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Creating win-wins from trade-offs? Ecosystem services for human well-being: A meta-analysis of ecosystem service trade-offs and synergies in the real world

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ABSTRACT

Ecosystem services can provide a wide range of benefits for human well-being, including provisioning, regulating and cultural services and benefitting both private and public interests in different sectors of society. Biophysical, economic and social factors all make it unlikely that multiple needs will be met simultaneously without deliberate efforts, yet while there is still much interest in developing win-win outcomes there is little understanding of what is required for them to be achieved. We analysed outcomes in a wide range of case studies where ecosystem services had been used for human well-being. Using systematic mapping of the literature from 2000 to 2013, we identified 1324 potentially relevant reports, 92 of which were selected for the review, creating a database of 231 actual or potential recorded trade-offs and synergies. The analysis of these case studies highlighted significant gaps in the literature, including: a limited geographic distribution of case studies, a focus on provisioning as opposed to non-provisioning services and a lack of studies exploring the link between ecosystem service trade-offs or synergies and the ultimate impact on human well-being. Trade-offs are recorded almost three times as often as synergies and the analysis indicates that there are three significant indicators that a trade-off will occur: at least one of the stakeholders having a private interest in the natural resources available, the involvement of provisioning ecosystem services and at least one of the stakeholders acting at the local scale. There is not, however, a generalisable context for a win-win, indicating that these trade-off indicators, although highlighting where a trade-off may occur do not indicate that it is inevitable. Taking account of why trade-offs occur (e.g. from failures in management or a lack of accounting for all stakeholders) is more likely to create win-win situations than planning for a win-win from the outset. Consequently, taking a trade-offs as opposed to a win-win approach, by having an awareness of and accounting for factors that predict a trade-off (private interest, provisioning versus other ES, local stakeholder) and the reasons why trade-offs are often the outcome, it may be possible to create the synergies we seek to achieve.

1. Introduction

One core idea from the Millennium Ecosystem Assessment (MA) is that human well-being is tightly linked to environmental conditions and therefore good environmental management could, in principle, also deliver better outcomes for people, resulting in win-wins (Tallis et al., 2008). While win-wins may be attractive, they are not inevitable and several lines of evidence suggest they may be unlikely in practice (Bennett et al., 2009), at least in the absence of carefully designed interventions. Pressures on all ecosystem services (ES) worldwide are likely to increase (Rodriguez et al., 2006) as a result of increasing demands on natural resources from a growing human population, and model-based estimates of future worldwide ES suggest intensification of trade-offs between ESs increasing globally and certain regions experiencing rapid changes in ES (Alcamo et al., 2005).

While win-win language has become common in international conservation and development organisations to describe the simultaneous achievement of the conservation and development

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outcomes (Lele et al., 2013; McShane et al., 2011) many studies are now starting to question the underlying assumptions behind win-wins especially for the many situations on the ground that involve competing rather than complementary social, economic and ecological goals (McShane et al., 2011). It is important to note, however, that in the context of this paper win-wins or trade-offs do not refer to conservation and development exclusively, but relate to the competing use for ES, whether that is the same ES or multiple ecosystem services within an area.

Trade-offs occur when the provision of one ES is reduced as a consequence of increased use of another ES, or when more of a particular ES is captured by one stakeholder at the expense of others (Rodriguez et al., 2006). Trade-offs occur among stakeholders as well as among the ES being delivered in any location, and they can be understood in disparate ways, influenced by social norms and life experience (McShane et al., 2011). Such changes may be the result of explicit choices or arise without premeditation or awareness. Trade-offs can occur spatially (across locations) or temporally (over time) and ES perturbations may or may not be reversible (Rodriguez et al., 2006).

ES ultimately depend on the ecological communities and functions within ecosystems, and so a good knowledge of the underpinning processes can indicate where there are likely to be trade-offs. Ecological syntheses show that because multiple species traits affect different ecosystem services, and individual ES often depend on multiple traits, there are in practice clusters of linked traits and services within which there are both positive and negative feedbacks that are currently poorly understood (de Bello et al., 2010). A priori it may be difficult to define the circumstances under which win-wins will result, though functional trait approaches afford, to some degree, generalisations about expected win-wins from an ecological perspective (Lavorel and Grigulis, 2012).

ES have been typically presented as being site-based on static maps, without dynamics (Tallis et al., 2008), however, environmental change, ecosystem feedbacks and food-web dynamics can lead to unexpected consequences (Dobson et al., 2006; Nicholson et al., 2009; Rodriguez et al., 2006). These ecological feedbacks can intensify human modification of ecosystems, creating a spiral of poverty and ecosystem degradation (Carpenter et al., 2006). ES functions may also lag by decades, in contrast to economic signals that respond much more quickly (Tallis et al., 2008). Ignoring dynamics may increase the risk of regime shifts that alter the ability of an ecosystem to provide goods and services for future generations (Bennett et al., 2009; Carpenter et al., 2006; Coggan et al., 2010; Nicholson et al., 2009). Thus, more recent approaches consider both capacity (static) and flow (dynamic) of ES, such as Villamagna et al. (2013).

The majority of ES studies focus on single services but understanding trade-offs requires broader studies that consider several ES in the same system (Bennett et al., 2009; Suich et al., submitted for publication; Tallis et al., 2008; Zhang et al., 2007). An understanding of the ecological mechanisms underpinning ES delivery and therefore trade-offs and synergies is evolving and frameworks, such as that developed by Bennett et al. (2009), help in framing mechanistic analyses. One principal challenge in managing ES is that they are not independent of each other and relationships may be highly non-linear, with unintentional trade-offs resulting when we are ignorant of the interactions among them (Rodriguez et al., 2006). For example, changing ecosystem components which generate regulating services may undermine the long-term existence of provisioning services (Carpenter et al., 2006).

Different groups of people derive wellbeing from a variety of ES, with different stakeholders valuing different management options for particular resources. Thus, winners and losers are created as ES change and trade-offs between different ES can also lead to trade-offs in the wellbeing of different groups of people (Daw et al., 2011). The explicit inclusion of stakeholders in the consideration of trade-offs makes values intrinsic to ES, whether or not those values are monetised (Brauman et al., 2007) and regardless of whether or not users are actively involved in ES changes.

Different actors have different perceptions of and access to ES and therefore they have different wants and capacities to manage directly or indirectly for particular biodiversity and ecosystem characteristics (Díaz et al., 2011). Mechanisms of access are dynamic and determine which individuals or groups can benefit from different ES (Daw et al., 2011), and there can be vast geographic, economic and cultural disconnects between those who control land use and those who benefit from services produced on that land (Brauman et al., 2007). This fact highlights the importance of the role of power in ES trade-offs, of which there are three layers: agency (the capacity of agents to mobilise resources to realise the most desirable outcomes), institutional (institutions as sets of rules that define such things as which norms are legitimate) and structural (macro-societal structures that shape the nature and conduct of agents) (Takeda and Røpke, 2010). Although multi-stakeholder planning can improve the assessment of under-appreciated services and users it does not eliminate the effect of unequal power relations between the stakeholders of different ES (Lebel and Daniel, 2009).

The influence that external forces and global markets, including corruption and governance, have on the likelihood that ES projects will achieve win-wins cannot be ignored (Tallis et al., 2008). For example, agricultural management, primarily influencing the ES related to food supply, is influenced by both biophysical and socio-economic variation and management practices, and access to markets and patterns of trade (Power, 2010). Socio-cultural preferences (such as those related to gender, education, and rural versus urban) also influence what people are willing to trade-off (Martin-Lopez et al., 2012). Management choices often lead to trade-offs between private financial gains and social losses (Zhang et al., 2007) and as either the temporal or spatial scales increase, trade-offs become more uncertain and difficult to manage (Rodriguez et al., 2006).

