. If not dealt with appropriately, they can even lead to conflicts (TEEB, 2010; Gómez-Baggethun et al., 2013; Kandziora et al., 2013; Kovács et al., 2015).

The choices stakeholders make when they deal with ES trade-offs are influenced by social, economic, institutional, and ecological factors, which often are highly context-specific. Knowledge about ES trade-offs is therefore difficult to generalize or transfer from one location to another. Place-based studies that focus on the local specificities of trade-off mechanisms, involving local knowledge, are often the most efficient and reliable way to study these ES trade-offs. As such studies are rare, it is not surprising that knowledge is lacking on when and where to expect trade-offs, the mechanisms that cause them, or how to deal with specific trade-offs (Bennett et al., 2009; Ostrom, 2009; Howe et al., 2014). There is an immediate need to bring ES trade-off analysis closer to the real-world problems and practice of spatial planners and decision-makers. Several authors suggested that better understanding of the underlying causes and mechanisms for trade-offs can be beneficial for planning and managing ES, because it can help to: predict where and when trade-offs might take place; encourage honest dialogue, learning and trust between concerned stakeholder groups; potentially lead to more effective, efficient and credible management decisions; and help to obtain more equitable and fair outcomes by taking into account distributive impacts of ES trade-offs (derived from: Rodriguez et al., 2006, Bennett et al., 2009; Nelson et al., 2009; Hirsch et al., 2010; Raudsepp-Hearne et al., 2010; Elmqvist et al., 2011; McShane et al., 2011; Phelps et al., 2012; Hicks et al., 2013).

The goal of this research is to make ecosystem services (ES) trade-off research more relevant for spatial planning and to obtain a better insight into how ES trade-offs express themselves in the real-world. Therefore we propose an analytical framework, which puts stakeholders, their land-use/management choices and their impact on ES at the centre. Based on 24 cases from around the world, we used this framing to assess the appearance and diversity of real-world ES trade-offs. Although we realize that the sample size is limited, the comparative analysis can shed some light on the following issues:

(1) What types of stakeholder groups are typically involved in trade-offs?
(2) What are recurrent trade-offs in spatial planning?
(3) Which ES are frequently implicated in trade-offs?
(4) What are the typical drivers that cause trade-offs?
(5) How do stakeholders respond to these trade-offs?

In the discussion, we reflect on the implications of the findings for future research and on how it can help spatial planners and decision-makers to deal better with ES trade-offs.

2. Stakeholder-centred framework for ES trade-offs

To emphasize that stakeholders and their use of ecosystems are at the heart of ES trade-offs, we propose an analytical framework (Fig. 1), which consists of five main elements: stakeholders involved in trade-offs, ecosystem use and ES trade-offs, implicated ES, drivers and stakeholder responses.

Stakeholders (orange boxes in Fig. 1): Stakeholders are the central actors in ES trade-offs, as it are their values, materialized demands and leverage in decisions that result in ecosystem use and consequent impact on ES (Mouchet et al., 2014; Iniesta-Arandia et al., 2014). However, stakeholders also include those actors who are affected by these decisions (Freeman, 1984). In the context of ecosystem use, stakeholders are defined as "*a(ny) group or individual who can affect or is affected by the ecosystem's services*" (Hein et al., 2006). The economic definition of trade-off implicitly assumes that the trading-off between alternatives and the making of a final choice happens by one person or one group. In the context of spatial planning and management of ES, there are usually many stakeholders involved in the (influencing of the) decision-making and many stakeholders that are affected, which makes it a complex process. Therefore, 'level of influence' and 'level of impact faced' are important characteristics of stakeholders involved in ES trade-offs:

- Stakeholders have 'influence' if their decisions contribute to the resolution, mitigation or exacerbation of the trade-off. These stakeholders are the ones who are contributing to the actual trading-off of options. Influence can be exercised via the policy-making process itself, by setting or influencing the rules of ecosystem use, by informal agreements (e.g. agreements between user groups), or by direct decisions on land or resource use (e.g. by farmers, land owners). The actual choices are likely to depend on power relationships among stakeholders (Felipe-Lucia et al., 2015) and on institutional and knowledge mechanisms that mediate the interactions between stakeholders and with their environment (Gómez-Baggethun and Kelemen, 2008).
- Stakeholders are 'impacted' when they face negative or positive impacts of certain ecosystem uses. Impact can range from mild (e.g. urban mountain bikers face restricted access in protected areas) to very severe (e.g. inhabitants facing severe pollution). Impacted stakeholders can be local, remote, or even future generations.

On the basis of these two characteristics, three stakeholder positions in relation to ES trade-offs can be identified (modified from Reed et al., 2009; Iniesta-Arandia et al., 2014):

- 'Influential users' have (significant) influence over the decisions made in relation to the trade-off, and at the same time face a negative or positive impact of the trade-off (e.g. farmers, foresters).
- 'Non-influential users' face a negative or positive impact of the trade-off, but have no or little influence on decision-making (e.g. citizens, tourists).
- 'Context setters' have a significant influence on the decision-making, but do not experience directly the negative or positive impacts of the trade-off (e.g. spatial planners, administrations, municipalities).

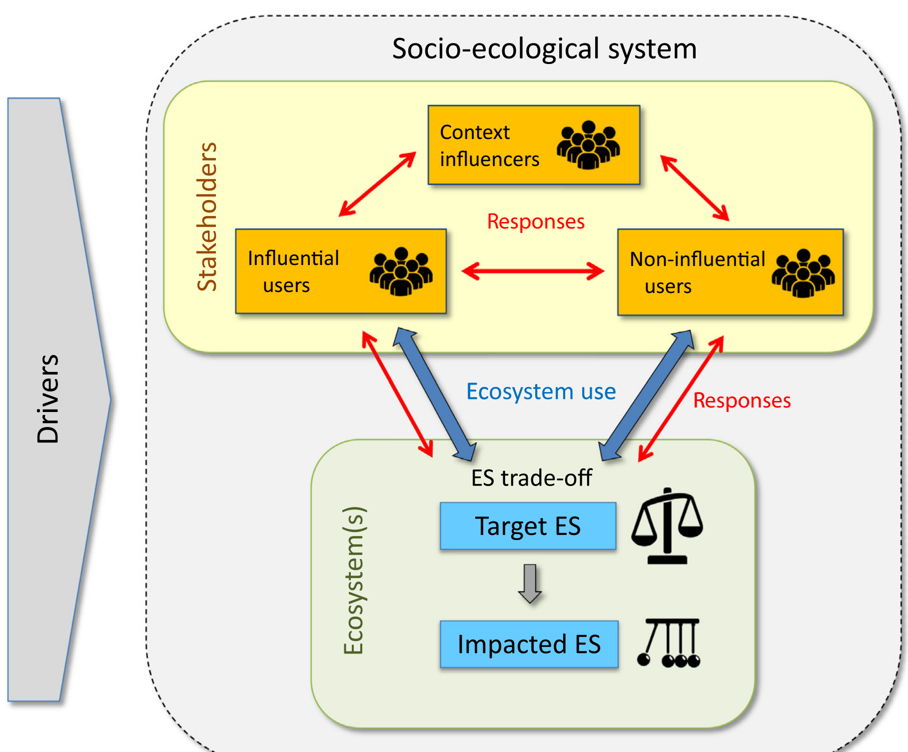

Fig. 1. Visualisation of a stakeholder-centred framework of ES trade-offs.

