NERC Open Research Archive
sharing our research

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Article (refereed) - postprint

Smith, A.C.; Harrison, P.A.; Pérez Soba, M.; Archaux, F.; Blicharska, M.; Egoh, B.N.; Erős, T.; Fabrega Domenech, N.; György, Á.I.; Haines-Young, R.; Li, S.; Lommelen, E.; Meiresonne, L.; Miguel Ayala, L.; Mononen, L.; Simpson, G.; Stange, E.; Turkelboom, F.; Uiterwijk, M.; Veerkamp, C.J.; Wyllie de Echeverria, V.. 2017. **How natural capital delivers ecosystem services: a typology derived from a systematic review**. *Ecosystem Services*, 26 (A). 111-126. 10.1016/j.ecoser.2017.06.006

© 2017 Elsevier B.V.

This manuscript version is made available under the CC-BY-NC-ND 4.0 license http://creativecommons.org/licenses/by-nc-nd/4.0/
(cc) BY-NC-ND

This version available http://nora.nerc.ac.uk/517273/

NERC has developed NORA to enable users to access research outputs wholly or partially funded by NERC. Copyright and other rights for material on this site are retained by the rights owners. Users should read the terms and conditions of use of this material at
http://nora.nerc.ac.uk/policies.html#access

NOTICE: this is the author's version of a work that was accepted for publication in *Ecosystem Services.* Changes resulting from the publishing process, such as peer review, editing, corrections, structural formatting, and other quality control mechanisms may not be reflected in this document. Changes may have been made to this work since it was submitted for publication. A definitive version was subsequently published in *Ecosystem Services*, 26 (A). 111-126. 10.1016/j.ecoser.2017.06.006

www.elsevier.com/

Contact CEH NORA team at
noraceh@ceh.ac.uk

The NERC and CEH trademarks and logos ('the Trademarks') are registered trademarks of NERC in the UK and other countries, and may not be used without the prior written consent of the Trademark owner.

How natural capital delivers ecosystem services: a typology derived from a systematic review

A.C. Smith[a,*], P.A. Harrison[b], M. Pérez Soba[c], F. Archaux[d], M. Blicharska[e,f], B. N. Egoh[g,h], T. Erős[i], N. Fabrega Domenech[j], Á. I. György[i], R. Haines-Young[k], S. Li[a], E. Lommelen[l], L. Meiresonne[l], L. Miguel Ayala[c], L. Mononen[m], G. Simpson[a], E. Stange[n], F. Turkelboom[l], M. Uiterwijk[c], C. J. Veerkamp[o,p] and V. Wyllie de Echeverria[a]

*Corresponding author Alison C. Smith, Alison.smith@eci.ox.ac.uk, tel 44 (0)7748 480211

[a]Environmental Change Institute, University of Oxford, Dyson Perrins Building, South Parks Road, Oxford OX1 3QY, UK.

[b]Centre for Ecology and Hydrology, Lancaster Environment Centre, Library Avenue, Bailrigg, Lancaster LA1 4AP, UK.

[c]Wageningen Environmental Research, Wageningen University & Research, P.O. Box 47, 6700AA Wageningen, The Netherlands.

[d]Irstea, UR EFNO, Domaine des Barres, F-45290 Nogent-sur-Vernisson, France.

[e]Department of Aquatic Sciences and Assessment, Swedish University of Agricultural Sciences, Box 7050, 750 07 Uppsala, Sweden.

[f]Department of Earth Sciences Uppsala University, Villavägen 16, 75 236 Uppsala, Sweden.

[g]Council for Scientific and Industrial Research, Natural Resources and the Environment, PO Box 320, Stellenbosch 7599, South Africa.

[h]School of Agricultural, Earth and Environmental Sciences, University of KwaZulu-Natal, 27 27 Private Bag X01, Scottsville 3209, South Africa.

[i]MTA Centre for Ecological Research, Klebelsberg K. u. 3., H-8237 Tihany, Hungary.

[j]University of Nottingham, Nottingham, NG7 2RD, UK.

[k]European Commission Joint Research Centre, Institute for Environment and Sustainability (JRC-IES), Italy

[l]Research Institute for Nature and Forest (INBO), Kliniekstraat 25, 1070 Brussels, Belgium.

[m]Finnish Environment Institute, SYKE, Mechelininkatu 34, PO Box 140, FI-00251 Helsinki.

[n]Norwegian Institute for Nature Research – NINA, Fakkelgården, Vormstuguvegen 40, NO-2624 Lillehammer, NORWAY.

[o]Environmental System Analysis Group, Wageningen University, PO Box 47, 6700AA Wageningen, The Netherlands.

[p]PBL Netherlands Environmental Assessment Agency, PO Box 30314, 2500 GH Den Haag The Netherlands.

Abstract

There is no unified evidence base to help decision-makers understand how the multiple components of natural capital interact to deliver ecosystem services. We systematically reviewed 780 papers, recording how natural capital attributes (29 biotic attributes and 11 abiotic factors) affect the delivery of 13 ecosystem services. We develop a simple typology based on the observation that five main attribute groups influence the capacity of natural capital to provide ecosystem services, related to: A) the physical amount of vegetation cover; B) presence of suitable habitat to support species or functional groups that provide a service; C) characteristics of particular species or functional groups; D) physical and biological diversity; and E) abiotic factors that interact with the biotic factors in groups A-D. 'Bundles' of services can be identified that are governed by different attribute groups. Management aimed at maximising only one service often has negative impacts on other services and on biological and physical diversity. Sustainable ecosystem management should aim to maintain healthy, diverse and resilient ecosystems that can deliver a wide range of ecosystem services in the long term. This can maximise the synergies and minimise the trade-offs between ecosystem services and is also compatible with the aim of conserving biodiversity.

Keywords

Biodiversity; functional diversity; trait; attribute; trade-offs; land management.

1 Introduction

Natural capital is the elements of nature that directly or indirectly produce value for people, including ecosystems, species, freshwater, land, minerals, air and oceans, as well as natural processes and functions (Mace et al., 2015; Potschin et al., 2016). It thus comprises both biotic components (living organisms and non-living biotic matter such as leaf litter) and abiotic components (rocks, minerals, air, water). These components interact to deliver the ecosystem services that are vital to human wellbeing, sometimes with additional input from social, human, financial or manufactured capital assets (Biggs et al. 2015; Palomo et al. 2016; Reyers et al. 2013).

It is more than ten years since the Millennium Ecosystem Assessment revealed that 60% of ecosystem services were at risk due to unsustainable use (MA, 2005), yet the stocks of natural capital from which these services flow are still shrinking due to habitat degradation and species loss (Costanza et al., 2014). Decision-makers in policy, practice and business are increasingly aware of the need to manage natural capital sustainably, but they lack suitable tools and evidence to enable them to assess the impact of different management decisions (Guerry et al., 2015; Maseyk et al., 2017). In particular, there is a lack of understanding on how the biotic and abiotic attributes of natural capital influence the capacity of ecosystems to supply different services (Maseyk et al., 2017).

There is also considerable debate over the compatibility of the ecosystem services approach with the goals of biodiversity conservation. The ecosystem services approach offers opportunities to develop broader constituencies for conservation and to expand possibilities to influence decision-making (Haslett et al., 2010; Ingram et al., 2012; Reyers et al., 2012), as well as adding new value to protected areas (García Llorente et al., 2016), and promoting sustainable management of ecosystems outside of protected areas (Haslett et al., 2010). Various studies have demonstrated a certain degree of spatial congruence between areas that have high biodiversity and those that have high potential to deliver ecosystem services (e.g. Egoh et al., 2009; Maes et al., 2012; Strassburg et al., 2010) or shown that land use scenarios that favour biodiversity conservation can also benefit ecosystem service provision (e.g. Nelson et al., 2009). However, there is growing concern that focussing on the provision of benefits for humans may conflict with conservation priorities (Schröter et al., 2014) and that win-wins for people and wildlife are hard to achieve in practice (McShane et al., 2011). A focus on single ecosystem services may result in additional exploitation of ecosystems, e.g. for provision of food or timber; rare or endemic species that are of high conservation interest may have no obvious value for ecosystem service provision; and it may seem that ecosystem services can be delivered adequately by areas with very limited biodiversity value (Ingram et al., 2012).

In order to design management strategies that can deliver the multiple ecosystem services required to sustain quality of life for people at the same time as maintaining healthy and diverse ecosystems with space for wildlife, in line with the Sustainable Development Goals, we need to understand:

i. what natural capital attributes are important for delivering different services, including both biotic attributes and abiotic factors;
ii. what are the potential synergies or trade-offs between different bundles of services;
iii. what management strategies can deliver benefits for multiple ecosystem services and minimise conflicts between different priorities?

This knowledge is critical to inform the sustainable long-term management of natural resources, to manage trade-offs and synergies between different services, and to design ecosystem management strategies that are compatible with the goals of biodiversity conservation (Mace et al., 2012).

There is evidence on the links between natural capital attributes and ecosystem services in the scientific literature, but it is highly fragmented. A systematic review by Harrison et al. (2014) that searched for links between 11 ecosystem services and 28 biotic natural capital attributes found 530 individual studies, but most of these focus on just one service and only a few natural capital attributes, most commonly habitat area, species abundance or species richness. Similar reviews have made useful advances but they often focus mainly on the natural capital attributes that are related to biological diversity, such as species richness or functional diversity, neglecting other attributes such as species abundance or habitat area (e.g. Balvanera et al., 2014; Cardinale et al., 2012; Cimon-Morin et al., 2013; Lefcheck et al., 2015); or cover a smaller range of ecosystem services (Balvanera et al., 2014; Ricketts et al., 2016); or focus on a particular case study context (Bastian, 2013) or ecosystem type (Isbell et al., 2011).

The review by Harrison et al. (2014) increased our understanding of how ecosystem service delivery is governed by a variety of biotic attributes such as the area of specific habitats, the abundance of particular species and the diversity of functional traits. However, it also identified the need to extend coverage to include further ecosystem services, to fill in knowledge gaps, to address interactions between services (synergies and trade-offs), and to gather information on the influence of ecosystem condition, especially on the existence of any thresholds beyond which service delivery could be compromised. In addition, although Harrison et al. (2014) demonstrated the complexity of the patterns of links between multiple natural capital attributes and ecosystem services, there is still a need for a simpler framework to enable the knowledge synthesised by the review to be applied in practice by land use managers and other decision-makers.

This study therefore builds on the work of Harrison et al. (2014), updating and extending it significantly to cover 13 ecosystem services, including new research carried out since the review date of 2012, and recording new evidence on: (i) the influence (positive, negative or mixed) of both biotic attributes and abiotic factors on service delivery; (ii) the effect of ecosystem condition on service delivery; (iii) the presence of any thresholds; (iv) the impact of human management and policies on ecosystem service delivery; and (v) qualitative or quantitative information on synergies or trade-offs between services.

This study aimed to:

- build a coherent database that identifies the structural and functional factors (natural capital attributes) that link natural capital stocks to ecosystem service flows in different contexts, thus increasing understanding of the biophysical control of ecosystem services;
- evaluate the feasibility of detecting possible thresholds where further biodiversity loss would severely compromise ecosystem functioning and service delivery;
- develop a simple typology for understanding and classifying the links between natural capital and ecosystem service delivery, to help reduce complexity and to guide the application of the ecosystem service approach in research, policy and practice for sustainable land, water and urban management;
- apply the results of the review to explore whether the ecosystem services approach is compatible with conservation objectives, especially regarding the impact of biological diversity on service delivery.

2 Method

The review covers a representative selection of the most commonly studied ecosystem services: four provisioning services (freshwater fishing; timber production; food crop production; water supply), seven regulating services (air quality regulation; atmospheric regulation via carbon sequestration; mass flow regulation via erosion protection; water quality regulation; water flow regulation via flood protection; pollination; pest regulation) and two cultural services (species-based recreation and aesthetic landscapes).

The search conformed to the methodology developed during the BESAFE project (Harrison et al., 2014). The search protocol used a standard set of terms to cover the biotic attributes of interest (e.g. “richness”, “trait”, “habitat”), plus a set of keywords specific to each ecosystem service (e.g. “carbon storage”). This strategy usually returned thousands of articles, many of which were not relevant – for example, many dealt with the impact of activities such as fishing or crop production on natural capital, rather than the other way round. Additional service-specific terms were therefore used if necessary to refine results. The full list of search terms is presented in Appendix A of the Supplementary Material.

The search was carried out using Web of Science and covering articles published up until the end of June 2014. Web of Science was chosen because it provides full coverage of the relevant journals across many different disciplines, and because it is possible to enter complex search strings.

Because of the large number of results returned, the analysis for each service was restricted to the first 60 articles that met the study criteria when the search results were ordered in terms of relevance according to the keyword search string used in the Web of Science search engine, making a total of 780 articles. For services where the hit rate for relevant articles was low, the search was supplemented by snowballing (examining the reference lists of the most relevant articles) and reverse snowballing (looking for articles that cite the most relevant articles).

Each article reviewed was analysed in detail and the following information was recorded in a database:

- the ecosystem service covered;

- the location of the study (geographical co-ordinates and place name);
- type and condition of ecosystems, including whether they are actively managed;
- the main ecosystem service provider (ESP): this can be an entire community or habitat (such as a forest or lake); a functional group (such as pollinating insects); or one or more individual species;
- the biotic attributes that affect service delivery, and their direction of influence (positive, negative, both or unclear) (see Appendix B of the Supplementary Material for a full list);
- the abiotic factors which affect service delivery, and their direction of influence see Appendix B of the Supplementary Material for a full list);
- the indicators used to assess the level of service provision (see Appendix C of the Supplementary Material)
- any qualitative or quantitative information on interactions between different ecosystem services, and the direction of interaction;
- any qualitative or quantitative information on human input and management, and its direction of impact;
- any evidence for thresholds or tipping points.

We also recorded other information including the spatial and temporal scale of the study and the type of evidence presented in the paper. However these are not discussed in this paper, which focuses on the biotic and abiotic attributes, the interactions between ecosystem services and the impact of any human input or management.

The 13 ecosystem services were allocated across a team of 16 reviewers according to their expertise. This large number introduced the potential for inconsistency between different reviewers, so a final quality check of the database entries across all services was undertaken by a single reviewer.

In order to gain a full understanding of the factors linking natural capital attributes to ecosystem service delivery, the scope of the review was very wide, covering 29 biotic attributes, 11 abiotic factors and 13 ecosystem services. The studies reviewed included a wide range of experimental and observational approaches and used many different indicators (see Appendix C in the Supplementary Material). It was therefore necessary to use a vote-counting approach, because meta-analysis was not possible for such a diverse dataset using so many incompatible indicators and approaches.

The database was analysed by generating descriptive statistics based on the frequency of citations related to different biotic attributes and abiotic factors, and their direction of influence. This analysis was performed across all services and also individually for each service. Network diagrams were created for each ecosystem service to illustrate the links with abiotic factors and biotic attributes. In these diagrams, generated with the Pajek software, the thickness of the lines is proportional to $n^{0.1}$ where n is the number of papers supporting the existence of a link (including unclear links). The colour of the lines refers to the predominant direction of the links, with dark red or green indicating where all papers support a negative or positive link respectively, and light red or green indicating where the link is “mostly negative” or “mostly positive”, i.e. at least one paper supports the opposite direction. Grey indicates either that all links are unclear, or that there are equal positive and negative links (‘neutral’). In these diagrams we group the attributes into the following categories.

- Habitat: community or habitat characteristics such as type, area, successional stage, biomass and stem density. Community structure is included under ‘diversity’ (see below).

- Species or functional group: characteristics such as type, abundance and species size or behaviour.
- Diversity: biological (species richness, functional diversity etc.) and physical (landscape diversity and community/habitat structure, which generally refers to structural diversity).
- Population dynamics: mortality rate, natality rate, life span and population growth rate. These attributes can be related to particular species but are also partly influenced by environmental conditions and human activity. They may affect many of the attributes in the other categories.
- Other (attributes appearing in the literature but not pre-defined in the review database).

These categories form the primary nodes in the network diagrams, and the individual attributes form the secondary nodes. Similar diagrams were also created to summarise the pattern of evidence for positive and negative interactions between different ecosystem services.

In all these network diagrams, the line thickness indicates only the number of papers citing the existence of a link: this is not necessarily equivalent to the strength or importance of the link. The absence of a link, or a thin line, does not necessarily mean that no link exists, but that there is currently no evidence or only weak evidence for such a link in the literature base.

Visual examination of the network diagrams and the tabulated results of the review enabled the researchers to develop a simple typology for classifying the ways in which natural capital supports ecosystem services.

3 Results

3.1 Links between natural capital attributes and ecosystem services

The literature reviewed is dominated by evidence on the positive influence of natural capital attributes on ecosystem services (Table 1a) with few examples of negative influence (Table 1b). Of the 2607 links identified in the 780 studies, 73% are positive, 9% are negative, 7% show both positive and negative impacts, and for 11% the direction of influence is unclear. The red lines in Table 1b highlight the two most commonly cited negative influences, in the column for mortality rate — often as a result of human activity that leads to degradation of ecosystems — and the row for water supply, where timber plantations can reduce supply in water-scarce regions (see section 3.1.4).

Community/habitat area is the attribute that is most often found to influence service provision, in 37% of studies (Figure S1, Supplementary Material). This reflects the large number of studies that focus mainly on the size of the area covered by an ecosystem, such as studies on the relationship between forest area and flood risk. Of the other habitat-related attributes, habitat type and structure are each cited in 31% of studies. A link to the presence of a specific species is found in 34% of studies, and a link to species abundance in 17% of studies. The most commonly cited species-specific attribute is size/weight (in 13% of studies). The presence and abundance of specific functional groups (such as ‘trees’ or ‘pollinators’) is found to be significant in 21% and 11% of studies respectively. Of the diversity-related attributes, a link to species richness is found in 30% of studies. Functional diversity and functional richness are investigated less often, but are found to be important in 9% and 6% of studies, respectively. Some attributes, including sapwood amount (0.5%), wood density (1%) and natality rate (1.3%), are mentioned very rarely.

The literature search focused on biotic attributes, but we also recorded the impact of any abiotic factors that are mentioned in the articles. Abiotic factors can affect service delivery directly (e.g. through the role of precipitation in improving water supply) or indirectly, by affecting the condition of the ecosystem. A range of factors are found to influence service provision, with precipitation, soil type and temperature being the most frequently cited, but the direction of impact is variable and highly dependent on the context (Figure S2, Supplementary Material). For example, heavy precipitation may reduce the ability of ecosystems to provide flood protection if the ground becomes saturated, but lack of precipitation may lead to forest dieback which will reduce provision of flood protection and many other services. Note that soil type, geology and 'other' are categorical rather than quantitative variables so it was not meaningful to record the direction of impact, and these impacts are therefore all recorded as 'unclear'.

The breakdown of positive and negative links for each ecosystem service (see Table 1 for biotic factors; Tables S1 and S2 for abiotic factors) reveals some interesting patterns. Bundles of ecosystem services can be identified, which are influenced by different broad groups of natural capital attributes (Figure 1). In this section we present an overview of the main findings, which leads to the development of a simple typology for classifying the links. This is underpinned by more detailed descriptions and network diagrams for each service, which are presented in the Supplementary Material (Figures S3 to S15). Further details are available in a technical report (Perez-Soba et al., 2017).

Figure 1: Network diagram mapping the evidence on how groups of biotic attributes and abiotic factors influence bundles of ecosystem services. Line thickness is proportional to number of studies supporting each link and line colour indicates predominant direction of link. For abiotic factors the links are all shown as neutral because the direction of influence is highly context-dependent. When interpreting line thickness, note that the bundles contain different numbers of services (the air, water and soil bundle contains five services; pollination and pest regulation and food and timber provision contain two services; the rest contain only one service).

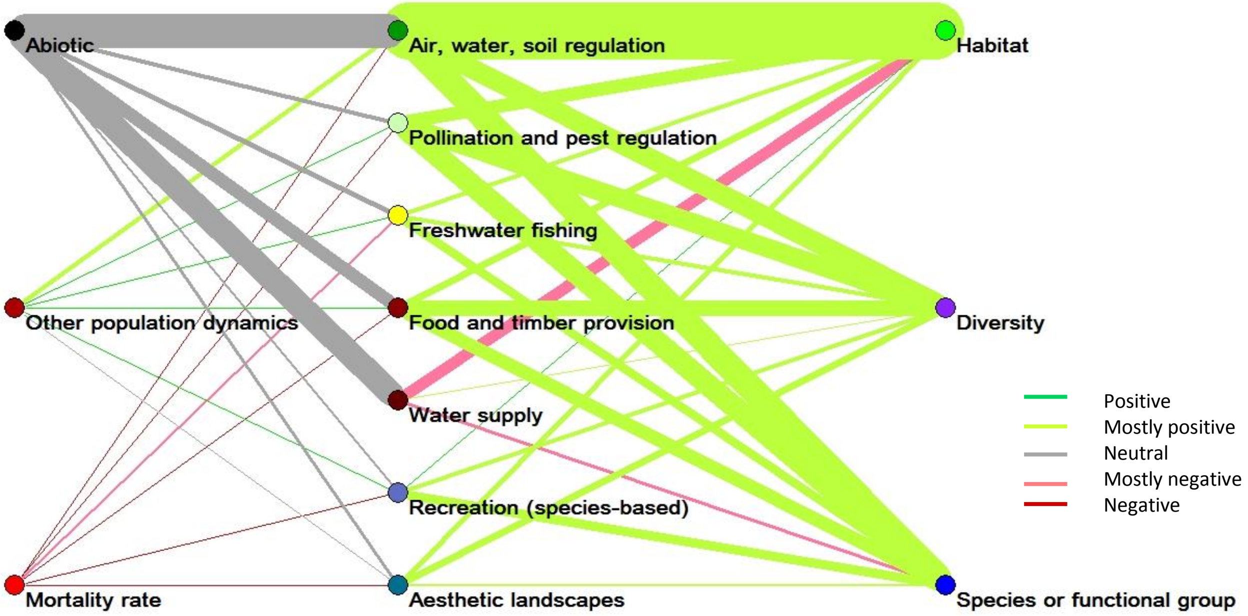


Table 1a: Number of studies showing a positive link (not including mixed or unclear) between an ecosystem service and a specific biotic attribute. More frequently cited links are highlighted in darker shades of green. Total number of studies reviewed for each service = 60.

	Community / habitat										Diversity					Specific species or functional group										Population dynamic				
	Presence of a specific community/habitat	Community/habitat area	Community/habitat structure	Community/habitat/stand age	Successional stage	Primary productivity	Aboveground biomass	Belowground biomass	Stem density	Litter/crop residue quality	Landscape diversity	Species richness	Functional richness	Functional diversity	Species population diversity	Presence of a specific functional group	Abundance of a specific functional group	Presence of a specific species type	Species abundance	Species size/weight	Wood density	Sapwood amount	Leaf N content	Flower-visiting behavioural traits	Predator behavioural traits (biocontrol)	Population growth rate	Life span/longevity	Natality rate	Mortality rate	Other biotic
Air quality regulation	5	27	4	1		2	5		1			4	1	1	1	12	3	15	2	9							1			18
Atmospheric regulation	12	17	14	18	8	9	35	25	2	6		16	2	8	5	6	8	15	4	12	6		1			8	2			1
Water flow regulation	5	41	21	10	2		1	2		2						4	3	3	1	3						1				1
Mass flow regulation	34	31	28	5	8	1	11	21	8	14		7	3	7		22		20	1	3						7				1
Water quality regulation	40	37	8	3	1	3	5	5	4	3		6	1	3	2	7	4	17	6	6						1				
Pollination	22	15	19						1		8	25	10	11	7	32	21	17	20	3				15						4
Pest regulation	17	20	22	1	2	1	2		1	5	5	9	8	7	1	10	13	4	11	1					11	3	2	2		5
Freshwater fishing	12	12	10		1	6	1			2	5	8	1	1	4	4	2	16	17	21			1			6	1	2	1	
Timber production	1		7	2	1	1	2		7	3		35	5	9		6		18	7	4		1	6			2				
Food production (crops)	1	4	2				11	8		10	1	35	4	5	11	23	9	19		1			10			7				
Water supply	8	7	5	2	1			2	1	1		1			1	2		1		1										1
Recreation (species-based)	4	3										18	1	3	10	7	5	43	15	10								2		6
Aesthetic landscapes	26	7	34	2	1		1		2		7	8		2		1		5	2	3										3

Table 1b: Number of studies showing a negative link (not including mixed or unclear) between an ecosystem service and a specific biotic attribute. More frequently cited links are highlighted in darker shades of red. Total number of studies reviewed for each service = 60. Red lines highlight that most of the negative impacts are related to mortality rate and water supply.

	Community / habitat										Diversity					Specific species or functional group										Population dynamic				
	Presence of a specific community/habitat	Community/habitat area	Community/habitat structure	Community/habitat/stand age	Successional stage	Primary productivity	Aboveground biomass	Belowground biomass	Stem density	Litter/crop residue quality	Landscape diversity	Species richness	Functional richness	Functional diversity	Species population diversity	Presence of a specific functional group	Abundance of a specific functional group	Presence of a specific species type	Species abundance	Species size/weight	Wood density	Sapwood amount	Leaf N content	Flower-visiting behavioural traits	Predator behavioural traits (biocontrol)	Population growth rate	Life span/longevity	Natality rate	Mortality rate	Other biotic
Air quality regulation							1									1													2	3
Atmospheric regulation			1				2					1		1				2									1		8	1
Water flow regulation	1	3		1					1							1		1	3	1										
Mass flow regulation	1		1	1	2											2		2		2										
Water quality regulation				2	1					1							1	1		2			1							
Pollination		1																2	2											
Pest regulation			2				1																1						2	1
Freshwater fishing												1						1		1									14	
Timber production			1		3				4			5	1	2		3	1												2	
Food production (crops)								1				1				1		2											1	
Water supply	20	26		12			2	2	9	1						5	1	10		2		2				5				1
Recreation (species-based)												2			1				5										5	
Aesthetic landscapes			1															1	1										1	

3.1.1 Air, soil and water regulation

There is a bundle of five services related to air, soil and water regulation (Figures S3 to S7). For three of these services — atmospheric regulation (carbon storage), water flow regulation (flood protection) and water quality regulation — the literature is dominated by studies focusing on entire habitats. Often two or more habitats are compared, e.g. forest and grassland, or natural forest and plantation. Typically the studies find that the service is related to the amount of vegetation cover and the quantity of biomass per unit area, so forests tend to offer a higher level of service than shrubland or grassland, and the service increases in forests with older and larger trees. For example, larger trees store more carbon and intercept and absorb more water, and larger plants trap or absorb more pollution from water. For water flow regulation, 41 out of the 60 studies reviewed focus mainly on the role of habitat area, typically in 'paired catchment' studies which compare two similar catchments with different forest cover, or the same catchment before and after felling. For atmospheric regulation and water quality regulation, a wider range of habitat and species attributes are found to play a role, including above and below-ground biomass, stand age, species size, stem density, successional stage, growth rate and wood density.

For air quality regulation and mass flow regulation (erosion control), the pattern is slightly different. Habitat attributes are still influential, with the area covered by vegetation being crucial, but so are species characteristics. Many studies compare different species of tree, shrub or herbaceous plants to determine which perform best for stabilising eroded slopes or trapping air pollution. For mass flow regulation, functional characteristics such as root depth, strength, density and structure are often found to be important for binding soil particles together and increasing soil infiltration (e.g. de Baets et al., 2009; Pohl et al., 2012). The structure, strength and elasticity of the above-ground vegetation is also important for intercepting rainfall, resisting water flow and trapping sediment, and the thickness and quality of the litter layer plays a key role in improving soil structure and protecting the soil surface from erosion (e.g. Andry et al., 2007). For air quality regulation, species characteristics such as leaf size, shape (needle or broad-leaved), stickiness and hairiness are also often investigated. Most articles conclude that coniferous trees are more effective at trapping pollution because their needle-shaped leaves have a high surface area, and because they are mainly evergreens and therefore can contribute to air quality all year round (e.g. Tallis et al., 2011). However, they may not be tolerant of high roadside pollution levels and salt from road run-off, so might not be appropriate for the 'front-line' positions immediately next to busy roads (Saebo et al., 2012).

Physical and biological diversity can enhance three of these services: carbon storage, water quality regulation and mass flow regulation. This is typically related to resource-use complementarity, where more diverse assemblages (e.g. with a range of canopy heights, root depths or photosynthetic responses) are more productive because they can exploit more of the available resources such as nutrients, water and sunlight (e.g. Cadotte, 2013; Cardinale et al., 2011; Lang'at et al. 2013). As these services tend to improve with the amount of biomass, a more productive ecosystem will tend to provide a better service. However, sometimes a less diverse mix of high-performing species (e.g. large trees for carbon storage, or pollution-tolerant reeds for water quality regulation) can be more productive or provide a better service (e.g. Ahmad et al., 2014; Cavanaugh et al., 2014). In contrast, diversity is rarely mentioned for air quality regulation, and water flow regulation is the only service for which no biological diversity attributes are studied in the literature reviewed. However, physical diversity in the form of structural complexity ('roughness') is found to increase protection against storm surges in coastal vegetation (Mazda et al., 1997; Ferrario et al., 2014) and to increase floodwater retention in floodplain woodlands (Thomas and Nisbet, 2006).

Most of the links cited in the literature have a beneficial effect, but three studies find that species abundance has a negative impact on flood protection as a result of invasive species (mangrove, willow or tamarisk) reducing river channel capacity and trapping sediment (Lee and Shih, 2004; Erskine and Webb, 2003; Zavaleta, 2000).

For the abiotic factors, the pattern varies considerably. Although rarely mentioned for carbon storage and water quality regulation, they are found to play an important role in the other services. Precipitation and slope have a direct negative impact on flood protection and mass flow regulation, as most erosion occurs during extreme rainfall events and on steep slopes. However, water availability has a beneficial impact as water is necessary for vegetation to become established, thus stabilising and protecting the slope. Drought conditions therefore often lead to more intense soil erosion. For air quality regulation the impacts of abiotic factors are complex and context-dependent. Wind can have a beneficial effect locally by dispersing pollution away from city streets or increasing deposition rates on leaves, but it can also re-suspend deposited particles (Nowak et al., 2006). High temperatures can decrease uptake of pollutants by plants (Alonso et al., 2011) and may also have a negative impact because certain tree species emit biogenic volatile organic compounds (B-VOCs) such as isoprene in hot weather, and these react with nitrogen oxides from traffic to form ground-level ozone pollution (Salmond et al., 2013). However, there can also be a beneficial effect in the range where warmer temperatures enhance plant growth, thus increasing the amount of vegetation that can trap pollutants.

3.1.2 Pollination and pest control

For pollination and pest regulation (Figures S8 and S9), studies tend to focus on the presence and abundance of the particular species or functional groups such as bees, butterflies, beetles, wasps or bats that provide the service. Species behaviour, i.e. flower-visiting or pest predation traits, is often cited as being important. For example, traits such as foraging distance, flight range, pollinator size and bee tongue length determine which pollinators can access certain flowers (e.g. Bommarco et al., 2011). Diversity (species richness) is also found to be important because a mix of pollinators of different shapes and sizes can provide a better landscape-level pollination service, and a mix of pest predators can target a larger range of pests, or pests at different life cycle stages (e.g. Badano and Vergara, 2011; Casulo et al., 2013; Garibaldi et al., 2014; Hoehn et al., 2008; Munyuli, 2013).

However, these services generally could not exist without the presence of the surrounding natural or semi-natural habitat to support the species providing the service, especially by providing food and shelter to beneficial insects after crops have been harvested. Habitat area is often found to be positively linked to the services of pollination and pest control, and the provision of these services tends to decline as the distance to natural habitat increases (e.g. Carvalheiro et al., 2010; Garibaldi et al., 2011). More diverse habitats support higher abundance and diversity of beneficial species, so vegetation species richness, structural diversity and landscape diversity are correlated with pollination and pest regulation efficiency (e.g. Daghela Bisseleua et al., 2013; Holzschuh et al., 2012; Rusch et al., 2013). The impact of abiotic factors on these services is rarely studied.

3.1.3 Food crops, fish and timber provision

For provision of fish, timber and food crops (Figures S10, S11 and S12), the service depends strongly on the existence of particular species that have favourable characteristics, such as palatability for food crops and fish, or straight growth habits for timber, as well as ease of cultivation. However, diversity also plays an important role: species richness is the most frequently cited attribute for food and timber production. This is not richness in the familiar sense of a diverse natural ecosystem (and indeed the term richness is not generally used in the literature reviewed), but the use of a relatively small number of species in practices such as intercropping and crop rotation for food crops, and mixed-species plantations for timber production. The principle is that co-production of species that exploit different resource niches can maximise yield. This is also observed for freshwater fishing, both in natural ecosystems and in aquaculture ponds or managed lakes stocked with mixed species of fish (e.g. Carey and Wahl, 2011; Lapointe et al., 2014; Rahman et al., 2008; Schindler et al., 2010). For food crops, intra-species genetic diversity (e.g. growing cultivar mixes) is often found to improve productivity or resilience; this is classified as species population diversity in our review.

For food crops, the benefit of diversity is often linked to co-cultivation with a leguminous crop that fixes nitrogen from the air, indicated by the attribute of ‘Leaf N content’. For example, Smith et al. (2008) find that corn yields are over 100% higher with a three crop rotation including soy. However, negative impacts of crop diversity can arise due to competition for resources. Bayala et al. (2012) find that alley cropping grain with some tree species in the West

African drylands causes a decrease in yield due to shading, but using the *Faidherbia albidia* tree improves average yield because this species sheds its leaves during the rainy season.

Although polycultures and cultivar mixes often out-perform monocultures, there are also cases where the presence of a particular high-performing species or variety is cited as being important. For example, Cowger and Weisz (2008) find that it is necessary to include at least one high-yielding variety in wheat cultivar blends in the eastern USA. For food crop production, 48 out of the 60 studies find positive impacts of diversity, four find mixed impacts, five find unclear impacts and only one finds purely negative effects (Schroth and Lehmann, 1995, in their study of alley-cropped maize). The other two studies do not examine the impact of diversity. For timber production, 35 studies find that polycultures out-yield monocultures but five studies find the opposite.

Diversity is also cited as playing an important role in improving resistance to pests and diseases, and providing resilience to changing climatic conditions. For example, Hauggaard-Nielsen et al. (2008) find that intercropping legumes and barley reduces the incidence of barley disease by 20–40% compared to sole-cropping, and also suppresses weeds. Enhanced crop diversity can boost populations of natural pest and weed seed predators (Liebman et al., 2013), and the improved robustness and productivity also allows the use of agrochemicals to be reduced, which decreases production costs and provides further environmental benefits (e.g. Davis et al., 2012; Smith et al., 2008; Zhu et al., 2000). Even if more diverse systems do not provide higher yields in the short term, they can provide stability to changing conditions and reduce risk to producers in the long term (Smithson and Lenne, 1996). The evidence applies not just to field-scale studies but also to agro-biodiversity at the landscape level. Chavas and di Falco (2012) estimate that regional-scale crop diversity in Ethiopia boosts the productivity of Teff, the staple grain, by 65%.