Unfortunately, planning is conventionally based on supposedly neat physical and institutional separation into conservation and use (Lebel and Daniel, 2009), with (unanticipated and perhaps unintended) trade-offs resulting when management focuses on only one ES at a time (Bennett et al., 2009), although it is important to note that trade-offs may also occur when considering bundles of ES. Similarly, focusing on individual-level management structures, such as farms, can lead to trade-offs, at least for the ES that transcend borders between them (Goldman et al., 2007), for example, the quantity and quality of the water supply.

The complexity of these linked ecological, social, physical and economic factors mean that generalisations about trade-offs and synergies in ES are hard to draw from theory, case studies or in principle. Thus, the purpose of this research was to perform a systematic mapping of the literature on trade-offs and synergies in ecosystem services for human wellbeing and to test a number of hypotheses regarding potential key indicators for a trade-off occurring.

Trade-offs between provisioning and almost all regulating and cultural ES have been demonstrated at the landscape scale (Raudsepp-Hearne et al., 2010), whilst recent empirical evidence from China demonstrates that while economic growth and its associated provisioning services have been progressively enhanced, regulating services have been declining continuously over time (Dearing et al., 2012). Consequently, we predict that one key condition for a trade-off is when at least one stakeholder is utilising a provisioning service. Another core ES concept is that the contribution of biotic nature to human well-being is under-recognised and under-valued, which results in the alteration of ecosystems and the degradation of the resource base on which people rely (Lele et al., 2013). Thus, we suggest that another potential predictor of a trade-off may be when one or more of the stakeholders have a private interest in one or more of the ES involved. For example, the sale of trees for timber (private interest) as opposed to their maintenance for climate regulation (public interest).

In order to address these hypotheses we asked a number of questions:

(1) What are the generalisable environmental or social conditions that result in a trade-off, either between ES or between ES and well-being outcomes?
(2) What are the characteristics of the winners, and the losers (ES and human) of a trade-off (and synergy)?
(3) What are the characteristics of a win–win outcome that can be incorporated into the design of an ES management programme? What are the factors that lead to trade-offs, and can the avoidance of these be incorporated into the design of ES management programmes?

2. Methods

2.1. Systematic mapping

The systematic mapping was based on the "Guidelines for Systematic Review in Environmental Management" developed by the Centre for Evidence Based Conservation at Bangor University (CEBC, 2010). The aim of the literature-based search was to collate evidence on where the use of ES for human well-being have resulted in, or have the potential to result in synergies and/or trade-offs, with an emphasis on the benefits from ecosystem services and the use of those benefits from a well-being perspective.

The UK National Ecosystem Assessment provided the definition for ecosystem services, which separates ES from benefits and ultimate well-being (UKNEA, 2011). The definition of trade-offs included two outcome: (i) a situation where the quality or quantity of an ES being utilised by one stakeholder (an individual or group utilising a particular ES) was reduced as the result of other stakeholders utilising that or other ecosystem service(s); or (ii) when the wellbeing of one stakeholder declined as the result of another stakeholder utilising an ES[s]. Synergies were defined as the converse of a trade-off. Potential opportunities for trade-offs or synergies were also recorded.

The databases searched were ISI Web of Knowledge and Google Scholar, and searches were finalised in July 2013. All peer-reviewed journal articles written in English were considered. For each web search, the first 100 results were taken into account (results were filtered based on relevance to the search terms and number of citations). Due to the volume of literature available, as well as emerging concepts and terminology the search was restricted to work published since 2000. This marks a period of time with more consistent use of the terms ecosystems and ecosystem services and embraces the work of the Millennium Ecosystem Assessment (MA, 2005). A pilot search and scoping project was carried out prior to the actual systematic review in order to refine the search strategy with careful consideration to ensure that it was as focused and specific as possible (Eysenbach et al., 2001). An effort curve (a plot of new papers found per additional search term used) was employed to ensure that the search had been sufficiently comprehensive.

A number of relevant terms and descriptive words were compiled from the referenced literature and derived directly from the questions addressed in the review. Boolean nomenclatures '*' = all letters were allowed after the *, were used on the root of words where several different endings applied. Search terms used were:

"ecosystem service*"	**AND**	trade-off*/tradeoff*
"environment* service*"		synerg*
"ecosystem* approach*"		win-win*
"ecosystem good*"		cost*and benefit*
"environment* good*"		

Selection criteria for inclusion were based on a sequential assessment. Document abstracts were first scanned to ensure the papers were broadly about ES-related issues and contained some reference to either trade-offs, synergies or both, and were excluded if they did not meet the criteria. Remaining papers were then subject to a full-text read-through, and were accepted if the subject matter was the use (or potential use) of ES for human well-being, they considered different types of services and stakeholders and reported [potential] trade-offs and synergies. Only papers containing quantitative information on ecosystems, services and/or benefits were considered following the full-text read through. The protocol was checked for consistency using a Kappa analysis (Edwards et al., 2002), with a result of 0.623. A Kappa analysis tests for agreement between two or more people over and above that expected by chance.

2.2. Variables

The literature search found 1324 papers containing the relevant search terms. During the first stage (abstract scanning) this was reduced to 196, and the final database, based on a full text read through contained 92 papers (see Appendix A). Each case study listed in a paper was documented as a record in the dataset, as was each trade-off or synergy discussed. The final database contained 231 actual or potential trade-offs or synergies based on 108 case studies from 92 papers. The full list of variables, definitions and assumptions made are provided in Appendix B.

2.3. Analysis

The response variable modelled was "*trade-off yes or no*": did an actual or potential trade-off occur and under what circumstances? Spearman's rank correlation, Mann–Whitney and chi-squared tests were used in a preliminary analysis to remove/combine variables for explanatory power, removing confounding correlations between explanatory variables, those with too many missing data points, those which proved too subjective and when another variable provided similar information more reliably. The final explanatory variables used for the data analysis in non-modelling sections are listed in Table 1. Note that for "*trade-off yes or no*" the stakeholders involved in the trade-off or synergy are not considered independently, for example, if one stakeholder is acting at a local level and another at a regional level, both local and regional will be recorded as a 1 for that particular trade-off/synergy.

The response variable was modelled to explore which factors determined whether a trade-off occurred or not, and the characteristics of winners and losers. In order to control for the effect of case study site, linear mixed effects models were used with case study reference (see Appendix B) treated as a random effect. The error structure was binomial.

Explanatory variables were first explored through the use of tree models, which highlighted the variables that explained the greatest amount of variance in the dependent variable (Crawley, 2007). Two-way interactions between explanatory variables,

Table 1
Details of explanatory variables used. Each category within each variable explanatory variable was coded as a binary response for each trade-off/synergy recorded.