Ecosystem use and ES trade-offs (blue arrows in Fig. 1): An ES trade-off can only be invoked whenever an ecosystem is 'used'. This can take the form of management, alteration, access, protection or enjoyment of an ecosystem. 'Use' is aimed at increasing the delivery of one (or several) desired ES by the ecosystem, which often is at the expense of other ES. When these impacted ES are important or appreciated by other stakeholders, then an ES trade-off emerges.

Drivers (large grey arrow in Fig. 1): External forces or drivers, such as large-scale ecological change, population growth, economic competition, can have an important effect on the demand of stakeholders and their actual use of ecosystems (Tallis et al., 2008). It is useful to identify these drivers, although they are often difficult to influence at the local scale.

Ecosystem services implicated in trade-offs (blue boxes in Fig. 1): To better understand ES trade-offs in the context of spatial planning, it is useful to look at the implicated ES from different angles. We propose to use three different typology logics:

- ES are typically classified in provisioning, regulating and cultural ecosystem services (MA, 2005; Haines-Young and Potschin, 2013). This classification is useful as it provides broad categories of typical benefits of ecosystems: i.e. products, regulatory benefits, and nonmaterial benefits (MA, 2005).
- An additional useful way to group ES is via the property rights regime (Ostrom, 2009; Muradian and Gómez-Baggethun, 2013), as this has a large impact on the utilisation of ES and how ES benefit human well-being. Property rights of ES are characterised based on rivalry and excludability features (Costanza, 2008). *Rivalry* expresses the way in which use of a service impacts other stakeholders use. A service is rival in its use if the use by one (group) of stakeholder(s) prevents simultaneous use by other stakeholders. *Excludability* defines the extent to which one stakeholder group can prevent in a practical way other stakeholders access or use of the ES. By using this characteristics, a distinction can be made between *market goods and services* (= rival and excludable), *club goods* (= non-rival and excludable), *common-pool resources* (= rival and non-excludable), and *public goods and services* (= non-rival and non-excludable) (Cornes and Sandler, 1996).
- From a trade-off perspective, the implicated ES can be divided in two groups. The ES which are traded-off with each other are called 'target ES'. These are the ES at the core of the trade-off decision-making. However, the increased/decreased delivery and/or consumption of the target ES are likely to affect other ES, which can be important for stakeholders who are not (directly) involved in the trade-off debate. These 'impacted ES' are the ES which are not traded-off consciously with each other, but are impacted due to socio-ecological interdependencies of ES. For instance, in a trade-off where agricultural production and flood protection are the target ES, the impacted ES could be recreation, carbon sequestration, water purification, etc. Sometimes, the provoked effect might be unintentional as decision-makers can be unaware of the consequences of their decisions for other stakeholders.

Stakeholder concerns and responses (red arrows in Fig. 1): When there is an impact on one or more ES desired by stakeholders or on components of their well-being, then it is likely they become concerned. Depending on their socio-economic context, stakeholders might articulate their concern to other stakeholders or undertake action(s). These stakeholder responses can be targeted at one of the other involved stakeholder groups in order to influence their use or their decision-making (upper red arrows, Fig. 1), or it can be direct action to increase the use of a desired ES (lower red arrows, Fig. 1).

3. Methodology: Learning from real world examples & local experts

3.1. The 24 ES trade-off case studies

For this research we selected cases where trade-offs are expressed in the 'real-world': this means that the choices that are made (or are to be made in the near future) about ecosystem use have real implications for the involved stakeholder groups. Research focussing on potential trade-offs or spatial co-occurrence of ES supply were not included. At least two stakeholders needed to be involved and at least two ES needed to be concerned. In addition, researchers were required to have conducted empirical place-based research on the trade-off case. ES trade-off cases were primarily collected from researchers participating in the FP7 OpenNESS project ($N = 15$) (Dick et al., 2018). This project was a response to an EU call for a transdisciplinary approach to determine the advantages and limitations of the natural capital and ES concepts in real world situations (Jax et al., 2018). However, the invitation for ES trade-off case studies was extended to non-OpenNESS researchers working in areas where ES trade-offs were of particular interest ($N = 9$).

In total 24 trade-off cases were selected that covered a wide range of ecosystems (Table 1, Suppl. material N°1): agriculture-dominated ($N = 8$), forest-dominated ($N = 7$), rangelands-dominated ($N = 3$), mixed-rural ($N = 3$), urban ($N = 2$) and coastal ($N = 1$) ecosystems. The cases were situated mainly in Europe (19 case studies), but there were also cases from South-America (3), Africa (1) and Asia (1) (Fig. 2, see also KML file: Suppl. material N°2).

Table 1
Short descriptions of the ES trade-off case studies.

N°	Country	Short description of ES trade-off case
14	Argentina	Sheep grazing and native herbivore mammals (Guanaco)
15	Argentina	Forestry versus other land-uses
16	Argentina	Trade-off between farmer wellbeing and maintenance of forest cover
8	Belgium	Managing recreation in a fruit-growing rural area
20	Belgium	Multifunctional grassland-dairy based landscapes vs. agricultural intensification
21	Belgium	Green versus grey solution for flood control
23	Belgium	Trade-offs related to the reappearance of wild boar and the measures to control them
1	Finland	Preserving natural state vs. concentrated urban development
4	Finland	Use of tree stumps: bioenergy vs. keep them in forest (with multifunctional benefits)
3	France	Economically and ecologically sustainable forestry
5	Germany	Bioenergy vs. food production
7	Hungary	Water management for biodiversity vs. agricultural production in a drying region
18	Hungary	Pasture reconstruction for biodiversity vs. agricultural production
12	India	Mining versus multifunctional land-use
13	Kenya	Biodiversity protection vs. overharvesting of natural resources in forests
11	Netherlands	Artificial foreshore versus maintaining a natural saltmarsh
2	Norway	Beekeeping vs. wild bees in urban context
22	Norway	Reappearance of large carnivores vs. sheep husbandries
9	Romania	Intensive agriculture versus local agriculture/wetland restoration
6	Scotland	Sitka Spruce plantation vs. multifunctional landscapes
10	Spain	Traditional vineyards (adapted to wetland ecosystems) vs. berry plantations
17	Spain	Recreational activities versus conservation goals
19	Spain	Greenhouse crop production vs. groundwater recharge
24	Spain	Multi-functional agri-landscapes vs. more mono-functional agri-landscapes & abandoned land