Abiotic factors are cited as having important impacts on yield for food, fish and timber provision. For food production, for example, nutrient availability and water availability have mainly positive impacts but temperature and precipitation can have either a positive or negative impact depending on the context; they may improve crop growth, but crops are also susceptible to extremes of heat or cold and to waterlogging and storm damage.

3.1.4 Water supply

Water supply (Figure S13) is more similar to the regulating services than to the other provisioning services discussed here, because it depends largely on the entire community/habitat area rather than on species characteristics. However, in contrast to the other ecosystem services, the impact of biotic attributes is often negative. Although the interception of rainwater and absorption of groundwater by forests is beneficial for flood protection, as described above, it can also reduce water supply, which can cause problems where water is scarce. Most (42 out of 60) of the articles reviewed describe the negative effects of forests on water supply in water-scarce countries such as Australia and South Africa, although these are typically timber plantations of fast-growing non-native species such as pine or eucalyptus. Community/habitat area, presence of a community/habitat (forest), and stand age all tend to have negative impacts, as older/larger trees use more water (e.g. Nosetto et al., 2005), although Cavaleri and Sack (2010) found that forests used more water at earlier successional stages due to faster growth. Similarly, higher stem density and higher sapwood area can increase water use (Kagawa et al., 2009), and harvesting and thinning are found to significantly increase runoff and therefore increase provision in many studies (e.g. Petheram et al., 2002; Sahin and Hall, 1996).

In natural forests, in contrast, seven studies find beneficial impacts on water supply, with four showing how cloud forests intercept water from the air (e.g. Gomez-Peralta et al. 2008, Brauman et al. 2010) and three showing how forests can increase water yield by improving infiltration and soil water storage capacity (e.g. Singh and Mishra, 2012). Some studies show that native forests consume less water than pine plantations (Rowe and Pearce, 1994; Komatsu et al., 2008).

For the abiotic factors the situation is largely reversed compared to the service of flood protection, with precipitation and water availability having positive impacts and evaporation (i.e. transpiration) negative impacts.

3.1.5 Cultural services

Species-based recreation and aesthetic landscapes were reviewed as examples of cultural services. These show very different relationships between natural capital attributes and the service delivered.

For species-based recreation (e.g. wildlife viewing, hunting or fishing) the most frequently cited biotic attributes are the presence and abundance of specific species (Figure S14). These include charismatic species such as whales and dolphins for marine eco-tourism; rare birds or large mammals such as lions, tigers and elephants for land-based eco-tourism; game species such as deer for hunting; and fish such as salmon and trout for recreational fishing. Species size or weight can be significant, with visitors, fishermen and hunters often expressing a preference for larger species such as sharks and lions. Species richness and diversity are also valued by visitors. For example, Lindsey et al. (2007) find that tourists in South Africa consider functional group diversity (in this case, the variety of large mammals) to be the most important feature of their wildlife viewing experience, and Ruiz-Frau et al. (2013) find that marine biodiversity is important for scuba divers. Clearly the presence of suitable habitat to support the species of interest is important, but this is rarely addressed in the literature — possibly because many of the studies are set in protected areas where the existence of the supporting habitat may be taken for granted to some extent. There are five cases where species abundance is negatively linked to the service of species-based recreation (Table 1b) because, somewhat ironically, nature-watchers often place a higher value on rare species. Abiotic factors are rarely mentioned.

For aesthetic landscapes (Figure S15) the presence of a particular habitat is cited in 30 of the 60 papers, with forests and water features being most often mentioned, as well as urban trees and green space (e.g. Kaplan, 2007). Habitat structure is the most frequently cited attribute, with the term ‘structure’ being interpreted as covering a broad range of characteristics including landscape diversity and complexity, vegetation density, naturalness and uniqueness. Many studies find a preference for wilder, more complex, more natural landscapes (e.g. Acar and Sakici, 2008; Heyman, 2012; Daniel et al., 2012), especially in developed countries, but some cultural groups may prefer more open, managed landscapes with man-made elements. Abiotic attributes that are positively correlated with aesthetic appreciation are the presence of water (lakes and rivers) and steep slopes, which add interest and variety to the landscape.

3.2 Typology of links between natural capital attributes and ecosystem services

The information presented in section 3.1 and Table 1 enables identification of five pathways by which natural capital attributes influence the delivery of different bundles of ecosystem services (see Figure S17, Supplementary Material, for an indication of how the pathways are derived from the information in Table 1).

A. **Amount of vegetation**. The air, soil and water regulating services — air quality, atmospheric regulation, water flow, mass flow and water quality — are governed mainly by a group of biotic attributes related to the physical amount of vegetation within an ecosystem. These services all tend to improve as the vegetated area increases, or as the density of the above- and below-ground vegetation increases. Attributes such as community/habitat type and area, structure, stand age, successional stage, stem density and above- and below-ground biomass control the provision of these services. For the service of water supply, these attributes all tend to have a negative impact.

B. **Provision of supporting habitat**. For services that rely on particular animal species — pollination, pest regulation and freshwater fishing — the existence of suitable habitats to support those species is found to be important: natural or semi-natural habitats surrounding crops to support pollinators and predators after the crop is harvested, and suitable aquatic habitats with the right ecological, hydrological and climatic conditions to support fish through all stages of their life cycle. Community type, area and structure are therefore often correlated with these services. It is likely that supporting habitat is equally important for the service of species-based recreation, but this does not emerge strongly in the literature reviewed. As a sub-division of this category, habitat type is also important for providing aesthetic value to humans.

C. **Presence of a particular species, functional group or trait**. The presence of particular species is found to be important for most services, especially species-based recreation and the provision of fish, timber and food. Specific functional groups are cited as being important for some services: these include groups of pollinators and pest predators such as bees and wasps, and also, for air quality and mass flow regulation, functional groups of plants such as large-leaved vs small-leaved trees or deep vs shallow-rooted shrubs. A range of species-specific attributes are positively correlated with service supply, including species size for fishing, species-based recreation and carbon storage; and species behaviour for pollination and pest regulation.

D. **Biological and physical diversity**. Biological diversity, reflected in the attributes of species and functional richness, functional diversity and (for food crops) intra-species population diversity, is often positively correlated with timber, food and fish production due to resource-use complementarity (section 3.1.1) or inter-species facilitation such as nitrogen fixation from the atmosphere by leguminous plants (section 3.1.3). Species richness is also often positively correlated with the service of pollination and (though reported to a lesser extent) pest control, as a mix of organisms with different characteristics (e.g. size, shape, flight patterns) can provide a more efficient service. Physical diversity is also often found to be significant, and this is reflected in the attributes of landscape diversity and, to a large extent, community or habitat structure, though the latter also includes other aspects of structure. More complex physical structures often provide a better service, e.g. a forest with a range of vegetation heights and root depths often provides more carbon storage; more diverse habitats provide better food and shelter for pollinating insects and pest predators; structural diversity enhances the aesthetic appeal of landscapes; and structural complexity tends to improve regulation of water flow and water quality.

E. **Abiotic factors** interact with the biotic attributes in complex and context-dependent ways, with much variation between services (Tables S1 and S2). Water supply appears to be particularly highly influenced by abiotic factors, with soil, precipitation and evaporation mentioned in over 70% of the articles reviewed. Food production is also dependent on a range of abiotic factors including nutrient availability, soil and precipitation. A number of services depend on water availability for establishment and survival of vegetation. In contrast, there is much less evidence on the influence of abiotic factors on pest regulation, species-based recreation and aesthetic landscapes.

These five pathways form the basis of a simple typology that describes the main ways in which different groups of biotic natural capital attributes influence the delivery of ecosystem services. **Error! Reference source not found.** summarises the typology, indicating the general direction of impact of each attribute group. Most attributes have a positive impact on service delivery, but the table also shows that mortality rate can have negative impacts, and that attributes in group A can have adverse impacts on water supply. For groups C and D the attributes are identified as having ‘mainly positive’ impacts on the bundles of services in the third column, to reflect the exceptions where certain (usually non-native) species have negative effects, e.g. introduced fish species wiping out native fish; or managed honeybees competing with wild pollinators. There are also some studies for food and timber production where diversity has a negative impact because a single high-performing species can provide a higher yield than a polyculture, at least in the short term.

Note that some attributes appear in more than one group:

- community/habitat type, area and age appear in groups A and B;
- community/habitat structure appears in group A (in terms of shape or form, such as patch size or connectivity) and in group D (in terms of structural complexity);
- species size and wood density appear in groups A (affecting the amount of vegetation) and C;

- population dynamics attributes (mortality rate, natality rate, life span/longevity and population growth rate) can affect biotic attributes in groups A to D.

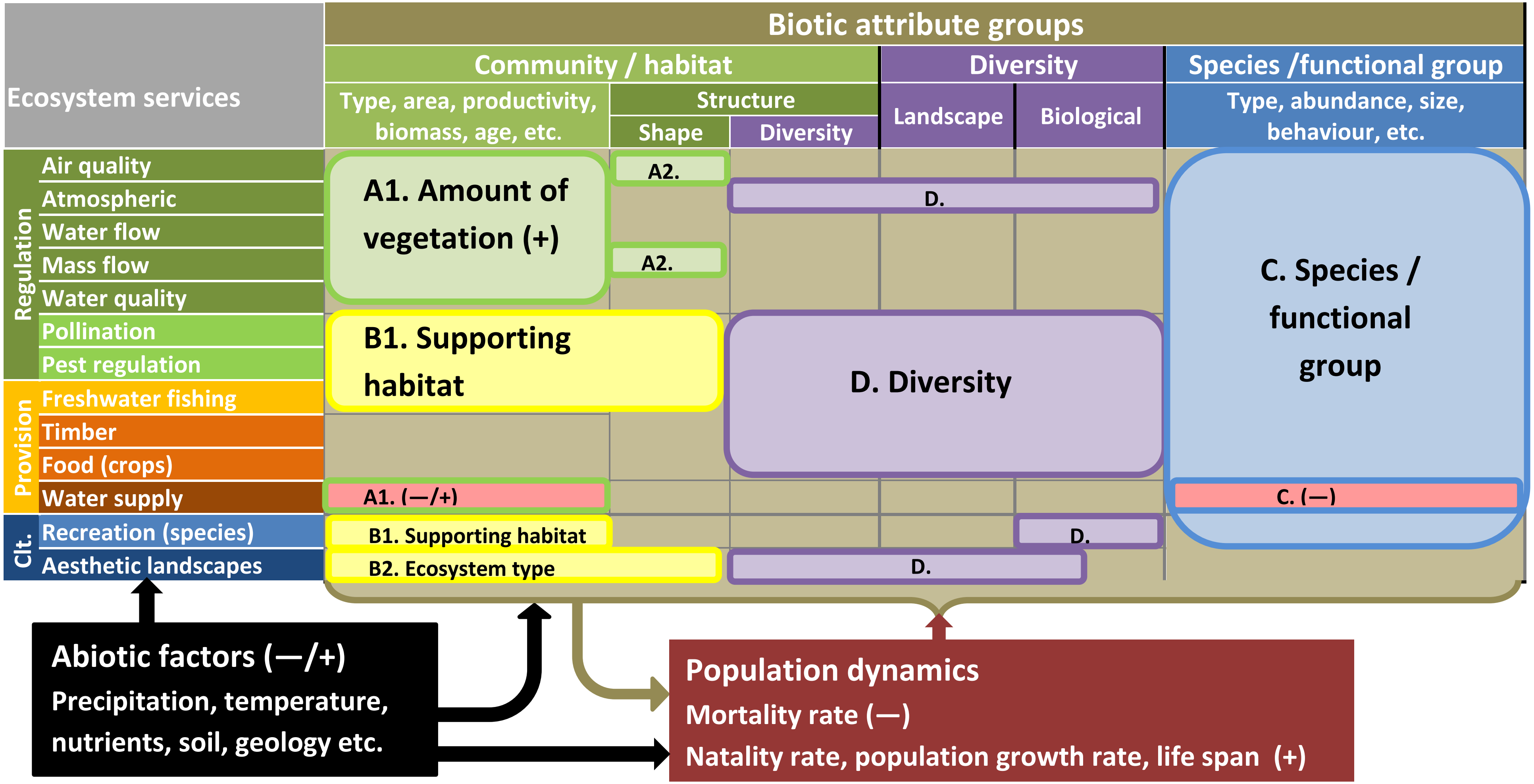
This grouping is not rigorous and there will be exceptions, such as in cases where invasive vegetation contributes to flooding by blocking river channels, so that the attributes in group A would have a negative impact on flood protection. Also, apparently weak links may indicate a lack of evidence rather than the absence of a causal link: for example there are no papers explicitly linking timber provision with plantation biomass, probably because the link is too obvious to merit investigation. Nevertheless, the typology provides a broad framework for classifying the pathways through which natural capital influences ecosystem services.

The typology is shown schematically in Figure 2, in which the population dynamics attributes have been separated from the main table to show how they can affect all the other attributes. The abiotic factors are shown as influencing the ecosystem services directly (e.g. through higher rainfall increasing water supply) and indirectly, through their impact on population dynamics which in turn affects all the other attributes. There is also a feedback loop to population dynamics from the other biotic attributes, because factors such as habitat area and the abundance of different species clearly influence population dynamics. Also, the attribute of community/habitat structure has been separated into two components: shape (classed as a sub-division of group A: A2) and structural diversity (part of group D). This distinction became apparent during the analysis but was not recorded in the database. Similarly, group B has been separated into two sub-divisions: B1 (supporting habitat for beneficial species) and B2 (aesthetic value to humans).

Table 2. Summary of typology to classify the pathways by which groups of natural capital attributes provide bundles of ecosystem services. Services for which there is more evidence for the influence of the pathway are highlighted in bold font.

Attribute group	Biotic attributes	Ecosystem services
A. Amount of vegetation	**Positive impact** + Presence of a specific community/habitat type + Community/habitat area + Aboveground biomass + Belowground biomass + Primary productivity + Community/habitat/stand age + Stem density + Successional stage + Litter/crop residue quality + Species size/weight + Wood density + Population growth rate + Natality rate **Negative impact** - Mortality rate	**Positive impact on:** + **Atmospheric regulation** + **Water flow regulation** + **Mass flow regulation** + **Water quality regulation** + **Air quality regulation** **Potentially negative impact on:** - **Water supply**
B. Provision of supporting habitat	**Positive impact** + Presence of a specific community/habitat type + Community/habitat area + Community/habitat structure	**Positive impact on:** + **Freshwater fishing** + **Pollination** + **Pest control** + **Aesthetic value**
C. Presence of a particular species, functional group or trait	**Positive impact** + Presence of a specific species type + Species abundance + Presence of a specific functional group + Abundance of a specific functional group + Flower-visiting behavioural traits (pollination) + Predator behavioural traits (biocontrol) + Sapwood amount + Wood density + Leaf N content + Species size/weight + Population growth rate + Life span/longevity + Natality rate **Negative impact** - Mortality rate	**Mainly positive impact on:** + **Freshwater fishing** + **Timber** + **Food production (crops)** + Air quality regulation + Atmospheric regulation + Mass flow regulation + Water quality regulation + **Pollination** + **Pest regulation** + **Species-based recreation**
D. Biological and physical diversity	**Positive impact** + Species richness + Species population diversity + Functional richness + Functional diversity + Landscape diversity + Community/habitat structure	**Mainly positive impact on:** + Freshwater fishing + **Timber** + **Food production (crops)** + Air quality regulation + **Atmospheric regulation** + Mass flow regulation + Water quality regulation + **Pollination** + Pest regulation + **Species-based recreation** + **Aesthetic landscapes**
E. Abiotic attributes	± Temperature ± Evaporation ± Wind ± Precipitation, snow ± Water availability ± Water quality ± Nutrient availability ± Soil, geology, slope	**Affect all services in context-specific ways**

Figure 2 Summary schematic diagram of pathways by which groups of natural capital attributes deliver bundles of ecosystem services



3.3 Interactions between services

Interactions between ecosystem services are mentioned in 40% of the articles reviewed. Most (56%) of the interactions identified are positive, highlighting the multiple benefits that particular ecosystems can provide (Figure 3). There are strong links between the bundle of air, soil and water regulating services and the cultural service of aesthetic landscapes, as these services are all underpinned by similar attribute groups (with a high contribution from A, amount of vegetation, and D, diversity), and thus are often provided by the same habitat type, with forests typically providing a high level of all these services. The links from air quality regulation to the other services in this bundle are particularly strong, as many studies cite the multiple benefits of urban trees in helping to improve air quality, reduce flood risk, store carbon and provide aesthetic value. Links from pollination and pest regulation to food crop production are also strong.

There are also some negative interactions between services, especially between provisioning services and regulating or cultural services, although these are mentioned less frequently. These negative interactions are usually linked to human management activities that benefit one service but at the same time have negative impacts on another. A strong negative link is evident between timber production and water supply: this refers to the impact of timber plantations on water supply in water-scarce regions. Timber and food crop production also have negative links with atmospheric and water flow regulation, arising from the decrease in these services when forests are felled for timber or cleared for agriculture. Cultivation of land for food crops can also exacerbate soil erosion, and fertiliser application benefits food and timber production but has negative impacts on water quality regulation and freshwater fishing. Some management activities may have short-term benefits but may result in adverse consequences in the long-term (such as a decline in pollinators and thus increased risks to food security due to intensive farming). Improved analysis of these interactions could help decision-makers to develop management strategies that exploit synergies and balance trade-offs more effectively.

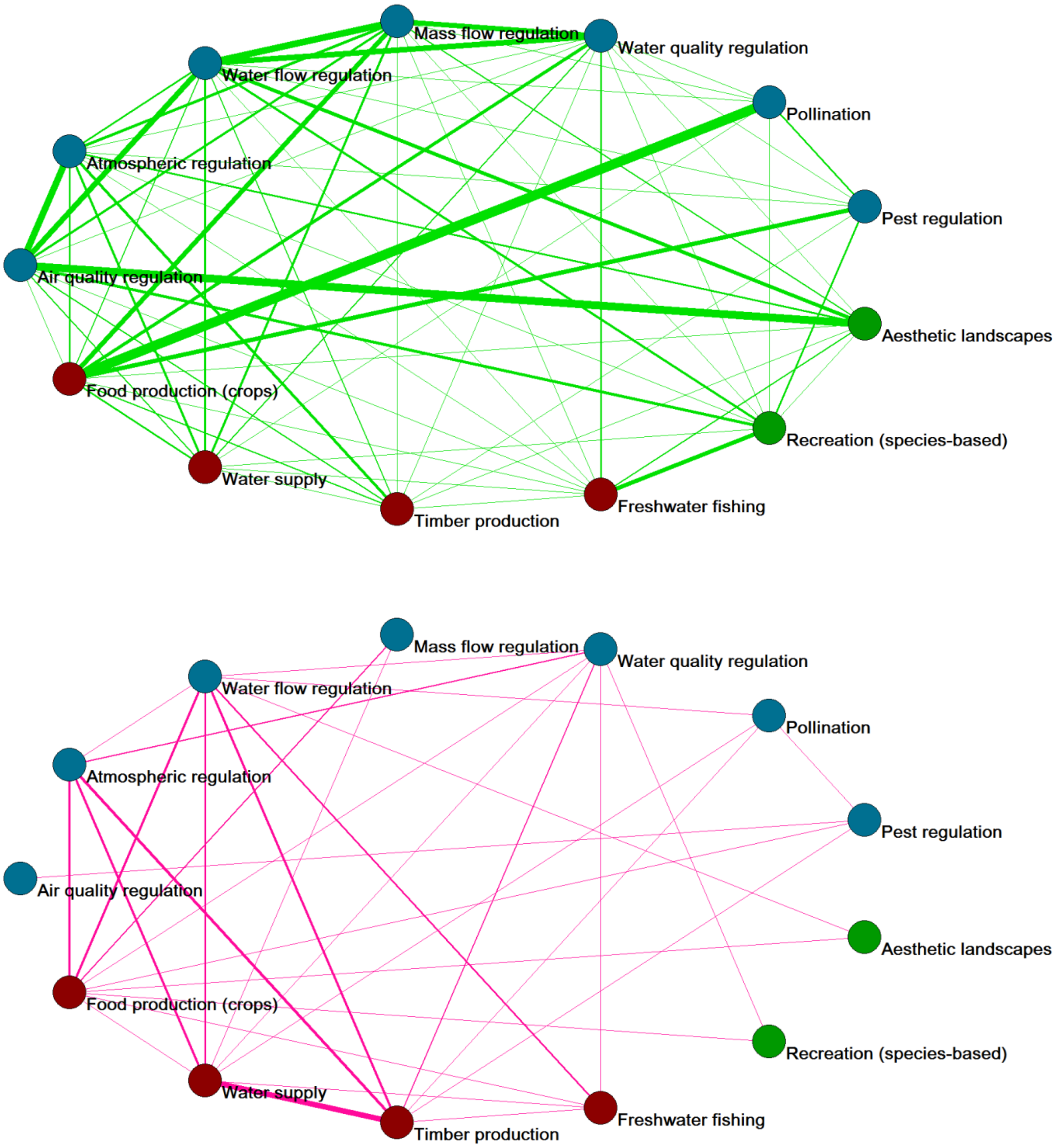


Figure 3. Network diagram showing all positive (top) and negative (bottom) interactions between services. Thickness of lines is proportional to number of studies supporting a link. Water flow regulation = flood protection; mass flow regulation = erosion protection.

3.4 Human impacts

Human activities are shown to have a range of positive (21%) and negative (15%) impacts on ecosystem service delivery, and 18% of studies cite a mix of both (Figure S19). This part of the review was expected to record any direct human input and management activities intended to boost the service (such as the use of fertilisers), but we found that it is far more common for the articles reviewed to cite impacts related to other human activities, some of which are related to other ecosystem services (and thus also covered under the ‘Interactions’ section above). Thus there are many examples in which ecosystems have been lost or damaged through urban development or over-exploitation, altering the functioning of the ecosystems and reducing some of the services they deliver. However, there are also many examples of ways in which protection, restoration and sustainable management of habitats can actively enhance ecosystem service delivery.

Although for most services we found a split between positive, negative and mixed impacts, for food crop and timber production no studies show purely negative human impacts on service delivery. This is because food crop production always requires a certain level of positive human input: sowing, tending and harvesting the crop. The same is true for timber production, as all the articles reviewed concern production from managed or experimental plantations as opposed to felling of unmanaged forest. For freshwater fishing, many of the studies cover managed systems where beneficial human activity includes stocking and sometimes feeding the fish (e.g. Boukal et al., 2012), but negative impacts also arise from over-fishing or habitat degradation, e.g. through pollution, dredging, deforestation or dam construction (e.g. Dugan et al., 2010; Hoeinghaus et al., 2009). Air quality regulation is the only other service where human impacts are cited as being largely positive, reflecting the need for active management of urban vegetation.

Careful regulation and sustainable management, along with protection of key habitats, offers opportunities to maximise the delivery of multiple ecosystem services and avoid over-exploitation. For mass flow regulation, for example, 37 out of 60 papers cite negative (or mixed positive and negative) human impacts, mainly from overgrazing or intensive cultivation of arable land, though also from fuelwood collection, ski-run construction and road building (e.g. Garcia Nacinovic et al., 2014; Liu et al., 2014; Pohl et al., 2012). However, 20 of these papers show how impacts could be mitigated through restoration and soil-water conservation methods such as re-planting or re-seeding with protective vegetation, constructing low walls or terraces on steep slopes, establishing contour hedges or grass buffer strips between fields, using cover crops to avoid bare soil in winter, and shifting to no-till agriculture (e.g. Gao et al., 2011; Liu et al., 2014; Munro et al., 2008). For pest regulation and pollination, adverse impacts are recorded from clearance of natural habitats and over-use of agro-chemicals, but there is also considerable evidence of benefits from shifting to organic agriculture and establishing supporting habitat, e.g. at field margins (e.g. Colloff et al., 2013; Munyuli et al., 2013; Watson et al., 2011). For species-based recreation, many of the studies are set in protected areas with active conservation policies, but monitoring and regulation (such as limiting the size of tour groups) is also often found to be necessary to avoid damage or disturbance to species from tourist activities (e.g. Zhang et al., 2012). Deforestation has a severe impact on carbon storage and flood protection, but several studies highlight the benefits of protecting or restoring forested areas (e.g. Gonzalez et al., 2014; Ogden et al., 2013).

4 Discussion

4.1 Comparison with other studies

Our systematic review built a coherent database recording the direction of links between natural capital attributes and ecosystem services, based on the number of papers presenting evidence for each link. Previous studies of the links between ecosystem services and natural capital have often been based only on one attribute — usually species richness — or have investigated a limited range of ecosystem services (Cimon-Morin et al., 2013; Duncan et al., 2015). By including 29 biotic attributes, 11 abiotic factors and 13 ecosystem services in our analysis, we have been able to examine not just the impact of diversity but also the influence of attributes related to specific habitats, species and functional groups. This enables a comprehensive overview of the pathways by which natural capital contributes to ecosystem services, which underpins the typology we developed. However it is important to note that this is a vote-counting approach and not a meta-analysis. The number of papers citing a positive or negative link is not proportional to the importance or strength of that link. Similarly, the absence of evidence for a link does not necessarily mean that the link does not exist, but only that evidence for it has not been reported in the literature.

This review extends the knowledge base compiled by Harrison et al. (2014). We add information on the direction of influence of abiotic factors, thus providing a more complete picture of the way in which both biotic and abiotic elements of natural capital interact to deliver ecosystem services. This review also adds two more ecosystem services and 250 recent papers, as well as collecting information on interactions between services and human impacts. A detailed comparison with Harrison et al. (2014) shows that the net direction of the links between biotic attributes and ecosystem services is the same for all attributes, but our new review finds stronger evidence for a number of links, including:

- the positive role of the set of attributes related to the amount of vegetation (habitat area, above- and belowground biomass, stem density, growth rate, primary productivity, successional stage, stand age, species size and wood density) in the provision of services of atmospheric regulation, mass flow and water flow regulation;
- the importance of the area of supporting habitat to underpin the species-related services of pollination, pest control and freshwater fishing;
- the role of species richness and functional diversity in boosting timber production and pollination;
- the role of species behaviour in providing pollination and pest control;
- the importance of habitat structure (including structural diversity) in enhancing the services of pollination, pest control, mass flow and water flow regulation.

The new typology offers several advantages over the one developed by Harrison et al. (2014), which was structured around Ecosystem Service Providers (ESPs), which are the species, functional groups or communities/habitats that provide services (see Supplementary Material Section 2 and Figure S16). One problem is that ESPs are rarely explicitly identified in the literature and have to be inferred by the reviewer, leading to some potential for inconsistency. Also they are often determined mainly by the study design (i.e. whether the researchers choose to investigate the role of one or more species, functional groups or entire habitats), rather than reflecting the ecosystem components required to provide the service. And finally, although the network diagrams linking services to ESPs and attributes are very effective in illustrating the complexity of the links that underpin different services, they cannot easily be used to inform management decisions. The new typology presented here offers a simpler way to trace the pathways by which natural capital provides ecosystem services, and links the delivery of ecosystem services more clearly with the ecosystem functions that underpin them.

This review has helped to improve understanding of the links between ecosystem functions and ecosystem services – a research gap that has been noted by several reviews (Cardinale et al., 2012; Duncan et al., 2015; Wong et al., 2015). The biotic attribute groups (A to D) have parallels with the groups of ecosystem functions that Duncan et al. (2015) identify as underpinning bundles of ecosystem services. For example, Duncan et al. (2015) note that the service of mass flow regulation is underpinned by a group of ecosystem functions including Net Primary Productivity, below-ground biomass and soil texture — equivalent to several of the attributes identified in our typology. The breadth of the literature covered by our systematic review enables us to provide a complete typology in line with this framework.

Our findings are also broadly in line with two studies that use spatial correlations between ecosystem service proxy indicators (such as water quality, agricultural production or tourism) to identify ecosystem service bundles. Maes et al. (2012) identify a bundle of ecosystem services spatially correlated with forests, including air quality regulation, carbon storage and erosion protection, in line with group A in our typology, as well as recreation and timber production. Rausdepp-Hearne et al. (2010) identify a similar ‘Country homes’ bundle located in undeveloped forests that includes carbon storage, soil organic matter and water quality (similar to group A) as well as recreation. Both these studies also identify trade-offs between the provisioning services (especially food production) and the regulating and cultural services, in agreement with our findings (section 3.3).

Our typology is also consistent with the framework proposed by Maseyk et al. (2017), who identify three ecological processes that underpin ecosystem services: the species-area relationship (equivalent to our group C, specific species; and B, supporting habitat); landscape ecology (group D, physical and biological diversity); and biodiversity-ecosystem function (group D, biological diversity). However our typology also identifies group A – amount of vegetation.

4.2 Implications for ecosystem management

The database identifies the structural and functional factors (natural capital attributes) that link natural capital stocks to ecosystem service flows in different contexts, thus increasing understanding of the biophysical control of ecosystem services. This can be used to inform sustainable ecosystem management. Here we address three issues: the impact of ecosystem condition on service delivery; the compatibility of the ecosystem service approach with conservation objectives; and how the typology can be used to inform management decisions in practice.

4.2.1 Ecosystem condition and thresholds

As part of the review, we aimed to gather any information on the condition of ecosystems and to evaluate the feasibility of detecting possible thresholds beyond which service delivery would be compromised. However, very few studies explicitly mentioned either ecosystem condition or thresholds. One exception was for the service of flood protection, where several papers cited a threshold effect where storm flows increase noticeably when forest cover in the catchment falls below 20-30% (Bathurst et al., 2011; Lin & Wei, 2008; Schnorbus & Alila, 2013).

As an alternative, we propose that many of the natural capital attributes in our typology could be used as indicators of ecosystem condition. This could include the area of different habitats, biological and physical diversity attributes, the presence and abundance of specific species and functional groups (including undesirable species such as pests or invasive species), population dynamics attributes such as natality, mortality and growth rates, and abiotic indicators such as water quality and water availability. The typology enables these attributes to be linked to the services that depend on them.

4.2.2 Compatibility of the ecosystem services approach with conservation objectives

The findings of this review may help to inform the debate over whether the ecosystem service concept is compatible with conservation objectives. In particular, it highlights the role of biological and physical diversity in delivering many ecosystem services. Diversity can increase productivity through at least three mechanisms: resource-use complementarity (see section 3.1.1); the selection or sampling effect, where the presence of a greater number of species increases the chances that some of them will be good providers of a particular ecosystem service (Cavanaugh et al., 2014); and inter-species facilitation such as nitrogen fixation from the atmosphere by leguminous plants (Hulvey et al., 2013). More recently, van der Plas et al. (2016) have proposed the existence of an additional mechanism which they term the ‘Jack-of-all-trades’ effect, caused by the averaging of individual species contributions to ecosystem functions.

Our review finds that diversity can enhance the delivery not only of regulating and cultural services, but also provisioning services. For food, timber and fish provision, more diverse systems often provide higher yields in the short term, as well as greater yield stability in the long term. Although diversity in managed systems is far more limited than within natural ecosystems, it can still offer benefits for wildlife when compared to a monoculture, for example through a mosaic landscape that offers a mix of species and cultivars both within and across fields, coupled with networks of natural or semi-natural habitats to support pollinators and pest predators (Scherr and McNeely, 2008). Increased diversity can also enhance resistance to pests and diseases and reduce the need for agro-chemical inputs, which brings further ecosystem benefits (see Section 3.1.3). Although there is a conflict between forests and water supply, this mainly applies to monocultures of non-native species such as pine or eucalyptus, and there is evidence that biodiverse native forests have lower impacts or even benefits (see Section 3.1.4 and also more recent work e.g. Carvalho-Santos et al., 2016).

For the regulating and cultural services reviewed, the strength of the relationship between diversity and ecosystem service delivery is often context-dependent, which may explain why there is not always a good spatial correlation between biodiversity and ecosystem service delivery (Cimon-Morin et al., 2013). For example, the studies on carbon storage reveal that the relationship may depend on the scale of the study, the structural complexity of the forest (Tran van Con et al., 2013), the productivity of the site (Potter and Woodall, 2014) or the successional stage (Gonzalez et al., 2014) (see Supplementary Material section 2.1.1). The nature of the study may also have an impact. Ricketts et al. (2016) review 81 studies for four ecosystem services (carbon storage, pest control, pollination and water purification) and find that the strength of biodiversity-ES relationships varied depending on whether the studies focused on spatial correlations between biodiversity and ES, the impact of management interventions, or the functional mechanisms by which biodiversity affects ES. It would be useful to investigate these issues in further work.

Despite this evidence on the positive links between diversity and ecosystem services, there are still a number of potential conflicts. Firstly, the information collected on human impacts confirms that over-exploitation of provisioning services, and sometimes cultural services (e.g. tourism), often has negative impacts on ecosystems. Secondly, the review highlights that forests have a particular value in providing multiple ecosystem services, but over-emphasis on protecting forests could lead to loss of other ecosystems such as heathland, natural grasslands or sparsely vegetated land that provide fewer regulating services but may still be home to rare or threatened species and have cultural value. Thirdly, species richness may reach a plateau beyond which service delivery does not increase (Balvanera 2006; Chen, 2006). This means that there may be no incentive to restore or protect the richest ecosystems, as moderately rich systems such as managed plantations with three or four timber species could provide the same level of service (Cardinale et al., 2006; Ingram et al., 2012). Fourthly, some services may be delivered adequately by relatively common species (Ridder, 2008) or by non-native species such as managed honeybees, which have little conservation interest or may even have negative impacts through competition with native species (Paini and Roberts, 2005).

To resolve these potential conflicts it is necessary to ensure that the ecosystem service concept is applied within a holistic management framework that balances stakeholder demands for a wide range of provisioning, regulating and cultural services, and aims to maintain resilient ecosystems that can deliver a sustainable supply of services in the long term (Haslett et al., 2010; Macfadyen et al., 2012; Smith et al., 2016). Synergies with conservation goals can be improved by ensuring that due weight is given to cultural ecosystem services, such as eco-tourism or the existence value of wildlife, and highlighting their links to the attributes of ecosystems (Blicharska et al., 2017; Reyers et al., 2012). Short-term over-exploitation of specific services is not compatible with a sustainable ecosystem service management approach. The review highlights the vulnerability of ecosystems to changing abiotic factors such as temperature and precipitation, especially for the provisioning services, and provides evidence for the role of diversity in providing resilience to climate change, particularly for production of food crops (e.g. di Falco and Chavas, 2008).

There is ample evidence that diversity is necessary to ensure that ecosystems are multifunctional and that they are stable over time under changing environmental conditions, reducing risks to the service beneficiary (Cardinale et al., 2012; Duncan et al., 2015; Isbell et al., 2011; Lefcheck et al., 2015). This shows that maintaining diverse and healthy ecosystems is fundamental both to conservation goals and sustainable ecosystem service delivery.