Variable	Definition	Categories
Modelling section response variable: "trade-off yes or no"		
Country type	Country was defined by (i) development level according to the World Bank (WB, 2013); (ii) Human Development Index Rank (UN, 2013); (iii) continent. During the modelling exercise it was shown that the results were the same under all three country-type variables and therefore only country development was used in the final models.	(i) Low income, lower-middle income, upper-middle income and high income; (ii) Human Development Index Rank; (iii) Europe and Central Asia, South and East Asia, North America, South and Central America, Australia and New Zealand, Africa.
Habitat	Habitat-type in which the trade-off or synergy is recorded, based on the Millennium Ecosystem Assessment categories (MA, 2005).	Marine or coastal, inland water, forest, cultivated
Ecosystem service	Ecosystem services involved in the trade-off or synergy, based on the (UKNEA, 2011).	Crops or fish (provisioning), wood (provisioning), water (provisioning/ regulating/cultural), species [ecosystem services derived from the abundance and diversity traits] (provisioning/cultural/ supporting), climate (regulating/supporting)
Ecosystem service type	What type of ecosystem services are involved in the trade-off or synergy (UKNEA, 2011)?	Provisioning versus provisioning services, provisioning versus regulating and/or supporting and/or cultural services (RCS), RCS services only
Stakeholder type (where a stakeholder is an individual or group using a particular ecosystem service)	Do the stakeholders have private or public interest in the ecosystem service or benefit? E.g. logging companies have a private interest in a forest for timber, whereas the global population may have a public interest in the same forest for its climatic services. If the resource can ultimately be used by more than the original stakeholder and/or there is no personal financial interest in the resource then it was considered to be a public good. NGOs, although a cooperative, may manage a resource as a public good.	Private, public
Stakeholder scale	At what scale are the stakeholders acting? Local refers to communities within the immediate vicinity of the resource[s] of interest, whilst regional refers to those communities that fall within the possible administrative (i.e. may be affected by any changes to the resource[s]) region of the resource[s] (this may vary in size depending on the resource and geographical locality of the resource).	Local, regional, national, global
Non-modelling section explanatory variables		
Stakeholder scale, stakeholder type, ecosystem service	See sections above for more detailed information.	
Stakeholder wealth	What is the relative wealth of the different stakeholders in a trade-off or synergy, in relation to each other. This is a subjective category and was based on a reading of the background description of the case studies.	Poorer, wealthier or mixed (i.e. a combination or poorer and wealthier individuals within a group).
Ecosystem service type	What type of ecosystem services are involved in the trade-off or synergy (UKNEA, 2011)?	Provisioning, regulating, cultural, supporting
Ecosystem service benefit	The benefit provided by the ecosystem service (UKNEA, 2011).	Food, timber, water, climate, wildlife (e.g. wildlife tourism), aesthetic (e.g. recreational value from an aesthetically pleasing site)
Ecosystem service benefit use	How the benefit resulting from the ecosystem service is ultimately used.	Current uses (where the resource is depleted): sale and consumption; future uses: security (protection against vulnerability to environmental or socio-economic fluctuations and resilience); future (potential future uses and also current and continued aesthetic enjoyment) and climate (long-term protection from climatic changes)

which could a priori be of interest, were included in the model. Due to the highly correlated nature of the habitat and ES variables, different model combinations were run: habitat variables alone, ES variables alone, ES type variables alone, ES and ES type variables in combination, and habitat and ES variables in combination. Additionally the models were run with only one of the country type variables (income category, HDI, or continent) at a time, because of the highly correlated nature of these variables. It was impossible to use relative wealth between stakeholders in the model due to its highly subjective nature and too many missing data points. The results were shown to be the same under all three country variable types and therefore only country income category was used in the final models.

Stepwise deletion was carried out on the basis of non-significant *p*-values (5% and 10% significance), with largest *p*-values and two-way interactions removed first. Non-significant main effects were removed only if they were not involved in two-way interactions. After each variable removal, the model was checked with an ANOVA or *F*-test (where over-dispersion occurred), to assess the significance of the subsequent increase in deviance (Crawley, 2007). Fixed effects were analysed with Maximum Likelihood and random effects with Restricted

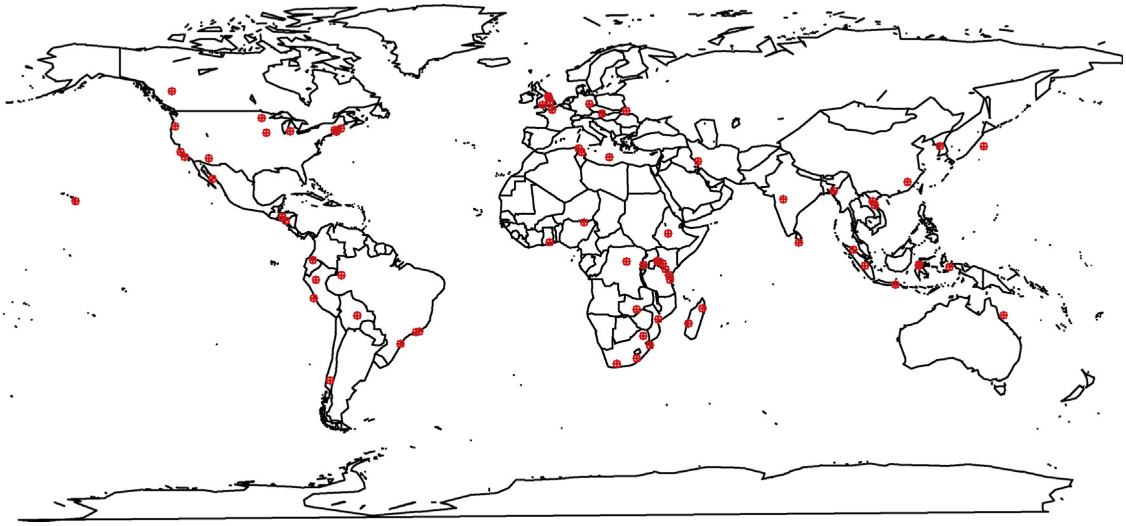

Fig. 1. Global map showing the distribution of case studies recorded in the final database.

Maximum Likelihood. Residuals versus fitted values plots were used for informal exploration and the Breusch-Pagan test used to test for heteroscedasticity. R.app GUI 1.61 version 3.0.2 was used for all statistical analyses (R Foundation for Statistical Computing, 2013).

3. Results

3.1. Summary of database

Of 231 trade-offs/synergies identified, 96 were trade-offs, 53 potential trade-offs, 29 synergies and 16 potential synergies. Additionally, six studies recorded the presence of both trade-offs and synergies with a further 29 potential cases of both, and two did not have enough evidence for either.

Fig. 1 provides a distribution map of the case studies in the final database, demonstrating a broad spread across the globe, with notable absences in north Africa and Russia.

46 studies looked at trade-offs and synergies in inland water habitats, 42 in forests, 23 in cultivated lands, 18 in coastal or marine habitats, and seven in drylands. There were no studies on mountains or polar regions and only three in urban environments. Fig. 2 shows the ecosystem services involved in the recorded trade-offs and synergies. Most of the ES are provisioning services with very few papers recording trade-offs or synergies involving supporting or cultural services.