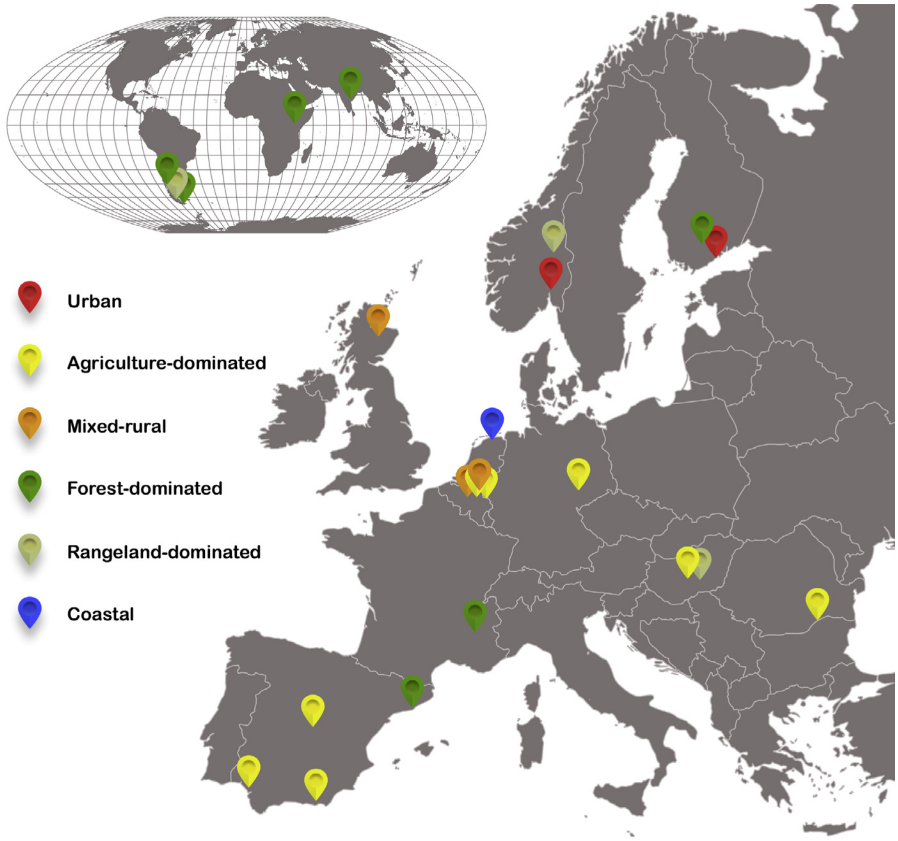

Fig. 2. Location of the 24 ES trade-off case studies.

3.2. Data collection

Information on the trade-off case studies was collected via a questionnaire. The questionnaire consisted of 22 questions and covered four themes (see also Suppl. material N°3): (1) characterization of the ES trade-off(s) in the case study, (2) identification of the role and position of the involved/affected stakeholders, (3) scoring of trade-off types, and (4) actions and strategies of involved stakeholders. Most of the questions were qualitative, while some questions required scoring. The questionnaires were completed by researcher(s) who were familiar with the case study via previous research (reference material on the cases: See Supp. material N°4), hereafter referred to as *respondents*. The collected data can be considered as 'expert opinion', which entail certain risks such as biases, misunderstandings and omissions. We tried to minimize this risk by thoroughly reviewing the completed questionnaire, and we contacted all the 24 respondents one to three additional times for further clarifications. In this way, we also ensured that all the questions were interpreted in the same way throughout the 24 cases.

3.3. Data analysis

Stakeholder analysis and responses: For the stakeholder analysis, we followed the methodological steps proposed by Reed et al. (2009). Focus and system boundaries (step 1 and 2) were identified by asking the respondents to describe the trade-off (What is the issue at hand? What is at stake?), the geographical area where the trade-off took place, and how long the trade-off has been going on.

Stakeholder identification (step 3): The respondents were asked to list in their own words the most important stakeholders who have a stake in the trade-off. To avoid biases, no pre-defined lists of stakeholder groups were proposed. When analysing the answers of the 24 cases, a list of stakeholder groups involved in ES trade-offs was gradually developed (bottom-up approach). As a complete list of stakeholders appeared after the review of the 24 cases, a second screening was done to make sure that all the stakeholders were allocated to the proper stakeholder group.

Seven generic types of stakeholder groups were shortlisted in the end: land-users (i.e. land-occupying land-users – e.g. farmers and foresters), recreationists (incl. tourists and local recreationists), citizens, NGOs (also incl. unions and CBOs), companies (which are using resources and/or services produced in the study area), agencies (e.g. local and regional governments; sector-focussed government organisations, such as spatial planning organisation, park authority, tourism promotion agency), and research organisations. A limited number ($N = 8$) of stakeholders had a double role (e.g. a company owning land and using local resources), and were included twice in the stakeholder database.

Stakeholder analysis (step 4): Respondents were asked to provide several descriptions regarding the involved stakeholders, and to score three trade-off related characteristics of stakeholders: (1) experiencing (positive or negative) impact (yes–no), (2) able to influence decisions to resolve or mitigate the trade-off (yes–no), and 3) concern of the stakeholder in relation to the trade-off (5 levels: not aware, no concern, little concern, medium concern, serious concern).

Responses of stakeholders: We asked the respondents to provide information on the actual responses from the stakeholders in relation to the trade-off. Responses could vary from an expression of a concern related to the trade-off to concrete interventions. A distinction was made between the responses of the influential stakeholders (influential users and context setters) and the responses of the non-influential users. The stakeholder response typology was developed in a similar bottom-up manner as for the stakeholder group typology.

ES trade-offs characterization: An ES trade-off typology was developed together with OpenNESS researchers during three iterations in the preparatory stage of this research. The main idea for this typology was to base it on choices which are common for spatial planners and decision-makers (instead of starting from conceptual considerations). However, during the preparatory stage it became obvious that the respondents could not easily link their trade-off case to one single trade-off type. Instead, respondents often linked their trade-off example to two or more proposed trade-off types. Therefore, the approach was adjusted and respondents were asked to score how relevant the proposed trade-off types were for their case (from 'not relevant' (0) to 'very relevant' (4)). In addition, we asked whether the ES trade-offs resulted in exclusive use (i.e. one desired use excluding another type of desired use) or gradual use (i.e. an increase of one type of use gradually impact another use).