Despite the opportunities for synergies between ecosystem services and biodiversity conservation, win-wins can be hard to achieve in practice and trade-offs must be explicitly tackled (McShane et al., 2011). For example, Barnett et al. (2016) found trade-offs between reforestation to improve water quality (focusing on riparian buffers) and reforestation to connect black bear habitats. Joint management of biodiversity and ecosystem services (Cordingley et al., 2016; Reyers et al., 2012) coupled with appropriate regulation (Albert et al., 2016) is needed to minimise trade-offs and avoid adverse impacts.

4.2.3 Informing management decisions

This review provides an extensive evidence base that can be used to demonstrate the value of natural capital to decision-makers. Our typology of links between natural capital and ecosystem service delivery can help to guide the application of the ecosystem service approach in research, policy and practice for sustainable land, water and urban management.

The typology is not intended to cover every aspect of ecosystem service delivery, and it has already been noted that there can be exceptions to the broad classifications, as many of the links are context-dependent. Nevertheless, it is intended to be a clear and simple classification that can be used by land managers and other decision makers to raise awareness of the different pathways by which natural capital attributes affect ecosystem service delivery. Selected attributes can be used as biophysical indicators for monitoring and managing ecosystems. A manager might then be able to estimate the impact of a land management action on different bundles of ecosystem services. One approach that has already been applied in practice is to use the typology as a basis for a simple land-use scoring approach to mapping the ability of different habitats to provide different ecosystem services (Smith and Dunford, 2017).

The studies reviewed contain many examples of successful initiatives to restore degraded ecosystems and manage services more sustainably (section 3.4). To assist with this, Maseyk et al. (2017) suggested dividing the attributes of natural capital (soils and vegetation) into manageable and unmanageable attributes, so that management strategies can focus on the manageable attributes. The review of potential interactions between services (Section 3.3) can help to inform the development of management strategies to maximise synergies and minimise undesirable trade-offs.

5 Conclusions

This review has compiled a significant evidence base of 780 papers that demonstrates the ways in which different elements of natural capital influence the delivery of ecosystem services. This has been used to develop a simple typology that defines five groups of attributes that support specific bundles of services in different ways: A) the physical amount of vegetation cover; B) presence of suitable habitat to support specific species or functional groups that provide a service; C) the characteristics of particular species or functional groups; D) physical and biological diversity; and E) abiotic factors. This provides a consistent framework to inform further research, analysis and decision-making.

The evidence base can be used to demonstrate the value of natural capital, and can thus support decisions to protect, restore or enhance ecosystems in order to ensure the long-term provision of the range of services needed to underpin human wellbeing. We have also provided an overview of positive and negative interactions between services, and evidence on the impact of human management on service delivery. This can be used to identify opportunities to gain multiple ecosystem service benefits, and also to recognise situations where there could be trade-offs between ecosystem services, and determine suitable management actions to avoid or mitigate any problems. Finally, the review provides evidence on the value of physical and biological diversity both in enhancing short-term performance and underpinning the long-term resilience of ecosystem services to environmental change. This shows that the ecosystem approach, if applied correctly, can provide additional motivation to conserve healthy, diverse ecosystems that simultaneously deliver services for people and habitat for wildlife. The review thus supports the objectives of the Intergovernmental science-policy Platform on Biodiversity and Ecosystem Services (IPBES) by providing pertinent evidence for the conservation and sustainable use of biodiversity, long-term human well-being and sustainable development.

Acknowledgements

We acknowledge the contributions of Grazia Julian and Chiara Polce of the European Commission Joint Research Centre in supervising the work of Nina Fabrega.

Funding

This work was supported by the European Union’s Seventh Programme for research, technological development and demonstration under grant agreement No 308428 (OpenNESS). Co-financing was provided by the strategic research program KBIV “Sustainable spatial development of ecosystems, landscapes, seas and regions", funded by the Dutch Ministry of Economic Affairs, and carried out by Wageningen Environmental Research (Marta Pérez Soba and Laura Miguel Ayala).

References

Acar, C. and Sakıcı, C. (2008), 'Assessing landscape perception of urban rocky habitats', *Building and Environment*, **43** (6), pp. 1153–1170.

Ahmad, S.S., Reshi, Z.A., Shah, M.A., Rashid, I., Ara, R. & Andrabi, S.M.A. (2014) Phytoremediation Potential of Phragmites australis in Hokersar Wetland - A Ramsar Site of Kashmir Himalaya. International Journal of Phytoremediation, 16:12, 1183-1191. DOI: 10.1080/15226514.2013.821449

Albert, C., Hermes, J., Neuendorf, F., von Haaren, C. and Rode, M. (2016) Assessing and Governing Ecosystem Services Trade-Offs in Agrarian Landscapes: The Case of Biogas. Land 5: 1. doi:10.3390/land5010001

Alonso, R., Vivanco, M.G., González-Fernández, I., Bermejo, V., Palomino, I., Garrido, J.L., Elvira, S., Salvador, P., Artíñano, B. (2011) Modelling the influence of peri-urban trees in the air quality of Madrid region (Spain). Environmental Pollution 158 (8-9): 2138-2147. http://dx.doi.org/10.1016/j.envpol.2010.12.005

Andry, H., Yamamoto, T., and Inoue, M. (2007) Effectiveness of hydrated lime and artificial zeolite amendments and sedum (Sedum sediforme) plant cover in controlling soil erosion from an acid soil. Australian Journal of Soil Research, 45: 266–279. DOI 0004-9573/07/040266.

Badano, E.I., Vergara, C.H. (2011) Potential negative effects of exotic honey bees on the diversity of native pollinators and yield of highland coffee plantations. Agricultural and Forest Entomology. 13. 365-372.

Balvanera, P. et al. (2006) Quantifying the evidence for biodiversity effects on ecosystem functioning and services. Ecol. Lett. 9: 1146–1156.

Balvanera, P., Siddique, I., Dee, L., Paquette, A., Isbell, F., Gonzalez, A., et al. (2014). Linking biodiversity and ecosystem services: current uncertainties and the necessary next steps. Bioscience, 64, 49–57.

Barnett, A., Fargione, J. and Smith, M.P. (2016) Mapping Trade-Offs in Ecosystem Services from Reforestation in the Mississippi Alluvial Valley. BioScience Advance Access.

Bastian, O. (2013) The role of biodiversity in supporting ecosystem services in Natura 2000 sites, Ecological Indicators 24: 12‑22.

Bathurst, J. et al. (2011), 'Forest impact on floods due to extreme rainfall and snowmelt in four Latin American environments 1: field data analysis', *Journal of Hydrology*, **400**, pp. 281-91.

Bayala, J., G.W. Sileshi, R. Coe, A. Kalinganire, Z. Tchoundjeu, F. Sinclair and D. Garrity (2012) Cereal yield response to conservation agriculture practices in drylands of West Africa: A quantitative synthesis. Journal of Arid Environments 78:13-25. doi:10.1016/j.jaridenv.2011.10.011

Biggs, R., Schlüter, M., Schoon, M.L., 2015. *Principles for Building Resilience*. Cambridge University Press, UK. ISBN: 9781107082656.

Blicharska, M., Smithers, R.J., Hedblom, M., Hedenås, H., Mikusinski, G., Pedersen, E., Sandström, P., & Svensson, J. (2017) Shades of grey challenge practical application of the cultural ecosystem services concept. *Ecosystem Services* 23:55-70. https://doi.org/10.1016/j.ecoser.2016.11.014

Bommarco, R., Lundin, O., Smith, H.G., Rundlof, M. (2011) Drastic historic shifts in bumble-bee community composition in Sweden. Proceedings of the Royal Society of Biological Sciences,279: 309-315.

Boukal, D.S., M. Jankovsky, J. Kubeckad and M. Heino (2012) Stock-catch analysis of carp recreational fisheries in Czech reservoirs: Insights into fish survival, water body productivity and impact of extreme events. Fisheries Research. 119-120: 23-32.

Brauman, K. A., Freyberg, D. L. and Daily, G.C. (2010), ‘Forest structure influences on rainfall partitioning and cloud interception: A comparison of native forest sites in Kona, Hawaii’, *Agricultural and Forest Meteorology* **150,** pp. 265–275.

Cadotte, M.W. (2013), 'Experimental evidence that evolutionarily diverse assemblages result in higher productivity', *PNAS* **110**(22), pp. 8996–9000.

Cardinale, B. J. et al. (2006) Effects of biodiversity on the functioning of trophic groups and ecosystems. Nature 443, 989–992.

Cardinale, B. J. et al. (2011) The functional role of producer diversity in ecosystems. Am. J. Bot. 98, 572–592.

Cardinale, B.J., Duffy, J.E., Gonzalez, A., Hooper, D.U., Perrings, C., Venail, P., .. and Naeem, S. (2012), ‘Biodiversity loss and its impact on humanity’, *Nature*, **486**, pp. 59-67.

Carey, M. P. and D. H. Wahl (2011) Determining the mechanism by which fish diversity influences production. Oecologia 167: 189-198. DOI 10.1007/s00442-011-1967-3

Carvalheiro, L. G., Seymour, C. L., Veldtman, R. and Nicolson, S. W. (2010) Pollination services decline with distance from natural habitat even in biodiversity-rich areas. Journal of Applied Ecology, 47(4), 810-820.

Carvalho-Santos, C., Sousa-Silva, R., Goncalves, J., Pradinho Honrado, J. (2016) Ecosystem services and biodiversity conservation under forestation scenarios: options to improve management in the Vez watershed, NW Portugal. Reg Environ Change (2016) 16:1557–1570 DOI 10.1007/s10113-015-0892-0.

Casula, Paolo and Mauro Nannini (2013) Evaluating the Structure of Enemy Biodiversity Effects on Prey Informs Pest Management. ISRN Ecology Volume 2013, Article ID 619393, 15 pages. http://dx.doi.org/10.1155/2013/619393

Cavaleri, M.A., Sack, L. (2010) Comparative water use of native and invasive plants at multiple scales: a global meta-analysis. Ecology, 91(9) 2705-2715. 10.1890/09-0582.1

Cavanaugh, Kyle C., J. Stephen Gosnell, Samantha L. Davis, Jorge Ahumada, Patrick Boundja, David B. Clark, .. and Sandy Andelman (2014), 'Carbon storage in tropical forests correlates with taxonomic diversity and functional dominance on a global scale', *Global Ecology and Biogeography*, **23**, pp. 563–573.

Chavas, Jean-Paul and Salvatore Di Falco (2012) On the Productive Value of Crop Biodiversity: Evidence from the Highlands of Ethiopia. Land Economics, 88(1): 58-74. DOI: 10.1353/lde.2012.0009

Chen, X. (2006) Tree diversity, carbon storage and soil nutrient in an old-growth forest at Changbai Mountain. Northeast China, Communications in Soil Science and Plant Analysis, 37, 363-375. DOI:10.1080/00103620500440210

Cheng, J.D., Lin, L.L. and Lu, H.S. (2002), ‘Influences of forests on water flows from headwater watersheds in Taiwan’, *Forest Ecology and Management*, **165**, pp. 11-28.

Cimon-Morin, J., Darveau, M. and Poulin, M. (2013) Fostering synergies between ecosystem services and biodiversityin conservation planning: A review. Biological Conservation 166 (2013) 144–154.

Clark, C. (1987), ‘Deforestation and floods’, *Environmental Conservation*, **14,** pp. 67-69.

Colloff, Matthew J., Elizabeth A. Lindsay, David C. Cook (2013) Natural pest control in citrus as an ecosystem service: Integrating ecology, economics and management at the farm scale. Biological Control 67 (2013) 170–177. doi:10.1016/j.biocontrol.2013.07.017.

Cordingley, J.E., Newton, A.C., Rose, R.J., Clarke, R.T and Bullock, J.M. (2016) Can landscape-scale approaches to conservation management resolve biodiversity–ecosystem service trade-offs? Journal of Applied Ecology 2016, 53, 96–105. doi: 10.1111/1365-2664.12545.

Costanza, R. de Groot, R., Sutton, P., van der Ploeg, S., Anderson, S.J., Kubiszewski, I., Farber, S., (...), Turner, R.K. (2014) Changes in the global value of ecosystem services. Glob. Environ. Change 26, 152–158.

Cowger, C. and Weisz, R. (2008) Winter Wheat Blends (Mixtures) Produce a Yield Advantage in North Carolina. Agronomy Journal 100:169–177. doi: 10.2134/agronj2007.0128.

Daghela Bisseleua HB, Fotio D, Yede, Missoup AD, Vidal S (2013) Shade Tree Diversity, Cocoa Pest Damage, Yield Compensating Inputs and Farmers' Net Returns in West Africa. PLoS ONE 8(3): e56115. doi:10.1371/journal.pone.0056115

Daniel, T.C., A. Muhar, A. Arnberger, O. Aznar, J.W. Boyd, K.M.A. Chan, R. Costanza, T. Elmqvist, C.G. Flint, P.H. Gobster, A. Grêt-Regamey, R. Lave, et al. (2012), 'Contributions of cultural services to the ecosystem services agenda', *PNAS* **109**(23), pp. 8812-19.

Davis AS, Hill JD, Chase CA, Johanns AM, Liebman M (2012) Increasing Cropping System Diversity Balances Productivity, Profitability and Environmental Health. PLoS ONE 7(10): e47149. doi:10.1371/journal.pone.0047149

De Baets, S., J. Poesen, B. Reubens, B. Muys, J. De Baerdemaeker and J. Meersmans (2009) Methodological framework to select plant species for controlling rill and gully erosion: application to a Mediterranean ecosystem. Earth Surface Processes and Landforms 34: 1374-1392. DOI: 10.1002/esp.1826

Di Falco, S. and J.-P. Chavas (2008) Rainfall Shocks, Resilience, and the Effects of Crop Biodiversity on Agroecosystem Productivity. Land Economics 84 (1): 83–96.

Dugan P.J., Barlow C., Agostinho A.A., Baran E., Cada G.F., et al. and Winemiller K.O. (2010) Fish Migration, Dams, and Loss of Ecosystem Services in the Mekong Basin. AMBIO, 39:344-348.. 10.1007/s13280-010-0036-1

Duncan C, Thompson JR, Pettorelli N. (2015) The quest for a mechanistic understanding of biodiversity–ecosystem services relationships. Proc. R. Soc. B 282:20151348. http://dx.doi.org/10.1098/rspb.2015.1348

Egoh, B., Reyers, B., Rouget, M., Bode, M. & Richardson, D.M. (2009) Spatial congruence between biodiversity and ecosystem services in South Africa. Biological Conservation, 142, 553–562.

Erskine, W.D. and Webb, A.A. (2003), 'Desnagging to resnagging: new directions in river rehabilitation in southeastern Australia', *River Research and Applications*, **19**, pp. 233-249.

Ferrario F., Beck M.W., Storlazzi C.D., Micheli F., Shepard C.C and Airoldi L. (2014), 'The effectiveness of coral reefs for coastal hazard risk reduction and adaptation', *Nature Communications*, **5**, pp. 3794.

Gao, Y., B. Zhong, H. Yue, B. Wu and S. Cao (2011) A degradation threshold for irreversible loss of soil productivity: a long-term case study in China. Journal of Applied Ecology 48: 1145-1154. doi: 10.1111/j.1365-2664.2011.02011.x

García-Llorente, Marina, Paula A. Harrison, Pam Berry, Ignacio Palomo, Erik Gómez-Baggethun, Irene Iniesta-Arandia, Carlos Montes, David García del Amo, Berta Martín-López (2016) What can conservation strategies learn from the ecosystem services approach? Insights from ecosystem assessments in two Spanish protected areas. *Biodivers Conserv* DOI 10.1007/s10531-016-1152-4.

Garcia Nacinovic, M. G., C. F. Mahler and A. d. S. Avelar (2014) Soil erosion as a function of different agricultural land use in Rio de Janeiro. *Soil & Tillage Research* 144: 164-173. doi/10.1016/j.still.2014.07.002

Garibaldi, L.A., et al. (2011) Stability of pollination services decreases with isolation from natural areas despite honey bee visits. *Ecology Letters*, 14: 1062-1072.

Garibaldi, Lucas A., Ingolf Steffan-Dewenter, Rachael Winfree, Marcelo A. Aizen, Riccardo Bommarco et al (2014) Wild Pollinators Enhance Fruit Set of Crops Regardless of Honey Bee Abundance. *Science* 339:1608-11.

Gomez-Peralta, D., Oberbauer, S.F., McClain, M.E., Philippi, T.E. (2008) Rainfall and cloud-water interception in tropical montane forests in the eastern Andes of Central Peru. Forest Ecology and Management 255: 1315-1325. 10.1016/j.foreco.2007.10.058

Gonzalez, Patrick, Benjamín Kroll, Carlos R. Vargas (2014), 'Tropical rainforest biodiversity and aboveground carbon changes and uncertainties in the Selva Central, Peru', *Forest Ecology and Management*, **312**, pp. 78–91.

Green, K. and Alila, Y. (2012), ‘A paradigm shift in understanding and quantifying the effects of forest harvesting on floods in snow environments’, *Water Resour. Res*., **48**, W10503.

Guerry A. D., Polasky S., Lubchenco J., Chaplin-Kramer R., Daily G. C., Griffin R., Ruckelshaus M. H., et al. (2015). Natural capital informing decisions: from promise to practice. *PNAS, 112* (24), 7348-7355.

Harrison, P.A., Berry, P.M., Simpson, G., Haslett, J.R., Blicharska, M., Bucur, M., Dunford, R., .. and Turkelboom, F. (2014), ‘Linkages between biodiversity attributes and ecosystem services: A systematic review’. *Ecosystem Services* **9**, pp. 191-203.

Haslett, J.R., Berry, P.M., Bela, G. et al. (2010), ‘Changing conservation strategies in Europe: a framework integrating ecosystem services and dynamics’. Biodivers Conserv 19: 2963. doi:10.1007/s10531-009-9743-y.

Hauggaard-Nielsen H., Jørnsgaard B., Kinane J. and Jensen E.S. (2008) Grain legume–cereal intercropping: The practical application of diversity, competition and facilitation in arable and organic cropping systems. Renewable Agriculture and Food Systems: 23(1); 3–12. doi:10.1017/S1742170507002025

Heyman, E. (2012), ‘Analysing recreational values and management effects in an urban forest with the visitor-employed photography method’, *Urban Forestry and Urban Greening*, **11**(3), pp. 267-277.

Hoehn, P., Tscharntke, T., Tylianakis, J.M., Steffan-Dewenter, I. (2008) Functional Group Diversity of Bee Pollinators Increases Crop Yield. Proceedings: Biological Sciences, 275 (1648): 2283-2291.

Hoeinghaus, D. J., Agostinho, A. A., Gomes, L. C., Pelicice, F. M., Okada, E. K., Latini, J. D., Kashiwaqui, E. A. L. and Winemiller, K. O. (2009) Effects of River Impoundment on Ecosystem Services of Large Tropical Rivers: Embodied Energy and Market Value of Artisanal Fisheries. Conservation Biology, Volume 23, No. 5, 1222–1231. doi: 10.1111/j.1523-1739.2009.01248.x

Holzschuh, A., J.-H. Dudenhoeffer and T. Tscharntke (2012) Landscapes with wild bee habitats enhance pollination, fruit set and yield of sweet cherry. Biological Conservation 153: 101-107. doi/10.1016/j.biocon.2012.04.032

Huang, Z. L., L. D. Chen, B. J. Fu, Y. H. Lu, Y. L. Huang and J. Gong (2006) The relative efficiency of four representative cropland conversions in reducing water erosion: Evidence from long-term plots in the loess Hilly Area, China. Land Degradation & Development 17: 615-627. DOI: 10.1002/ldr.739

Hulvey, Kristin B., Richard J. Hobbs, Rachel J. Standish, David B. Lindenmayer, Lori Lach and Michael P. Perring (2013), 'Benefits of tree mixes in carbon plantings', *Nature Climate Change* **3**, pp. 869-74.

Hümann, M., Schüler, G., Müller, C., Schneider, R., Johst, M. and Caspari, T. (2011), 'Identification of runoff processes - the impact of different forest types and soil properties on runoff formation and floods', *Journal of Hydrolog*y **409**, pp. 637-649.

Ingram, J.C., Redford, K.H. and Watson, J.E.M. (2012) Applying Ecosystem Services Approaches for Biodiversity Conservation: Benefits and Challenges, S.A.P.I.E.N.S [Online], 5.1 http://sapiens.revues.org/1459.

Isbell F et al. (2011) High plant diversity is needed to maintain ecosystem services. Nature 477, 199–202. (doi:10.1038/nature10282)

Kagawa, A., Sack L., Duarte, K., James, S. (2009) Hawaiian native forest conserves water relative to timber plantation: Species and stand traits influence water use. Ecological Applications, 19(6) 1429-1443.

Kaplan R. (2007), 'Employees' reactions to nearby nature at their workplace: The wild and the tame', *Landscape and Urban Planning* **82** (1–2), pp. 17–24.

Komatsu H, Kume T, Otsuki K. (2008) The effect of converting a native broad-leaved forest to a coniferous plantation forest on annual water yield: a paired-catchment study in northern Japan. Forest Ecology and Management 255: 880-886. 10.1016/j.foreco.2007.10.010

Lang'at, Joseph K. Sigi, Bernard K. Y. Kirui, Martin W. Skov, James G. Kairo, Maurizio Mencuccini, Mark Huxham (2013), 'Species mixing boosts root yield in mangrove trees', *Oecologia* **172**, pp. 271–278.

Lange, Benjamin, Peter F. Germann and Peter Luscher (2013), 'Greater abundance of Fagus sylvatica in coniferous flood protection forests due to climate change: impact of modified root densities on infiltration', *Eur J Forest Res* **132,** pp. 151–163.

Lapointe, N. W. R., S. J. Cooke, J. G. Imhof, D. Boisclair, J. M. Casselman, R. A. Curry, O. E. Langer, R. L. McLaughlin, C. K. Minns, J. R. Post, M. Power, J. B. Rasmussen, J. D. Reynolds, J. S. Richardson and W. M. Tonn (2014) Principles for ensuring healthy and productive freshwater ecosystems that support sustainable fisheries. Environmental Reviews 22: 110-134. dx.doi.org/10.1139/er-2013-0038

Lee, H.-Y. and Shih, S.-S. (2004), 'Impacts of vegetation changes on the hydraulic and sediment transport characteristics in Guandu mangrove wetland', *Ecological Engineering*, **23**, pp. 85-94.

Lefcheck J. S., Byrnes E.K, Isbell F., Gamfeldt L., Griffin J.M. et al. and Duffy J.E. (2015) Biodiversity enhances ecosystem multifunctionality across trophic levels and habitats. Nat. Commun. 6:6936 doi: 10.1038/ncomms7936.

Liebman M., Helmers M.J., Schulte L.A. and Chase C.A. (2013) Using biodiversity to link agricultural productivity with environmental quality: Results from three field experiments in Iowa. Renewable Agriculture and Food Systems: 28(2); 115–128. doi:10.1017/S1742170512000300

Lin, Y. and Wei, X. (2008), 'The impact of large-scale forest harvesting on hydrology in the Willow watershed of Central British Columbia', *Journal of Hydrology*, **359**, pp. 141-149.

Lindsey, P. A., Alexander, R., Mills, M. G. L., Romanach, S. and Woodroffe, R. (2007), 'Wildlife viewing preferences of visitors to protected areas in South Africa: implications for the role of ecotourism in conservation', *Journal of Ecotourism*, **6**(1), pp. 19-33.

Liu, Y.-J., T.-W. Wang, C.-F. Cai, Z.-X. Li and D.-B. Cheng (2014) Effects of vegetation on runoff generation, sediment yield and soil shear strength on road-side slopes under a simulation rainfall test in the Three

Gorges Reservoir Area, China. Science of the Total Environment 485–486: 93–102. doi 10.1016/j.scitotenv.2014.03.053

MA (2005) 'Ecosystems and human well-being: synthesis'. Millennium Ecosystem Assessment, Island Press, Washington, DC.

Mace GM, Norris K, Fitter AH. (2012) Biodiversity and ecosystem services: a multilayered relationship. Trends Ecol. Evol. 27: 19–26. doi:10.1016/j.tree. 2011.08.006.

Mace, G.M., Hails, R.S., Cryle, P., Harlow, J. and Clarke, S.J. (2015), Towards a risk register for natural capital, *J. Appl. Ecol*. **52**, 641–653, http://dx.doi.org/10.1111/1365-2664.12431

Macfadyen, S., Cunningham, S.A., Costamagna, A.C. and Schellhorn, N.A. (2012) Managing ecosystem services and biodiversity conservation in agricultural landscapes: are the solutions the same? Journal of Applied Ecology 2012, 49, 690–694 doi: 10.1111/j.1365-2664.2012.02132.x.

Maes J, Paracchini ML, Zulian G, Dunbar MB, Alkemade R. (2012) Synergies and trade-offs between ecosystem service supply, biodiversity and habitat conservation status in Europe. Biol. Conserv. 155, 1–12. doi:10.1016/j.biocon.2012.06.016)

Maseyk, F.J.F., A.D. Mackay, H.P. Possingham, E.J. Dominati, Y.M. Buckley (2017) Managing natural capital stocks for the provision of ecosystem services, Conserv. Lett.

Mazda, Y., Magi, M., Kogo, M. and Hong, P.N. (1997), 'Mangroves as a coastal protection from waves in the Tong Kind delta, Vietnam', *Mangroves and Salt Marshes*, **1**, pp. 127-135.

McShane T.O. et al. (2011) Hard choices: making tradeoffs between biodiversity conservation and human well-being. Biol. Conserv. 144, 966–972. (doi:10. 1016/j.biocon.2010.04.038)

Moore, R.D. and Wondzell, S.M. (2005), 'Physical hydrology and the effects of forest harvesting in the Pacific Northwest: A review', *Journal of the American Water Resources Association*, **41(**4), pp. 763-784.

Munro, R. N., J. Deckers, M. Haile, A. T. Grove, J. Poesen and J. Nyssen (2008) Soil landscapes, land cover change and erosion features of the Central Plateau region of Tigrai, Ethiopia: Photo-monitoring with an interval of 30 years. Catena 75: 55-64. doi:10.1016/j.catena.2008.04.009

Munyuli, T.M.B. (2013) Socio-ecological drivers of the economic value of pollination services delivered to coffee in Uganda. International Journal of Biodiversity Science, Ecosystem Services and Management.

Nelson E et al. (2009) Modelling multiple ecosystem services, biodiversity conservation, commodity production, and tradeoffs at landscape scales. Front. Ecol. Environ. 7, 4–11. (doi:10.1890/080023)

Nosetto, M.D.; Jobbagy, E.G.; Paruelo, J.M. (2005) Land-use change and water losses: the case of grassland afforestation across a soil textural gradient in central Argentina. Global Change Biology 11: 1101-1117. 10.1111/j.1365-2486.2005.00975.x

Nowak, David J., Crane, Daniel E., Stevens, Jack C. (2006) Air pollution removal by urban trees and shrubs in the United States. Urban Forestry & Urban Greening 4: 115-123. 10.1016/j.ufug.2006.01.007

Paini, D.R. & Roberts, J.D. (2005) Commercial honey bees (Apis mellifera) reduce the fecundity of an Australian native bee (Hylaeus alcyoneus). *Biological Conservation*, 123, 103–112.

Ogden, Fred L., Trey D. Crouch, Robert F. Stallard and Jefferson S. Hall (2013) Effect of land cover and use on dry season river runoff, runoff efficiency, and peak storm runoff in the seasonal tropics of Central Panama. Water Resources Research, VolL. 49, 8443–8462. doi:10.1002/2013WR013956.

Palomo I., M.R. Felipe-Lucia, E.M. Bennett, B. Martín-López, U. Pascual. 2016. Chapter Six - Disentangling the Pathways and Effects of Ecosystem Service Co-Production, in: G.W. and D.A. Bohan (Ed.), *Advances in Ecological Research*, Academic Press, pp. 245–283.

Park, Young-Seuk, Yong-Su Kwon, Soon-Jin Hwang & Sangkyu Park (2014) Characterizing effects of landscape and morphometric factors on water quality of reservoirs using a self-organizing map. *Environmental Modelling & Software* 55:214-221. doi:10.1016/j.envsoft.2014.01.031

Pérez Soba, M., P.A. Harrison, A.C. Smith, G. Simpson, M. Uiterwijk, L. Miguel Ayala, F. Archaux, M. Blicharska, T. Erős, N. Fabrega, Á. I. György, R. Haines-Young, S. Li, E. Lommelen, L. Meiresonne, L. Mononen, E. Stange, F. Turkelboom, C. Veerkamp and V. Wyllie de Echeverria (2017). *Database and operational classification system of ecosystem service -natural capital relationships*. Deliverable 3.1 of the OpenNESS project, Version 2.1. European Commission FP7, 2015.

Petheram, C., Walker, G., Grayson, R., Thierfelder, T., Zhang, L. (2002) Towards a framework for predicting impacts of land-use on recharge: 1. A review of recharge studies in Australia. *Australian Journal of Soil Research*, 40, 397-417.

Pohl, M., F. Graf, A. Buttler and C. Rixen (2012) The relationship between plant species richness and soil aggregate stability can depend on disturbance. Plant and Soil 355: 87-102. DOI 10.1007/s11104-011-1083-5

Potschin, M., Haines-Young, R., Heink, U. and Jax, K. [eds] (2016) *OpenNESS Glossary* (V3.0), 39 pp. OpenNESS project, Grant Agreement No 308428. Available from: http://www.openness-project.eu/glossary.

Potter, Kevin M. and Christopher W. Woodall (2014), 'Does biodiversity make a difference? Relationships between species richness, evolutionary diversity, and aboveground live tree biomass across U.S. forests', *Forest Ecology and Management* **321** (2014) 117–129.

Rahman, M.M., Verfegem, M., Wahab, M.A. (2008) Effects of tilapia (Oreochromis niloticus L.) stocking and artificial feeding on water quality and production in rohu-common carp bi-culture ponds. Aquaculture Research 39-15:1579-1587.

Raudsepp-Hearne C, Peterson GD, Bennett EM (2010) Ecosystem service bundles for analyzing tradeoffs in diverse landscapes. Proc. Natl Acad. Sci. USA 107, 5242–5247. (doi:10.1073/pnas.0907284107)

Reyers, B., Biggs, R., Cumming, G.S., Elmqvist, T., Hejnowicz, A.P., Polasky, S., 2013. Getting the measure of ecosystem services: a social–ecological approach. *Front. Ecol. Environ*. 11, 268–273. http://dx.doi.org/10.1890/120144.

Reyers, B., Polasky, S., Tallis, H., Mooney, H.A. & Larigauderie, A. (2012) Finding common ground for biodiversity and ecosystem services. *BioScience*, 62: 503–507.

Ricketts, T.H., Watson, K.B., Koh, I., Ellis, A.M., Nicholson, C.C., Posner, S., Richardson, L.L & Sonter, L.J. (2016) Disaggregating the evidence linking biodiversity and ecosystem services. Nature Comms 7:13106, DOI: 10.1038/ncomms13106.

Ridder, B. (2008) Questioning the ecosystem services argument for biodiversity conservation. Biodivers. Conserv. 17, 781–790.

Rowe, L.K., Pearce, A.J. (1994) Hydrology and related changes after harvesting native forest catchments and establishing Pinus radiata plantations. part 2. The native forest water balance and changes in streamflow after harvesting. Hydrological Processes. 10.1002/hyp.3360080402

Ruiz-Frau, A., H.Hinz, G.Edwards-Jones & M.J.Kaiser (2013), ‘Spatially explicit economic assessment of cultural ecosystem services: Non-extractive recreational uses of the coastal environment related to marine biodiversity’, *Marine Policy* **38**, pp. 90–98.

Rusch, Adrien, Riccardo Bommarco, Mattias Jonsson, Henrik G. Smith and Barbara Ekbom (2013) Flow and stability of natural pest control services depend on complexity and crop rotation at the landscape scale. Journal of Applied Ecology 2013, 50, 345–354. doi: 10.1111/1365-2664.12055

Saebo, A., R. Popek, B. Nawrot, H. M. Hanslin, H. Gawronska and S. W. Gawronski (2012) Plant species differences in particulate matter accumulation on leaf surfaces. Science of the Total Environment 427: 347-354. doi:10.1016/j.scitotenv.2012.03.084

Sahin, V.; Hall, M.J. (1996) The effects of afforestation and deforestation on water yields. Journal of Hydrology 178: 293-309. 10.1016/0022-1694(95)02825-0

Salmond, J. A., Williams, D. E., Laing, G., Kingham, S., Dirks, K., Longley, I., Henshaw, G. S. (2013) The influence of vegetation on the horizontal and vertical distribution of pollutants in a street canyon. Science of the Total Environment 443: 287-298. 10.1016/j.scitotenv.2012.10.101

Scherr, S. and McNeely, J. (2008) Biodiversity conservation and agricultural sustainability: towards a new paradigm of ‘ecoagriculture’ landscapes. Phil. Trans. R. Soc. B 363, 477–494. DOI: 10.1098/rstb.2007.2165

Schindler D. E., Hilborn R., Chasco B., Boatright C.P., Quinn T.P., Rogers L.A. and Webster M.S. (2010) Population diversity and the portfolio effect in an exploited species. *Nature* **465**: 609-612. doi:10.1038/nature09060

Schnorbus, M. and Alila, Y. (2013), ‘Peak flow regime changes following forest harvesting in a snow-dominated basin: Effects of harvest area, elevation, and channel connectivity’, *Water Resources Research,* **49**, 517–535.

Schröter, M., Emma H. van der Zanden, Alexander P.E. van Oudenhoven, Roy P. Remme, Hector M. Serna-Chavez, Rudolf S. de Groot, & Paul Opdam (2014) ‘Ecosystem Services as a Contested Concept: A Synthesis of Critique and Counter-Arguments’. Conservation Letters, 7(6), 514–523. doi: 10.1111/conl.12091.

Schroth G. and Lehmann J. (1995) Contrasting effects of roots and mulch from 3 agroforestry tree species on yields of alley cropped maize, *Agriculture, Ecosystems and Environment* **54**: 89-101.

Singh, S. and Mishra, A. (2012), ‘Spatiotemporal analysis of the effects of forest covers on water yield in the Western Ghats of peninsular India’, *Journal of Hydrology*, **446–447**, pp. 24–34.

Smith, A.C., Berry, P.M. and Harrison, P.A. (2016) Sustainable Ecosystem Management. In: Potschin, M. and K. Jax (eds): *OpenNESS Ecosystem Services Reference Book*. EC FP7 Grant Agreement no. 308428. Available via: www.openness-project.eu/library/reference-book.

Smith, A.C. and Dunford, R.W. (2017) Land use scores for ecosystem service assessment. Project report from the NERC Green Infrastructure Innovation project ‘Tools for Planning and Evaluating Urban Green Infrastructure: Bicester and beyond’. Available on request from Alison.smith@eci.ox.ac.uk.

Smith, Richard G., Katherine L. Gross and G. Philip Robertson (2008) Effects of Crop Diversity on Agroecosystem Function: Crop Yield Response. Ecosystems 11: 355–366. DOI: 10.1007/s10021-008-9124-5

Smithson, J.B. and J.M. Lenne (1996) Varietal mixtures: a viable strategy for sustainable productivity in subsistence agriculture. Ann. appl. Biol.128:127-158.