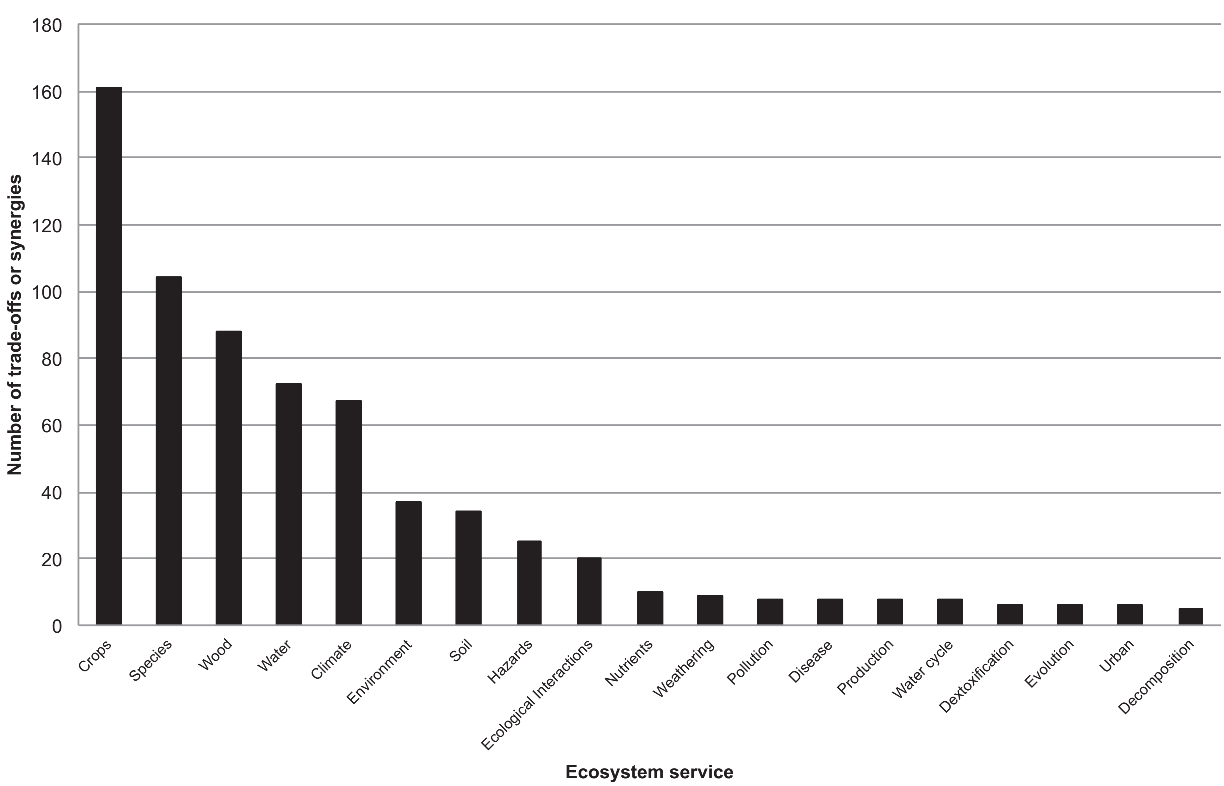

Fig. 2. The number of case-studies looking at different ecosystem services.

Table 2
The minimum adequate model (MAM) for "trade-off yes or no". Trade-off yes = 1, Trade-off no = 0. Model is a linear mixed effects model (LME) with binomial error structure. All variables are non-ordered factor variables. AIC = 190.950; n = 191. "National" = one or both stakeholders operating at the national scale, "Global" = one or both stakeholders acting at the global scale, "Private" = a private interest in the ES held by one or both stakeholders. "Crops" = the use of crops as an ecosystem service by one or both stakeholders, "RCS" (regulating, cultural supporting services only) = no provisioning services being used by either or both stakeholders.

Parameter	95% confidence interval			
	Estimate	Standard error	*t*-Statistic	*p*-Value
(Intercept)	0.653	0.079	8.246	0.000
National	0.037	0.069	0.528	0.599
Global	−0.037	0.065	−0.562	0.576
Private	0.353	0.096	3.661	0.000***
Crops	0.333	0.232	1.434	0.155
RCS	−0.483	0.211	−2.290	0.024**
Private: crops	−0.565	0.244	−2.315	0.023**
National: RCS	−0.749	0.228	−3.289	0.001***
Global: RCS	0.589	0.254	2.317	0.023**

* Significance: 0.050–0.099.
** Significance: 0.010–0.049.
*** Significance: <0.010.

Table 3
The minimum adequate model (MAM) for "trade-off yes or no" where either one or both stakeholders have a private interest. Model is a linear mixed effects model (LME) with binomial error structure. All variables are non-ordered factor variables. AIC = 141.712. n = 153. "Crops" = the use of crops as an ecosystem service by one or both stakeholders, "RCS" (regulating, cultural and supporting services only) = no provisioning services being used by either or both stakeholders.

Parameter	95% confidence interval			
	Estimate	Standard error	*t*-Statistic	*p*-Value
(Intercept)	1.009	0.068	14.861	0.000
Crops	−0.245	0.077	−3.184	0.002***
RCS	−0.391	0.181	−2.164	0.034**

* Significance: 0.050–0.099.
** Significance: 0.010–0.049.
*** Significance: <0.010.

Although there was an intention to collate data on the gender of stakeholders, no studies looked at trade-offs between males and females. There was limited information available on the relative wealth of stakeholders as well as the ultimate well-being outcome of the trade-off or synergy recorded. Often this information was assumed.

3.2. What conditions result in a trade-off?

The minimum adequate model for "trade-off yes or no" was achieved through combining ES and ES type variables (alongside other potential explanatory variables detailed in Table 1). See Table 2.

The over-riding explanatory variable is the presence of a private interest in the ecosystem services being used by either one or both of the stakeholders involved. In 81% of cases where there was a private interest from one or both of the stakeholders, a trade-off occurred. In contrast if there was no private interest involved, there was a 60:40 probability of a trade-off:no trade-off.

In 56% of trade-offs recorded there is both a private interest in the ES being used, and one or both stakeholders are using crops[fish]. When there is a private interest that involves crops[fish] as an ES, the probability of a trade-off occurring increases. However, when there is no private interest in any of the ES, the presence of crops[fish] reduces the probability of a trade-off occurring (Fig. 3). Controlling for private interest, by running the model for only those cases where there is a private interest, demonstrates the negative effect of crops[fish] on the likelihood of a trade-off occurring (Table 3).

Another variable influencing whether a trade-off occurs or not, is whether the ES involved include at least one provisioning service. There are only 11 cases where "*RCS (regulating, cultural and supporting services only)*" is true (i.e. there are no provisioning services involved). Seven of those resulted in a synergy (64%). Where there is a trade-off, only 5% of cases do not involve provisioning services. The effect of no provisioning services on the probability of a trade-off occurring is also observed in a model controlling for private interests only (Table 3).

"RCS" also appears to interact with the scale at which the stakeholders are acting. When there are no provisioning services involved (i.e. "RCS" = 1), at the national scale there are no trade-offs,

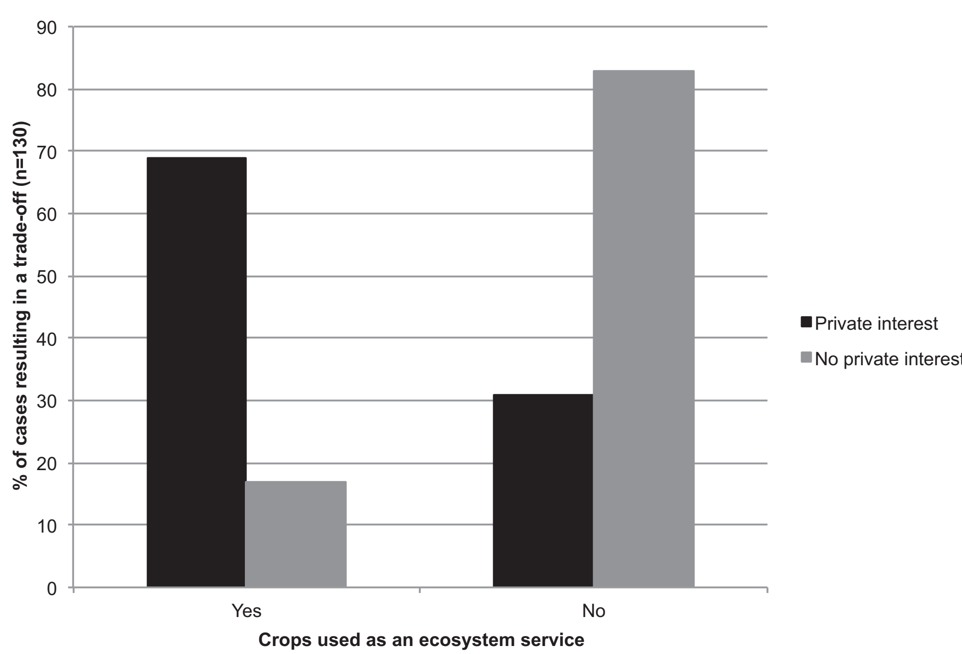

Fig. 3. Relationship between the occurrence of trade-offs under different combinations of private/non-private interest and the use of crops[fish] as an ecosystem service.