Drivers: Respondents were asked to list and describe the most important underlying driver(s) of the trade-off. No-predefined lists were used, but the list of drivers was gradually built up when analysing the results (similar to the list of stakeholders).

ES implicated in trade-offs: The lists of implicated trade-offs were obtained in a similar fashion to list of stakeholders. No predefined lists were provided, but respondents were asked to list and describe all the target ES and the most important impacted ES. The CICES 4.3 classification of EEA (Haines-Young and Potschin, 2013) was used as a reference base, but at the same time we also tried to remain loyal to the wordings used by the respondents. Especially for the cultural ES, this resulted in alternative wordings for ES compared to the CICES classification. The property rights regimes of ES as proposed by Costanza (2008) were pre-defined in the questionnaire. Respondents were asked to allocate the target ES to the appropriate property right categories.

4. Results

4.1. What kind of stakeholder groups are typically involved in ES trade-offs?

The number of directly involved stakeholder in an ES trade-off is quite high: ranging from 3 to 11 stakeholders per case (median: 6 stakeholders/case). The stakeholder groups that are most commonly involved with ES trade-offs are government agencies ($N = 42$) and land-users ($N = 30$) (Fig. 3). Spatial planners are mainly found in government agencies with a territorial mandate. Other involved stakeholder groups are (in declining order): companies, recreationists, citizen and NGOs/unions. Research organisations were mentioned only in 4 cases, but there might be some bias here as the questionnaire was filled in by researchers themselves.

The 7 identified stakeholder groups relate quite differently to the ES trade-offs (Fig. 3). **Impact** of the trade-off is most strongly **faced** by stakeholder groups who have a direct link to the territory (i.e. recreationist, citizens, NGOs/unions, companies using resources and land-users): at least 80% of these groups face an impact. Impact is experienced much less by the involved government agencies (36%) or by the research agencies (0%). **Power to influence decisions** is very dependent on the stakeholder group as well: more than 90% of the agencies and research organisations can influence decisions, whereas citizens and recreationists can rarely influence decision-making. When these two stakeholder characteristics are combined, then we can assess the three stakeholder positions as proposed in the trade-off analytical framework (Fig. 3 – right side):

- Non-influential users ($N = 67$, 48% of all mentioned stakeholder groups in the 24 cases) is the most common stakeholder position, and include the following groups (in declining order of frequency): recreationists, citizens, companies using local resources, land-users and NGOs. A typical example can be found in the Indian case study (N°12), where community members (especially women) depend on the forest for fuel wood and non-timber products and on the river for water and fishing, but who have no say in the mining operations and the conservation and rehabilitation plans.
- Context setters ($N = 40$, 29%) are predominantly government agencies with a territorial mandate (who can set or influence the rules of ecosystem use) and research organisations. These organisations do not (or hardly) face the impact of the trade-off, mainly because they are operating in distinct locations. Some companies and NGOs are also considered context setters. A representative example of this position is the renewable energy strategy planners in the Finnish case study (N°4) who are mainly assessing whether the renewable energy EU targets are met, but who are not directly affected by the local impacts.

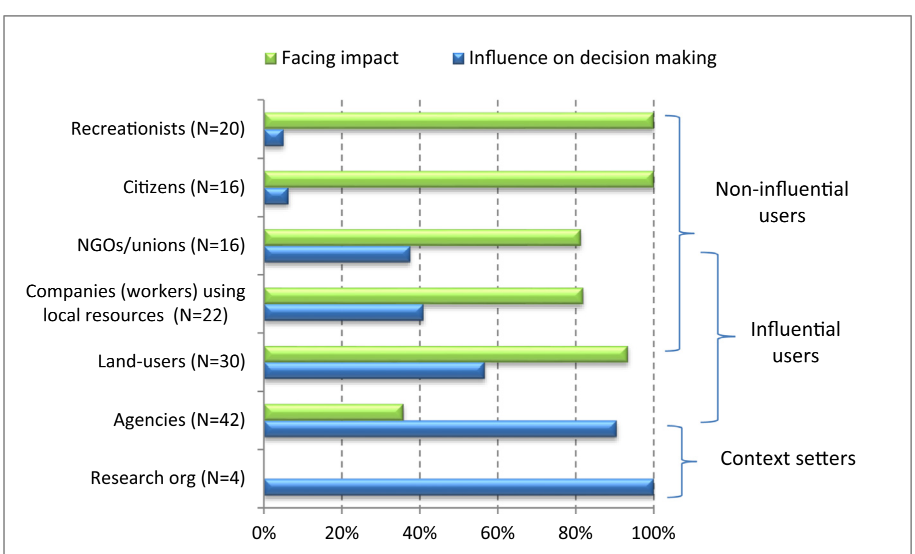

Fig. 3. Frequency of facing impact or having influence on decision making for the 7 identified stakeholders groups in 24 ES trade-off case studies. (100% means that all stakeholders of a certain stakeholder group either face impact or have influence; N = number of stakeholders per stakeholder group in 24 cases)

- Influential users ($N = 32$, 23%) is the least common stakeholder position. Here we find mainly land-users (especially farmers, foresters and ranchers who make decisions about use and management of their land) ($N = 15$), agencies with a territorial mandate ($N = 11$), and companies ($N = 5$).

The level of influence provides information on which stakeholders can exert power and therefore should be considered as key players in managing the trade-off. However, the relationships between the stakeholders in the specific situation are at least as important as their relative power position. In some cases, stakeholders with interest in and influence over certain ES are situated at different scales. This is the case of the Doñana case study (N°10), in which the claims of non-influential local users do not easily reach context setters working at the regional government. The same occurs in the Hungarian cases (N°7 and N°18), where the distance between context setters (regional and national agencies) and local users appear both in hierarchical and geographical terms, contributing to unequal power in making local land use decisions. Interaction among influential users at the local level is also an important factor of the trade-offs, especially if influential users tend to compete with each other. Such situations often lead to explicit conflicts among the stakeholders, as happened in the Hungarian cases.