Strassburg BBN et al. (2010) Global congruence of carbon storage and biodiversity in terrestrial ecosystems. Conserv. Lett. 3, 98–105. (doi:10.1111/j.1755-263X.2009.00092.x)

Tallis, M., Taylor, G., Sinnett, D., Freer-Smith, P. (2011) Estimating the removal of atmospheric particulate pollution by the urban tree canopy of London, under current and future environments. Landscape and Urban Planning 103: 129-138. 10.1016/j.landurbplan.2011.07.003

Thomas, H. and Nisbet, T.R. (2006), 'An assessment of the impact of floodplain woodland on flood flows', *Water and Environ. J.,* **21**, pp. 114-126.

Tran Van Con, Nguyen Toan Thang, Do Thi Thanh Ha, Cao Chi Khiem, Tran Hoang Quy, Vu Tien Lam, Tran Van Do, Tamotsu Sato (2013), 'Relationship between aboveground biomass and measures of structure and species diversity in tropical forests of Vietnam', *Forest Ecology and Management* **310,** pp. 213–218.

Van der Biest K, D'Hondt R, Jacobs S, Landuyt D, Staes J, Goethals P, Meire P. (2014) EBI: an index for delivery of ecosystem service bundles. Ecol. Indic. 37, 252–265. (doi:10.1016/j.ecolind.2013.04.006)

Van der Plas F., Manning P., Allan E., Scherer-Lorenzen M. … and Fischer, M. (2016) Jack-of-all-trades effects drive biodiversity–ecosystem multifunctionality relationships in European forests. Nature Comms 7:11109, DOI: 10.1038/ncomms11109.

Wang, Z., Y. Hou, H. Fang, D. Yu, M. Zhang, C. Xu, M. Chen and L. Sun (2012) Effects of plant species diversity on soil conservation and stability in the secondary succession phases of a semihumid evergreen broadleaf forest in China. Journal of Soil and Water Conservation 67: 311-320. doi: 10.2489/jswc.67.4.311

Watson, J. C., Wolf, A. T. and Ascher, J. S. (2011) Forested Landscapes Promote Richness and Abundance of Native Bees (Hymenoptera: Apoidea: Anthophila) in Wisconsin Apple Orchards. Environmental Entomology, 40(3), 621-632.

Wong CP, Jiang B, Kinzig AP, Lee MN, Ouyang Z. (2015) Linking ecosystem characteristics to final ecosystem services for public policy. Ecol. Lett. 18, 108–118. (doi:10.1111/ele.12389)

Zavaleta, E. (2000), 'The economic value of controlling an invasive shrub', *AMBIO: A Journal of the Human Environment,* **29**(8), pp. 462-467.

Zhang, J.T., Xiang C., Min, L. (2012) Effects of Tourism and Topography on Vegetation Diversity in the Subalpine Meadows of the Dongling Mountains of Beijing, China. *Environmental Management*, 49: 403-411.

Zhu, Youyong , Hairu Chen, Jinghua Fan, Yunyue Wang, Yan Li, Jianbing Chen, JinXiang Fan, Shisheng Yang, Lingping Hu, Hei Leung, Tom W. Mew, Paul S. Teng, Zonghua Wang & Christopher C. Mundt (2000) Genetic diversity and disease control in rice. *Nature* 406: 718-722.

How natural capital delivers ecosystem services: a typology derived from a systematic review. Supplementary Material

1 Overview across all ecosystem services

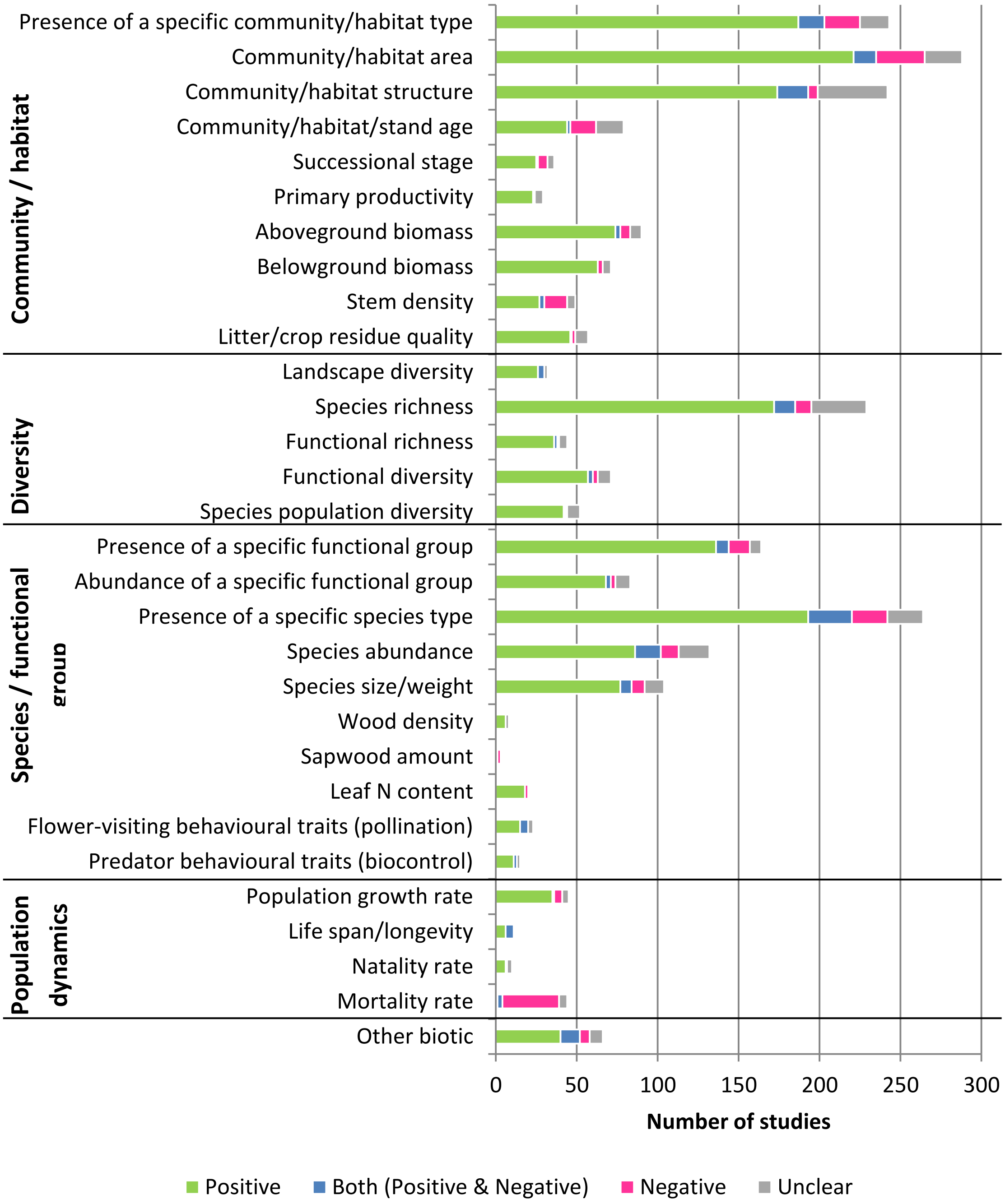


Figure S1: Number of studies reviewed that cite links between biotic attributes and ecosystem service delivery. A total of 780 studies were reviewed. The colours of the bar segments indicate the direction of influence of the biotic attribute on the ecosystem service. “Both” indicates cases where an attribute had both a positive and negative influence on the service. “Unclear” indicates cases where the direction of the link was uncertain.

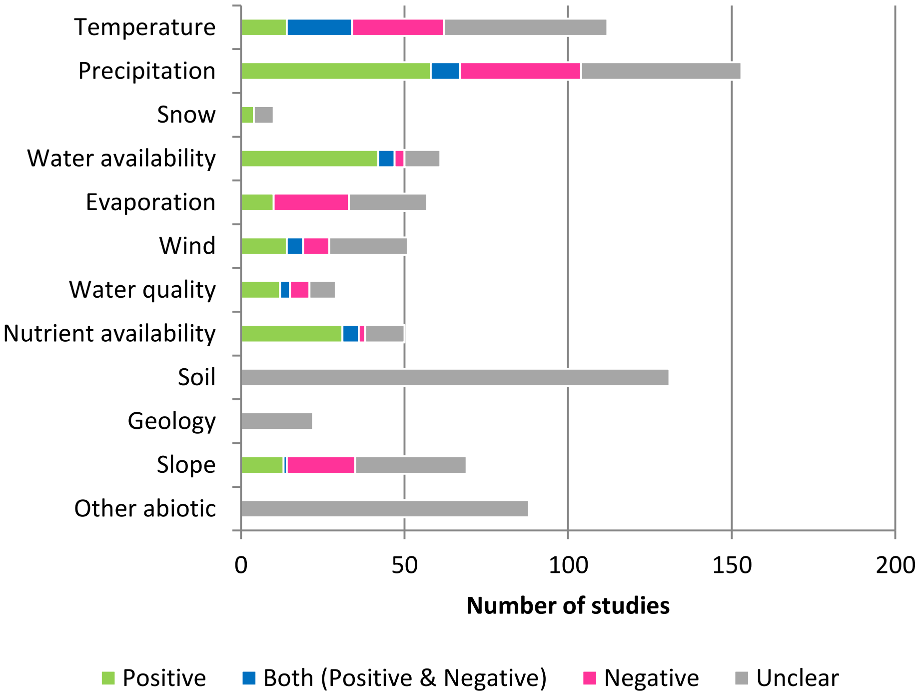


Figure S2: Number of articles reviewed that cite links between abiotic factors and ecosystem service delivery. A total of 780 studies were reviewed. The colours of the bar segments indicate the direction of influence of the abiotic factor on the ecosystem service. “Both” indicates cases where an attribute had both a positive and negative influence on the service. “Unclear” indicates cases where the direction of the link was uncertain.

2 Network diagrams for ecosystem services

References for this section are in Appendix D.

2.1 Regulating services

2.1.1 Atmospheric regulation (carbon storage)

Most of the studies on atmospheric regulation are experimental measurements of vegetation biomass at a particular local site – often sampling a group of plots in a forest, or comparing two different habitats such as forest and farmland, or logged forest and intact forest. The estimates of biomass are then used to estimate carbon storage in tons per hectare, or carbon sequestration in tons/hectare/year. Most of the studies assess the service at the level of the entire community or habitat, which can include not just trees and shrubs but also grass, understory plants, dead wood, leaf litter and soil carbon. However, some studies focus on specific species or functional groups.

The main determinant of carbon storage is simply the amount of biomass, so key attributes are community (forest) area, above- and below-ground biomass, stand age, primary productivity, growth rate and species size/weight. For example, Kirby and Potvin (2007) find that trees with diameter at breast height (DBH) over 10cm account for 90% of the aboveground carbon stocks in the forest area studied. A number of studies investigate the impact of species richness, functional richness, functional diversity and structural diversity, finding that this has a positive impact in many studies, but that sometimes a less diverse mix could store more carbon if it consists of large tree species. Chen (2006) reports that carbon storage increases with species richness but that it may saturate at a low number of species, after which it increases more slowly:

this is the only example of a threshold found in the review. Many of the more recent articles highlight an interesting debate over the role of niche complementarity versus the selection effect. For example, Tran van Con et al. (2013) find that the link between diversity and carbon storage is highest within a particular site, and may not be evident in broader scale comparisons due to differences in other environmental factors. They suggest that resource-use complementarity is most evident in structurally complex forests with multiple canopy layers, and that diversity may have a lower impact in simpler forests with few species. Site productivity may also be important: Potter and Woodall (2014) find that although higher carbon storage can be achieved by a monoculture of large trees in fertile sites, resource-use complementarity is important for boosting productivity in less fertile sites or those which are challenged by adverse environmental conditions such as droughts. Successional stage may be a confounding factor, as more mature (and therefore more diverse) natural forests have older and larger trees (Gonzalez et al., 2014).

Mortality rate is the only attribute to negatively affect carbon storage, for example as a result of wildfire (e.g. Haugaasen et al., 2003), pests such as bark beetle (Seidl et al., 2008), or grazing (Klumpp et al., 2009).

The relationships between abiotic factors and atmospheric regulation are less clear, with the review finding that these are highly dependent on the ecosystem and location considered. Factors include water availability, precipitation, evaporation, temperature and soil (including the effect of pH; Keeton et al., 2010; and soil moisture; Yurova and Lankreiger, 2007). Drought and high temperatures, both exacerbated by climate change, are often cited as having a negative impact on this service (e.g. Beier et al., 2009, Law et al., 2003), and wildfire occurrence is an additional (often related) abiotic factor (e.g. Wardle et al., 2012).

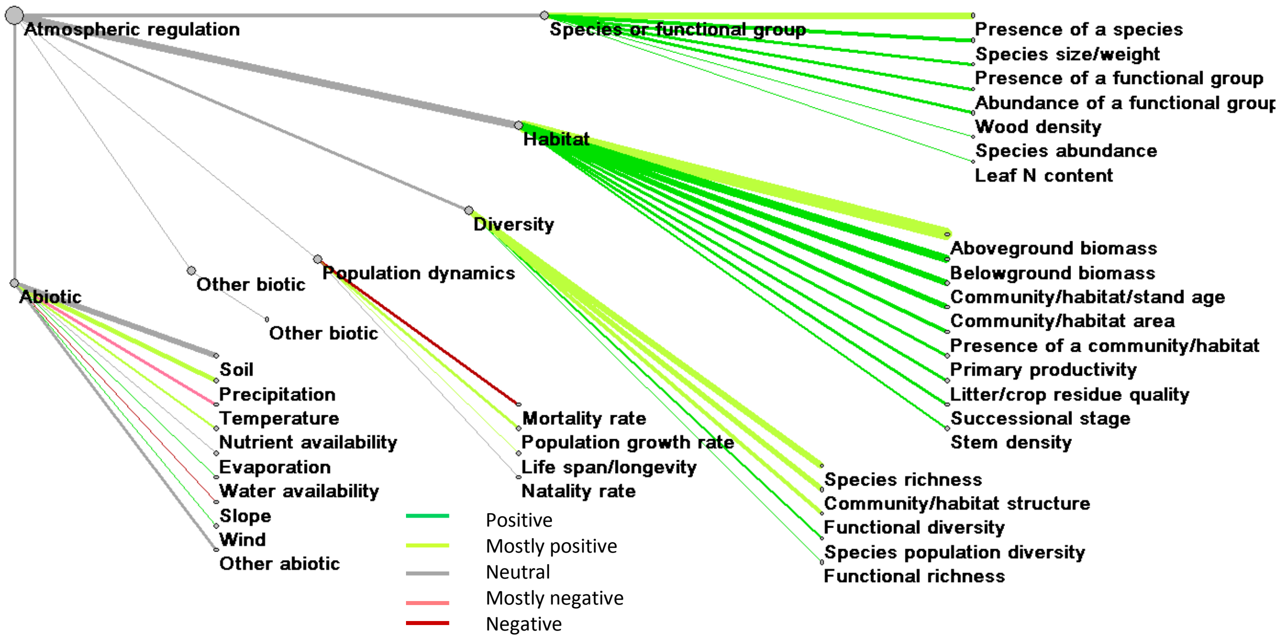


Figure S3. Network diagram mapping the evidence on how biotic attributes and abiotic factors influence the service of atmospheric regulation. Line thickness is proportional to number of studies supporting each link and line colour indicates predominant direction of link.

2.1.2 Air quality regulation

For air quality regulation, there is a split between attributes related to the entire habitat (typically urban woodland), and particular species or functional groups such as ‘urban trees’ or ‘coniferous trees’ (Figure S6). Community/habitat area (i.e. the percentage of tree cover) is a key attribute, and so is the leaf area index (i.e. the ratio between leaf surface area and ground area), which was not included in the original list of attributes and so is recorded under ‘other biotic’. However, many of the studies compare different tree species, trying to find those most suitable for planting in urban areas in order to improve air quality. Species characteristics such as leaf size, shape (needle or broad-leaved), stickiness and hairiness are often investigated. Most articles conclude that coniferous trees are more effective at trapping pollution because their needle-shaped leaves have a high surface area, and because they are mainly evergreens and therefore can contribute to air quality all year round (e.g. Tallis et al., 2011). However, they may not be tolerant of high roadside pollution levels and salt from road run-off, so might not be appropriate for the 'front-line' positions immediately next to busy roads (Saebo et al., 2012).

The impacts of the abiotic factors are complex and context-dependent. Wind can have a beneficial effect locally by dispersing pollution away from city streets or increasing deposition rates on leaves, but it can also re-suspend deposited particles (Nowak et al., 2006). High temperatures can decrease uptake of pollutants by plants (Alonso et al., 2011) and may also have a negative impact because certain tree species emit biogenic volatile organic compounds (B-VOCs) such as isoprene in hot weather, and these react with nitrogen oxides from traffic to form ground-level ozone pollution (Salmond et al., 2013). However, there can also be a beneficial effect in the range where warmer temperatures enhance plant growth, thus increasing the amount of vegetation that can trap pollutants.

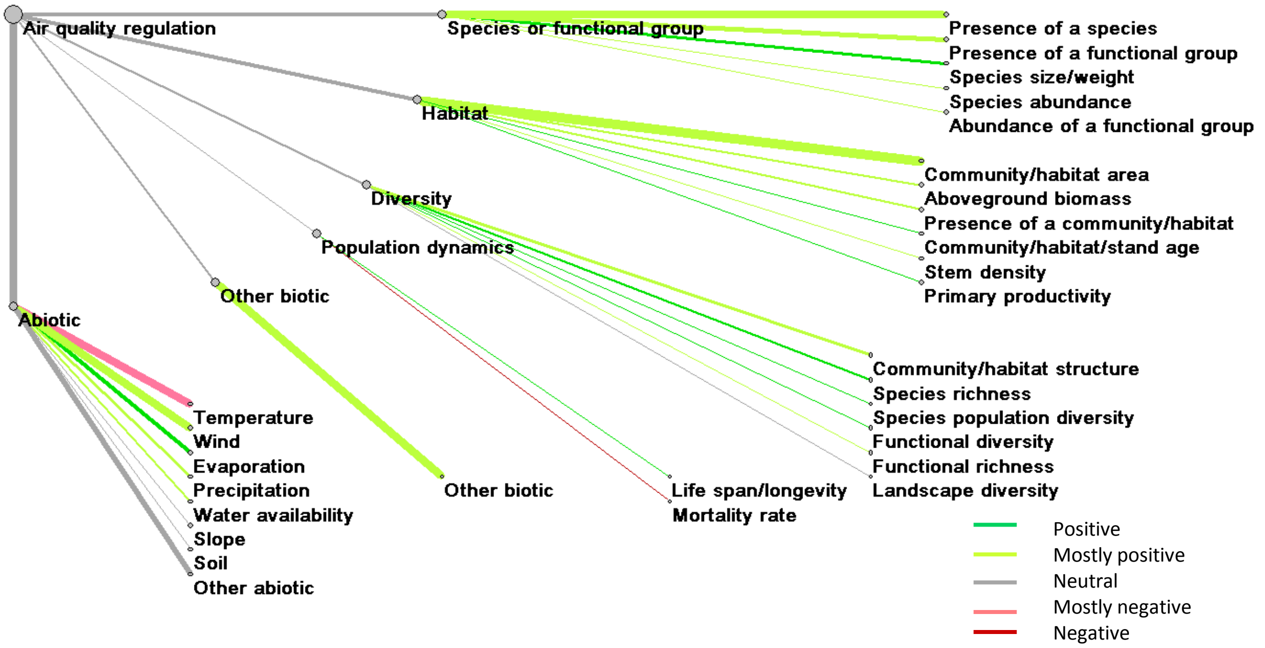


Figure S4. Network diagram mapping the evidence on how biotic attributes and abiotic factors influence the service of air quality regulation. Line thickness is proportional to number of studies supporting each link and line colour indicates predominant direction of link.

2.1.3 Water flow regulation (flood protection)

Most of the articles reviewed for this service describe 'paired catchment' studies which compare two similar catchments with different forest cover, or the same catchment before and after felling. Forests reduce peak run-off, by intercepting precipitation, absorbing groundwater through transpiration and improving the infiltration capacity of the soil, so storm flows in streams and rivers increase when catchments are deforested. Community/habitat area is the most commonly identified biotic attribute, as shown by the thickness of the line, and it has a predominantly positive influence on water flow regulation as shown by the light green colour. Several papers cite a threshold effect where storm flows increase noticeably when forest cover in the catchment falls below 20-30% (Bathurst et al., 2010; Lin & Wei, 2008; Schnorbus & Alila, 2013). As larger trees tend to intercept and absorb more water, stand age is also cited a number of times, as are above- and below-ground biomass, successional stage, species size/weight and growth rate. Several studies show a positive impact of litter quality on rainwater infiltration rates.

Some articles focus on particular species: these are mainly studies of plantations dominated by single species such as pine or beech. Characteristics of particular species or functional groups are mentioned in some studies, but the results vary depending on the context. For example, Lange et al. (2013) find that the high root density and transpiration rates in beech forest provide greater infiltration and better flood protection than spruce forest, but Hümann et al. (2011) find that conifer forests (spruce and fir) have deeper root systems and lower runoff coefficients than deciduous forests. Both studies therefore agree on the importance of a particular functional group — species with a dense, deep root system — but in one case this function is greater in the deciduous forest and in the other it is greater in the coniferous forest. In three studies, species abundance is cited as having a negative impact on flood protection as a result of invasive species reducing river channel capacity and trapping sediment. These include mangrove (*Kandelia candel*) (Lee and Shih, 2004), willow (Erskine and Webb, 2003) and tamarisk (Zavaleta, 2000).

Interestingly, water flow regulation is the only service for which no attributes connected to species/functional richness or diversity are mentioned in the literature. However, structural complexity (‘roughness’) is found to increase protection against storm surges in coastal vegetation (Mazda et al., 1997; Ferrario et al., 2014) and to increase floodwater retention in floodplain woodlands (Thomas and Nisbet, 2006).

For the abiotic factors, precipitation has a direct negative impact, but there is an interesting debate over the impact of rainfall intensity on the ability of the ecosystem to provide flood protection. The established view is that forest cover has a limited effect for more extreme rainfall events (e.g. Bathurst et al., 2007; Bruijnzeel, 2004; Cheng et al., 2002; Clark, 1987; Moore and Wondzell, 2005). However, Green and Alila (2012) argue that forest cover will always decrease both the frequency and the magnitude of flood events.

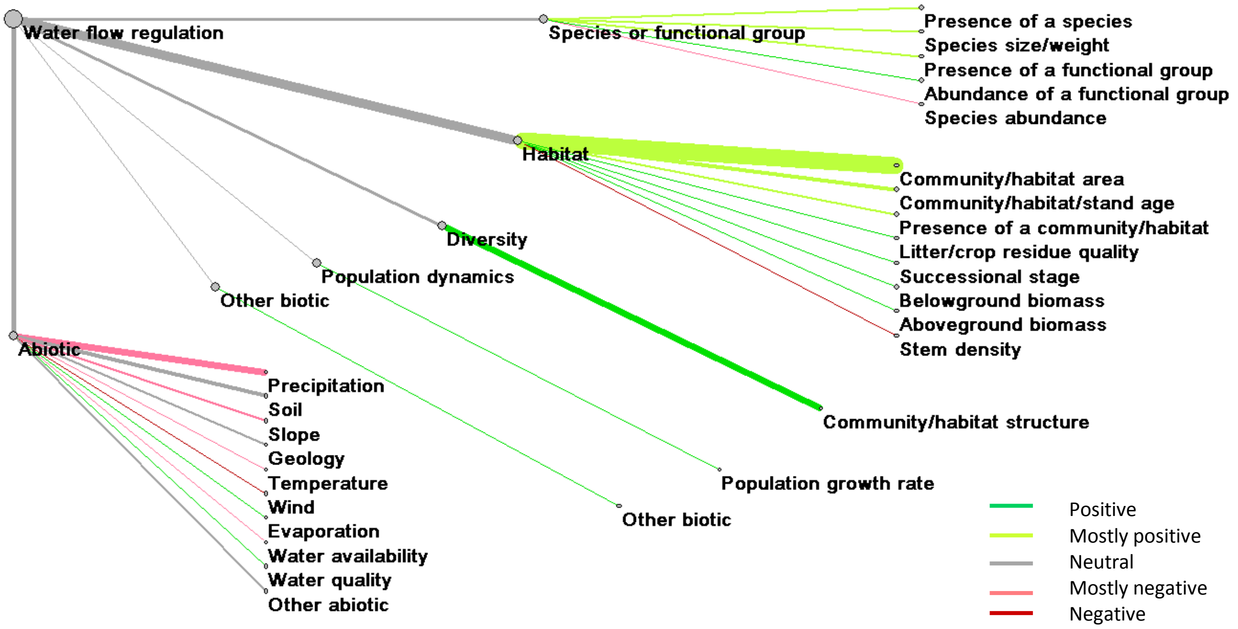


Figure S5. Network diagram mapping the evidence on how biotic attributes and abiotic factors influence the service of water flow regulation (flood protection). Line thickness is proportional to number of studies supporting each link and line colour indicates predominant direction of link.

2.1.4 Mass flow regulation (erosion protection)

For mass flow regulation habitat area is frequently cited, with the area covered by vegetation being crucial, but so are species characteristics. Many studies compare different species of tree, shrub or herbaceous plants to determine which perform best for stabilising eroded slopes. Characteristics such as root depth, strength, density and structure are often found to be important for binding soil particles together and increasing soil infiltration (e.g. de Baets et al., 2009; Pohl et al., 2012). These are classified in the review as below-ground biomass or presence/abundance of a functional group such as ‘deep-rooted shrubs’. However, the structure, strength and elasticity of the above-ground vegetation is also cited as being important for intercepting rainfall, resisting water flow and trapping sediment, and the thickness and quality of the litter layer plays a key role in improving soil structure and protecting the soil surface from erosion (e.g. Andry et al., 2007).

For mass flow regulation, forests are not always the best-performing habitat: sometimes fast-growing herbaceous vegetation or permanent grassland can provide better ground cover in the short term, compared to a newly planted forest where the gaps between the trees are bare (Huang et al., 2006). Also, taller trees are not always best as they can exert more pressure on slopes (e.g. Bochet et al., 2006). Species richness and diversity is found to be beneficial by increasing the total vegetation cover and the range of root depths in the soil (e.g. Wang et al., 2012).

With regard to the abiotic factors, precipitation clearly has an adverse impact as most erosion occurs during extreme rainfall events. Steep slopes also exacerbate soil erosion. However, water availability has a beneficial impact as water is necessary for vegetation to become established, thus stabilising and protecting the slope. Drought conditions therefore often lead to more intense soil erosion.

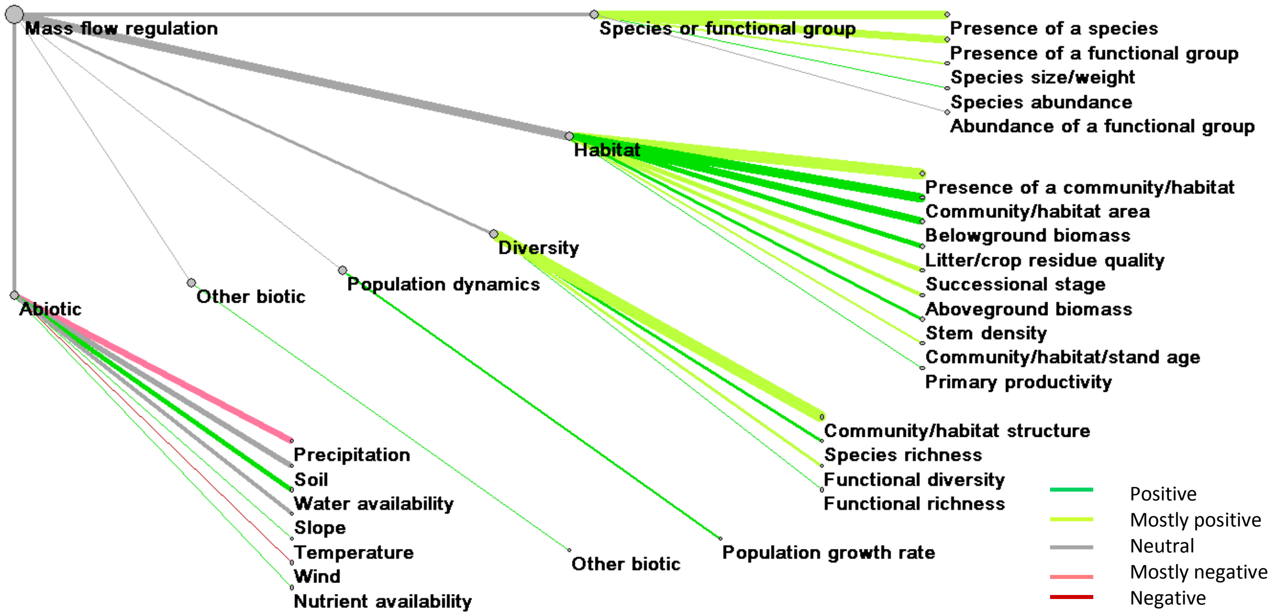


Figure S6. Network diagram mapping the evidence on how biotic attributes and abiotic factors influence the service of mass flow regulation (erosion protection). Line thickness is proportional to number of studies supporting each link and line colour indicates predominant direction of link.

2.1.5 Water quality regulation

The articles reviewed include large-scale land use studies such as the impact of deforestation on water quality in rivers and lakes; smaller scale experimental studies of the impact of vegetation type on water quality in wetlands; and studies of the impact of riparian buffer zones along streams and rivers. The main indicators were direct measurements of water quality, typically concentrations of various forms of nitrogen and phosphorous and/or suspended sediments, and measurements of nutrient removal rates.

The review identifies a number of ways in which ecosystems such as forests, wetlands and grassland can improve water quality:

(i) Permanent vegetation reduces soil erosion compared to bare ground or farmland;
(ii) Vegetation and marshes can trap sediment before it reaches water courses;
(iii) Vegetation can absorb and adsorb excess nutrients and other impurities;
(iv) Soils can host de-nitrifying bacteria that break down nitrates from fertiliser runoff into harmless nitrogen gas;
(v) Vegetation roots can improve infiltration, allowing more impurities to be filtered out by the soil and preventing pollution of adjacent streams and lakes.

Because of the role of vegetation in preventing erosion, physically trapping sediment and absorbing pollution, biotic attributes related to the amount of vegetation are found to have a positive impact. By far the most commonly cited attributes are the presence of a specific community/habitat (43 studies) and community/habitat area (40 studies), but community / habitat structure and age, above- and below-ground biomass, primary productivity, stand age, stem density and species size or weight are all found to have a generally positive impact. There are a few exceptions, with some studies finding that younger forest with a high density of small trees was more effective at filtering out pollutants than more mature forest with widely spaced trees (de Souza et al., 2013). Several studies focus on the abundance of highly effective species, such as California bulrush, poplar, willow or seagrass, or functional groups such as mangroves.

Ten studies also find an impact from various types of diversity, including species richness, species population diversity, functional richness and functional diversity. The impacts are predominantly positive and seem to be related to the ability of more diverse mixtures to be more productive, and therefore take up more nutrients, due to niche complementarity (i.e. exploitation of a wider range of resources) (Fisher et al., 2009; Cardinale, 2011). However, in two studies the impact is unclear, with Cardinale et al. (2011) stating that there is no evidence that polycultures out-perform the most efficient monocultures. Similarly, Weisner and Thiere (2010) found that wetlands dominated by a less diverse mix of tall, emergent vegetation are more efficient at nitrogen removal. These two studies therefore demonstrate the selection effect rather than the niche complementarity effect.

The main abiotic factor cited in the literature is, unsurprisingly, water quality. This is classified as having a mainly negative impact as badly polluted water can damage the ecosystem, reducing its ability to provide the service. Other abiotic factors mentioned include temperature, slope, precipitation, and soil. The relationship with water quality regulation is often unclear or mixed (both positive and negative), and varies between studies. For example, Tomimatsu et al. (2014) find that higher temperatures in summer speed up nitrogen removal in wetlands due to higher plant growth rates, but Rodrigo et al. (2013) find that warmer weather stimulates algal blooms.

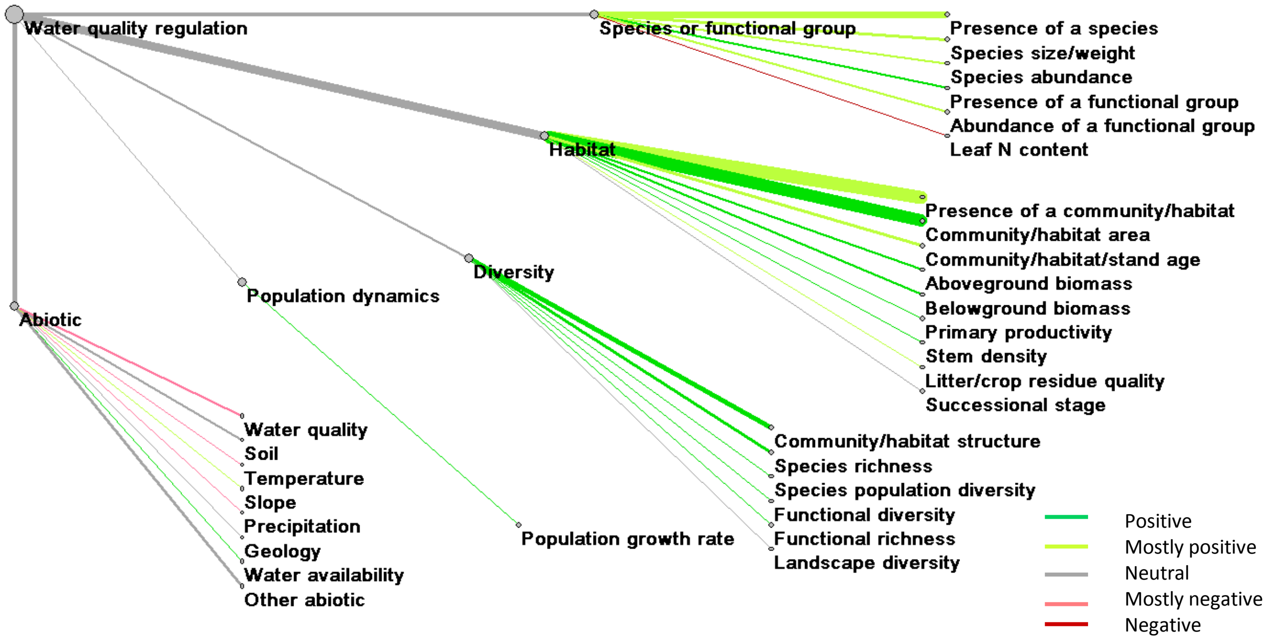


Figure S7. Network diagram mapping the evidence on how biotic attributes and abiotic factors influence the service of water quality regulation. Line thickness is proportional to number of studies supporting each link and line colour indicates predominant direction of link.