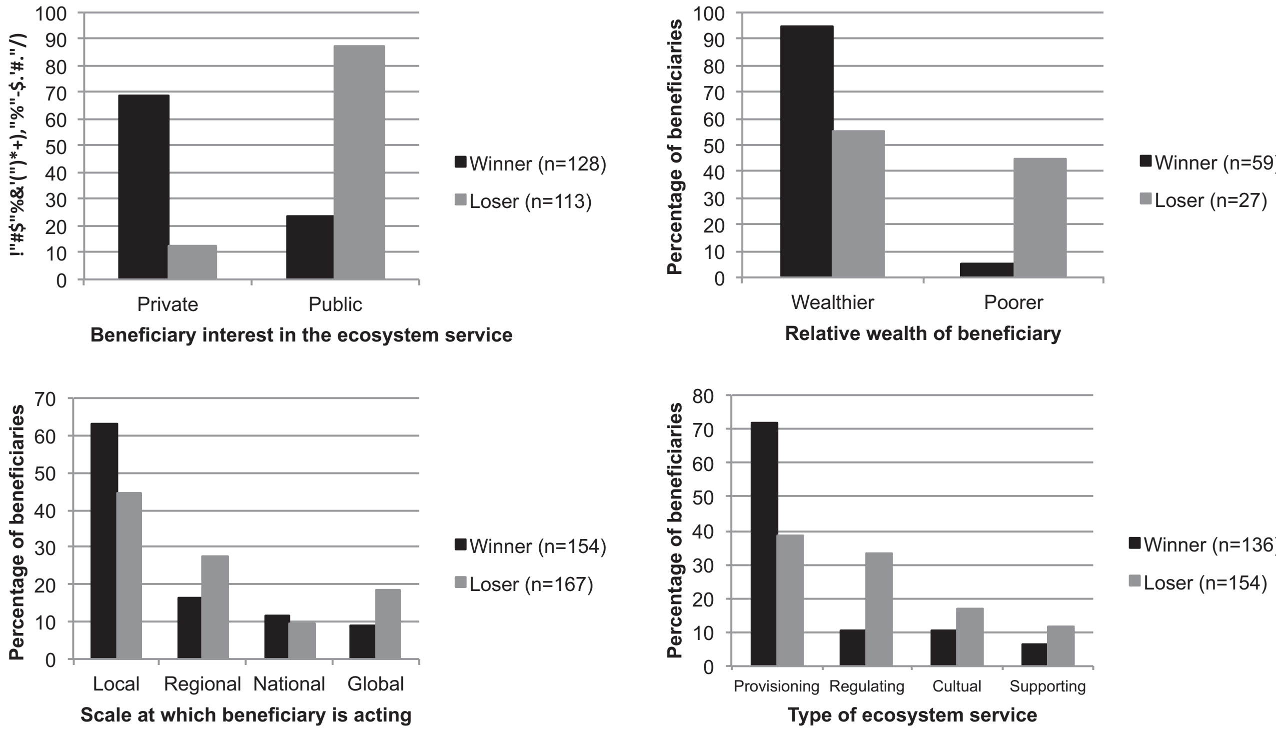

Fig. 4. Profile distribution differences between winners and losers of a trade-off. Percentage of beneficiaries is given as percentage of particular categories of stakeholders e.g. winners or losers.

whilst at the global scale there are an equal number of trade-offs and synergies. When "RCS" = 0 (i.e. there is a least one provisioning service involved) the number of trade-offs observed appears to decrease with increasing scale. However, as the number of cases where "RCS" is true is small ($n = 11$) it is difficult to define precisely the impact or direction of the effect of "RCS" on a trade-off or its interaction with scale.

Where explanations for why trade-offs had occurred were given, they were relatively evenly distributed: unequal economic returns from different services (15%); failure to account for all stakeholders/benefits (20%); failed management (22%); pollution/destruction knock-on effects (19%); and, provisioning versus other services (24%).

3.3. Winner and loser profiles

Where trade-offs are recorded, there are distinct profile differences between winners and losers (Fig. 4), the most notable of which is the number of stakeholders with a private interest in the ES as opposed to a public interest. Winners are three times as likely to hold a private interest, whilst losers were seven times as likely to hold a public interest ($\chi^2 = 9.172$, $p = 0.002$, $n = 113$). Winners were also likely to have greater relative wealth compared to losers ($\chi^2 = 5.085$, $p = 0.0241$, $n = 113$). Likewise winners were more likely to use provisioning services such as crops[fish] and wood ($\chi^2 = 5.679$, $p = 0.017$, $n = 113$), compared to losers who had a broader profile of ecosystem service use. Relative wealth between stakeholders was a difficult variable to analyse due to its subjective nature and number of missing data points, hence it is only used for illustrative purposes only and not in the quantitative model.

In 69% of trade-offs, the winner acted at the local scale, utilised provisioning services and had a private interest these services. In these examples, the loser had a public interest in a competing resource (95%) and used RCS services in 97% of the cases. In 35% of cases, losers also used provisioning services. In terms of the scale at which the trade-off losers acted, this was much more mixed: 64% local, 47% regional, 19% national and 29% global.

Fig. 5 illustrates how trade-offs played out between the winners and losers across different ES, the benefits derived from the ES and how these ES benefits were ultimately used, with different patterns observed within each category (ES, benefit, use).

Where the winner utilised provisioning services, such as crops[fish], wood and water ($n = 103$), there was a loss of regulating, cultural and supporting services. However, looking at how these trade-offs played out from the perspective of the benefits derived from ES, where the winner utilised provisioning benefits (e.g. food, timber and water) there was a more equal distribution of loss across both provisioning and RCS (aesthetic, wildlife and climate) benefit categories. Looking at how those benefits are used, when current uses such as sale or consumption (strongly correlated with provisioning services) won out, the loser suffered from both current and future (security, future and climate) use losses (Fig. 5).

Where the winner used RCS ($n = 22$), the loser suffered from lost provisioning services and benefits and the loss of current uses, whilst winners gained future uses (Fig. 5).

There are a couple of interesting patterns observed amongst the studied ES, for example, when the winner used water as an ES the loser lost both their water services as well as related provisioning services such as crops[fish]. In the cases where species [ES derived from the abundance and diversity traits] were the RCS service used by the winner, there were trade-offs in provisioning services, often in the form of wood, and with other ES. At the benefit use level, the general pattern was a loss of provisioning benefits when the winner gained RCS benefits, except for aesthetic benefits where loss is more evenly spread across both provisioning and RCS benefits.