4.2. Characteristics of ES trade-offs

Ecosystem uses are very diverse in the case studies, but 5 archetypes of trade-offs could be identified during the preparatory phase of the questionnaire. The typology was tested during the questionnaire:

i. Change in land-use: When a choice needs to made about the main purpose of a specific piece of land, it is usually a choice between two excludable options. As a consequence, there is always a trading off with the opportunities lost. An example is the urban development in Sibbesborg (N°1, Finland) where a choice has to made between preserving the natural shoreline or concentrating the most intensive development right next to the shoreline.
ii. Change in management objective: In such cases the land-use type is fixed, but in function of certain stakeholder(s) objectives, the management measures or regimes are adapted. A choice of a certain management objective will result in a bundle of ES which will be traded off with another management objective. Examples are: forest management in Patagonia for forestry or for tourism (e.g. sky centres) (N°15), wheat/maize production in Germany for food/feed or for bioenergy (same crop, but different crop and fertilizer management, N°5).
iii. Technical versus nature-based solutions: Here the desired ES is fixed, but a choice needs to made in the approach how to deliver this ES. The trade-off will depend on which mix of natural and non-renewable resources are used, as this will determine the delivery other ES. An example is the required flood control for Leuven city (Belgium) where a choice needed to be made between constructed holding basins or natural flood areas (N°21).
iv. Use of natural resources: Natural resources (e.g. soil, water) can be used for different purposes, each of them having effects on other ES. Example is the Hungarian case (N°7) where in a drying region there is an intense discussion about the use of water, either for agricultural production or for biodiversity.
v. Management of conflict species: Conflict species refer to (semi)-wild species whose presence results in diverse impacts for different stakeholders and opposing stakeholder positions. Examples are the (re)appearance of large carnivores in Europe (e.g. wolves, brown bears, lynx and wolverines in south-eastern Norway, N°22; wild boar in the east of Belgium, N°23).

Several of the trade-off case studies could be related to more than one trade-off archetypes. Examples are the forest management in Argentina (N°16) which related both to land-use change (i) and management aspects (ii), and the greenhouse development in Almeria, Spain (N°19) which entails both the conversion of land-use (i) and the use of precious water resources (iv). Rather than a discrete ES trade-off typology, reality shows a fuzzy typology.

In the majority of the cases (esp. type ii to v), trade-offs are related to the **intensity of use**. In other words, the higher the intensity of a certain use, the more severe the trade-off tends to be. Examples of intensity of use are: percentage of land converted, level of extraction/intensification (N°15, Patagonia), number of wild animals present or harvested (N°22, Norway), level of protection/restoration (N°16, Patagonia), or intensity of recreational use (N°8, Belgium). The **timing of use** is another use characteristic that can explain trade-offs. For example, in the wild boar case (N°23, Belgium), recreation and hunting cannot take simultaneously, but this can be avoided with separate time slots for each.

Most of the trade-offs have been going on for long periods in time, ranging from 1 year to more than 20 years (median: 5–20 years). The size of the area where the trade-off takes place varies from 6 km^2 to 200,000 km^2 (Fig. 4).

4.3. Drivers

The decision-making about ecosystem use that causes the trade-off, is influenced by underlying causes, o**r drivers**. In the studied cases, the number of underlying drivers identified ranged from one to six drivers per trade-off (median: three), and are related to socio-economic, institutional and/or biophysical factors (Fig. 5). Socio-economic and institutional drivers were by far the most mentioned by the respondents: policy targets and regulations, macro-economic processes (e.g. EU subsidies) and socio-cultural factors (e.g. shifting demand for recreational uses) appeared as the most common drivers. Biophysical processes (e.g. climate change, sedimentation process) were less often cited as drivers.

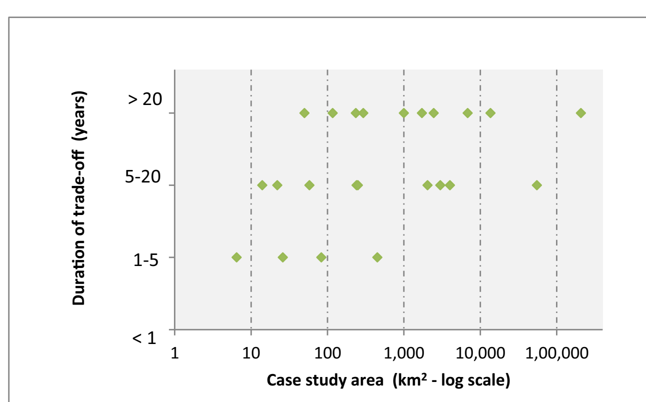

Fig. 4. Case study area and duration of the trade-off for the 24 case studies (each green dot represents a case). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

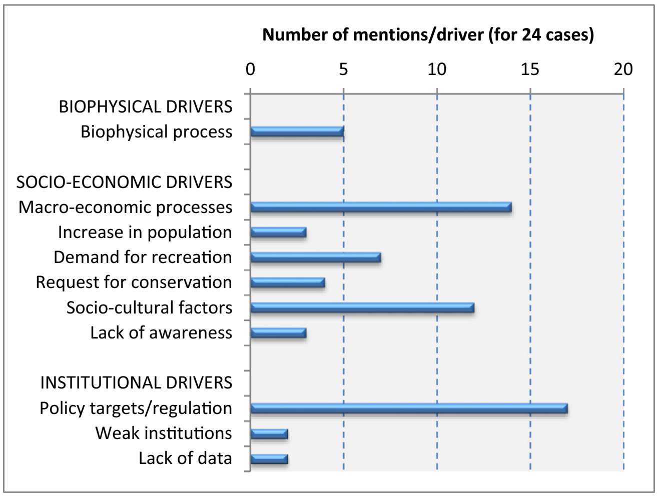

Fig. 5. Drivers for ES trade-offs in 24 case studies.

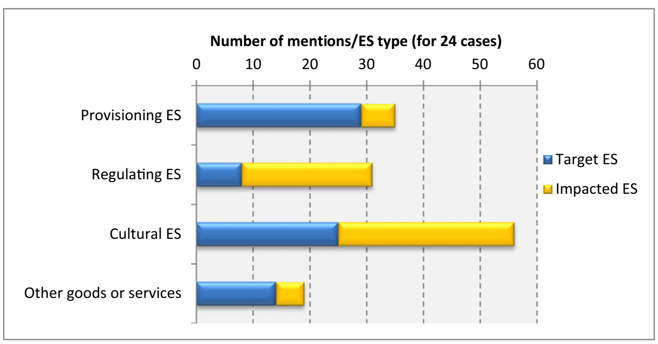

Fig. 6. Target ES and impacted ES in the 24 trade-offs cases.

4.4. Which types of ecosystem services are traded-off?

If we count the target ES and the most important impacted ES, there are between 3 and 10 ES implicated per case, with a median of 6 ES per case. The 'target ES' are primarily provisioning (38% of all targeted ES in 24 cases) and cultural ES (33%) (Fig. 6), while regulating ES are rarely directly targeted by a trade-off (11%). The most frequently mentioned provisioning ES are: agricultural foods (plant and animal-based), forest products and bioenergy. The most frequently mentioned cultural ES are: recreation, tourism, landscape aesthetics, heritage and the presence of charismatic species. In some cases, ES are traded-off with elements other than ES ('other goods and services', 18%), e.g. mining of iron ore, urban housing, risk of car accidents (with wild boar), biodiversity.