2.1.6 Pollination

It is difficult to measure pollination effectiveness directly, so a range of proxy indicators were used, including crop yield, fruit or seed set, the number of pollinating insects, the percentage of natural land cover, or distance of agricultural fields to natural or semi-natural habitats.

The most commonly cited biotic attribute is the presence of a functional group (33 counts). Related to this, the abundance of a functional group (23 counts), presence of particular species (22 counts) and abundance of species (27 counts) are also important, with behavioural traits such as foraging distance, flight range, pollinator size, and bee tongue length (Bommarco et al., 2011) being important in determining which pollinators can access certain flowers (23 counts). However, the second most common attribute is community/habitat structure (30 counts), emphasising the importance of nearby habitats in providing shelter for pollinators and alternative food when crops are harvested. Many articles mentioned that a diverse, natural habitat with a variety of flowering plants was needed to support populations of pollinators. Pollinating services and the diversity of pollinators tended to decline with increasing distance from natural habitat (e.g. Carvalheiro et al., 2010).

Diversity appears to be very important for pollination, with species richness being the third most frequently cited attribute (28 counts). Studies refer both to the diversity of the pollinators, and to the diversity of the plant species in the habitats needed to sustain the pollinators. The impact of pollinator diversity is mainly positive, with various studies finding that more diverse populations of pollinators increased seed production (e.g. Albrecht et al., 2007), coffee fruit set (e.g. Vergara and Badano, 2009) and pollination efficiency (Hoehn et al., 2008; Balvanera et al., 2005). This is generally because different species visit different plants (Winfree et al., 2008) or visit different areas and at different times (Hoehn et al., 2008), so that a more diverse community provides a more complete pollination service. Many articles also discuss the need for plant species richness and functional diversity in the surrounding habitat, in order to support populations of pollinators (e.g. Holzschuh et al., 2011). In fact, the strong relationship between plant diversity and pollinator diversity is demonstrated by Batary et al. (2010) who find that the richness of insect-pollinated plant species is directly correlated with bee species richness in three different European countries. The relationship works both ways, with Fontaine et al. (2006) showing that after two years, plant communities pollinated by more functionally diverse pollinator assemblages contained about 50% more species than those pollinated by less diverse assemblages. However, there are also examples of negative impacts on pollination, associated with the introduction of honey bees which compete with native bees (Shavit et al., 2009; Badano and Vergara, 2011).

Abiotic factors such as temperature and wind speed are mentioned in a number of journal articles, but the direction of impact on pollination is usually unclear.

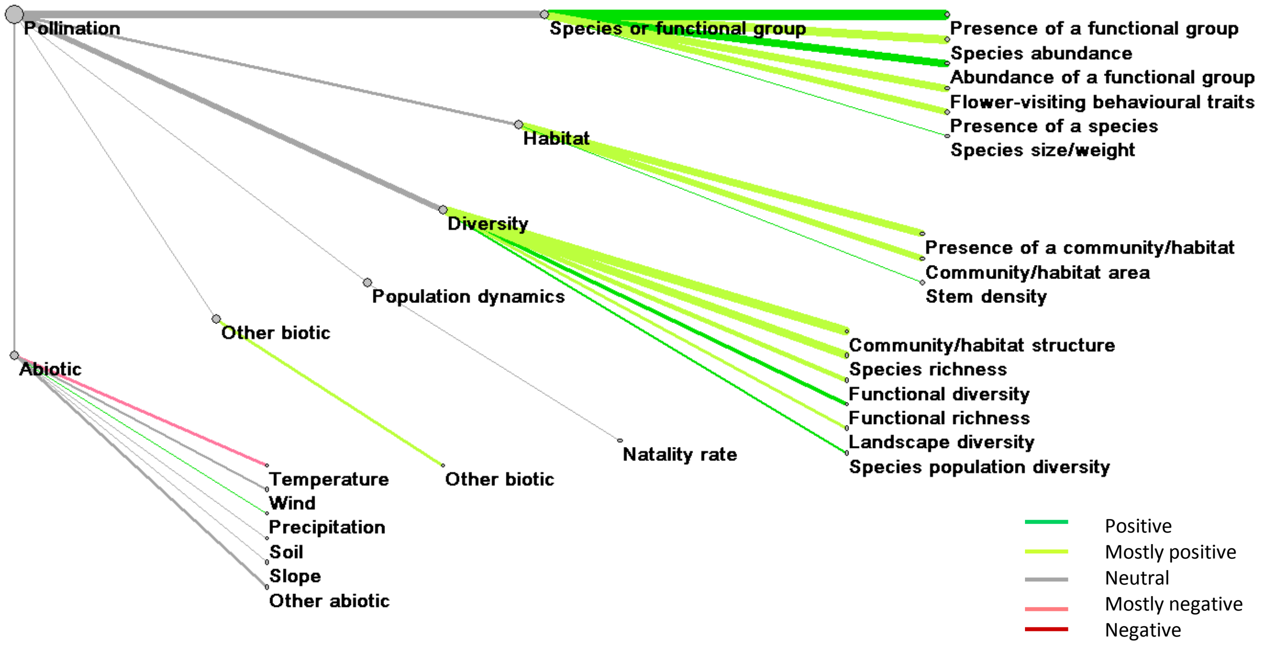


Figure S8. Network diagram mapping the evidence on how biotic attributes and abiotic factors influence the service of pollination. Line thickness is proportional to number of studies supporting each link and line colour indicates predominant direction of link.

2.1.7 Pest regulation

The most commonly cited attributes are community/habitat presence, area and structure, because many articles focus on the importance of natural or semi-natural habitats for supporting populations of pest predators. The studies find that pest predation is positively influenced by complex habitats (e.g. Bianchi et al., 2006); by crop lands interspersed with and/or surrounded by semi-natural habitat (e.g. Letourneau et al., 2012); by good connectivity between patches (e.g. Boccaccio and Petacchi, 2009); and by diverse plant communities (e.g. Drapela et al., 2008). Habitat management can therefore influence predator density through modifications such as thicker ground cover (Colloff et al., 2013) or creation of semi-natural field edges (Krauss et al., 2011).

Other important attributes include the presence and abundance of a specific functional group (i.e. predators), and species abundance. A number of studies found that species richness, functional richness and functional diversity are important, though while several find that land use management can enhance predator diversity, fewer demonstrate that predator diversity reduces pest activity. Those that do attribute this to niche complementarity, with different predators attacking different prey sizes, life stages, population densities and behaviour (e.g. flying vs. ground dwelling), but other studies find no effect of diversity. Predator behavioural traits are also cited, such as the ability to disperse over long distances (e.g. Öberg, 2007) or the ability to form aggregations during dormancy so that they can hatch en masse and attack prey (Iperti, 1999). These linkages are predominantly positive.

A small range of abiotic factors are discussed in the literature, with temperature and precipitation being the most common, although the effect is variable.

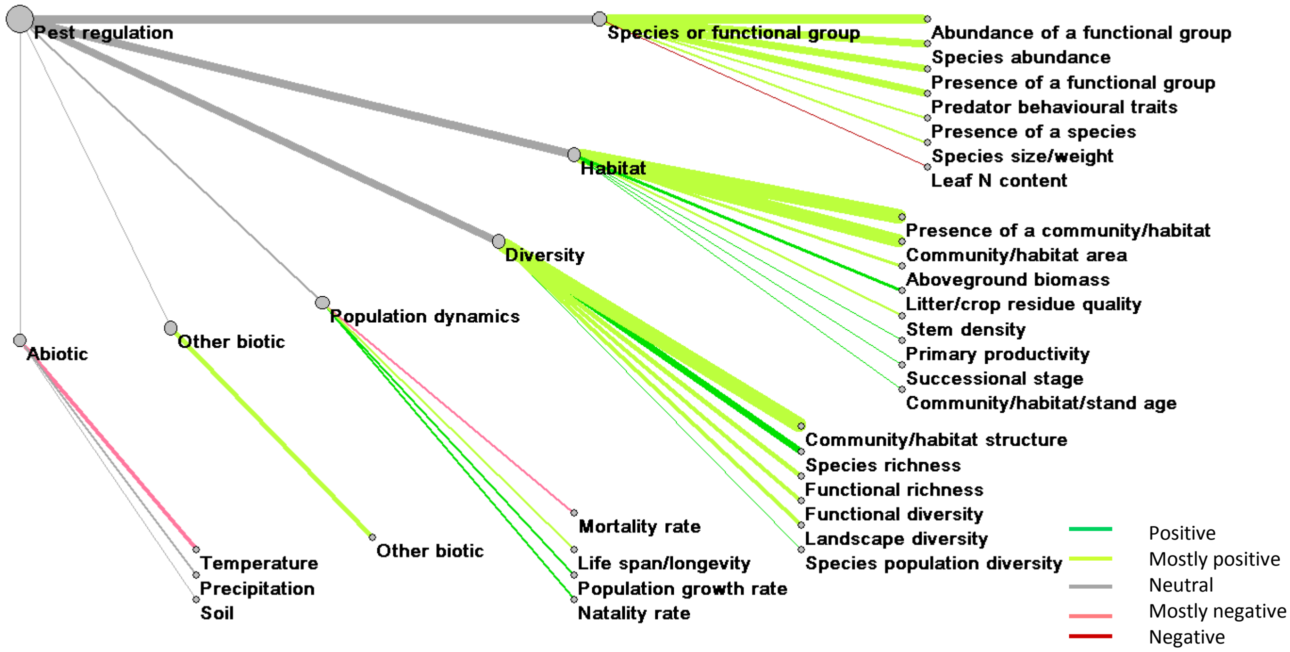


Figure S9. Network diagram mapping the evidence on how biotic attributes and abiotic factors influence the service of pest regulation. Line thickness is proportional to number of studies supporting each link and line colour indicates predominant direction of link.

2.2 Provisioning services

2.2.1 Freshwater fishing

Species-level attributes are the most frequently discussed, with species abundance (stocking rate), species size/weight and population growth rate all having a predominantly positive impact on freshwater fishing. Larger fish were preferred by fishermen, and were also found to produce larger yields due to their higher survival rate (Li, 1999). Mortality rate was the only biotic attribute found to have a purely negative impact. However, there was a trade-off between species abundance and yield, because over-stocking reduces fish size and eventually leads to increased mortality (e.g. Lorenzen, 1995). Species abundance of particular non-native species can also have a negative impact in a few cases due to predation: for example, sea lamprey (*Petromyzon marinus*) caused a large decrease in populations of commercially important fish in Lake Superior (Lawrie, 1978). Species richness was also found to have a positive influence, with a number of studies finding higher productivity and yield in polycultures compared to monocultures. Although the main focus was on species attributes, a number of papers emphasised the importance of the habitat, i.e. the lake or river, with primary productivity, community/habitat area and structure all being important.

A range of abiotic factors are discussed, of which water quality and nutrient availability are the most frequently cited. Nutrient availability has mixed impacts: it can improve fish production, e.g. through feeding fish in aquaculture ponds, but excess nutrients can also cause eutrophication.

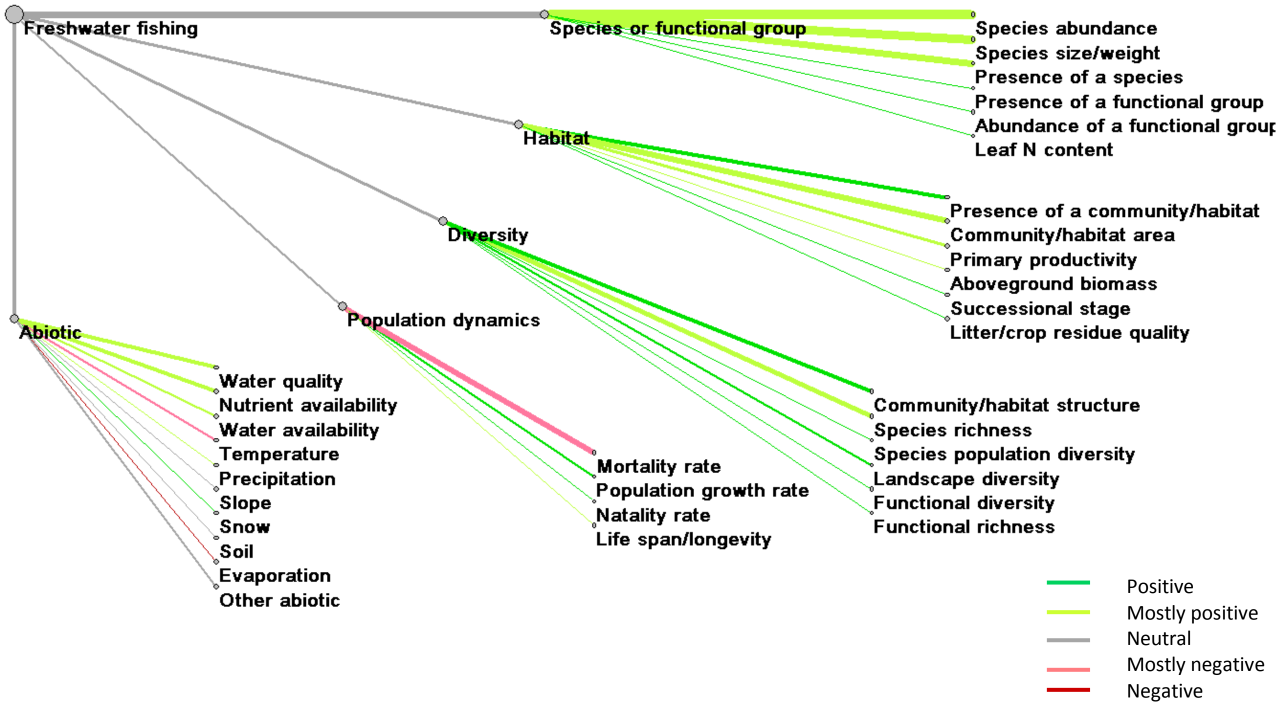


Figure S10. Network diagram mapping the evidence on how biotic attributes and abiotic factors influence the service of freshwater fishing. Line thickness is proportional to number of studies supporting each link and line colour indicates predominant direction of link.

2.2.2 Timber production

The impact of biotic attributes seems to be predominantly positive, with species richness being cited the most often. Most studies (35) found evidence that plantation species are more productive in mixtures than in monocultures (e.g. Erskine et al., 2006), but there is some conflicting evidence, with five studies finding monocultures to be more productive (e.g. Nguyen et al., 2012). Other factors with a mainly positive impact on timber production include presence of a particular species (i.e. those with most commercial value), species abundance, stem density, functional diversity, and community/habitat structure. For example, Donoso et al. (2007) found that forests with mixed canopy heights are more productive due to better use of the available light. However there were some examples of negative impacts, including lower productivity at later successional stages (e.g. Vila et al., 2003), lower quality timber at higher stem densities due to overcrowding (e.g. Adame et al., 2014), and competition from functional groups such as understorey vegetation or tall trees with dense canopies that shade those beneath them.

For the abiotic factors, the most commonly mentioned is soil, though other factors such as precipitation and temperature are also found to have a positive impact in a small number of cases. Water availability sometimes had a negative impact due to waterlogging of the soil.

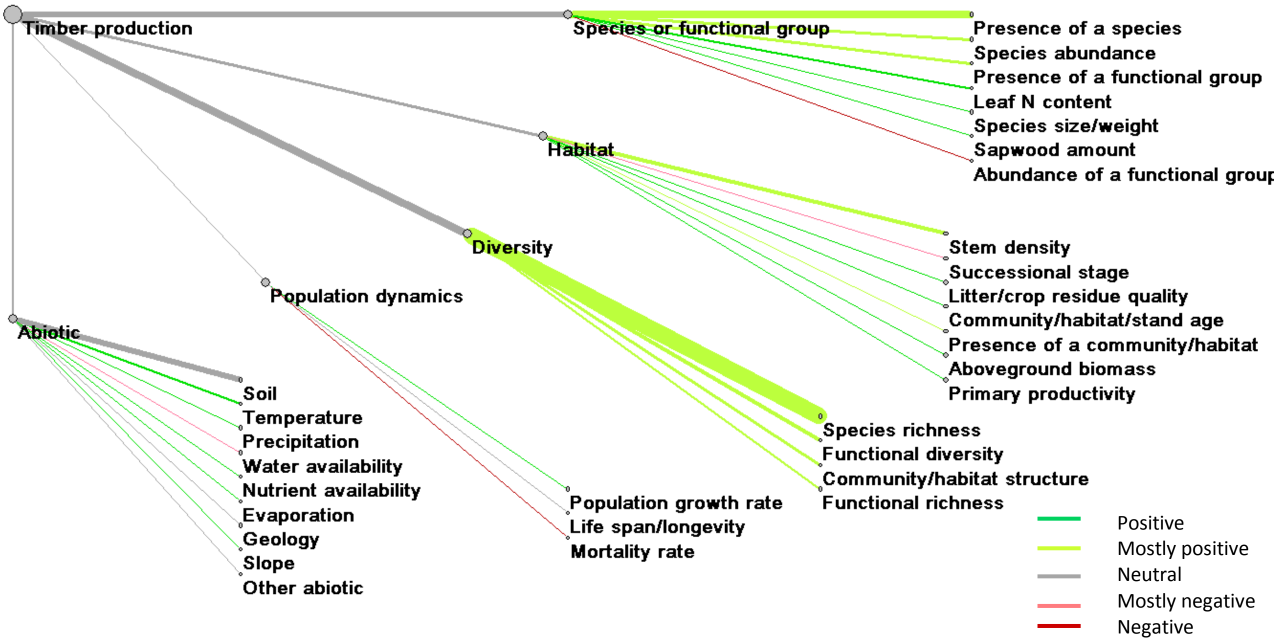


Figure S11. Network diagram mapping the evidence on how biotic attributes and abiotic factors influence the service of timber production. Line thickness is proportional to number of studies supporting each link and line colour indicates predominant direction of link

2.2.3 Food crop production

Species richness is the most frequently mentioned biotic attribute, as many of the studies look at sustainable agricultural techniques such as intercropping, crop rotation or the use of cover crops, all of which increase the number of crop species grown. The presence of particular functional groups or species is of course crucial, as only certain crops are palatable and suitable for cultivation, though this relationship is so obvious that it is not always explicitly mentioned in the literature. A number of studies explore the use of cultivar mixes, i.e. growing mixtures of several varieties of the same species (such as wheat), which is classed as species population diversity (genetic diversity). This often has a beneficial effect due to niche complementarity, e.g. when the different cultivars can access nutrients or water at different depths, and these mixtures are often more resistant to pests and diseases. However, sometimes a monoculture of the most productive species can be more successful, at least in the short term.

Aboveground and belowground biomass are clearly important as these are strongly related to crop yield for most crops, but the link to biomass was often too obvious to be explicitly mentioned. Litter / crop residue quality was also found to be important in a number of studies that looked at the impacts of mulching, especially with nitrogen-fixing legumes that can increase soil fertility as they decompose.

Abiotic factors are frequently mentioned. Unsurprisingly, nutrient availability has a positive effect, with yields being increased by synthetic fertilisers and by more sustainable methods such as intercropping with legumes. Precipitation and water availability are also mainly beneficial, although heavy precipitation can wash away soil and nutrients, and waterlogged ground can cause problems in some contexts. Soil quality and temperature are also mentioned.

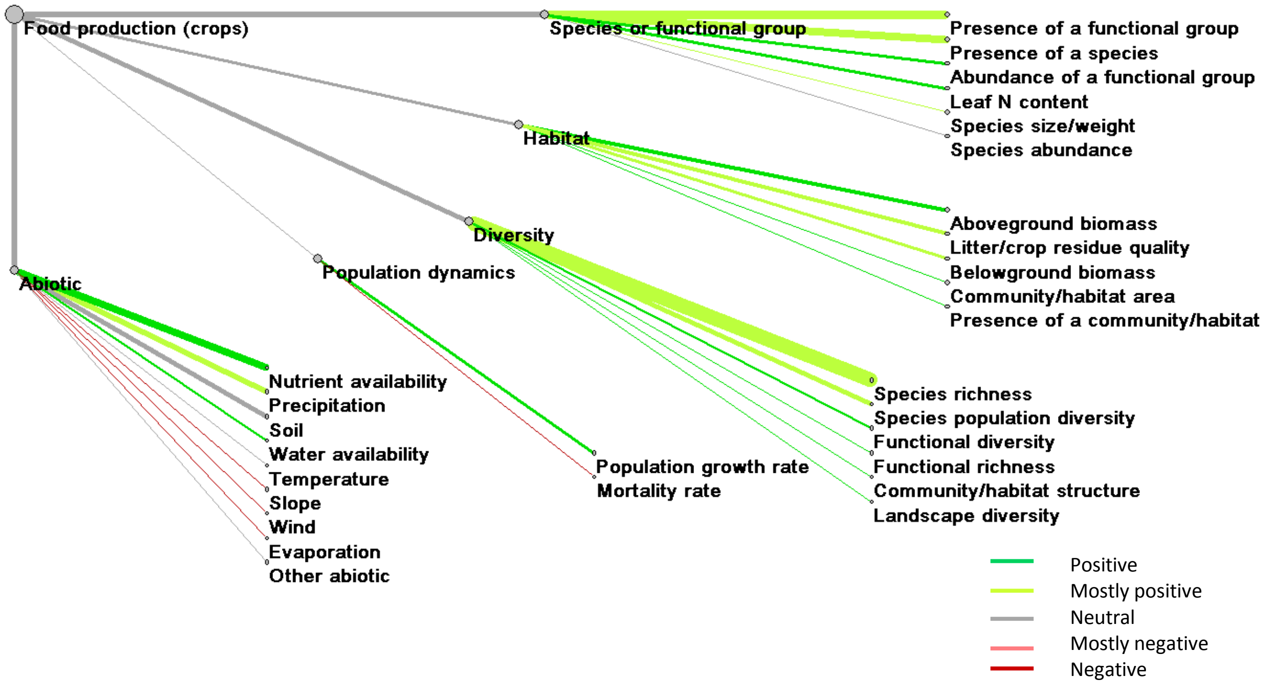


Figure S12. Network diagram mapping the evidence on how biotic attributes and abiotic factors influence the service of food crop production. Line thickness is proportional to number of studies supporting each link and line colour indicates predominant direction of link.

2.2.4 Water supply

Water supply (

Figure S13) is more similar to the regulating services than to the other provisioning services discussed here, because it depends largely on the entire community/habitat area rather than on species characteristics. However, in contrast to the other ecosystem services, the impact of biotic attributes is often negative. Although the interception of rainwater and absorption of groundwater by forests is beneficial for flood protection, as described above, it can also reduce water supply, which can cause problems where water is scarce. Most (42 out of 60) of the articles reviewed describe the negative effects of forests on water supply in water-scarce countries such as Australia and South Africa, although these are typically timber plantations of fast-growing non-native species such as pine or eucalyptus. Community/habitat area, presence of a community/habitat (forest), and stand age all tend to have negative impacts, as older/larger trees use more water (e.g. Nosetto et al., 2005), although Cavaleri and Sack (2010) found that forests used more water at earlier successional stages due to faster growth. Similarly, higher stem density and higher sapwood area can increase water use (Kagawa et al., 2009), and harvesting and thinning are found to significantly increase runoff and therefore increase provision in many studies (e.g. Petheram et al., 2002; Sahin and Hall, 1996).

In natural forests, 7 studies find beneficial impacts on water supply, with four showing how cloud forests intercept water from the air (e.g. Gomez-Peralta et al. 2008, Brauman et al. 2010) and three showing how forests can increase water yield by improving infiltration and soil water storage capacity (e.g. Singh and Mishra, 2012). Some studies show that native forests consume less water than pine plantations (Rowe and Pearce, 1994; Komatsu, 2008).

For the abiotic factors the situation is largely reversed compared to the service of flood protection, with precipitation and water availability having positive impacts and evaporation (i.e. transpiration) negative impacts.

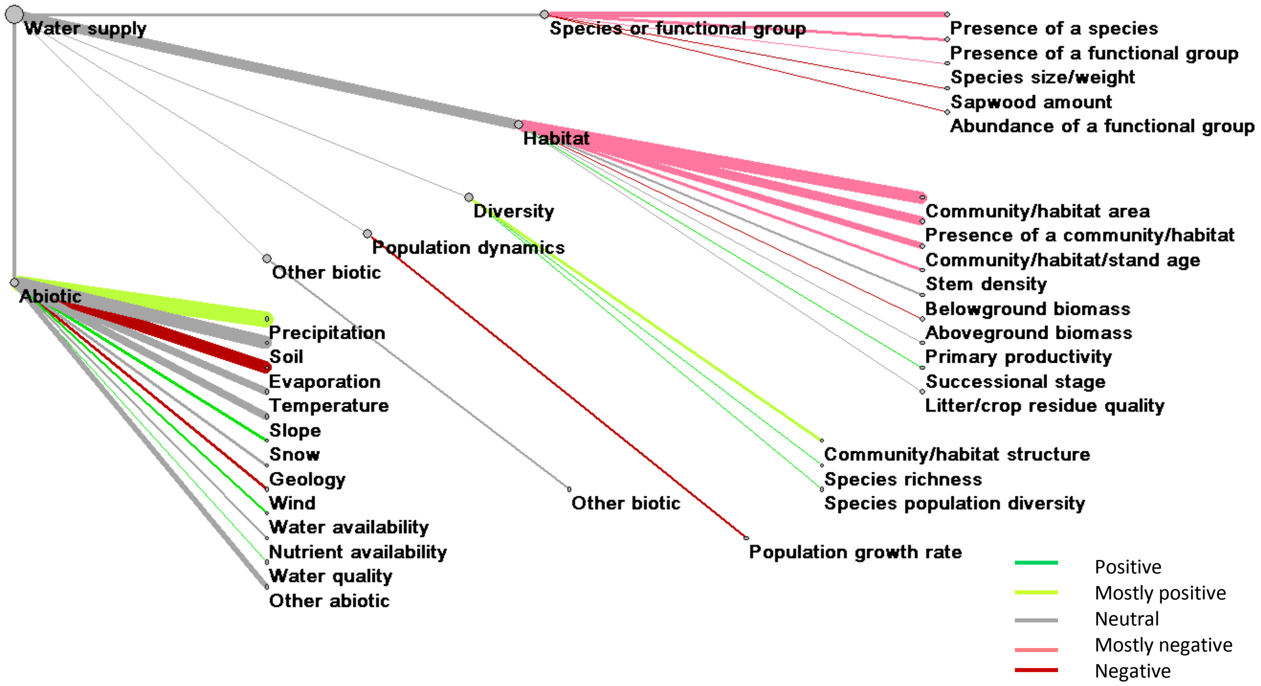


Figure S13. Network diagram mapping the evidence on how biotic attributes and abiotic factors influence the service of water supply. Line thickness is proportional to number of studies supporting each link and line colour indicates predominant direction of link.

2.3 Cultural services

2.3.1 Species-based recreation

For species-based recreation (e.g. wildlife viewing, hunting or fishing), as shown in Figure S13, the most frequently cited biotic attributes are the presence and abundance of specific species. These include charismatic species such as whales and dolphins for marine eco-tourism, or large mammals such as lions, tigers and elephants for land-based eco-tourism, as well as mammals such as deer for hunting, and fish such as salmon and trout for recreational fishing. Species size or weight can also be significant, with visitors, fishermen and hunters often expressing a preference for larger species such as sharks and lions. Species richness and diversity are also valued by visitors. For example, Lindsey et al. (2007) find that tourists in South Africa consider functional group diversity (in this case, the variety of large mammals) to be the most important feature of their wildlife viewing experience, and Ruiz-Frau et al. (2013) find that marine biodiversity is important for scuba divers. Clearly the presence of suitable habitat to support the species of interest is important, though this is mentioned less frequently in the literature.

A number of abiotic factors are cited in the literature. Weather-related factors such as precipitation and temperature are often cited, especially for fishing (e.g. Smallwood et al., 2006). These have mixed effects, with extreme conditions found to negatively affect recreation (Cooke and Suski, 2005).

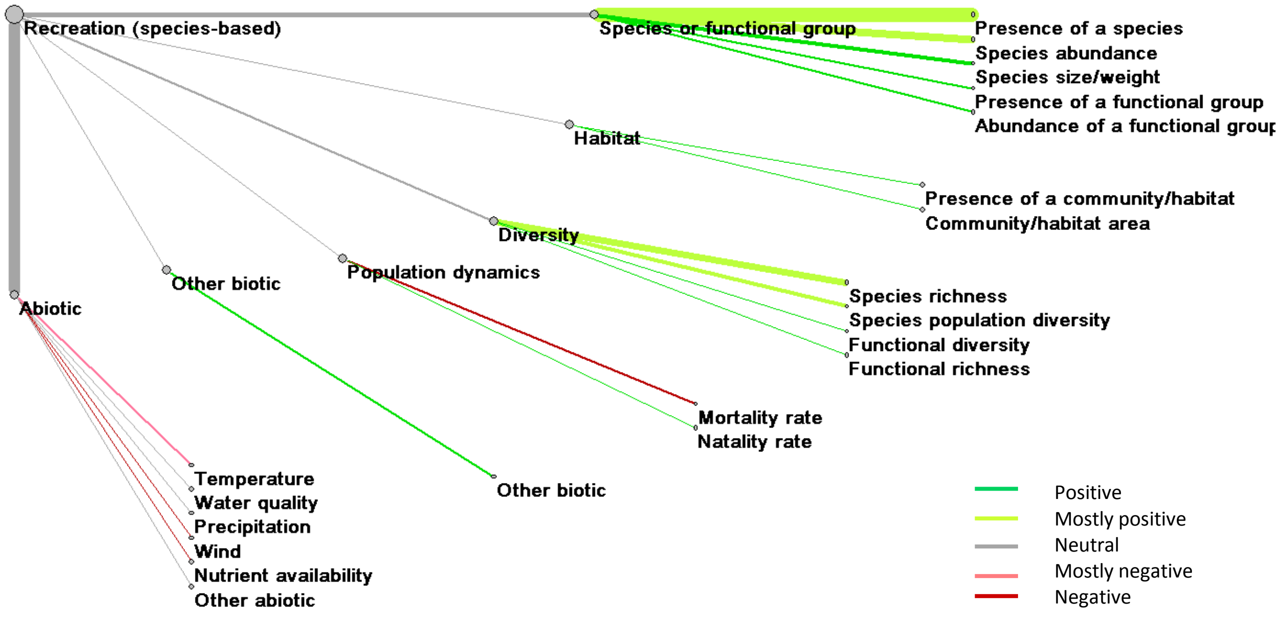


Figure S14. Network diagram mapping the evidence on how biotic attributes and abiotic factors influence the service of species-based recreation. Line thickness is proportional to number of studies supporting each link and line colour indicates predominant direction of link.

2.3.2 Aesthetic landscapes

For aesthetic landscapes (Figure S12) the service is provided by the entire habitat. The presence of a particular habitat is cited in 30 of the 60 papers, with forests and water features being most often mentioned, as well as urban trees and green space (e.g. Kaplan, 2007). Habitat structure is the most frequently cited attribute, with the term 'structure' being interpreted as covering a broad range of characteristics including landscape diversity and complexity, vegetation density, naturalness and uniqueness. Many studies find a preference for wilder, more complex, more natural landscapes (e.g. Acar and Sakici, 2008; Heyman, 2012; Daniel et al., 2012), especially in developed countries, but some cultural groups may prefer more open, managed landscapes with man-made elements. Abiotic attributes that are positively correlated with aesthetic appreciation are the presence of water (lakes and rivers) and steep slopes, which add interest and variety to the landscape

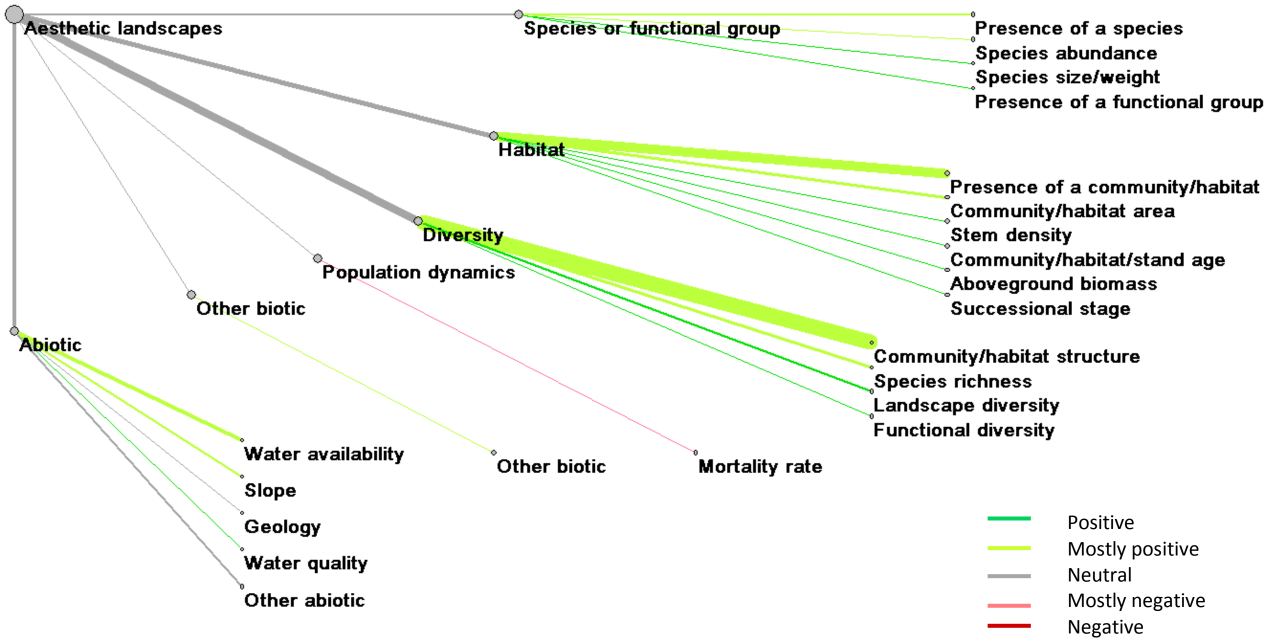


Figure S15. Network diagram mapping the evidence on how biotic attributes and abiotic factors influence the service of aesthetic landscapes. Line thickness is proportional to number of studies supporting each link and line colour indicates predominant direction of link.

3 Ecosystem service providers (ESPs)

The ESP is a useful concept for researchers working on ecosystem services, but it is rarely stated explicitly in the articles reviewed, even when literature refers to the ecosystem service concept. More often, the ESP was inferred by the reviewer from the information given in the article. It is also partly determined by the design and framing of each study, i.e. whether the researchers choose to investigate the role of one or more species, functional groups or entire communities, rather than by the ecosystem components required to provide the service.

Nevertheless, some strong patterns emerge in the ESPs studied for each ecosystem service (Figure S16). Studies of food crop, fish and timber provision generally compare the performance of different species. In contrast, studies of water supply and atmospheric, water flow and water quality regulation focus mainly on comparisons of two or more habitats, e.g. forest and grassland. Studies of mass flow regulation are split between those looking at the entire habitat and those comparing species characteristics, such as root structure. For pollination and pest regulation, the focus is typically on one or more functional groups (such as wasps, bees or pest predators in general), and this is also true for air quality regulation where the functional groups are usually urban trees and/or shrubs, or urban vegetation in general. For cultural services, species-based recreation is (unsurprisingly) dominated by studies of one or more specific species, whereas for aesthetic landscapes the ESP is always the entire habitat.