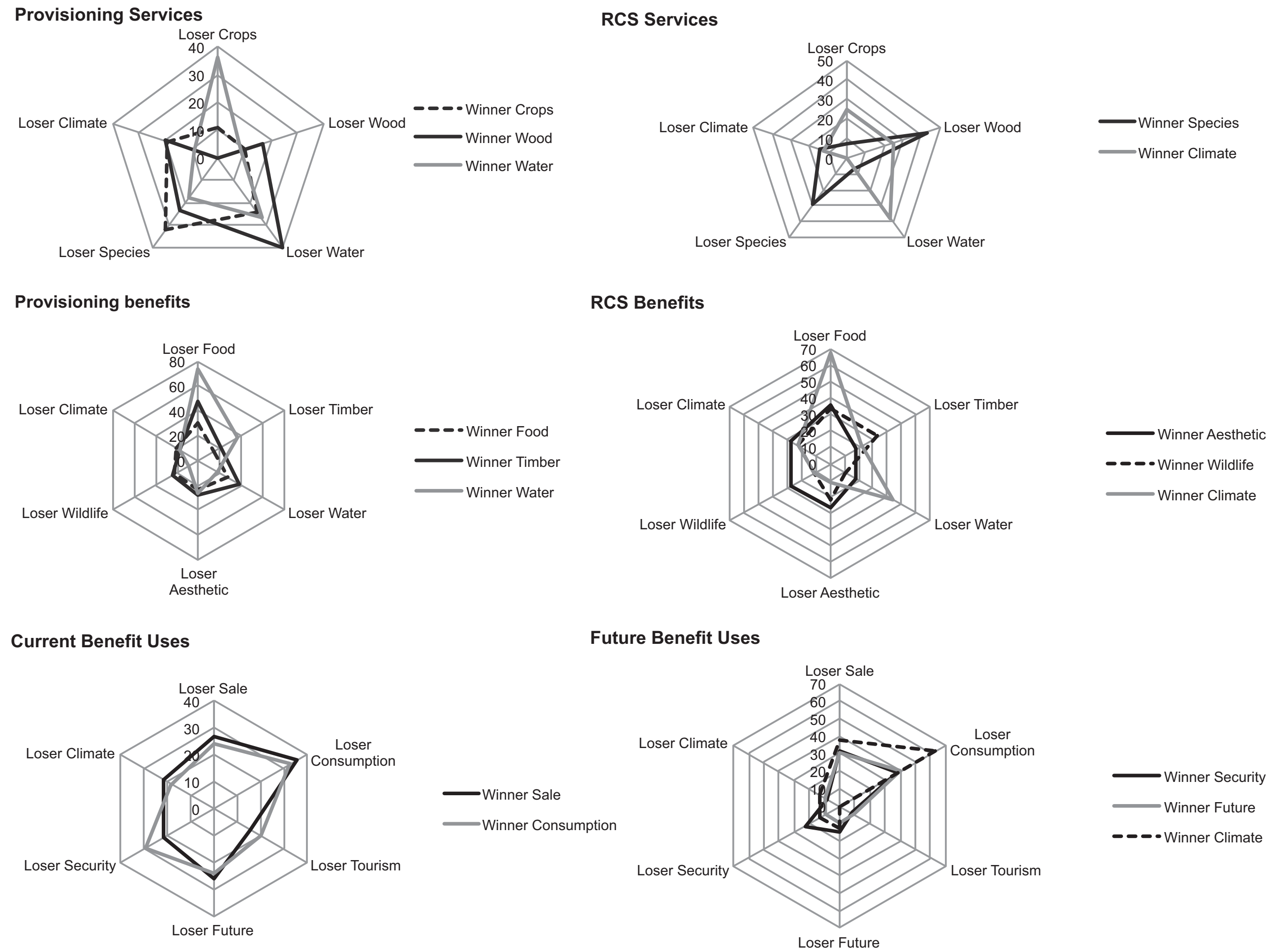

Fig. 5. How trade-offs play out between winners and losers across different ecosystem services, their benefits and uses. Scale on the spider diagram axes is of those cases in which a trade-off is recorded what percentage of the have these characteristics. (Note that the percentages do not necessarily add up to 100 as a winner or loser may fall into more than one category e.g. they may use both crops[fish] and wood.) RCS = regulating, cultural and supporting. Where the winner utilised provisioning services or benefits ($n = 103$), there was a loss of regulating, cultural and supporting services, however, within the benefit category there was a more equal distribution of loss across both provisioning and RCS benefit types. Within the benefit use category, when current uses (strongly correlated with provisioning services) win out, the loser suffers from both current and future use losses. Where the winner used non-provisioning (RCS) services ($n = 22$), the loser suffered from lost provisioning services. This is mirrored within the benefit and benefit use categories, with losers suffering from lost provisioning services and the loss of current uses, whilst the winners gained future uses.

3.4. What defines a win-win?

The database records 29 win-wins and a further 16 potential win-wins. In terms of the stakeholder type, i.e. whether the stakeholders have a private or public interest, in cases that involve one stakeholder with a private interest and one with a public interest, 16% result in a win-win, compared to 30% of win-wins resulting from cases where both stakeholders have a public interest in the resources, or 8% where they both have a private interest in the resource. Although the absence of provisioning services reduces the probability of a trade-off, the presence of a provisioning service does not reduce the probability of a win-win.

Table 4 illustrates that win-wins most often include a provisioning service versus either another provisioning service or RCS service. However, a chi-squared test indicates that none of the combinations of services are significant in predicting a win-win. In terms of the scale at which stakeholders were acting, 93% of the win-wins involved one or both of the stakeholders acting at a local scale, followed by 69% at the regional scale, 36% at the national scale and 44% at the global scale.

The most notable differences between win-wins and trade-offs arise when the ES, their benefits and their uses are analysed in detail (Fig. 6). The patterns for crops[fish] versus other ES are similar for win-wins and trade-offs (which correlates with the finding that crops[fish] alone without a private interest have a negative effect on the likelihood of a trade-off occurring). With

Table 4
Ecosystem services being utilised by both stakeholders of a win-win. Number of win-wins and potential win-wins = 45.

		User 2 – Ecosystem service (% of total cases)			
		Provisioning	Regulating	Cultural	Supporting
User 1 – Ecosystem service (% of total cases)	Provisioning	14 (n=98)	17 (n=99)	11 (n=53)	13 (n=45)
	Regulating		31 (n=16)	22 (n=9)	29 (n=7)
	Cultural			33 (n=6)	33 (n=6)
	Supporting				33 (n=6)