The ES that are indirectly affected by the trade-off (impacted ES) are mostly cultural (48% of all impacted ES in 24 cases) and regulating ES (35%) (Fig. 6). The impacted cultural ES are more or less the same as the target ES. Impacted regulating ES are predominantly water-related ES, such as water cycle regulation, ground water supply, erosion control, flood control, and water purification.

If we zoom in to the ES at the core of the trade-off ('target ES'), then the **property regime** of the ES can provide an extra dimension of the nature of the trade-offs (Fig. 7). In our case studies, the target ES are mainly market goods and services and public goods and services. Trade-offs can take place between market goods/services (e.g. bioenergy vs. food production - N°5, Germany), between public goods/services and market goods/services (e.g. water for biodiversity vs. agricultural production, N°7 Hungary; forest cover and habitat for native biodiversity vs. meat and fire-wood production, N°16 Patagonia) and between public goods/services (e.g. recreational activities vs. conservation goals, N°17 Barcelona). The market goods and services overlap to a large extent with the earlier mentioned provisioning ES. The public goods and services include the previously mentioned cultural ES and regulating ES (such as water cycle regulation, erosion control, flood control).

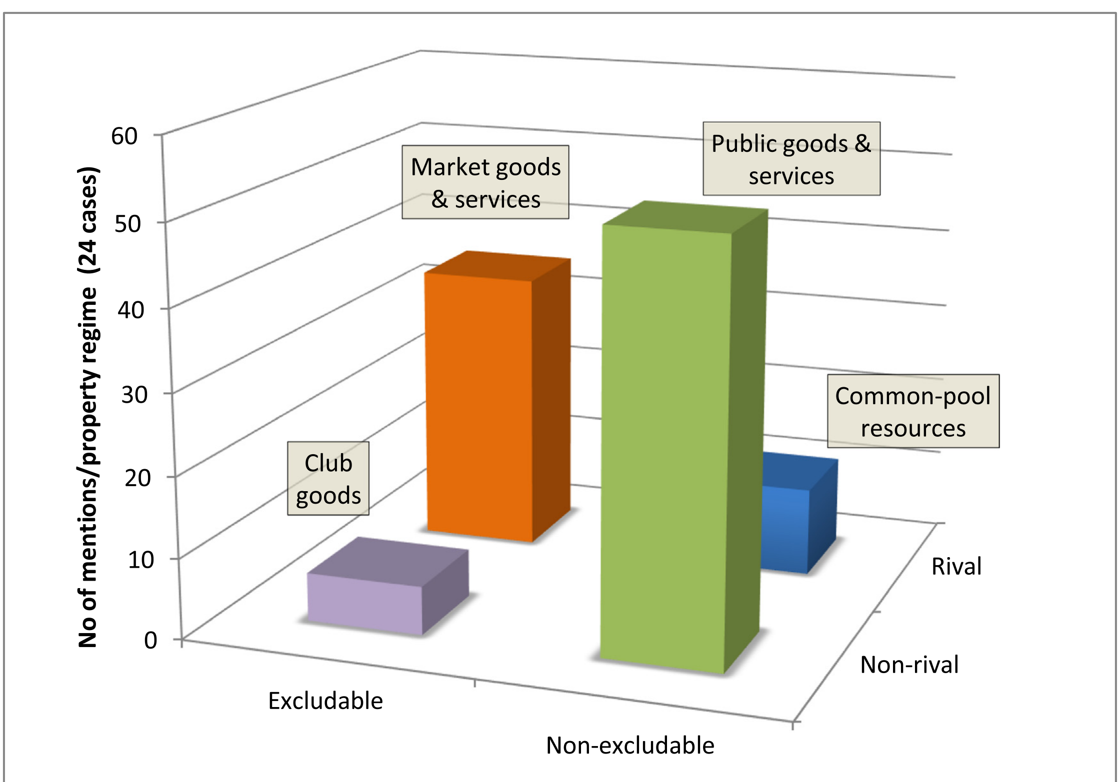

Fig. 7. Property regimes for the target ES in the 24 trade-offs cases.

Common-pool resources and club goods are less common in ES trade-offs. Common-pool resources which are traded off are mainly provisioning ES, where it is difficult to exclude other stakeholders from making use of them, such as non-timber forest products (N°12 India), nectar and pollen for honey production (N°2 Norway), and water for agricultural use (N°10 Spain). Club goods are quite rare in ES trade-offs. Examples include tourism activities on private land, such as hiking and enjoying scenic views (N°15 & N°16 Patagonia), or outdoor recreation activities (e.g. trail races) with controlled participation by organizers and park authority (N °17 Barcelona).

4.5. Stakeholder concerns and responses to ES trade-offs

About two-thirds of all involved stakeholders were reported to be concerned about the ES trade-offs ('concern' refers to medium to serious levels of concern, Fig. 8), but the level of concern differs according to stakeholder group. The highest levels of concern were reported for NGOs and researchers (100%). Amongst land-users, citizens, and agencies, around 70% are concerned. Relatively less concerned stakeholders are recreationists (53%) and companies using local resources (41%). The majority of the concerned stakeholders did not remain idle in face of the impacts of the trade-offs, and responded in one way or the other to the trade-offs. The level of concern seems to be a good indicator for stakeholder response to the trade-off (Fig. 8). When the level of concern is medium or serious, the percentage of stakeholders that respond (=response rate) is greater than 90%.

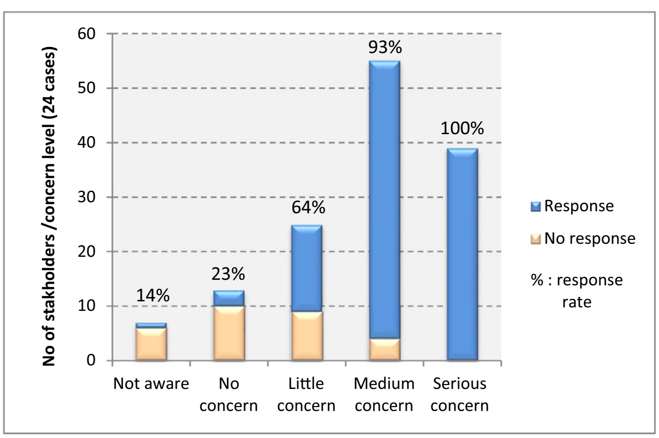

Fig. 8. The relation between level of concern and stakeholder responses to trade-offs in 24 cases.