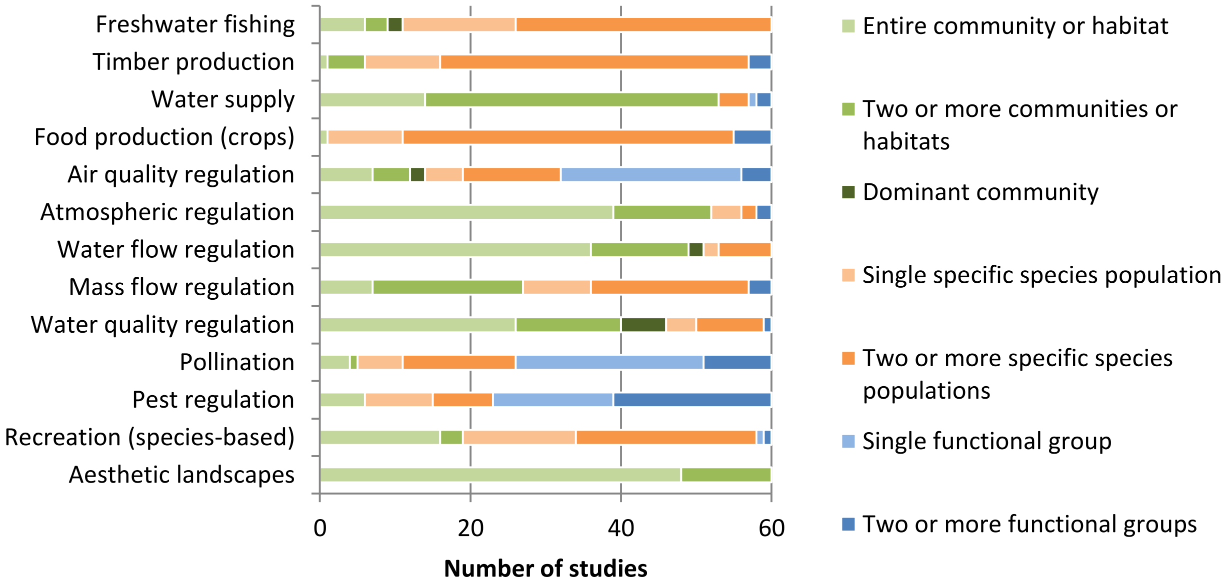


Figure S16: Number of studies showing a linkage between a specific ESP and ecosystem services.

4 Abiotic factors

Table S1: Percentage of studies showing a positive linkage between a specific abiotic factor and ecosystem service. Greatest percentages are highlighted in darker shades of green.

	Temperature	Precipitation	Snow	Water availability	Evaporation	Wind	Water quality	Nutrient availability	Soil	Geology	Slope	Other
Freshwater fishing		2	1	6			6	5			2	
Timber production	4	2		1	1			1	9		1	1
Water supply)		33	3	3			1		1			1
Food production (crops)	1	6		5				21	4			
Air quality regulation	3	4		3	7	13					1	3
Atmospheric regulation	1	5		3		1		3	1			1
Water flow regulation	1	1			2		1		5	2	1	1
Mass flow regulation	2	3		10				1	3		1	
Water quality regulation	1			1					2		1	2
Pollination		2										2
Pest regulation	1											
Recreation (species-based)							1					
Aesthetic landscapes				10			3			2	6	5

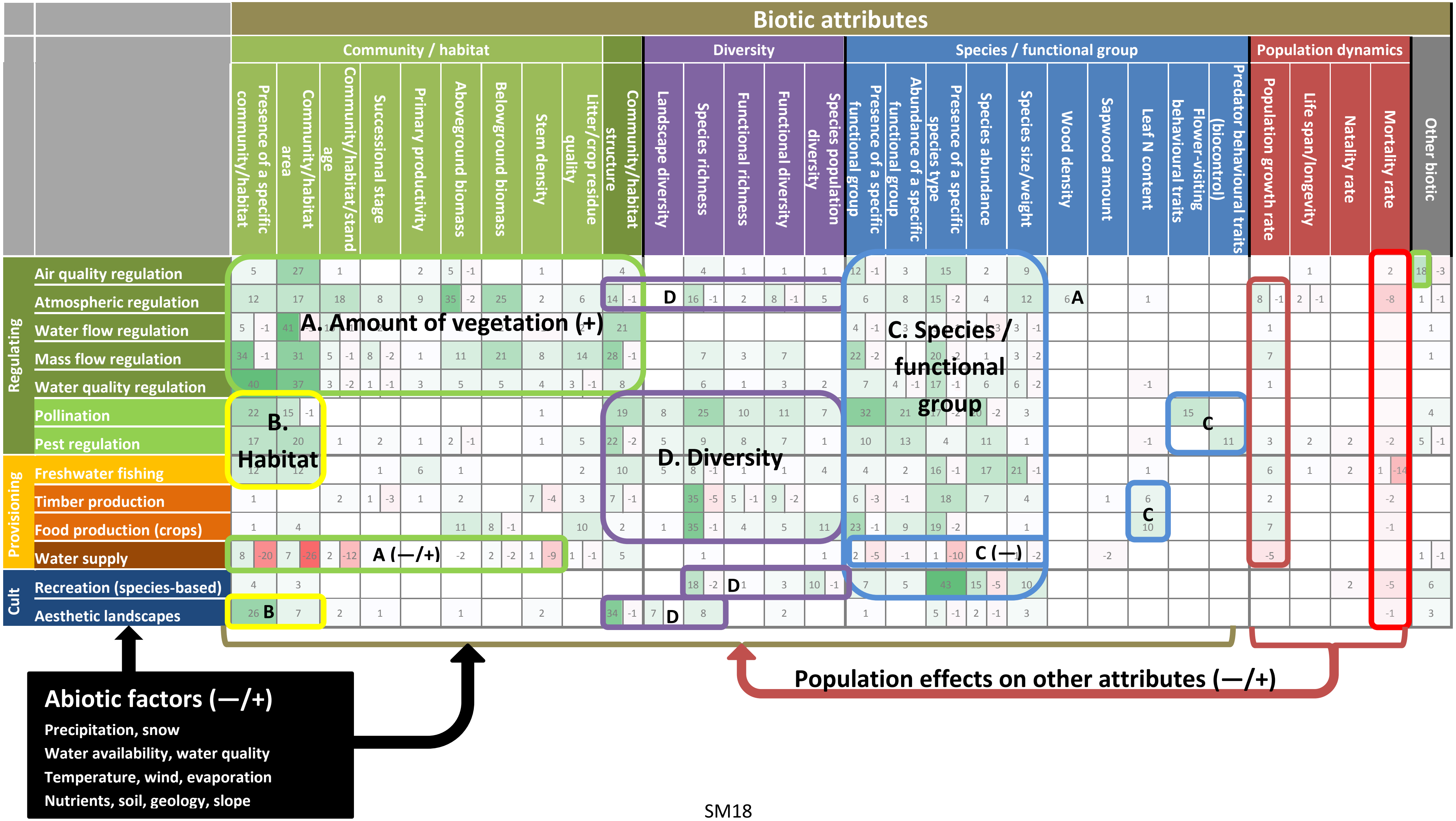
Table S2: Percentage of studies showing a negative linkage between a specific abiotic factor and ecosystem service. Greatest percentages are highlighted in darker shades of red.

	Temperature	Precipitation	Snow	Water availability	Evaporation	Wind	Water quality	Nutrient availability	Soil	Geology	Slope	Other abiotic
Freshwater fishing	3				1		3	1			2	3
Timber production				2					3			1
Water supply					21	1						1
Food production (crops)	1	5			1	1			3		3	
Air quality regulation	11	1				1					1	6
Atmospheric regulation	3	2							2		1	4
Water flow regulation	3	14		1		3			2		5	4
Mass flow regulation		13				1			5		8	
Water quality regulation	3	2					2			1		1
Pollination	1											1
Pest regulation	2											
Recreation (species-based)	1					1	1	1				1
Aesthetic landscapes											1	1

5 Typology

Figure S17 Pathways by which groups of natural capital attributes deliver bundles of ecosystem services

Cell values are the number of papers in the review (out of 60 per ecosystem service) that support a positive (green shading) or negative (red shading and – sign) link between an ecosystem service and a biotic attribute of natural capital. Darker shades indicate more papers supporting the link.



		Biotic attributes: Community / habitat										Diversity					Species / functional group										Population dynamics				
		Presence of a specific community/habitat	Community/habitat area	Community/habitat/stand age	Successional stage	Primary productivity	Aboveground biomass	Belowground biomass	Stem density	Litter/crop residue quality	Community/habitat structure	Landscape diversity	Species richness	Functional richness	Functional diversity	Species population diversity	Presence of a specific functional group	Abundance of a specific functional group	Presence of a specific species type	Species abundance	Species size/weight	Wood density	Sapwood amount	Leaf N content	Flower-visiting behavioural traits	Predator behavioural traits (biocontrol)	Population growth rate	Life span/longevity	Natality rate	Mortality rate	Other biotic
Regulating	Air quality regulation	5	27	1		2	5, -1		1		4		4	1	1	1	12, -1	3	15	2	9							1		2	18, -3
	Atmospheric regulation	12	17	18	8	9	35, -2	25	2	6	14, -1		16, -1	2	8, -1	5	6	8	15, -2	4	12	6		1			8, -1	2, -1		-8	1, -1
	Water flow regulation	5, -1	41, -3	10, -1	2		1	2	-1	2	21						4, -1	3	[illegible], -1	1, -3	3, -1						1				1
	Mass flow regulation	34, -1	31	5, -1	8, -2	1	11	21	8	14	28, -1		7	3	7		22, -2		20, -2	1	3, -2						7				1
	Water quality regulation	40	37	3, -2	1, -1	3	5	5	4	3, -1	8		6	1	3	2	7	4, -1	17, -1	6	6, -2			-1			1				
	Pollination	22	15, -1						1		19	8	25	10	11	7	32	21	17, -2	20, -2	3				15						4
	Pest regulation	17	20	1	2	1	2, -1		1	5	22, -2	5	9	8	7	1	10	13	4	11	1			-1		11	3	2	2	-2	5, -1
Provisioning	Freshwater fishing	12	12		1	6	1			2	10	5	8, -1	1	1	4	4	2	16, -1	17	21, -1			1			6	1	2	1, -14	
	Timber production	1		2	1, -3	1	2		7, -4	3	7, -1		35, -5	5, -1	9, -2		6, -3	-1	18	7	4		1	6			2			-2	
	Food production (crops)	1	4				11	8, -1		10	2	1	35, -1	4	5	11	23, -1	9	19, -2		1			10			7			-1	
	Water supply	8, -20	7, -26	2, -12			-2	2, -2	1, -9	1, -1	5		1			1	2, -5	-1	1, -10		1, -2		-2				-5				1, -1
Cult	Recreation (species-based)	4	3										18, -2	1	3	10, -1	7	5	43	15, -5	10								2	-5	6
	Aesthetic landscapes	26	7	2	1		1		2		34, -1	7	8		2		1		5, -1	2, -1	3									-1	3

Abiotic factors (—/+)

Precipitation, snow
Water availability, water quality
Temperature, wind, evaporation
Nutrients, soil, geology, slope

Figure S18 Summary schematic diagram of pathways by which groups of natural capital attributes deliver bundles of ecosystem services

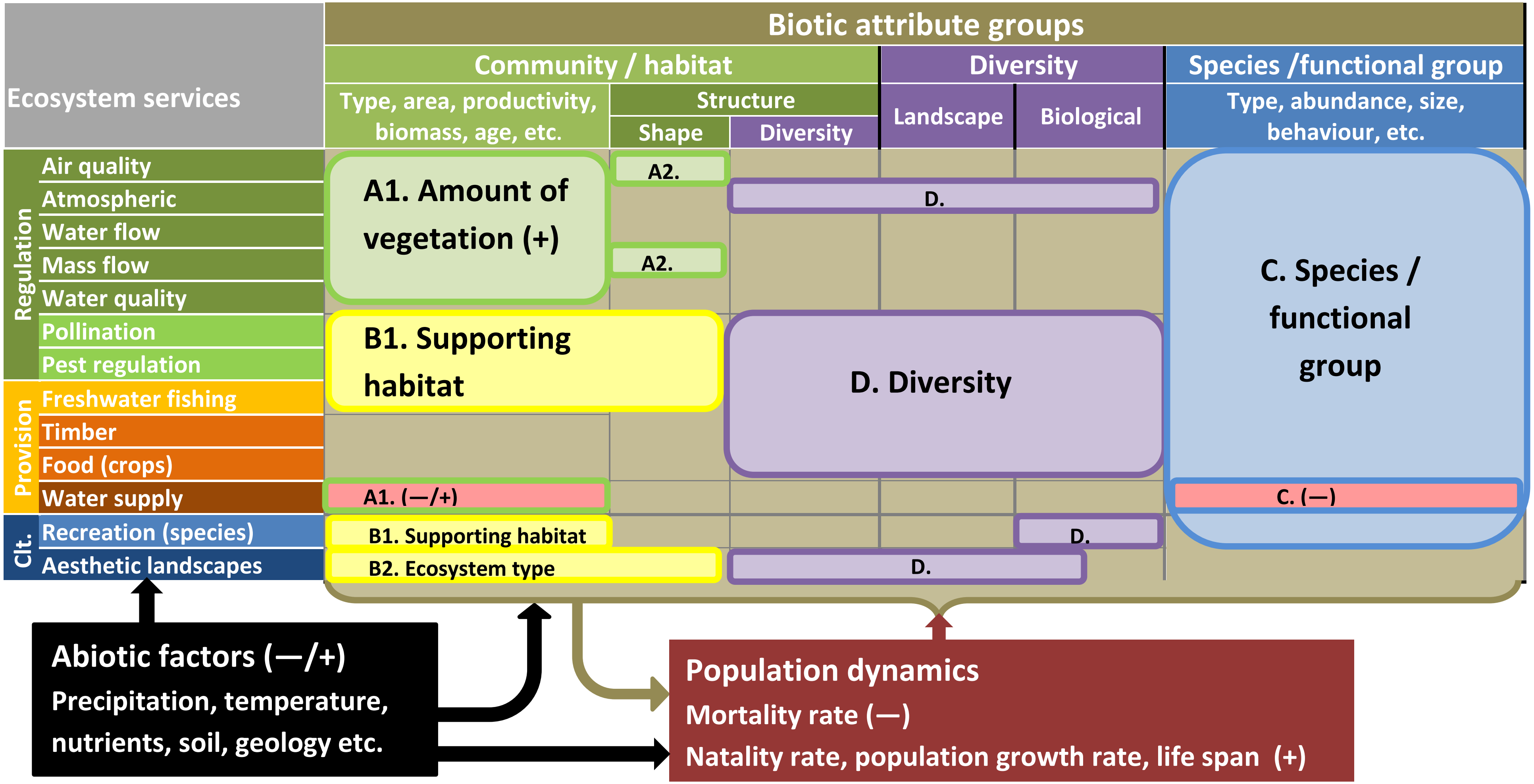
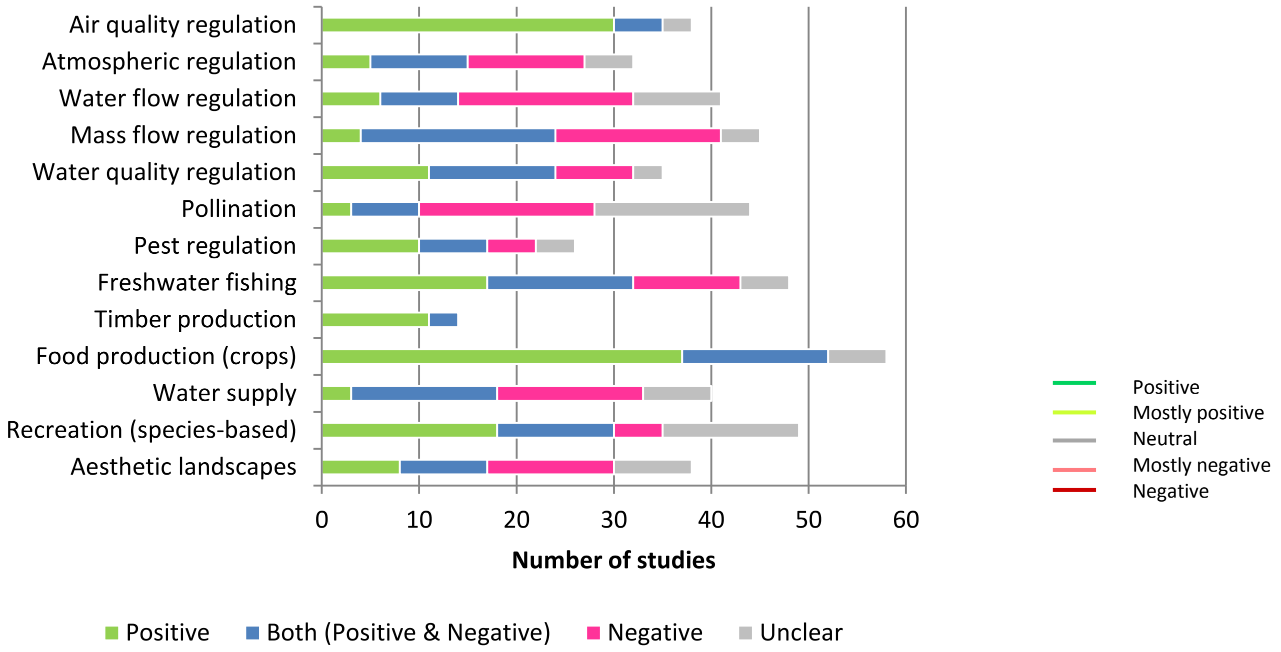


Figure S19. Impact (direction) of human input and management for each ecosystem service reviewed.



Appendix A: Search terms for the systematic literature search

Standard set of terms related to biotic attributes

*diversity OR *diverse OR species OR habitat* OR trait* OR landscape OR richness OR abundance

Note: “OR mix*” was also used for timber production to cover species mixtures.

Service-specific terms

Ecosystem service	Ecosystem service terms	Additional terms used to refine results
Freshwater fishing	(*fish*) AND (yield OR catch OR quantity OR 'ecosystem service' OR producti*)	(freshwater OR lake* OR river* OR reservoir* OR floodplain* OR inland)
Timber production	forestry OR plantation* OR timber OR wood	Yield OR producti* OR growth OR supply OR harvest OR "basal area"
Water supply	(water OR freshwater OR groundwater) AND (supply OR provision* OR yield OR budget OR reserve* OR resource*)	(*forest* OR soil OR vegetat* OR ecosystem* OR woodland*) AND (infiltrat* OR recharg* OR runoff)
Food production (crops)	TOPIC: (Food OR crop OR agricultur*) AND TITLE: (Producti* OR yield)	NOT TITLE: grassland OR meadow OR graz* OR pasture OR aquatic OR *alga* OR fish* OR milk OR dairy OR biofuel OR bioenergy OR biodiesel OR miscanthus OR bioethanol OR *foram* OR *benth* OR *plank* OR pest OR pollin* OR predat* OR bird*
Air quality regulation	"air quality" OR "air pollution" OR particulate*	(tree* OR vegetation OR forest* OR wood*) AND (absor* OR remov* OR regulat* OR adsor*)
Atmospheric regulation (carbon storage)	“Carbon storage” OR “carbon sequestration” OR “carbon loss” OR “carbon emissions”	Tree* OR soil* OR biomass
Water flow regulation (flood protection)	Flood* OR “water flow regulation”	(Flow* OR Attenuation OR Storage OR Protection OR Defence OR Prevention OR Runoff OR Evapotanspiration OR Infiltration OR interception) AND (vegetation OR forest OR wetland OR marsh)
Water quality regulation	Water quality OR Water regulation OR Water purification OR Nutrient* retention OR Nutrient* translocation	Tree* OR Soil* OR Forest* OR Vegetation OR Plant* OR Pollutant* OR Wetland* OR Microorganism* OR Accumulation OR Sediment*
Mass flow regulation (erosion protection)	soil OR sediment OR sand AND	Root OR vegetation

Ecosystem service	**Ecosystem service terms**	**Additional terms used to refine results**
	loss OR erosion OR trap* OR runoff OR stabil* OR erodab*	
Pollination	Pollinat*	yield OR Fruit OR "Seed set" OR reproduct*
Pest regulation	"Natural pest control" OR "Pest control" OR "Biological control" OR "Biological pest control"	
Species-based recreation	“species-based recreation” OR eco-tourism OR *watching OR viewing OR birding OR “nature tourism”	satisf* OR visit* OR appreciat* OR motivate* OR prefer*
Aesthetic landscapes	tourism OR recreation OR *esthetic* OR appreciation OR valuation OR preference* OR perception*	

Appendix B: List of biotic and abiotic attributes covered in the review

SPECIES ATTRIBUTES

- Presence of a specific species type (name of the species can be added in the free text box)
- Species abundance (number of individuals of a species expressed per unit area or volume of space. Synonymous with species population density)
- Species richness (number of different species represented in a set or collection of individuals)
- Species population diversity (the number, size, density, distribution and genetic variability of populations of a given species)
- Species size or weight (includes body size or weight, diameter at breast height – DBH – for trees, species/vegetation/tree height, basal area defined as the cross section area of the stem or stems of a plant or of all plants in a stand, generally expressed as square units per unit area) (free text box can specify the type of measurement)
- Population growth rate (change in the number of individuals of a species in a population over time)
- Mortality rate (number of deaths of individuals per unit time)
- Natality rate (number of new individuals produced per unit time)
- Life span/longevity (duration of existence of an individual/expected average life span)

FUNCTIONAL GROUP ATTRIBUTES

- Presence of a specific functional group type (the name of the functional group(s) can be recorded in the free text box)
- Abundance of a specific functional group
- Functional richness (the number of functional groups or trait attributes in the community)
- Functional diversity (range, actual values and relative abundance of functional trait attributes in a given community)
- Flower-visiting behavioural traits well suited to the system to provide pollination ecosystem services (free text box allows the behavioural type/preference/strategy to be entered)
- Predator behavioural traits well suited to the system to provide biocontrol ecosystem services (free text box allows the behavioural type/preference/strategy to be entered)

COMMUNITY/HABITAT ATTRIBUTES

- Presence of a specific community/habitat type (the name of the habitat(s) or ecosystem(s) can be entered in the free text box)
- Community/habitat area (includes width or diameter, i.e. for buffer zones)
- Community/habitat structure (in terms of complexity - amount of structure or variation attributable to absolute abundance of individual structural component - and heterogeneity - kinds of structure or variation attributable to the relative abundance of different structural components)
- Primary productivity (rate at which plants and other photosynthetic organisms produce organic compounds in an ecosystem)
- Aboveground biomass (the total mass of aboveground living matter within a given area)
- Belowground biomass (the total mass of belowground living matter within a given area)
- Sapwood amount (including allocation of carbon to sapwood and sapwood area)
- Stem density (measured as the number of stems/specified area)
- Wood density (measured as the weight of a given volume of wood that has been air-dried)

- Successional stage (changes in the number of individuals of each species of a community by establishment of new species populations that may gradually replace the original inhabitants; categorised into early and late stages)
- Habitat/community/stand age (includes young and old-growth forests, even and uneven-aged forests, or can specify the age)
- Litter/crop residue quality (quality of plant litter with respect to decomposition: often defined by the C:N ratio, but ratios of C, N, lignin and polyphenols are other chemical properties and particle size and surface area to mass characteristics are physical properties)
- Leaf N content

OTHER ATTRIBUTES:

- Landscape diversity (diversity of landscapes and landscape features)

Other (attributes not covered in the list can be added and described in the free text box)

ABIOTIC ATTRIBUTES

- Temperature (a positive relationship indicates that the ecosystem delivers a higher level of service when temperatures are higher)
- Precipitation (a positive relationship indicates that the ecosystem delivers a higher level of service when precipitation is greater)
- Snow (a positive relationship indicates that the ecosystem delivers a higher level of service when there is more snowfall)
- Water availability – the amount of water available in the ecosystem to be used by organisms or for aesthetic appreciation by humans (a positive relationship indicates that the ecosystem delivers a higher level of service when water availability is greater)
- Evaporation (a positive relationship indicates that the ecosystem delivers a higher level of service when evaporation – including evapo-transpiration - is greater)
- Wind (a positive relationship indicates that the ecosystem delivers a higher level of service when wind speed or duration of windy periods are higher)
- Water quality – (a positive relationship indicates that the ecosystem delivers a higher level of service when water quality is higher, i.e. water is cleaner and less polluted)
- Nutrient availability (a positive relationship indicates that the ecosystem delivers a higher level of service when nutrient availability is greater)
- Soil – this is a categorical variable based on soil type and a bundle of other factors including porosity, acidity and water content, so it is meaningless to ascribe a single direction of impact and all impacts are recorded as ‘unclear’
- Geology - this is a categorical variable based on rock type, topology and other factors such as porosity and permeability, so it is meaningless to ascribe a single direction of impact and all impacts are recorded as ‘unclear’
- Slope – angle of inclination of the landform (a positive relationship indicates that the ecosystem delivers a higher level of service when slopes are steeper)
- Other – any abiotic factors not included in the list above can be added and described in the free text box. As this covers a broad range of factors, it is meaningless to ascribe a direction of impact and all impacts are recorded as ‘unclear’.

Appendix C: Main indicators used in the literature for each service (with typical units)

Freshwater fishing

- Catch/ yield (kg/ha/year)
- Catch per unit effort
- Fish size/weight
- Growth rate (kg/year)
- Fish population
- Mortality rate
- Willingness to pay for a better fishing service

Timber production

- Yield (tonnes/ha/year; m3/ha/year)
- Basal area (m2/ha)
- Height (m) and diameter at breast height (m) of trees
- Growth rate (tonnes/ha/y; m2/ha/year; mean annual increment of diameter at breast height or basal area)
- Timber quality and tree health (qualitative)
- Sapling survival rates
- Profit from timber sales ($)

Water supply

- Water supply (m3/ha/year)
- Runoff from watershed (m3/year; mm)
- Evapotranspiration (mm/year)
- Stream height; low flow (mm)

Food production (cultivated crops)

- Crop yield (tonnes/ha; kg/household)
- Crop value ($/ha)

Air quality regulation

- Change in pollutant concentration (g/m3; ppm)
- Pollutants removed (kg/ha/year; kg/year; g/tree; g/cm2 leaf area)
- Deposition rates (mg/m2)
- Deposition velocity (m/s)
- Leaf area index
- Particle trapping efficiency (%)
- BVOC (biogenic volatile organic compound) emission factors

Atmospheric regulation (carbon sequestration)

- Carbon storage in soil and/or vegetation (Mt/ha)

- Carbon sequestration (Mt/ha/year)
- Soil carbon content (%)

Mass flow regulation (erosion protection)

- Soil erosion (t/ha/year; g/l run-off; g/m2; g/hour; mm)
- Soil retention (t/year; t/ha; g/cm3)

Water flow regulation (flood protection)

- Peak flow (m3/s)
- River depth / flood height (m)
- Surface water runoff (l/m2/minute; mm)
- Wave height attenuation (m)
- Flood frequency and severity (e.g. number of people displaced)
- Water velocity (m/s)

Water quality regulation

- Concentrations of pollutants (nitrogen; phosphorous; suspended solids; heavy metals) (g/m3)
- Water characteristics (clarity; dissolved oxygen; biological oxygen demand; chemical oxygen demand; pH)
- Nutrient removal or retention (g/y; % removed)
- Enrichment factor of pollutants in roots and shoots
- Ecological quality (qualitative assessment; plankton richness and abundance; species diversity)

Pollination

- Pollinator abundance (number/ha)
- Pollinator diversity (species richness; diversity index)
- Pollinator visitation rates (number/flower/hour; number/hour)
- Pollination efficiency (% flowers pollinated)
- Plant reproductive success (fruit set per plant; seed set per fruit)
- Crop yield (t/ha)
- Pollen grain deposition (grains/visit; grains/day)
- Value of pollinated crop ($/ha)
- Replacement cost of pollination (by non-insect means) ($/ha)

Pest regulation

- Pest abundance / density (number / plant; number / ha)
- Pest diversity (species richness; diversity index)
- Pest mortality due to predation
- Predator density (number / plant; number / ha)
- Predator diversity (species richness; diversity index)
- Crop damage (number of plants, leaves or fruits damaged)
- Crop yield (t/ha)
- Value of natural pest control ($/ha/year)

Recreation (species-based)

- Visitor numbers
- Frequency of visit
- Length of trip (hours; days)
- Visitor expenditure ($/capita; $/trip; $/year)
- Economic revenues from activities ($/year)
- Travel cost ($/trip; $/capita)
- Visitor satisfaction
- Visitor preferences
- Willingness to pay ($)
- Species abundance
- Species richness
- Frequency of species sightings
- Success rate of hunting trips
- Catch per unit effort for fishing
- Species reproductive success
- Species mortality rate
- Employment
- Recreation/ecotourism opportunities

Aesthetic landscapes

- Landscape preferences (ranking / prioritisation)
- Rating of qualities such as scenic beauty, naturalness, wilderness, recreational opportunities (point scale)
- Willingness to pay ($)
- Property values ($)
- Visitation rates

Appendix D: List of papers reviewed

Air quality regulation

Al-Dabbous, A.N., Kumar, P. (2014) The influence of roadside vegetation barriers on airborne nanoparticles and pedestrians exposure under varying wind conditions. Atmos. Environ. 90, 113e124. http://dx.doi.org/10.1016/j.atmosenv.2014.03.040

Alonso, Rocío; Vivanco, Marta G.; González-Fernández, Ignacio; Bermejo, Victoria; Palomino, Inmaculada; Garrido, Juan Luis; Elvira, Susana; Salvador, Pedro; Artíñano, Begoña (2011) Modelling the influence of peri-urban trees in the air quality of Madrid region (Spain). Environmental Pollution 158 (8-9): 2138-2147. http://dx.doi.org/10.1016/j.envpol.2010.12.005.

Amorim, J. H.; Rodrigues, V.; Tavares, R.; Valente, J.; Borrego, C. (2013) CFD modelling of the aerodynamic effect of trees on urban air pollution dispersion. Science of The Total Environment 461-462: 541-551. 10.1016/j.scitotenv.2013.05.031

Baró, Francesc; Chaparro, Lydia; Gomez-Baggethun, E.; Langemeyer, Johannes; Nowak, D. J.; Terradas, Jaume (2014) Contribution of Ecosystem Services to Air Quality and Climate Change Mitigation Policies: The Case of Urban Forests in Barcelona, Spain. Ambio 43: 466-479. 10.1007/s13280-014-0507-x

Baumgardner, D.; Varela, S.; Escobedo, F. J.; Chacalo, A.; Ochoa, C. (2012) The role of a peri-urban forest on air quality improvement in the Mexico City megalopolis. Environmental Pollution, 163: 174-183. 10.1016/j.envpol.2011.12.016

Beckett, K. P.; Freer-Smith, P. H.; Taylor, G. (2000) Particulate pollution capture by urban trees: effect of species and windspeed. Global Change Biology 6: 995-1003. 10.1046/j.1365-2486.2000.00376.x

Beckett, K. P., P. H. Freer-Smith and G. Taylor (2000) The capture of particulate pollution by trees at five contrasting urban sites. Arboricultural Journal 24: 209-230. DOI: 10.1080/03071375.2000.9747273

Benjamin, Michael T.; Winer, Arthur M. (1998) Estimating the ozone-forming potential of urban trees and shrubs. Atmospheric Environment 32(1): 53-68. 10.1016/S1352-2310(97)00176-3

Brack, C.L. (2002) Pollution mitigation and carbon sequestration by an urban forest. Environmental Pollution 116: S195-S200. 10.1016/S0269-7491(01)00251-2

Brantley, H., Gayle S.W. Hagler, Parikshit J. Deshmukh, Richard W. Baldauf (2014) Field assessment of the effects of roadside vegetation on near-road black carbon and particulate matter. Science of the Total Environment 468–469: 120–129. http://dx.doi.org/10.1016/j.scitotenv.2013.08.001

Cabaraban, M. T. I.; Kroll, C. N.; Hirabayashi, S.; Nowak, D. J. (2013) Modeling of air pollutant removal by dry deposition to urban trees using a WRF/CMAQ/i-Tree Eco coupled system. Environmental Pollution 176: 123-133. 10.1016/j.envpol.2013.01.006

Cardelino, C. A.; Chameides, W. L. (1990) Natural hydrocarbons, urbanization, and urban ozone. Journal of Geophysical Research 95 (D9): 13971-13979. 10.1029/JD095iD09p13971

Cavanagh, J. A. E.; Zawar-Reza, P.; Wilson, J. G. (2009) Spatial attenuation of ambient particulate matter air pollution within an urbanised native forest patch. Urban Forestry & Urban Greening 8: 21-30. 10.1016/j.ufug.2008.10.002

Cavanagh, Jo-Anne E.; Clemons, Janine (2006) Do Urban Forests Enhance Air Quality?. Australasian Journal of Environmental Management 13(2): 120 - 130. 10.1080/14486563.2006.9725122

Dadvand, P.; de Nazelle, A.; Triguero-Mas, M.; Schembari, A.; Cirach, M.; Amoly, E.; Figueras, F.; Basagana, X.; Ostro, B.; Nieuwenhuijsen, M. (2012) Surrounding Greenness and Exposure to Air Pollution During Pregnancy: An Analysis of Personal Monitoring Data. Environmental Health Perspectives 120(9): 1286-1290. 10.1289/ehp.1104609

Donovan, Rossa G.; Stewart, Hope E.; Owen, Susan M.; MacKenzie, A. Robert; Hewitt, C. Nicholas (2005) Development and Application of an Urban Tree Air Quality Score for Photochemical Pollution Episodes Using the Birmingham, United Kingdom, Area as a Case Study. Environmental Science and Technology 39: 6730-6738. 10.1021/es050581y

Escobedo, Francisco J.; Nowak, David J. (2009) Spatial heterogeneity and air pollution removal by an urban forest. Landscape and Urban Planning 90 (3-4): 102-110. http://dx.doi.org/10.1016/j.landurbplan.2008.10.021

Freer-Smith, P. H.; Holloway, Sophy; Goodman, A. (1997) The uptake of particulates by an urban woodland: Site description and particulate composition. Environmental Pollution 95 (1): 27 - 35. http://dx.doi.org/10.1016/S0269-7491(96)00119-4

Freer-Smith, P. H., A. A. El-Khatib and G. Taylor (2004) Capture of particulate pollution by trees: A comparison of species typical of semi-arid areas (Ficus nitida and Eucalyptus globulus) with European and North American species. Water Air and Soil Pollution 155: 173-187.