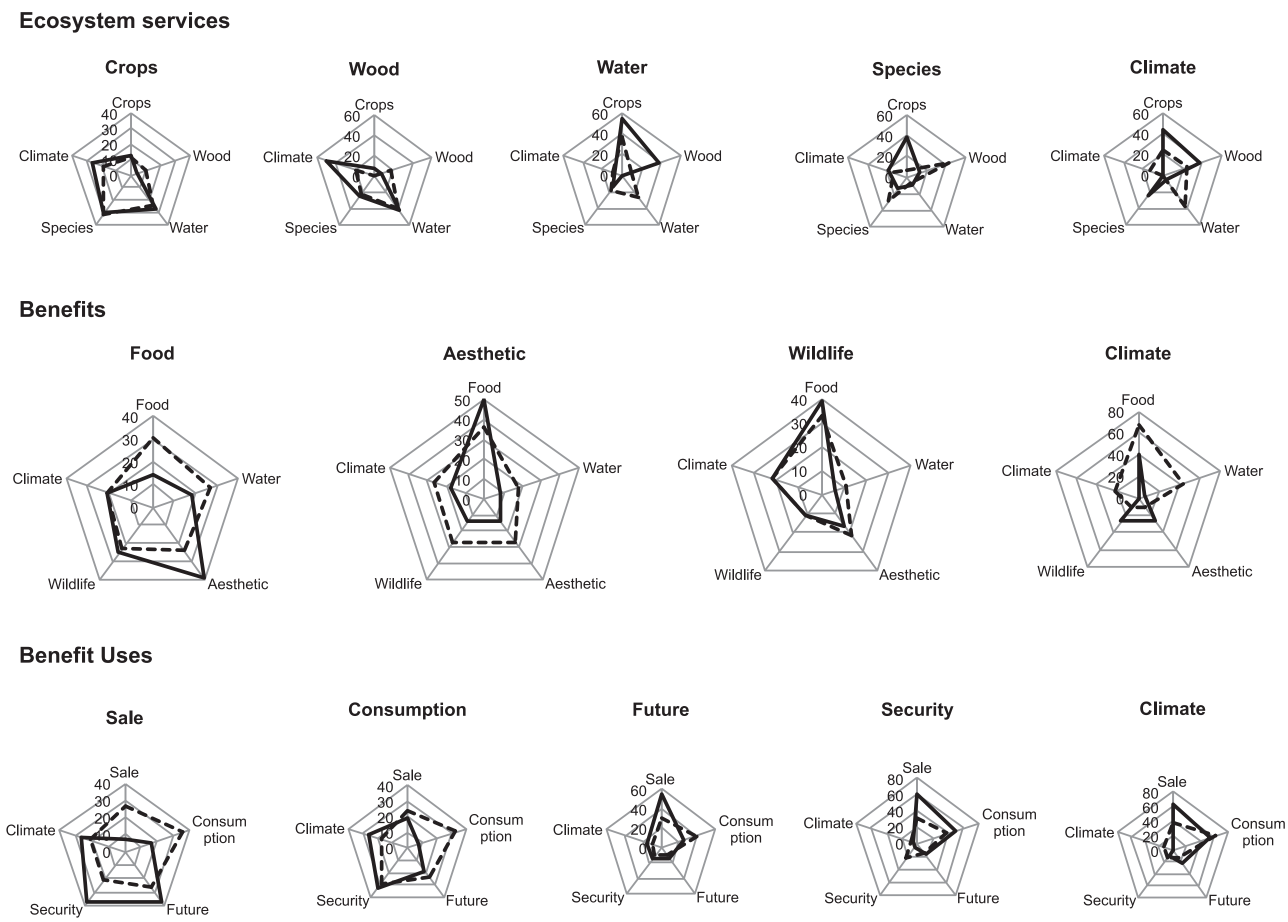

Fig. 6. Differences between win-wins and trade-offs across different ecosystem services, the benefits and their uses. A bold line represents win-wins and a dotted line trade-offs. The scale on the spider diagram axes report percentage of case studies reporting either a win-win or a trade-off. (Note that the percentages do not necessarily add up to 100 as a winner or loser may fall into more than one category e.g. using both crops[fish] and wood.)

regards to wood and climate, the probability of a win-win is greater when the stakeholders involved are interested in using both ES. Both water and species display very different patterns for win-wins and win-lose scenarios. Win-wins appear possible between water and provisioning services, such as crops and wood and between species and crops[fish] as a provisioning service.

There appear to be opportunities for win-wins with respect to combining food, aesthetic and wildlife uses. This reflects the finding that when there is a trade-off where the winner benefits from aesthetic uses, the loser does not suffer overtly from the loss of provisioning benefits such as food. Wildlife shows almost identical patterns for both win-win and win-lose situations, with win-wins and trade-offs appearing equally possible between wildlife and food, climate and aesthetic benefits. When exploring outcomes within the benefit-use category, the results illustrate that win-wins are possible between current and future uses, despite this also being a strong indicator of the outcome of a trade-off.

4. Discussion

4.1. Coverage within the peer-reviewed literature of trade-offs and synergies

There were almost three times as many actual or potential trade-offs recorded than synergies. It is unclear whether this is because trade-offs are observed more often than synergies, in which case it is important to study realised win-win outcomes in detail in order to determine whether or not there are generalisations that can be applied to other systems in order to achieve a greater number of synergies. It may also be important to study more win-win outcomes to see if they are more important or prevalent in practice than is reflected in the literature. Alternatively, it may be simply that there is a reporting bias, and trade-offs provide more intellectual interest, in which case further research is required to provide a more balanced sample.

The systematic mapping exercise revealed significant gaps in the literature. These gaps may be a result of the sampling method employed or more representative of ES research in general (Suich et al., submitted for publication). If they are a consequence of the latter, this review highlights important areas for future research. The main gaps observed were a lack of studies within coastal, marine, dryland and urban environments and none in mountain or polar-regions. There were also a limited number of case studies carried out in north Africa and Russia. This lack of coverage of large parts of the globe may have significant consequences for the findings of this study, and in the future it would be useful to expand the analysis to cover these areas, as and when data becomes available.

Unsurprisingly, cultural and supporting services were underrepresented. This has already been observed in the literature (DeFries et al., 2004; Rodriguez et al., 2006; Tallis et al., 2008), and could be due to the fact that these services are not as well defined/understood as provisioning or regulating services (Crossman et al., 2013) and are therefore are more difficult to study and/or measure. However, it may also be due to the fact that as they are often not captured by monetary valuations, there is a general lack of interest in these types of services.

There is a need to disaggregate data regarding the ES stakeholders, to determine the distribution of benefits between groups and individuals (Daw et al., 2011). Unfortunately, although this study attempted to record potentially relevant socio-economic indicators, there was insufficient data in the papers reviewed to enable a rigorous analysis. Even in studies specifically setting out to examine the issues around trade-offs, there was a dearth of disaggregated data regarding relatively simple categories such as gender and wealth, let alone for more complex and multi-dimensional concepts such as wellbeing. No studies specifically considered trade-offs between men and women, however, it has been shown in a number of studies that perceptions of a user's ability to draw benefits from them and their access to ES can be strongly dependent on gender and wealth, often with women and the poorest households losing out (Porter et al., 2008; Ronnbach et al., 2007). Consequently, this is an area of research that needs significant input, and these gaps may have affected the overall conclusions of this study.

Where relative wealth was considered in the reviewed studies, it was often assumed rather than measured, and in many cases impossible to record within the database at all. These results, based on limited data, showed a significant difference the wealth of winners and losers, so more information may have improved our conclusions relating to the indicators of trade-offs and who wins or loses. Further, an understanding of the differential impacts on different groups will be critical to understanding the potential for long run sustainability of any ES management options considered.

Finally, the impact of trade-offs or synergies on the pathway from ES, via benefits and the use of benefits, to wellbeing was impossible to track as possible impacts on/changes in wellbeing was either presumed or not considered at all. While ES are often assumed to affect wellbeing (MA, 2005), there are a limited number of studies that record a causal connection and this is a significant gap in the literature (Suich et al., submitted for publication).

4.2. Trade-off indicators

The results of this study show that there were three key indicators of whether or not a trade-off will occur. First, a private interest in one or more ES, often with the winner having the private interest and the loser having a public interest in the same or competing ES (e.g. private timber resources and public carbon) was the most significant variable in the model for whether a trade-off occurred. Thus it appears that trade-offs arising from management choices often occur between private financial gains and social losses (Zhang et al., 2007).

Second, trade-offs were more likely to involve provisioning services and, in general, it was the winner that benefited from the provisioning service with the loser having a broader profile of ES use (e.g. agricultural use versus land for water and species). This accords with the general assumptions and reported findings in the literature (Raudsepp-Hearne et al., 2010). However, trade-offs were also observed between different provisioning services, and there were a few cases where RCS services 'won' out in a trade-off against provisioning services. There appears to be a management incompatibility, or lack of consideration of the wider impacts by those making ES management/provision decisions, between provisioning and non provisioning services, with each losing one to another; however, it is not inevitable that provisioning services always dominate.

Third, trade-offs appeared to occur more often when one of the stakeholders, normally the winner, was acting at the local scale. This may be due to the fact that private interests are often held at a local scale (Power, 2010; Zhang et al., 2007). Losers typically had a more mixed profile in terms of the scale at which they were acting (e.g. water users along a river may be both local and/or regional depending on their location). It was also observed that when at least one provisioning service was involved (with no RCS services), the number of trade-offs decreased with increasing geographical scale.