The type of response depends on whether a stakeholder has influence or not (see Table 2). Most of the influential users and context setters (93%) responded to the trade-off. Their responses can be divided into three response categories: communication and negotiation-oriented actions, problem solving strategies that aim to modify the ecosystem use, and investment in new knowledge. The relative high amount of commissioned research is probably biased as we used researcher respondents. There seems to be a balance between more informative and deliberative approaches (such as awareness raising, meetings, negotiation) and more interventionist approaches (such as interventions, new regulation, enforcement). An example of the first type is the Madrid case (N°24) where local and regional planners started to promote participatory and training initiatives for farming. An example of the second type is a change in the amount of subsidy for bioenergy production in Germany (N°5).

A formal strategy to cope with the trade-off was in place in 40% of the cases. For example, in the case of Barcelona (N°17), Park authorities are already limiting mass recreational activities, such as trail races as a way to minimize impacts on biodiversity. In the Patagonia case (N°14), the Wildlife Committee of the CITES secretariat developed and approved the National Plan for Guanaco management and sustainable use, while at the same time a new law provides money for the recovery of sheep farming. In the other cases, they are in the process of developing such a strategy (22%), or no strategy is in place yet (30%). 'Escape strategies' are mainly used by farmers, and refer to strategies to find a solution outside the focused socio-ecological systems. For example, farmers buying fodder from other farmers instead of trying to produce it themselves (N°18 Hungary), or young farmers migrating to the Walloon region to avoid strict environmental regulation and land competition in the Flanders region (N°20 Belgium).

Among the non-influential users, the response level to the trade-offs is lower compared to the influential stakeholders, but still significant (64%). The same response categories were found (except commissioning research), but as their level of influence is much lower, their type of response is quite different (see Table 2). The communication and negotiation responses are mirroring the responses of the influential stakeholders (e.g. participating in meetings vs. organising meetings, express concern vs. negotiating with other stakeholders, protests vs. conflict reduction). These responses of non-influential users aim to bring un(der)represented concerns into the process of trade-off decision-making. Problem solving strategies are quite rare for non-influential users. An example of this can be found in the Madrid case (N°24) where local farmers organize themselves in groups to clean irrigation channels, and local residents started associations to maintain their culture by for example making fibre baskets.

Table 2
Type of stakeholder responses to ES trade-offs in relation to stakeholder positions. (N = number of stakeholder responses/24 cases)

Response categories	Influential users & context setters	N	Non-influential users	N
Communication and negotiation	Awareness campaign	10	Awareness campaign	1
	Organize meetings, training	11	Attending public meetings, filing complaints	9
	Contacting and negotiating with other involved stakeholders	10	Express interest/concern/support	19
			Contacting press	2
	Conflict reduction	1	Protests	3
Problem solving strategies	(Land-use) action plan	15	Proposal for an action plan	3
	Interventions, actions	18	–	
	New regulation	10	–	
	Enforcement	4	–	
	Establish new organisation	1	Organizing an (action) group	3
	Escape strategy	2	Buy land	2
Knowledge	*Commissioning of research*	*10*	–	
No response		5		24

5. Discussions and conclusions

5.1. Strengths and limitations of the stakeholder-centred framework

The proposed ES trade-off framework (Fig. 1) puts stakeholders and their ecosystem use (i.e. demand side in ES terminology) at the centre of the assessment. This is based on the premise that trade-offs not only originate primarily from stakeholders' values, needs and uses of ecosystems, but also that solutions can only be achieved via the involvement of stakeholders. The usefulness of this 'social' entry-point for analysing ES trade-offs seemed to be confirmed by the case studies, as these questions enabled the case respondents to quickly get a grip on the complexity at hand. Additionally, the fact that the drivers of ecosystem use and change are primarily dominated by socio-economic-institutional factors, confirms the importance of this social entry-point. Therefore, we argue that better understanding of stakeholders and their ecosystem use should always be at the core of any trade-off analysis. However, care should be taken not to simplify a stakeholder or stakeholder group to a one-dimensional actor. One example in this respect is that stakeholders can have different 'hats' in relation to trade-offs (e.g. in the forest bioenergy case in Finland, the same person could simultaneously be a forest owner, recreational user and a nature conservationist, N°4). Another is that stakeholders can be involved in more than one trade-off (e.g. maintenance of tree cover in silvopastoral farms to ensure firewood production and soil protection, and cattle ranching for meat production and social group identity, N°16 – Argentina). In addition, care should be taken with generalisations about a certain stakeholder group. Within one so-called stakeholder group there can be very different values, motivations, needs and use types. For example within the stakeholder group of small pine forest owners in Belgium, there were forest owners with economic, recreational and passive motivations (Van Herzele and Aarts, 2013).

The components of the proposed analytical trade-off framework (Fig. 1) can be considered as a useful checklist to start to assess real-world ES trade-offs. It can help to identify crucial aspects to analyse and address the trade-off, and can provide clues on how to manage and solve ES-trade-offs. However, in many cases, it is likely that more in-depth analysis of one of the components will be required, demanding more social, ecological and/or economic research. Social aspects that are not specifically addressed within the framework, but which could provide useful insights for a trade-off analysis, include: stakeholders' perceptions, attitudes and values (Iniesta-Arandia et al., 2014), social capital as a factor to address ES trade-offs (Barnes-Mauthe et al., 2016), stakeholder relationships (Berbés-Blázquez et al., 2016, Cáceres et al., 2016), ES co-production (Palomo et al., 2016), inequality in relation to access to resources and information, institutions and political economy. From the economic perspective, it can be useful to dig deeper into the notion of 'opportunity cost' and land-use as a driver of land-use change and trade-offs (Quintas-Soriano et al., 2016). Many trade-offs ultimately stem from biophysical limits in the capacity to provide the diversity or quantity of ES. To achieve comprehensive problem solving, it is therefore also important to link with the supply side of the trade-offs: e.g. supply–demand ES analysis (Mouchet et al., 2014; Baró et al., 2015), ES supply compatibilities, viable stocks, sustainable use levels, and impacts on biodiversity (Rusch et al., 2017). Finally, trade-offs can also have biophysical and socio-economic impacts outside the focussed socio-ecological system. For assessing such effects, the teleconnection and telecoupling concepts are useful analytical frames (Othoniel et al., 2016).