Freiman, M. T.; Hirshel, N.; Broday, D. M. (2006) Urban-scale variability of ambient particulate matter attributes. Atmospheric Environment 40 (29): 5670-5684. 10.1016/j.atmosenv.2006.04.060

Harris, Tanner B.; Manning, William J. (2010) Nitrogen dioxide and ozone levels in urban tree canopies. Environmental Pollution 158: 2384-2386. 10.1016/j.envpol.2010.04.007

Hein, L. (2011) Economic Benefits Generated by Protected Areas: the Case of the Hoge Veluwe Forest, the Netherlands. Ecology and Society 16(2): 13. N/A; Accession number = WOS:000292462800022

Jim, C. Y.; Chen, Wendy Y. (2008) Assessing the ecosystem service of air pollutant removal by urban trees in Guangzhou (China). Journal of Environmental Management 88(4): 665-676. 10.1016/j.jenvman.2007.03.035

Liu, L., D. Guan, M. R. Peart, G. Wang, H. Zhang and Z. Li (2013) The dust retention capacities of urban vegetation-a case study of Guangzhou, South China. Environmental Science and Pollution Research 20: 6601-6610. DOI 10.1007/s11356-013-1648-3

Lovasi, G. S.; O'Neil-Dunne, J. P. M.; Lu, J. W. T.; Sheehan, D.; Perzanowski, M. S.; MacFaden, S. W.; King, K. L.; Matte, T.; Miller, R. L.; Hoepner, L. A.; Perera, F. P.; Rundle, A. (2013) Urban Tree Canopy and Asthma, Wheeze, Rhinitis, and Allergic Sensitization to Tree Pollen in a New York City Birth Cohort. Environmental Health Perspectives. 10.1289/ehp.1205513

Manes, F.; Incerti, G.; Salvatori, E.; Vitale, M.; Ricotta, C.; Costanza, R. (2012) Urban ecosystem services: tree diversity and stability of tropospheric ozone removal. Ecological Applications 22(1): 349-360. N/A

Martin, N. A., A. H. Chappelka, E. F. Loewenstein and G. J. Keever (2012) Comparison of carbon storage, carbon sequestration, and air pollution removal by protected and maintained urban forests in Alabama, USA. International Journal of Biodiversity Science Ecosystem Services & Management 8: 265-272. DOI:10.1080/21513732.2012.712550

McDonald, A. G.; Bealey, W. J.; Fowler, D.; Dragosits, U.; Skiba, U.; Smith, R. I.; Donovan, R. G.; Brett, H. E.; Hewitt, C. N.; Nemitz, E. (2007) Quantifying the effect of urban tree planting on concentrations and depositions of PM10 in two UK conurbations. Atmospheric Environment 41: 8455-8467. 10.1016/j.atmosenv.2007.07.025

McPherson, E. Gregory; Nowak, David; Heisler, Gordon; Grimmond, Sue; Souch, Catherine; Grant, Rich; Rowntree, Rowan (1997) Quantifying urban forest structure, function, and value: the Chicago Urban Forest Climate Project. Urban Ecosystems 1: 49-61. 10.1023/A:1014350822458

McPherson, E. Gregory; Scott, Klaus I.; Simpson, James R. (1998) Estimating cost effectiveness of residential yard trees for improving air quality in Sacramento, California, using existing models. Atmospheric Environment 32 (1): 75-84. http://dx.doi.org/10.1016/S1352-2310(97)00180-5

Millward, A. A.; Sabir, S. (2011) Benefits of a forested urban park: What is the value of Allan Gardens to the city of Toronto, Canada?. Landscape and Urban Planning 100: 177-188. 10.1016/j.landurbplan.2010.11.013

Morani, A.; Nowak, D. J.; Hirabayashi, S.; Calfapietra, C. (2011) How to select the best tree planting locations to enhance air pollution removal in the MillionTreesNYC initiative. Environmental Pollution 159: 1040-1047. 10.1016/j.envpol.2010.11.022

Nowak, D. J.; Hirabayashi, S.; Bodine, A.; Hoehn, R. (2013) Modeled PM2.5 removal by trees in ten US cities and associated health effects. Environmental Pollution 179: 395-402. 10.1016/j.envpol.2013.03.050

Nowak, David J. (2006) Institutionalizing urban forestry as a “biotechnology” to improve environmental quality. Urban Forestry & Urban Greening 5: 93-100. 10.1016/j.ufug.2006.04.002

Nowak, David J.; Civerolo, Kevin L.; Trivikrama Rao, S.; Gopal, Sistla; Luley, Christopher J.; E. Crane, Daniel (2000) A modeling study of the impact of urban trees on ozone. Atmospheric Environment 34(10): 1601-1613. http://dx.doi.org/10.1016/S1352-2310(99)00394-5

Nowak, David J.; Crane, Daniel E.; Stevens, Jack C. (2006) Air pollution removal by urban trees and shrubs in the United States. Urban Forestry & Urban Greening 4: 115-123. 10.1016/j.ufug.2006.01.007

Nowak, DavidJ; McHale, PatrickJ; Ibarra, Myriam; Crane, Daniel; Stevens, JackC; Luley, ChrisJ (1998) Modeling the Effects of Urban Vegetation on Air Pollution. Air Pollution Modeling and Its Application XII, (Springer US), chapter 41 pages 399-407. 10.1007/978-1-4757-9128-0_41

Owen, S. M.; MacKenzie, A. R.; Stewart, H.; Donovan, R.; Hewitt, C. N. (2003) Biogenic volatile organic compound (VOC) emission estimates from an urban tree canopy. Ecological Applications 13(4): 927-938. 10.1890/01-5177

Paoletti, E. (2009) Ozone and urban forests in Italy. Environmental Pollution 157: 1506-1512. 10.1016/j.envpol.2008.09.019

Paoletti, Elena; Bardelli, Tommaso; Giovannini, Gianluca; Pecchioli, Leonella (2011) Air quality impact of an urban park over time. Procedia Environmental Sciences 4: 10-16. 10.1016/j.proenv.2011.03.002

Pederson, J. R.; Massman, W. J.; Mahrt, L.; Delany, A.; Oncley, S.; Hartog, G. Den; Neumann, H. H.; Mickle, R. E.; Shaw, R. H.; Paw U, K. T.; Grantz, D. A.; MacPherson, J. I.; Desjardins, R.; Schuepp, P. H.; Pearson Jr, R.; Arcado, T. E. (1995) California ozone deposition experiment: Methods, results, and opportunities. Atmospheric Environment 29(21): 3115-3132. 10.1016/1352-2310(95)00136-M

Powe, N. A.; Willis, K. G. (2004) Mortality and morbidity benefits of air pollution (SO2 and PM10) absorption attributable to woodland in Britain. Journal of Environmental Management 70: 119-128. 10.1016/j.jenvman.2003.11.003

Przybysz, A., A. Saebo, H. M. Hanslin and S. W. Gawronski (2014) Accumulation of particulate matter and trace elements on vegetation as affected by pollution level, rainfall and the passage of time. Science of the Total Environment 481: 360-369. http://dx.doi.org/10.1016/j.scitotenv.2014.02.072

Pugh, T. A. M.; MacKenzie, A. R.; Whyatt, J. D.; Hewitt, C. N. (2012) Effectiveness of Green Infrastructure for Improvement of Air Quality in Urban Street Canyons. Environmental Science and Technology 46: 7692-7699. 10.1021/es300826w

Ram, S. S.; Majumder, S.; Chaudhuri, P.; Chanda, S.; Santra, S. C.; Maiti, P. K.; Sudarshan, M.; Chakraborty, A. (2014) Plant canopies: bio-monitor and trap for re-suspended dust particulates contaminated with heavy metals. Mitigation and Adaptation Strategies for Global Change 19(5): 499-508. 10.1007/s11027-012-9445-8

Ram, S. S., S. Majumder, P. Chaudhuri, S. Chanda, S. C. Santra, P. K. Maiti, M. Sudarshan and A. Chakraborty (2014) Plant canopies: bio-monitor and trap for re-suspended dust particulates contaminated with heavy metals. Mitigation and Adaptation Strategies for Global Change 19: 499-508. DOI 10.1007/s11027-012-9445-8

Saebo, A., R. Popek, B. Nawrot, H. M. Hanslin, H. Gawronska and S. W. Gawronski (2012) Plant species differences in particulate matter accumulation on leaf surfaces. Science of the Total Environment 427: 347-354. doi:10.1016/j.scitotenv.2012.03.084

Salmond, J. A.; Williams, D. E.; Laing, G.; Kingham, S.; Dirks, K.; Longley, I.; Henshaw, G. S. (2013) The influence of vegetation on the horizontal and vertical distribution of pollutants in a street canyon. Science of the Total Environment 443: 287-298. 10.1016/j.scitotenv.2012.10.101

Saunders, S. M., E. Dade and K. Van Niel (2011) An Urban Forest Effects (UFORE) model study of the integrated effects of vegetation on local air pollution in the Western Suburbs of Perth, WA. 19th International Congress on Modelling and Simulation (Modsim2011) : 1824-1830.

Scott, Klaus I.; McPherson, E. Gregory; Simpson, James R. (1998) Air pollutant uptake by Sacramento's urban forest. Journal of Aboriculture 24(4): 224-234.

Speak, A. F., J. J. Rothwell, S. J. Lindley and C. L. Smith (2012) Urban particulate pollution reduction by four species of green roof vegetation in a UK city. Atmospheric Environment 61: 283-293. http://dx.doi.org/10.1016/j.atmosenv.2012.07.043

Taha, H. (1996) Modeling impacts of increased urban vegetation on ozone air quality in the South Coast Air Basin. Atmospheric Environment 30(29): 3423-3430. 10.1016/1352-2310(96)00035-0

Taha, H.; Douglas, S.; Haney, J. (1997) Mesoscale meteorological and air quality impacts of increased urban albedo and vegetation. Energy and Buildings 25: 169-177. 10.1016/s0378-7788(96)01006-7

Tallis, M.; Taylor, G.; Sinnett, D.; Freer-Smith, P. (2011) Estimating the removal of atmospheric particulate pollution by the urban tree canopy of London, under current and future environments. Landscape and Urban Planning 103: 129-138. 10.1016/j.landurbplan.2011.07.003

Terzaghi, E., E. Wild, G. Zacchello, B. E. L. Cerabolini, K. C. Jones and A. Di Guardo (2013) Forest Filter Effect: Role of leaves in capturing/releasing air particulate matter and its associated PAHs. Atmospheric Environment 74: 378-384. http://dx.doi.org/10.1016/j.atmosenv.2013.04.013

Vos, Peter E. J.; Maiheu, Bino; Vankerkom, Jean; Janssen, Stijn (2013) Improving local air quality in cities: To tree or not to tree?. Environmental Pollution 183: 113-122. 10.1016/j.envpol.2012.10.021

Wania, Annett; Bruse, Michael; Blond, Nadège; Weber, Christiane (2012) Analysing the influence of different street vegetation on traffic-induced particle dispersion using microscale simulations. Journal of Environmental Management 94: 91-101. 10.1016/j.jenvman.2011.06.036

Yang, Jun; McBride, Joe; Zhou, Jinxing; Sun, Zhenyuan (2005) The urban forest in Beijing and its role in air pollution reduction. Urban Forestry & Urban Greening 3: 65-78. 10.1016/j.ufug.2004.09.001

Yang, Jun; Yu, Qian; Gong, Peng (2008) Quantifying air pollution removal by green roofs in Chicago. Atmospheric Environment 42(31): 7266-7273. 10.1016/j.atmosenv.2008.07.003

Yin, Shan; Shen, Zhemin; Zhou, Pisheng; Zou, Xiaodong; Che, Shengquan; Wang, Wenhua (2011) Quantifying air pollution attenuation within urban parks: An experimental approach in Shanghai, China. Environmental Pollution 159: 2155-2163. 10.1016/j.envpol.2011.03.009

Atmospheric regulation

Asuming-Brempong, S., Gantner, S., Adiku, S.G.K., Archer, G., Edusei, V. and Tiedje, J.M. (2008) Changes in the biodiversity of microbial populations in tropical soils under different fallow treatments. Soil Biology and Biochemistry, 40, 11, 2811-2818. doi:10.1016/j.soilbio.2008.08.010

Bai Y.G., Colberg T., Romo J.T., McConkey B., Pennock D. & Farrell R. (2009) Does expansion of western snowberry enhance ecosystem carbon sequestration and storage in Canadian Prairies?. Agriculture, Ecosystems and Environment, 123, 269-276. 10.1016/j.agee.2009.07.009

Balvanera, Patricia, Claire Kremen and Miguel Martínez-Ramos (2005) Applying community structure analysis to ecosystem function: examples from pollination and carbon storage. Ecological Applications, 15, 1, 360-375. http://www.jstor.org/stable/4543359

Beier, Claus, Bridget A. Emmett, Albert Tietema, Inger K. Schmidt, Josep Pen˜uelas, Edit Kovacs Lang, Pierpaolo Duce, Paolo De Angelis, Antonie Gorissen, Marc Estiarte, Giovanbattista D. de Dato, Alwyn Sowerby, Gyorgy Kroel-Dulay,
Eszter Lellei-Kova´cs,6 (2009) Carbon and nitrogen balances for six shrublands across Europe. Global Biogechemical Cycles, 23, GB4008. doi:10.1029/2008GB003381

Bunker D.E., DeClerck F., Bradford J.C., Colwell R.K., Perfecto I., Phillips O.L., Sankaran M. & Naeem S. (2005) Species loss and aboveground carbon storage in a tropical forest. Science, 310, 1029-1031. 10.1126/science.1117682

Cadotte, M.W. (2013) Experimental evidence that evolutionarily diverse assemblages result in higher productivity. PNAS 110(22) 8996–9000. doi:10.1073/pnas.1301685110

Cahill, K.N, Kucharik, C.J. and Foley, J.A. (2009) Prairie restoration and carbon sequestration: difficulties quantifying C sources and sinks using a biometric approach. Ecological Applications, 19, 8, 2185-2201. doi/10.1890/08-0069.1

Caspersen, J.P. & Pacala, S.W. (2001) Successional diversity and forest ecosystem function. Ecological Research, 16, 895-903. DOI:10.1046/j.1440-1703.2001.00455.x

Cavanaugh, Kyle C., J. Stephen Gosnell, Samantha L. Davis, Jorge Ahumada, Patrick Boundja, David B. Clark, BadruMugerwa, Patrick A. Jansen, Timothy G. O'Brien, Francesco Rovero, Douglas Sheil, Rodolfo Vasquez and Sandy Andelman (2014) Carbon storage in tropical forests correlates with taxonomic diversity and functional dominance on a global scale. Global Ecology and Biogeography, (Global Ecol. Biogeogr.) (2014) 23, 563–573. DOI: 10.1111/geb.12143

Chen D.X., Li Y.D., Liu H.P., Xu H., Xiao W.F., Luo T.S., Zhou Z. & Lin M.X. (2010) Biomass and carbon dynamics of a tropical mountain rain forest in China. Science China-Life Sciences, 53(7): 798-810. 10.1007/s11427-010-4024-2

Chen, X. (2006) Tree diversity, carbon storage and soil nutrient in an old-growth forest at Changbai Mountain. Northeast China, Communications in Soil Science and Plant Analysis, 37, 363-375. DOI:10.1080/00103620500440210

Conard, S.G. & Ivanova, G.A. (1997) Wildfire in Russian boreal forests - potential impacts of fire regime characteristics on emissions and global carbon balance estimates. Environmental Pollution, 98, 3, 305-313. http://dx.doi.org/10.1016/S0269-7491(97)00140-1

Dickie, I. et al. (2011) Ecosystem service and biodiversity trade-offs in two woody successions. Journal of Applied Ecology, 48, 4, 926-934. doi: 10.1111/j.1365-2664.2011.01980.x

Emran M., Gispert M. & Pardini G. (2012) Comparing measurements methods of carbon dioxide fluxes in a soil sequence under land use and cover change in North Eastern Spain. Geoderma, 170, 176-185. 10.1016/j.geoderma.2011.11.013

Glenday, J. (2008) Carbon storage and emissions offset potential in an African dry forest, the Arabuko-Sokoke Forest, Kenya. Environ. Monit. Assess., 142, 85-95. DOI 10.1007/s10661-007-9910-0

Gonzalez, Patrick, Benjamín Kroll, Carlos R. Vargas (2014) Tropical rainforest biodiversity and aboveground carbon changes and uncertainties in the Selva Central, Peru. Forest Ecology and Management 312 (2014) 78–91. doi:10.1016/j.foreco.2013.10.019

Hager, Achim (2012) The effects of management and plant diversity on carbon storage in coffee agroforestry systems in Costa Rica. Agroforest Syst (2012) 86:159–174. DOI 10.1007/s10457-012-9545-1

Hantanaka, N., Wright, W., Loyn, R.H. and Mac Nally, R. (2011) Ecologically complex carbon - linking biodiversity values, carbon storage and habitat structure in some austral temperate forests. Global Ecol. Biogeogr., 20, 260-271. DOI: 10.1111/j.1466-8238.2010.00591.x

Haugaasen T., Barlow J. & Peres C.A. (2003) Surface wildfires in central Amazonia: short-term impact on forest structure and carbon loss. Forest Ecology and Management, 179, 321-331. 10.1016/S0378-1127(02)00548-0

Hector, A., Philipson, C., Saner, P., Chamagne, J., Dzulkifli, D., O'Brien, M., Snaddon, J.L., Ulok, P., Weilenmann, M., Reynolds, G. and Godfray, H.C.J. (2011) The Sabah Biodiversity Experiment: a long-term test of the role of tree diversity in restoring tropical forest structure and functioning. Phil. Trans. R. Soc. B, 366, 3303-3315. doi: 10.1098/rstb.2011.0094

Hollingsworth T.N., Schuur E.A.G., Chapin F.S. & Walker M.D. (2008) Plant community composition as a predictor of regional soil carbon storage in Alaskan Boreal Black Spruce ecosystems. Ecosystems, 11, 629-642. 10.1007/s10021-008-9147-y

Hulvey, Kristin B., Richard J. Hobbs, Rachel J. Standish, David B. Lindenmayer, Lori Lach1 and Michael P. Perring (2013) Benefits of tree mixes in carbon plantings. NATURE CLIMATE CHANGE, VOL 3, OCTOBER 2013, 869-74. DOI: 10.1038/NCLIMATE1862

Jonsson M. & Wardle D.A. (2010) Structural equation modelling reveals plant-community drivers of carbon storage in boreal forest ecosystems. Biology Letters, 6, 116-119. 10.1098/rsbl.2009.0613

Kaul M., Mohren G.M.J. & Dadhwal V.K. (2010) Carbon storage and sequestration potential of selected tree species in India. Mitigation and Adaptation Strategies for Global Change, 15, 489-510. 10.1007/s11027-010-9230-5

Keeton, W.S., M. Chernyavsky , G. Gratzer, M. Main-Knorn, M. Shpylchak & Y.
Bihun (2010) Structural characteristics and aboveground biomass of old-growth spruce-fir stands in the eastern Carpathian mountains, Ukraine. Plant Biosystems, 144:1, 148-159.
DOI:10.1080/11263500903560512

Kirby, K. & Potvin, C. (2007) Variation in carbon storage among tree species: Implications for the management of a small-scale carbon sink project. Forest Ecology & Management, 246: 208-221. DOI:10.1016/j.foreco.2007.03.072

Klumpp K., Fontaine S., Attard E., Le Roux X., Gleixner G. & Soussana J.F. (2009) Grazing triggers soil carbon loss by altering plant roots and their control on soil microbial community. Journal of Ecology, 97, 876-885. 10.1111/j.1365-2745.2009.01549.x

Koteen, L., Baldocchi, D. and Harte, J. (2011) Invasion of non-native grasses causes a drop in soil carbon storage in California grasslands. Environ. Res. Lett., 6, 044001. doi:10.1088/1748-9326/6/4/044001

Laclau (2003) Root biomass and carbon storage of ponderosa pine in a northwest Patagonia plantation. Forest Ecology and Management, 173, 353-360. http://dx.doi.org/10.1016/S0378-1127(02)00012-9

Langat, Joseph K. Sigi, Bernard K. Y. Kirui, Martin W. Skov, James G. Kairo, Maurizio Mencuccini, Mark Huxham (2013) Species mixing boosts root yield in mangrove trees. Oecologia (2013) 172:271–278. DOI 10.1007/s00442-012-2490-x

Lavorel,S. & Grigulis, K. (2012) How fundamental plant functional trait relationships scale-up to trade-offs and synergies in ecosystem services. Journal of Ecology, 100: 128-140. DOI: 10.1111/j.1365-2745.2011.01914.x

Law, B.E., Sun, O.J., Campbell, J., Van Tuyl, S. and Thornton, P.E. (2003) Changes in carbon storage and fluxes in a chronosequence of ponderosa pine. Global Change Biology, 9, 510-524. DOI: 10.1046/j.1365-2486.2003.00624.x

Lee J., Morrison I.K., Leblanc J.D., Dumas M.T. & Cameron D.A. (2002) Carbon sequestration in trees and regrowth vegetation as affected by clearcut and partial cut harvesting in a second-growth boreal mixedwood. Forest Ecology and Management, 169, 83-101. 10.1016/S0378-1127(02)00300-6

Mack M.C., Bret-Harte M.S., Hollingsworth T.N., Jandt R.R., Schuur E.A.G., Shaver G.R. & Verbyla D.L. (2011) Carbon loss from an unprecedented Arctic tundra wildfire. Nature, 475, 489-492. 10.1038/Nature10283

Meier I.C. & Leuschner C. (2010) Variation of soil and biomass carbon pools in beech forests across a precipitation gradient. Global Change Biology, 16, 1035-1045. 10.1111/j.1365-2486.2009.02074.x

Mills, A.J. & Cowling, R.M. (2006) Rate of carbon sequestration at two thicket restoration sites in the Eastern Cape. South Africa, Restoration Ecology, 14, 1, 38-49. doi: 10.1111/j.1526-100X.2006.00103.x

Mishra U., Ussiri D.A.N. & Lal R. (2010) Tillage effects on soil organic carbon storage and dynamics in Corn Belt of Ohio USA. Soil & Tillage Research, 107, 88-96. 10.1016/j.still.2010.02.005

Niu D., Wang S.L. & Ouyang Z.Y. (2009) Comparisons of carbon storages in Cunninghamia lanceolata and Michelia macclurei plantations during a 22-year period in southern China. Journal of Environmental Sciences, 21, 801-805. 10.1016/S1001-0742(08)62344-X

Persiani, O.M., Maggi, O., Montalvo, J., Casado, M.A. and Pineda, F.D. (2008) Mediterranean grassland soil fungi: Patterns of biodiversity, functional redundancy and soil carbon storage. Plant Biosystems, 142, 1, 111-119. DOI: 10.1080/11263500701872713

Potter, Kevin M. and Christopher W. Woodall (2014) Does biodiversity make a difference? Relationships between species richness, evolutionary diversity, and aboveground live tree biomass across U.S. forests. Forest Ecology and Management 321 (2014) 117–129. doi:10.1016/j.foreco.2013.06.026

Potvin et al. (2011) An ecosystem approach to biodiversity effects: Carbon pools in a tropical tree plantation. Forest Ecology and Management, 261, 1614-1624.

Qi G., Wang Q., Dai L., Wang X. & Qi L. (2010) Carbon sequestration in old-growth forest and plantations on Changbai Mountain in Northeast China. Bioinformatics and Biomedical Engineering, 4th International Conference. 10.1109/ICBBE.2010.5515118

Richards A.E., Cook G.D. & Lynch B.T. (2011) Optimal fire regimes for soil carbon storage in tropical savannas of northern Australia. Ecosystems, 14, 503-518. 10.1007/s10021-011-9428-8

Richards, Meryl Breton and V. Ernesto Mendez (2013) Interactions between Carbon Sequestration and Shade Tree Diversity in a Smallholder Coffee Cooperative in El Salvador. Conservation Biology, Volume 28, No. 2, 489–497. DOI: 10.1111/cobi.12181

Ruiz-Jaen, M.C. and Potvin, C. (2011) Can we predict carbon stocks in tropical ecosystems from tree diversity? Comparing species and functional diversity in a plantation and natural forest. New Phytologist, 189, 4, 978-987. doi: 10.1111/j.1469-8137.2010.03501.x.

Saha, S., Nair, P.K.R., Nair, V.D. and Kumar, B.M. (2009) Soil carbon stock in relation to plant diversity of homegardens in Kerala, India. Agroforestry Systems, 76, 1, 53-65. DOI 10.1007/s10457-009-9228-8

Seidl R., Rammer W., Jager D. & Lexer M.J. (2008) Impact of bark beetle (Ips typographus L.) disturbance on timber production and carbon sequestration in different management strategies under climate change. Forest Ecology and Management, 256, 209-220. 10.1016/j.foreco.2008.04.002

Sharma, C.M., Baduni, N.P., Gairola, S., Ghildiyal, S.K. and Suyal, S. (2010) Tree diversity and carbon stocks of some major forest types of Garhwal Himalaya. India, Forest Ecology and Management, 260, 2170-2179. doi:10.1016/j.foreco.2010.09.014

Steinbeiss, S., Beßler, H., Engels, C., Temperton, V. M., Buchmann, N., Roscher, C., Kreutziger, Y., Baade, J., Habekost, M. and Gleixner, G. (2008) Plant diversity positively affects short-term soil carbon storage in experimental grasslands. Global Change Biology, 14, 12, 2937-2949. doi: 10.1111/j.1365-2486.2008.01697.x

Sun D.S., Wesche K., Chen D.D., Zhang S.H., Wu G.L., Du G.Z. & Comerford N.B. (2011) Grazing depresses soil carbon storage through changing plant biomass and composition in a Tibetan alpine meadow. Plant Soil and Environment, 57, 6, 271-278.

Tolbert V.R., Joslin J.D., Thornton F.C., Bock B.R., Pettry D.E., Bandaranayake W., Tyler D., Houston A. & Schoenholtz S. (1999) Biomass crop production: benefits for soil quality and carbon sequestration. Biomass: A Growth Opportunity in Green Energy and Value-Added Products, Vols 1 and 2, 127-132.

Tran Van Con, Nguyen Toan Thang, Do Thi Thanh Ha, Cao Chi Khiem, Tran Hoang Quy, Vu Tien Lam, Tran Van Do, Tamotsu Sato (2013) Relationship between aboveground biomass and measures of structure and species diversity in tropical forests of Vietnam. Forest Ecology and Management 310 (2013) 213–218. doi:10.1016/j.foreco.2013.08.034

Wardle, David A., Micael Jonsson, Sheel Bansal, Richard D. Bardgett, Michael J. Gundale and Daniel B. Metcalfe (2012) Linking vegetation change, carbon sequestration and biodiversity: insights from island ecosystems in a long-term natural experiment. Journal of Ecology 2012, 100, 16–30. doi: 10.1111/j.1365-2745.2011.01907.x

Yang Bai, Changwei Zhuang, Zhiyun Ouyang, Hua Zheng, Bo Jiang (2011) Spatial characteristics between biodiversity and ecosystem services in a human-dominated watershed. Ecological Complexity, 8, 177-183. doi:10.1016/j.ecocom.2011.01.007

Yen, T-M. and Lee, J.S. (2011) Comparing aboveground carbon sequestration between moso bamboo (Phyllostachys heterocycla) and China fir (Cinninghamia lanceolata) forests based on the allometric model. Forest Ecology and Management, 261, 6, 995-1002. doi:10.1016/j.foreco.2010.12.015

Yurova A.Y. & Lankreijer H. (2007) Carbon storage in the organic layers of boreal forest soils under various moisture conditions: A model study for Northern Sweden sites. Ecological Modelling, 204, 475-484. 10.1016/j.ecolmodel.2007.02.003

Zhang, H., Guan, D and Song, M. (2012) Biomass and carbon storage of Eucalyptus and Acacia plantations in the Pearl River Delta, South China. Forest Ecology and Management, 227, 90-97. http://dx.doi.org/10.1016/j.foreco.2012.04.016

Zhao M.F., Xiang W.H., Peng C.H. & Tian D.L. (2009) Simulating age-related changes in carbon storage and allocation in a Chinese fir plantation growing in southern China using the 3-PG model. Forest Ecology and Management, 257, 1520-1531. 10.1016/j.foreco.2008.12.025

Zhao, M., Kong, Z., Escobedo, F.J. and Gao, J. (2010) Impacts of urban forests on offsetting carbon emissions from industrial energy use in Hangzhou. China, Journal of Environmental Management, 91, 807-813. doi:10.1016/j.jenvman.2009.10.010

Zimmermann, J., Dauber, J. and Jones, M. (2012) Soil carbon sequestration during the establishment phase of Miscanthus x giganteus: a regional-scale study on commercial farms using 13C natural abundance. GCB Bioenergy, 4, 453-361. doi: 10.1111/j.1757-1707.2011.01117.x

Water flow regulation (flood protection)

Acreman M. C., R. J. Harding, C. Lloyd, N. P. McNamara, J. O. Mountford, D. J. Mould, B. V. Purse, M. S. Heard, C. J. Stratford & S. J. Dury (2011) Trade-off in ecosystem services of the Somerset Levels and moors wetlands. Hydrological Sciences Journal, 56, 8, 1543. doi:10.1080/02626667.2011.629783

Acreman M.C., Fisher J., Stratford C.J., Mould D.J. & Mountford J.O. (2007) Hydrological science and wetland restoration: some case studies from Europe. Hydrology and Earth System Sciences, 11, 158-169. 10.5194/hess-11-158-2007

Acreman M.C., Riddington R. & Booker D.J. (2003) Hydrological impacts of floodplain restoration: a case study of the River Cherwell, UK. Hydrology and Earth System Sciences, 7, 75-85. 10.5194/hess-7-75-2003

Anderson B.G., Rutherfurd I.D. & Western A.W. (2006) An analysis of the influence of riparian vegetation on the propagation of flood waves. Environmental Modelling & Software, 21, 1290-1296. 10.1016/j.envsoft.2005.04.027

Aronica G., Candela A. & Santoro M. (2002) Changes in the hydrological response of two Sicilian basins affected by fire. FRIEND - Regional Hydrology: Bridging the gap between research and practice (Proceedings of the Fourth International FRIEND conference), 274.

Bathurst, J. et al. (2011) Forest impact on floods due to extreme rainfall and snowmelt in four Latin American environments 1: field data analysis. Journal of Hydrology, 400, 281-291. doi:10.1016/j.jhydrol.2010.11.044

Beschta R.L., Pyles M.R., Skaugset A.E. & Surfleet C.G. (2000) Peakflow responses to forest practices in the western cascades of Oregon, USA. Journal of Hydrology, 233, 102-120. 10.1016/S0022-1694(00)00231-6

Bradshaw, C.J.A., Sodhi, N.S., Peh, K.S.-H. and Brook, B.W. (2007) Global evidence that deforestation amplifies flood risk and severity in the developing world. Global Change Biology, 13, 2379-2395. doi:10.1111/j.1365-2486.2007.01446.x

Brien L. & Hopmans P. (2007) Paired catchments observations on the water yield of mature eucalypt and immature radiata pine plantations in Victoria, Australia. Journal of Hydrology, 336, 416-429. 10.1016/j.jhydrol.2007.01.018

Bruijnzeel, L.A. (2004) Hydrological functions of tropical forests: not seeing the soil for the trees?. Agriculture, Ecosystems and Environment, 104, 185-228. doi:10.1016/j.agee.2004.01.015

Bullock, A. & Acreman, M. (2003) The role of wetlands in the hydrological cycle. Hydrology and Earth System Sciences, 7, 3, 358-389. doi:10.5194/hess-7-358-2003

Carlyle-Moses, D.E. & Price, A.G. (2007) Modelling canopy interception loss from a Madrean pine-oak stand, Northeastern Mexico. Hydrol. Process., 21, 2572-2580. DOI: 10.1002/hyp.6790

Cheng, J.D., Lin, L.L. and Lu, H.S. (2002) Influences of forests on water flows from headwater watersheds in Taiwan. Forest Ecology and Management, 165, 11-28. doi:10.1016/S0378-1127(01)00626-0

Clark, C. (1987) Deforestation and floods. Environmental Conservation, 14, 67-69. DOI: http://dx.doi.org/10.1017/S0376892900011127

Cosandey C., Andreassian V., Martin C., Didon-Lescot J.F., Lavabre J., Folton N., Mathys N. & Richard D. (2005) The hydrological impact of the mediterranean forest: a review of French research. Journal of Hydrology, 301, 4, 235-249. 10.1016/j.jhydrol.2004.06.040

Darby S.E. (1999) Effect of riparian vegetation on flow resistance and flood potential. Journal of Hydraulic Engineering, 125, 443-454. 10.1061/(Asce)0733-9429(1999)125:5(443)

Erskine, W.D. & Webb, A.A. (2003) Desnagging to resnagging: new directions in river rehabilitation in southeastern Australia. River Res. Applic. 19, 233-249. DOI: 10.1002/rra.750

Ewel, K.C., Twilley, R. & Ong, J.E. (1998) Different kinds of mangrove forests provide different goods and services. Global Ecology and Biogeography Letters, 7, 83-94. http://links.jstor.org/sici?sici=0960-7447%28199801%297%3A1%3C83%3ADKOMFP%3E2.0.CO%3B2-O

Fahey, B. & Jackson, R. (1997) Hydrological impacts of converting native forests and grasslands to pine plantations, South Island, New Zealand. Agricultural and Forest Meteorology, 84, 69-82. doi:10.1016/S0168-1923(96)02376-3

Fang, Xiuqin; Liliang Ren; Qiongfang Li; Qiuan Zhu; Peng Shi; and Yonghua Zhu (2013) Hydrologic Response to Land Use and Land Cover Changes within the Context of Catchment-Scale Spatial Information. J. Hydrol. Eng. 2013.18:1539-1548. DOI: 10.1061/(ASCE)HE.1943-5584.0000482

Farley, K.A., Jobbagy, E.G. and Jackson, R.B. (2005) Effects of afforestation on water yield: a global synthesis with implications for policy. Global Change Biology, 11, 1565-1576. doi:10.1111/j.1365-2486.2005.01011.x

Ferrario, Filippo, Michael W. Beck, Curt D. Storlazzi, Fiorenza Micheli, Christine C. Shepard & Laura Airoldi (2014) The effectiveness of coral reefs for coastal hazard risk reduction and adaptation. NATURE COMMUNICATIONS | 5:3794. DOI: 10.1038/ncomms4794 |

Foote, A.L, Pandey, S., and Krogman, N. (1996) Processes of wetland loss in India. Environmental Conservation, 23, 01, 45-54. http://hdl.handle.net/10402/era.32766

Ford, Hilary, Angus Garbutt, Davey L. Jones, Laurence Jones (2012) Impacts of grazing abandonment on ecosystem service provision: Coastal grassland as a model system. Agriculture, Ecosystems and Environment 162 (2012) 108– 115. doi:10.1016/j.agee.2012.09.003

Gholzom, E.H. and Gholami, V. (2012) A Comparison between Natural Forests and Reforested Lands in Terms of Runoff Generation Potential and Hydrologic Response (Case Study: Kasilian Watershed). Soil & Water Res., 7, 2012 (4): 166–173.