Crops[fish], as provisioning services, are an interesting case with respect to trade-offs. Although not a significant indicator of a trade-off in their own right, when coupled with a private interest, the involvement of crops[fish] increased the likelihood of a trade-off, but reduced the likelihood when there was no private interest. The main reason for this is that there are inherent trade-offs between resource returns and social equity (Halpern et al., 2011). The profits derived from many crops/provisioning services drives many of these changes, such as mangrove conversion to shrimp farming or forest logging and conversion to palm oil plantations, which result in trade-offs (Fisher et al., 2011; Gunawardena and Rowan, 2005; McNally et al., 2011). In many cases there are opportunities to combine crops[fish] with more ecological management approaches that create opportunities for synergies between provisioning and other services. However, a private interest in the crops[fish], with higher immediate and direct financial returns, means trade-offs often result (Rasul, 2009; Steffan-Dewenter et al., 2007). This can lead to a cycle of ecological degradation, such as in Lake Victoria where poor management has led to losses of both RCS and provisioning services (Swallow et al., 2009), or Indonesia where forest conversion and subsequent loss of pollination services has reduced coffee yields (Priess et al., 2007).

Another interesting result regarding crops, was that the observed pattern of relationships between crops and other ecosystem services was the same for both trade-offs and win-wins. This is likely to be because of the opportunities available to grow crops via more ecological management methods that create synergies between different ES, such as shade-coffee, agroforestry or wildlife-friendly farming (Goldstein et al., 2012; Power, 2010; Wade et al., 2010). As mentioned previously, whether these options are pursued or not, due to private interest and financial return, will determine whether a particular situation results in a trade-off or synergy.

4.3. Profiles of winners and losers of a trade-off across ecosystem services, their benefits and their uses

This study also explored the profile differences of winners and losers across different ES, the benefits derived and how they were ultimately used. A key finding was that different trade-off outcomes are observed within different categories (ES, benefit and use). When considering the ES being used, where winners utilised provisioning services (crops[fish], wood and water), there was an observed loss of RCS services (species and climate). Where the winner utilised provisioning services, there were relatively even losses across provisioning (food, timber, water) and RCS (aesthetic, wildlife, climate) benefits and across current (sale and consumption) or future uses (security, future, climate). In contrast, where the winner exploited RCS services, the loser lost provisioning services, provisioning benefits and current benefit uses.

This research highlights the different outcomes observed between ES, benefits and users (and it can be assumed, though unfortunately not testable, well-being). Exploring trade-offs at all intervals of the pathway from ES to wellbeing will be necessary to determine the fundamental consequences for human wellbeing that will result from trade-offs and synergies between different ES.

The importance of looking at trade-offs in detail at different scales, and by ES type is beautifully illustrated by both water and species. With respect to water, in many cases there is a direct trade-off between upstream and downstream users (Asquith et al., 2008; Barbier, 2011), with changes induced by agriculture upstream affecting downstream water quality and quantity (Gordon et al., 2010; Viglizzo and Frank, 2006). Where water was the ES studied, the loser often suffered from both a loss of water as well as additional, indirect or knock-on effects such as soil erosion leading to (future) loss of crops (Jack et al., 2009) or fast-growing, water demanding tree species leading to a loss of water in other parts of the ecosystem (German et al., 2009). The reason is that water is not simply used for drinking or irrigation, but has multiple uses such as for fisheries, plantations, soil quality and recreation, creating many opportunities for trade-offs to arise (Polasky et al., 2011; Sanon et al., 2012).

Where species were the overriding ES being utilised, there was often a loss of wood and (different) species on the other side of the trade-off. This was often the result of stakeholders with conservation/biodiversity interests holding greater power than stakeholders competing for other services (Eigenbrod et al., 2009; McElwee, 2010), and being able to restrict the access of the losers to co-located ES.

4.4. Defining the characteristics of a win-win

Although the absence of provisioning services reduces the probability of a trade-off occurring, presence of provisioning services does not reduce the probability of a win-win. Likewise, other indicators of a trade-off, such as private versus public interests and a local-scale actor, do not mean a trade-off is inevitable. In fact, stakeholder profiles do not appear to predict a win-win at all, and the differences between trade-offs and synergies are only visible when looking at the ES used, their benefits and uses.

When examining the examples of win-wins in greater detail, it appears that in many cases the reasons why they succeeded in creating synergies between different ES is that managers have avoided or overcome the reasons for why trade-offs arise, namely; failure to account for all benefits or stakeholders, failed management and an assumption that provisioning services should always dominate any other services. Improved cropland and grassland management, expansion of agro-forestry systems and protection of forested areas, potentially through the creation of riparian buffer zones (Branca et al., 2013; Goldstein et al., 2012; Gundersen et al., 2010) or switching to alternative crop systems such as legumes or shade-grown coffee, can all create win-win opportunities (Farber et al., 2006; Quintero et al., 2009).

It has also been demonstrated, that despite pre-conceptions to the contrary, the establishment of marine reserves or restoration of coastal ecosystems, such as nursery feeding grounds, even if they are less than the 'optimal size', can in fact have positive economic effects on industries such as fishing by building resilience (Cordier et al., 2011; Grafton et al., 2005). With respect to accounting for all stakeholders, a number of the papers reporting synergies attributed the synergies to creation of effective market mechanisms, including differentiated payment structures taking into account socio-economic differences between stakeholders (Daly-Hassen et al., 2010; Newton et al., 2012). The use of wood, in particular, provides many additional opportunities for win-wins due to the link to climate change mitigation activities (Branca et al., 2013; Goldstein et al., 2012). In some cases however, these synergies may come at the cost of trade-offs between ES within different parts of the system (Haase et al., 2012; Raudsepp-Hearne et al., 2010).

The findings of this study are in agreement with other papers that suggest that win-wins are the exception and not the rule. As a result of growing recognition that situations on the ground often involve competing, rather than complementary social, economic and ecological goals, it has been suggested that we must readjust our thinking away from win-wins towards a trade-offs perspective (McShane et al., 2011). Focusing on trade-offs can open the way to a more complete consideration of the variety of positive and negative effects associated with both conservation and development initiatives (Hirsch et al., 2011). It has also been suggested that frameworks such as the MA and 'Critical Ecosystems' can benefit from incorporating trade-offs thinking as it provides a natural link between local, regional and global planning scales (Faith and Walker, 2002), and between different ES providers and users.

5. Conclusion

This study demonstrates that there are still a large number of gaps in the literature, providing opportunities for further research geographically, by ES type and into the links between socio-economic factors and human well-being and ES. This supports similar calls in other papers, which suggests the need for a global analysis of trade-offs (Turner et al., 2012) and more targeted trade-offs research (Zhang et al., 2007). It has been suggested that ES analysts must move away from thinking of ES assessments as a decision-making tool and treat them more as a framework for understanding and analysing the nature-society relationship (Lele et al., 2013).

The outcomes of this analysis suggest that there are key indicators of whether or not a trade-off will occur: one or both of the stakeholders having a private interest in the natural resources available, competition between provisioning and non-provisioning ES and one or both of the stakeholders acting at the local scale. However, the presence of these indicators alone does not indicate that a trade-off is inevitable. Further, it is impossible to create a generalisable context for a win-win situation, though win-wins are more likely where the key reasons for why trade-offs occur (failure to account for all benefits or stakeholders, failed management and the assumption that provisioning services should always dominate) have been overcome.

Taken together, these results suggest that by combining an awareness of what situations may produce a trade-off with an understanding of why (and what) trade-offs result, it may be possible to generate win-win situations more regularly than currently observed. In fact by considering the trade-offs, as opposed to attempting to direct a win-win, it may be possible to create the synergies we seek to achieve.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.gloenvcha.2014.07.005.

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