5.2. What do these findings mean for spatial planning?

Trade-off research focussing on only two interacting ES and two stakeholders (e.g. Elmqvist et al., 2011; King et al., 2015) will in most cases represent an over-simplification of reality, and hence risks being of limited relevance to spatial planners and decision-makers. The 24 trade-off examples indicate that real life ES trade-offs are more complicated than is often assumed in the (more theoretical) ES literature. Although our sample size is limited, we could identify some indicators of this complexity. For example, the trade-off cases had between 3 and 11 involved stakeholders (with different levels of faced impact, influence and concern), addressing often two or more 'trade-off archetypes', with 1–6 drivers in play, and affecting between 3 and 10 ES (when only considering the most important ES). Another complexity is that one trade-off can trigger other trade-offs. An example is the debate regarding re-emergence of wild boar in the Flanders region (N°23, Belgium). The focus was initially on what population level and distribution would be acceptable in relation to their impact on crop damage, biodiversity, traffic accidents and hunting opportunities. However, this triggered a secondary discussion about the choice of measures to control the wild boar population and the impacts of those measures on other ES. Finally, ES trade-offs are usually very context dependent. The above indicates that the socio-ecological dynamics of a trade-off can rapidly get complicated. The implication for trade-off research is that when they aim to support spatial planning, it is recommended to **embrace the full complexity**, rather than dissecting simple sub-systems of the trade-off at hand (Ostrom, 2007). In addition, a good understanding of real-world trade-offs cannot emerge without discussions with involved stakeholders and local knowledge holders. Especially when moving from regional to local scale assessments, the balance of relevant information shifts from formal scientific data toward **informal and tacit information** held **by local residents** (Fabricius et al., 2006). Conclusions based on generic/predictive ES trade-offs models without ground-truthing should therefore be handled with caution.

In most cases, trade-offs are gradually aggravated as a result of increasing ecosystem **use intensity**. In such cases, the impacts of trade-offs can be compared to a 'dimmer-switch'. This can explain the often long periods for which trade-offs are active (up to 20 years and longer). This **time lag** between the initiation of a trade-off and the appearance of a first response of one or more involved stakeholders may cause already detrimental impacts on the ecosystem capacity to deliver ES and/or on the relationships between the concerned stakeholders. An implication for spatial planning is that detection of ES trade-offs in the early stages is very useful, as it will enable a longer intervention time and avoid detrimental impacts. Another implication is that managing and optimising the 'use intensity' can, in many cases, be a proper way to manage trade-offs (see also Rusch et al., 2017).

Several authors have highlighted trade-offs between provisioning and **regulating ES** as the most common trade-offs and a major cause for concern, because regulating ES are important for the resilience of social-ecological systems and are often linked to the sustainable production of provisioning and cultural ES (Rodriguez et al., 2006; Bennett et al., 2009; Raudsepp-Hearne et al., 2010; Gómez-Baggethun et al., 2011; García-Llorente et al., 2012; Castro et al., 2015; Quintas-Soriano et al., 2016). We observed that mostly provisioning and cultural ES choices are traded-off against each other ('target ES'). While regulating ES are rarely at the core of the trade-off, they were often impacted by the trade-off at stake. A possible explanation for this lower concern about regulating ES could be that stakeholders are not directly affected in the short term by a change in regulating ES delivery, they are not aware about their contribution, or they feel that they cannot influence them. In addition, most regulating ES fall under the category of 'public goods and services'. The non-rival and non-excludable characteristics of these ES means that trade-offs with regulating ES are difficult to resolve and appropriate governance regimes are required (Ostrom, 1990; Farley and Costanza, 2010; Muradian and Gómez-Baggethun, 2013). The practical implication for spatial planning is that when addressing ES trade-offs it is crucial to look further than the focused ES in trade-offs, but also to consider the impacted ES. This will require special attention for the implications of trade-offs on regulating ES in particular and more generally on public goods and services. Possible ways to address these include: public awareness campaigns, regulations, and involving public agencies with a mandate to sustainably manage these public goods and services.

ES are not only traded-off with other ES, but also with **other goods and services** (which are usually not considered in ES classifications), for example mining and urban housing development. It is therefore recommended not to restrict oneself to predetermined ES lists when analysing trade-offs, but to be open-minded about all aspects that appear in the trade-off equation.

About half of the stakeholder groups involved in trade-offs are '**non-influential users**'. When absolute numbers of involved people are considered, this number is likely to be even higher. However, it is important to note that in our sample, 40% of the non-influential users show **no or little concern** about the trade-off. The level of concern was higher among the 'influential users' and 'context setters', but also for these groups a concern cannot be taken for granted as 22% and 28% of respondents respectively showed little concern. These were either stakeholders who are focussed on one economic benefit (e.g. companies, their workers and some land-users), stakeholders who feel they cannot influence the decision making related to a trade-off (e.g. residents), who are not aware about it (e.g. recreationists), or who have no access to relevant information (e.g. Rusch et al., 2017). If equitable solutions are desired, it is important to show how these non-influential users and less-concerned stakeholders can be engaged. As this can be challenging, tailor-made approaches for engaging these stakeholders might be required, such as improved access to information to increase awareness or empowerment to obtain more influence.

When facing the impacts of trade-offs, stakeholders are not passive, but often respond. **Responses of stakeholders to trade-offs** can range from raising concern, one-time actions to comprehensive strategies. These responses can lead to other types of use, other rules of use, but could also lead to changing interactions between stakeholders. In our case studies, we observed that the responses of stakeholders to the trade-off are related to the type of stakeholder, their level of influence, and their concern. Understanding these stakeholder responses can provide important insights for the development of problem-solving strategies. However, these responses are not often recorded in ES trade-off studies and seem to be an under-researched topic.

As the results showed, a **strategy** to cope with trade-offs was in place for only around 40% of the cases, this indicates that responsible agencies find it either not easy or not urgent to address them, or possibly they are not fully aware of the trade-off. One reason could be that successful management of ES is strongly dependent on institutional capacity and property right regimes, which are both factors which cannot be easily changed overnight. An understanding of property rights regimes, the constraints which they impose on ES users, and the distribution of use-benefits among users and non-users is essential if sustainable management is to be realised (Adger and Luttrell, 2000; Ostrom, 2009). As ES trade-offs involve many stakeholders, it is likely that participatory consultation and decision-making processes will increase the likelihood of successfully dealing with the impact of trade-offs. Such approaches have the advantage that they increase the opportinities for social learning, trust-building, compromise and ownership (Halcomb et al., 2007; Cáceres et al., 2015). Stakeholder inclusive approaches also increase the effectiveness and legitimacy of decision-making as well as their implementation rate (Cowling et al., 2008; Chan et al., 2012; Fontaine et al., 2013; Berry et al., 2016). But in any case, new interventions to solve trade-offs also need to be reflected upon carefully, as interventions may cause new trade-offs.

In cases where the impacts of trade-offs were severe and the situation cannot be resolved (e.g. due to power imbalances), it is possible that the situation escalates, impacted stakeholders turn to radical means of communication (e.g. vandalism) and/or illegal resource management of the ecosystem (e.g. poaching, farmers illegally opening or closing the ditches to drain the land or to retain the water in Hungary). When **conflicts** are emerging, analysing the trade-off will not be sufficient, and conflict-mediation and conflict-resolution tools will be required (incl. empowerment, mediation tools).

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.ecoser.2017.10.011. These data include Google maps of the most important areas described in this article.

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