Green, K. and Alila, Y. (2012) A paradigm shift in understanding and quantifying the effects of forest harvesting on floods in snow environments. Water Resour. Res., 48, W10503. doi:10.1029/2012WR012449

Hümann, M., Schüler, G., Müller, C., Schneider, R., Johst, M. and Caspari, T. (2011) Identification of runoff processes - the impact of different forest types and soil properties on runoff formation and floods. Journal of Hydrology, 409, 637-649. doi: 10.1016/j.jhydrol.2011.08.067

Iroumé, I., Mayen, O. and Huber, A. (2005) Runoff and peak flow responses to timber harvest and forest age in southern Chile. Hydrological Processes, 21, 37-50. DOI: 10.1002/hyp.5897

Kabanda, T.H. & L.G. Palamuleni (2013) Land use/cover changes and vulnerability to flooding in the Harts catchment, South Africa. South African Geographical Journal,95:1, 105-116. DOI: 10.1080/03736245.2013.806165

Lana-Renault, N., E. Nadal-Romero, M. P. Serrano-Muela, B. Alvera, P. Sánchez-Navarrete, Y. Sanjuan and J. M. García-Ruiz (2014) Comparative analysis of the response of various land covers to an exceptional rainfall event in the central Spanish Pyrenees, October 2012. Earth Surface Processes and Landforms 39, 581–592. DOI: 10.1002/esp.3465

Lange, Benjamin, Peter F. Germann and Peter Luscher (2013) Greater abundance of Fagus sylvatica in coniferous flood protection forests due to climate change: impact of modified root densities on infiltration. Eur J Forest Res (2013) 132:151–163. DOI 10.1007/s10342-012-0664-z

Lee, H-Y. & Shih, S-S. (2004) Impacts of vegetation changes on the hydraulic and sediment transport characteristics in Guandu mangrove wetland. Ecological Engineering, 23, 85-94. doi:10.1016/j.ecoleng.2004.07.003

Lin, Y. & Wei, X. (2008) The impact of large-scale forest harvesting on hydrology in the Willow watershed of Central British Columbia. Journal of Hydrology, 359, 141-149. doi:10.1016/j.jhydrol.2008.06.023

Martin P. (1999) Reducing flood risk from sediment-laden agricultural runoff using intercrop management techniques in northern France. Soil & Tillage Research, 52, 233-245. 10.1016/S0167-1987(99)00084-7

Mazda, Y., Magi, M., Kogo, M. and Hong, P.N. (1997) Mangroves as a coastal protection from waves in the Tong Kind delta, Vietnam. Mangroves and Salt Marshes, 1, 127-135. 10.1023/A:1009928003700

Ming, J., Xian-guoa, L., Lin-shuc, X., Li-juand, C. and Shouzhenga, T. (2007) Flood mitigation benefit of wetland soil - A case study in Momoge National Nature Reserve in China. Ecological Economics, 61, 217-223. doi:10.1016/j.ecolecon.2006.10.019

Möller, I., Spencer, T., French, J.R., Leggett, J. and Dixon, M. (2007) The sea-defence value of salt marshes: field evidence from north Norfolk. Water and Environment Journal, 15, 2, 109-116. doi:10.1111/j.1747-6593.2001.tb00315.x

Moore, R.D. & Wondzell, S.M. (2005) Physical hydrology and the effects of forest harvesting in the Pacific Northwest: A review. Journal of the American Water Resources Association, 41, 4, 763-784. doi:10.1111/j.1752-1688.2005.tb03770.x

Morris, J, Hess, T.M., Gowing, D.J.G., Leeds-Harrison, P.B., Bannister, M., Vivash, R.M.N. and Wade. M. (2005) A framework for integrating flood defence and biodiversity in washlands in England. International Journal of River Basin Management, 3, 2, 105-115.

Nedkov, S. & Burkhard, B. (2012) Flood regulating ecosystem services - mapping supply and demand, in the Etropole municipality, Bulgaria. Ecological Indicators, 21, 67-79. doi:10.1016/j.ecolind.2011.06.022

Ogden, Fred L., Trey D. Crouch, Robert F. Stallard and Jefferson S. Hall (2013) Effect of land cover and use on dry season river runoff, runoff efficiency, and peak storm runoff in the seasonal tropics of Central Panama. WATER RESOURCES RESEARCH, VOL. 49, 8443–8462. doi:10.1002/2013WR013956

Palmer, R.C. and Smith, R.P. (2013) Soil structural degradation in SW England and its impact on surface-water runoff generation. Soil Use and Management, December 2013, 29, 567–575. doi: 10.1111/sum.12068

Posthumus, H., J.R. Rouquette, J. Morris, D.J.G. Gowing & T.M. Hess (2010) A framework for the assessment of ecosystem goods and services; a case study on lowland floodplains in England. Ecological Economics, 69, 1510-1523. doi:10.1016/j.ecolecon.2010.02.011

Putuhena W.M. & Cordery I. (2000) Some hydrological effects of changing forest cover from eucalypts to Pinus radiata. Agricultural and Forest Meteorology, 100, 59-72. 10.1016/S0168-1923(99)00086-6

Qi S., Wang Y. & Wang Y. (2007) Effects of reforestation on the hydrological function of a small watershed in the Three Gorges Reservoir area. Frontiers of Forestry in China, 2, 148-156. 10.1007/s11461-007-0024-1

Robinson M., Gannon B. & Schuch M. (1991) A comparison of the hydrology of moorland under natural conditions, agricultural use and forestry. Hydrological Sciences Journal, 36, 6. 10.1080/02626669109492544

Robinson, M., A.-L. Cognard-Plancq, C. Cosandey, J. David, P. Durande, H.-W. Fuhrer, R. Hall, M.O. Hendriques, V. Marc, R. McCarthy, M. McDonnell, C. Martin, T. Nisbet, P. O'Dea, M. Rodgers, A. Zollner (2003) Studies of the impact of forests on peak flows and baseflows: a European perspective. Forest Ecology and Management, 186, 85-97. doi:10.1016/S0378-1127(03)00238-X

Schmittner, K.-E. & Giresse, P. (1996) Modelling and application of the geomorphic and environmental controls on flash flood flow. Geomorphology, 16, 337-347. doi:10.1016/0169-555X(96)00002-5

Schnorbus, M. and Alila, Y. (2013) Peak flow regime changes following forest harvesting in a snow-dominated basin: Effects of harvest area, elevation, and channel connectivity. WATER RESOURCES RESEARCH, VOL. 49, 517–535. doi:10.1029/2012WR011901,

Smakhtin, V.U. & Batchelor, A.L. (2005) Evaluating wetland flow regulating functions using discharge time-series. Hydrol. Procsess., 19, 1293-1305. doi:10.1002/hyp.5555

Smith, R.J., Hancock, N.H. & Ruffini, J.L. (1990) Flood flow through tall vegetation. Agricultural Water Management, 18, 317-332. doi:10.1016/0378-3774(90)90014-P

Stovin, V., Vesuviano, G. and Kasmin, H. (2012) The hydrological performance of a green roof test bed under UK climatic conditions. Journal of Hydrology 414–415 (2012) 148–161. doi:10.1016/j.jhydrol.2011.10.022

Temmerman, S., De Vries, M.B. and Bouma, T.J. (2012) Coastal marsh die-off and reduced attenuation of coastal floods: A model analysis. Global and Planetary Change, 92-93, 267-274. doi:10.1016/j.gloplacha.2012.06.001

Thomas, H. & Nisbet, T.R. (2006) An assessment of the impact of floodplain woodland on flood flows. Water and Environment Journal, 21, 114-126. DOI: 10.1111/j.1747-6593.2006.00056.x

Wahl, N.A., Wollecke B., Bens, O. and Huttl, R.F. (2005) Can forest transformation help reducing floods in forested watersheds? Certain aspects on soil hydraulics and organic matter properties. Physics and Chemistry of the Earth, 611-621. doi:10.1016/j.pce.2005.07.013

Wamsley, T.V., Cialone, M.A., Smith, J.M., Atkinson, J.H. and Rosati, J.D. (2010) The potential of wetlands in reducing storm surge. Ocean Engineering, 37, 59-68. doi:10.1016/j.oceaneng.2009.07.018

Wittmann, F. & Junk, W.J. (2003) Sapling communities in Amazonian white-water forests. Journal of Biogeography 30, 1533-1544. doi: 10.1046/j.1365-2699.2003.00966.x

Yang, Chuanguo, Zhongbo Yu, Zhenchun Hao, Zhaohui Lin and Huimin Wang (2013) Effects of Vegetation Cover on Hydrological Processes in a Large Region: Huaihe River Basin, China. J. Hydrol. Eng. 2013.18:1477-1483. DOI: 10.1061/(ASCE)HE.1943-5584.0000440

Yang, W., Wang, X., Liu, Y., Gabor, S., Boychuk, L. and Badiou, P. (2010) Simulated environmental effects of wetland restoration scenarios in a typical Canadian prairie watershed. Wetlands Ecol. Manage., 18, 269-279. doi:10.1007/s11273-009-9168-0

Zavaleta, E. (2000) The economic value of controlling an invasive shrub. AMBIO: A Journal of the Human Environment, 29, 8, 462-467. 10.1639/0044-7447(2000)029[0462:Tevoca]2.0.Co;2

Mass flow regulation

Aguilera, MO; Steinaker, DF; Demaria, MR (2003) Runoff and soil loss in undisturbed and roller-seeded shrublands of semiarid Argentina. J. Range Manage. 56: 227-233.

Andreu, V., J. L. Rubio, E. Gimeno-Garcia and J. V. Llinares (1998) Testing three Mediterranean shrub species in runoff reduction and sediment transport. Soil & Tillage Research 45: 441–454. 0167-1987/98/$19.00

Andry, Henintsoa, Tahei Yamamoto, and Mitsuhiro Inoue (2007) Effectiveness of hydrated lime and artificial zeolite amendments and sedum (Sedum sediforme) plant cover in controlling soil erosion from an acid soil. Australian Journal of Soil Research, 45: 266–279. 0004-9573/07/040266

Bautista, S., A. G. Mayor, J. Bourakhouadar and J. Bellot (2007) Plant spatial pattern predicts hillslope semiarid runoff and erosion in a Mediterranean landscape. Ecosystems 10: 987-998. DOI: 10.1007/s10021-007-9074-3

Bochet, E., J. Poesen and J. L. Rubio (2006) Runoff and soil loss under individual plants of a semi-arid Mediterranean shrubland: influence of plant morphology and rainfall intensity. Earth Surface Processes and Landforms 31: 536-549. 10.1002/esp.1351

Boer, M. and J. Puigdefabregas (2005) Effects of spatially structured vegetation patterns on hillslope erosion in a semiarid Mediterranean environment: a simulation study. Earth Surface Processes and Landforms 30: 149-167. DOI: 10.1002/esp.1180

Burylo, M., F. Rey, E. Bochet and T. Dutoit (2012) Plant functional traits and species ability for sediment retention during concentrated flow erosion. Plant and Soil 353: 135-144. DOI 10.1007/s11104-011-1017-2

Burylo, Melanie; Dutoit, Thierry; Rey, Freddy (2014) Species Traits as Practical Tools for Ecological Restoration of Marly Eroded Lands. Restoration Ecology 22: 633–640. doi: 10.1111/rec.12113

Cammeraat, ELH (2004) Scale dependent thresholds in hydrological and erosion response of a semi-arid catchment in southeast Spain. AGRICULTURE ECOSYSTEMS & ENVIRONMENT Volume: 104 Issue: 2 Pages: 317-332.

Chirino, E., Bonet, A., Bellot, J., Sánchez, J. R. (2006) Effects of 30-year-old Aleppo pine plantations on runoff, soil erosion, and plant diversity in a semi-arid landscape in south eastern Spain. Catena, 65(1): 19–29. http://dx.doi.org/10.1016/j.catena.2005.09.003

Comoss, E. J., D. A. Kelly and H. Z. Leslie (2002) Innovative erosion control involving the beneficial use of dredge material, indigenous vegetation and landscaping along the Lake Erie Shoreline. Ecological Engineering 19: 203-210. doi:10.1016/S0925-8574(02)00080-0

Coops, H., N. Geilen, H. J. Verheij, R. Boeters and G. van der Velde (1997) Interactions between waves, bank erosion and emergent vegetation: An experimental study in a wave tank. Aquatic Botany 53: 187-198.

De Baets, S., J. Poesen, B. Reubens, B. Muys, J. De Baerdemaeker and J. Meersmans (2009) Methodological framework to select plant species for controlling rill and gully erosion: application to a Mediterranean ecosystem. Earth Surface Processes and Landforms 34: 1374-1392. DOI: 10.1002/esp.1826

De Baets, S.; Poesen, J.; Meersmans, J.; et al. (2011) Cover crops and their erosion-reducing effects during concentrated flow erosion. Catena 85: 237–244. doi:10.1016/j.catena.2011.01.009

De Baets, S.; Poesen, J.; Reubens, B.; et al. (2008) Root tensile strength and root distribution of typical Mediterranean plant species and their contribution to soil shear strength. PLANT AND SOIL Volume: 305 Issue: 1-2 Pages: 207-226. DOI 10.1007/s11104-008-9553-0

Duran Zuazo, V. H.; Rodriguez Pleguezuelo, C. R.; Arroyo Panadero, L.; et al. (2009) Soil Conservation Measures in Rainfed Olive Orchards in South-Eastern Spain: Impacts of Plant Strips on Soil Water Dynamics. Pedosphere 19: 453-464.

Gao, Y., B. Zhong, H. Yue, B. Wu and S. Cao (2011) A degradation threshold for irreversible loss of soil productivity: a long-term case study in China. Journal of Applied Ecology 48: 1145-1154. doi: 10.1111/j.1365-2664.2011.02011.x

Garcia Nacinovic, M. G., C. F. Mahler and A. d. S. Avelar (2014) Soil erosion as a function of different agricultural land use in Rio de Janeiro. Soil & Tillage Research 144: 164-173. doi/10.1016/j.still.2014.07.002

Gaskin, S; Gardner, R (2001) The role of cryptogams in runoff and erosion control on bariland in the Nepal Middle Hills of the southern Himalaya. Earth Surf. Process. Landforms 26, 1303–1315. DOI: 10.1002/esp.277

Geissler, C., P. Kuehn, M. Boehnke, H. Bruelheide, X. Shi and T. Scholten (2012) Splash erosion potential under tree canopies in subtropical SE China. Catena 91: 85-93. doi:10.1016/j.catena.2010.10.009

Grace, J.M. (2002) Effectiveness of vegetation in erosion control from forest road sideslopes. Transactions of the Asae 45: 681-685.

Gyssels, G., and Poesen, J. (2003) he importance of plant root characteristics in controlling concentrated flow erosion rates. Earth Surface Processes and Landforms, 28: 371-384.

Hou, J., B. Fu, S. Wang and H. Zhu (2014) Comprehensive analysis of relationship between vegetation attributes and soil erosion on hillslopes in the Loess Plateau of China. Environmental Earth Sciences 72: 1721-1731. DOI 10.1007/s12665-014-3076-1

Hu, L.-J., P. Li and Q. Guo (2013) Positive Plant Diversity-Soil Stability Relationships are Mediated through Roots in the Songnen Grassland: Chronosequence Evidence. Notulae Botanicae Horti Agrobotanici Cluj-Napoca 41: 626-637.

Huang, Z. L., L. D. Chen, B. J. Fu, Y. H. Lu, Y. L. Huang and J. Gong (2006) The relative efficiency of four representative cropland conversions in reducing water erosion: Evidence from long-term plots in the loess Hilly Area, China. Land Degradation & Development 17: 615-627. DOI: 10.1002/ldr.739

Isselin-Nondedeu, F. and A. Bedecarrats (2007) Influence of alpine plants growing on steep slopes on sediment trapping and transport by runoff. Catena 71: 330-339. doi:10.1016/j.catena.2007.02.001

Kosmas, C. , Danalatos, N., Cammeraat, L.H., Chabart, M., Diamantopoulos, J., Farand, R., Gutierrez, L., Jacob, A., Marques, H., Martinez-Fernandez, J., Mizara, A., Moustakas, N., Nicolau, J. M., Oliveros, C., Pinna, G., Puddu, R., Puigdefabregas, J., Roxo, M., Simao, A., Stamou, G., Tomasi, N., Usai, D., Vacca, A. (1997) The effect of land use on runoff and soil erosion rates under Mediterranean conditions. Catena 29 (1) : 45–59. http://dx.doi.org/10.1016/S0341-8162(96)00062-8

Lin, Y.-m., P. Cui, Y.-g. Ge, C. Chen, D.-j. Wang, C.-z. Wu, J. Li, W. Yu, G.-s. Zhang and H. Lin (2014) The succession characteristics of soil erosion during different vegetation succession stages in dry-hot river valley of Jinsha River, upper reaches of Yangtze River. Ecological Engineering 62: 13-26.

Liu, Y.-J., T.-W. Wang, C.-F. Cai, Z.-X. Li and D.-B. Cheng (2014) Effects of vegetation on runoff generation, sediment yield and soil shear strength on road-side slopes under a simulation rainfall test in the Three Gorges Reservoir Area, China. Science of the Total Environment 485–486: 93–102. doi 10.1016/j.scitotenv.2014.03.053

López-Vicente, Manuel & Noemí Lana-Renault &
José Maria García-Ruiz & Ana Navas (2011) Assessing the potential effect of different land cover management practices on sediment yield from an abandoned farmland catchment in the Spanish Pyrenees. J Soils Sediments 11:1440–1455. DOI 10.1007/s11368-011-0428-2

Ludwig, J. A., R. Bartley, A. A. Hawdon, B. N. Abbott and D. McJannet (2007) Patch configuration non-linearly affects sediment loss across scales in a grazed catchment in north-east Australia. Ecosystems 10: 839-845. DOI: 10.1007/s10021-007-9061-8

Maetens, W., Vanmaercke, M., Poesen, J., Jankauskas, B., Jankauskiene, G., Ionita, I., (2012) Effects of land use on annual runoff and soil loss in Europe and the Mediterranean. A meta-analysis of plot data. Progress in Physical Geography 36(5): 597 - 651. doi:10.1177/0309133312451303

Martin, Cyrill; Pohl, Mandy; Alewell, Christine; et al. (2010) Interrill erosion at disturbed alpine sites: Effects of plant functional diversity and vegetation cover. Basic and Applied Ecology 11 (2010) 619–626. doi:10.1016/j.baae.2010.04.006

Mayor, A. G., S. Bautista and J. Bellot (2009) Factors and interactions controlling infiltration, runoff, and soil loss at the microscale in a patchy Mediterranean semiarid landscape. Earth Surface Processes and Landforms 34: 1702-1711. 10.1002/esp.1875

Michaelides, K., D. Lister, J. Wainwright and A. J. Parsons (2009) Vegetation controls on small-scale runoff and erosion dynamics in a degrading dryland environment. Hydrol. Process. 23, 1617–1630. DOI: 10.1002/hyp.7293

Molina, Armando; Govers, Gerard; Cisneros, Felipe; et al. (2009) Vegetation and topographic controls on sediment deposition and storage on gully beds in a degraded mountain area. Earth Surf. Process. Landforms 34, 755–767. DOI: 10.1002/esp.1747

Munoz-Robles, C., N. Reid, M. Tighe, S. V. Briggs and B. Wilson (2011) Soil hydrological and erosional responses in patches and inter-patches in vegetation states in semi-arid Australia. Geoderma 160: 524-534. doi:10.1016/j.geoderma.2010.10.024

Munro, R. N., J. Deckers, M. Haile, A. T. Grove, J. Poesen and J. Nyssen (2008) Soil landscapes, land cover change and erosion features of the Central Plateau region of Tigrai, Ethiopia: Photo-monitoring with an interval of 30 years. Catena 75: 55-64. doi:10.1016/j.catena.2008.04.009

Nadal-Romero, E., T. Lasanta and J. M. Garcia-Ruiz (2013) Runoff and sediment yield from land under various uses in a Mediterranean mountain area: long-term results from an experimental station. Earth Surface Processes and Landforms 38: 346-355. DOI: 10.1002/esp.3281

Pardini, G., M. Gispert and G. Dunjo (2003) Runoff erosion and nutrient depletion in five Mediterranean soils of NE Spain under different land use. Science of the Total Environment 309: 213-224. doi:10.1016/S0048-9697(03)00007-X

Pierson, F. B., C. A. Moffet, C. J. Williams, S. P. Hardegree and P. E. Clark (2009) Prescribed-fire effects on rill and interrill runoff and erosion in a mountainous sagebrush landscape. Earth Surface Processes and Landforms 34: 193-203. DOI: 10.1002/esp.1703

Pohl, M., F. Graf, A. Buttler and C. Rixen (2012) The relationship between plant species richness and soil aggregate stability can depend on disturbance. Plant and Soil 355: 87-102. DOI 10.1007/s11104-011-1083-5

Poudel, DD; Midmore, DJ; West, LT (2000) Farmer participatory research to minimize soil erosion on steepland vegetable systems in the Philippines. Agriculture, Ecosystems and Environment 79: 113–127.

Puttock, A., C. J. A. Macleod, R. Bol, P. Sessford, J. Dungait and R. E. Brazier (2013) Changes in ecosystem structure, function and hydrological connectivity control water, soil and carbon losses in semi-arid grass to woody vegetation transitions. Earth Surface Processes and Landforms 38: 1602-1611. DOI: 10.1002/esp.3455

Quinton, J. N., G. M. Edwards and R. P. C. Morgan (1997) The influence of vegetation species and plant properties on runoff and soil erosion: results from a rainfall simulation study in south east Spain. Soil Use and Management 13: 143-148.

Rey, F. (2003) Influence of vegetation distribution on sediment yield in forested marly gullies. Catena 50: 549– 562.

Ruiz-Colmenero, M., R. Bienes, D. J. Eldridge and M. J. Marques (2013) Vegetation cover reduces erosion and enhances soil organic carbon in a vineyard in the central Spain. Catena 104: 153-160. doi/10.1016/j.catena.2012.11.007

Shrestha, R.P., Schmidt-Vogt, D., Gnanavelrajah, N. (2010) Relating plant diversity to biomass and soil erosion in a cultivated landscape of the eastern seaboard region of Thailand. Applied Geography, 30: 606-617. doi:10.1016/j.apgeog.2010.01.005

Song, Y., C. Zhou and W. Zhang (2011) Vegetation coverage, species richness, and dune stability in the southern part of Gurbantunggut Desert. Ecological Research 26: 79-86. DOI 10.1007/s11284-010-0765-4

Spaan, W. P., A. F. S. Sikking and W. B. Hoogmoed (2005) Vegetation barrier and tillage effects on runoff and sediment in an alley crop system on a Luvisol in Burkina Faso. Soil & Tillage Research 83: 194-203. doi:10.1016/j.still.2004.07.016

Tenten, N., Z. Bo and M. Kazda (2010) Soil stabilizing capability of three plant species growing on the Three Gorges Reservoir riverside. Journal of Earth Science 21: 888-896. DOI: 10.1007/s12583-010-0142-9

Vasquez-Mendez, R., E. Ventura-Ramos, K. Oleschko, L. Hernandez-Sandoval, J.-F. Parrot and M. A. Nearing (2010) Soil erosion and runoff in different vegetation patches from semiarid Central Mexico. Catena 80: 162-169. doi:10.1016/j.catena.2009.11.003

Verbist, B., Poesen, J., van Noordwijk, M., Widianto, Suprayogo, D., Agus, F., Deckers, J. (2010) Factors affecting soil loss at plot scale and sediment yield at catchment scale in a tropical volcanic agroforestry landscape. Catena, 80(1): 34-46. http://dx.doi.org/10.1016/j.catena.2009.08.007

Wang, Z., Y. Hou, H. Fang, D. Yu, M. Zhang, C. Xu, M. Chen and L. Sun (2012) Effects of plant species diversity on soil conservation and stability in the secondary succession phases of a semihumid evergreen broadleaf forest in China. Journal of Soil and Water Conservation 67: 311-320. doi: 10.2489/jswc.67.4.311

Wei, W., L. Chen, B. Fu, Y. Lue and J. Gong (2009) Responses of water erosion to rainfall extremes and vegetation types in a loess semiarid hilly area, NW China. Hydrological Processes 23: 1780-1791. DOI: 10.1002/hyp.7294

Xu, Xian-Li, Ke-Ming Ma, Bo-Jie Fu, Wen Liu and Cheng-Jun Song (2009) Soil and water erosion under different plant species in a semiarid river valley, SW China: the effects of plant morphology. Ecol Res 24: 37–46. DOI 10.1007/s11284-008-0479-z

Zhang, G.-H., G.-B. Liu and G.-L. Wang (2010) Effects of Caragana Korshinskii Kom. cover on runoff, sediment yield and nitrogen loss. International Journal of Sediment Research 25: 245-257.

Zhang, X., G. Q. Yu, Z. B. Li and P. Li (2014) Experimental Study on Slope Runoff, Erosion and Sediment under Different Vegetation Types. Water Resour Manage 28:2415–2433. DOI 10.1007/s11269-014-0603-5

Zheng, H., F. Chen, Z. Ouyang, N. Tu, W. Xu, X. Wang, H. Miao, X. Li and Y. Tian (2008) Impacts of reforestation approaches on runoff control in the hilly red soil region of Southern China. Journal of Hydrology 356: 174-184. doi:10.1016/j.jhydrol.2008.04.007

Zuazo, V. H. Duran; Martinez, J. R. Francia; Pleguezuelo, C. R. Rodriguez; et al. (2006) Soil-erosion and runoff prevention by plant covers in a mountainous area (SE Spain): Implications for sustainable agriculture. Environmentalist 26: 309-319. DOI 10.1007/s10669-006-0160-4

Water quality regulation

Adhikari, A.R., Acharya, K., Shanahan, S.A., Zhou, X. (2011) Removal of nutrients and metals by constructed and naturally created wetlands in the Las Vegas Valley, Nevada. Environ Monit Assess, 180:97-113.

Ahmad, S.S., Reshi, Z.A., Shah, M.A., Rashid, I., Ara, R. & Andrabi, S.M.A. (2014) Phytoremediation Potential of Phragmites australis in Hokersar Wetland - A Ramsar Site of Kashmir Himalaya. International Journal of Phytoremediation, 16:12, 1183-1191. DOI: 10.1080/15226514.2013.821449

Amiri, B. J. And K. Nakane (2009) Modeling the Linkage Between River Water Quality and Landscape Metrics in the Chugoku District of Japan. Water Resources Management 23(5): 931-956.

Anderson, C. J., and W. J. Mitsch. (2006) Sediment, carbon and nutrient accumulation at two 10-year-old created riverine marshes. Wetlands 26:779-792.

Cardinale, B. J., K. L. Matulich, Hooper, D.U. Et al. (2011) The functional role of producer diversity in ecosystems. American Journal of Botany 98(3): 572-592.

Cardinale, B.J. (2011) Biodiversity improves water quality by niche partitioning. Nature 472, 86-90.

Carroll, C. And A. Tucker (2000) Effects of pasture cover on soil erosion and water quality on central Queensland coal mine rehabilitation. Tropical Grasslands 34(3-4): 254-262.

Christen, Benjamin and Tommy Dalgaard (2013) Buffers for biomass production in temperate European agriculture: A review and synthesis on function, ecosystem services and implementation. Biomass and bioenergy 55: 53-67. doi:10.1016/j.biombioe.2012.09.053

Clapcott, J.E., Collier, K.J., Death, R.G., Goodwin, E.O., Harding, J.S., Kelly, D., Leathwick, J.R & Young, R.G. (2012) Quantifying relationships between land-use gradients and structural and functional indicators of stream ecological integrity. Freshwater Biology 57, 74–90. doi:10.1111/j.1365-2427.2011.02696.x

de Souza, A.L.T., Fonseca, D.G., Libório, R.A. & Tanaka, M.O. (2013) Influence of riparian vegetation and forest structure on the water quality of rural low-order streams in SE Brazil. Forest Ecology and Management 298 (2013)12–18. doi:10.1016/j.foreco.2013.02.022

De Steven, D. & Lowrance, R. (2011) Agricultural conservation practices and wetland ecosystem services in the wetland-rich Piedmont-Coastal Plain region. Ecological Applications, 21, S3-S17.

Detenbeck, N. E., C. M. Elonen, taylor, D.L., et al. (2004) Region, landscape, and scale effects on Lake Superior tributary water quality. Journal of the American Water Resources Association 40(3): 705-720.

Doherty, J.M., Miller, J.F., Prellwitz,S.G., Thompson,A.M., Loheide, S.P. & Zedler, J.B. (2014) Hydrologic Regimes Revealed Bundles and Tradeoffs Among Six Wetland Services. Ecosystems (2014) 17: 1026–1039. DOI: 10.1007/s10021-014-9775-3

Fernandes, Janaına de F., Andrea L. T. de Souza and Marcel O. Tanaka (2014) Can the structure of a riparian forest remnant influence stream water quality? A tropical case study. Hydrobiologia (2014) 724:175–185. DOI 10.1007/s10750-013-1732-1

Fisher, J. Stratford, C.J., Buckton, S. (2009) Variation in nutrient removal in three wetland blocks in relation to vegetation composition, inflow nutrient concentration and hydraulic loading. Ecological Engineering 35, 1387-1394.

Greiner, M. And C. Hershner (1998) Analysis of wetland total phosphorus retention and watershed structure. Wetlands 18(1): 142-149.

Gruber, R. K., D. C. Hinkle, Kemp, W.M. (2011) Spatial Patterns in Water Quality Associated with Submersed Plant Beds. Estuaries and Coasts 34(5): 961-972.

Haidary, Azam, Bahman Jabbarian Amiri, Jan Adamowski, Nicola Fohrer & Kaneyuki Nakane (2013) Assessing the Impacts of Four Land Use Types on the Water Quality of Wetlands in Japan. Water Resour Manage 27:2217–2229. DOI 10.1007/s11269-013-0284-5

Hefting, Mariet M., Ronald N. van den Heuvel and Jos T.A. Verhoeven (2013) Wetlands in agricultural landscapes for nitrogen attenuation and biodiversity enhancement: Opportunities and limitations. Ecological Engineering 56: 5– 13. doi:10.1016/j.ecoleng.2012.05.001

Helfield, J. M. And M. L. Diamond (1997) Use of constructed wetlands for urban stream restoration: A critical analysis. Environmental Management 21(3): 329-341.

Hernandez, M. E., and W. J. Mitsch. (2006) Influence of hydrologic pulses, flooding frequency and vegetation on nitrous oxide emissions from created riparian marshes. Wetlands 26:862-877.

Hogan, J.N., Daniels, M.E., Fred G. Watson, Stori C. Oates, Melissa A. Miller, Patricia A. Conrad, Karen Shapiro, Dane Hardin, Clare Dominik, Ann Melli, David A. Jessup & Woutrina A. Miller (2013) Hydrologic and Vegetative Removal of Cryptosporidium parvum, Giardia lamblia, and Toxoplasma gondii Surrogate Microspheres in Coastal Wetlands. Applied and Environmental Microbiology 79(6): 1859–1865. doi:10.1128/AEM.03251-12

Kovacic, D. A., R. M. Twait, M. Wallace, et al. (2006) Use of created wetlands to improve water quality in the Midwest: Lake Bloomington case study. Ecological Engineering 28:258-270.

Lee, P. F. and K. A. McNaughton (2004) Macrophyte induced microchemical changes in the water column of a northern Boreal Lake. Hydrobiologia 522(1-3): 207-220.

Li, S., Gu, S.,Tan, X., Zhang, Q. (2009) Water quality in the upper Han River basin, China: The impacts of land use/land cover in riparian buffer zone. Journal of Hazardous Materials 165, 317-324.

Liu, W. Z., Zhang, Q. F., Liu, G. (2012) Influences of watershed landscape composition and configuration on lake-water quality in the Yangtze River basin of China. Hydrological Processes 26(4): 570-578.

Martin, T. L., Trevors, J.T., Kaushik, N. K. (1999) Soil microbial diversity, community structure and denitrification in a temperate riparian zone. Biodiversity and Conservation 8(8): 1057-1078.

Martinez, M.L., Perez-Maqueo, O., Vazquez, G., et al. (2009) Effects of land use change on biodiversity and ecosystem services in tropical montane cloud forests of Mexico. Forest Ecology and Management, 258, 1856-1863.

McCartney, M. P., C. Stratford, Neal, C., et al. (2003) Seasonality and water quality trends in a maturing recreated reed bed. Science of the Total Environment 314: 233-254.

McDowell, R. W. (2008) Water quality of a stream recently fenced-off from deer. New Zealand Journal of Agricultural Research 51(3): 291-298.

Miller, J. D., J. E. Schoonover, Williard, K.W.J., et al. (2011) Whole Catchment Land Cover Effects on Water Quality in the Lower Kaskaskia River Watershed. Water Air and Soil Pollution 221(1-4): 337-350.

Mitsch, W. J., J. W. Day, Jr., J. W. Gilliam, et al. (2001) Reducing nitrogen loading to the Gulf of Mexico from the Mississippi River basin: strategies to counter a persistent ecological problem. BioScience 51:373-388.

Mitsch, William J., Li Zhang, Kay C. Stefanik, Amanda M. Nahlik, Christopher J. Anderson, Blanca Bernal, Maria Hernandez and Keunyea Song (2012) Creating Wetlands: Primary Succession, Water Quality Changes, and Self-Design over 15 Years. BioScience 62: 237–250. doi: 10.1525/bio.2012.62.3.5

Miyazaki, A., T. Takeuchi, Nakamura, H., et al. (2004) Characteristics of nutrient absorption and water purification in some plant species grown by floating culture system. Soil Science and Plant Nutrition 50(3): 357-363.

Moore, K. A. (2004) Influence of seagrasses on water quality in shallow regions of the lower Chesapeake Bay. Journal of Coastal Research: 162-178.

Nakamura, K., Y. Kayaba, Nishihiro, J., et al. (2008) Effects of submerged plants on water quality and biota in large-scale experimental ponds. Landscape and Ecological Engineering 4(1): 1-9.

Nash, M. S., D. T. Heggem, Ebert, D. et al. (2009) Multi-scale landscape factors influencing stream water quality in the state of Oregon. Environmental Monitoring and Assessment 156(1-4): 343-360.

Oelmann, Y., Buchmann, N., Gleixner, G., et al. (2011) Plant diversity effects on aboveground and belowground N pools in temperate grassland ecosystems: Development in the first 5 years after establishment. Global Biogeochemical Cycles, 25.

Ontkean, G. R., D. S. Chanasyk, Riemersma, S., et al. (2003) Enhanced prairie wetland effects on surface water quality in Crowfoot Creek, Alberta. Water Quality Research Journal of Canada 38(2): 335-359.

Osborne, L. L., and D. A. Kovacic. (1993) Riparian vegetated buffer strips in water-quality restoration and stream management. Freshwater Biology 29:243-258.

Park, Young-Seuk, Yong-Su Kwon, Soon-Jin Hwang & Sangkyu Park (2014) Characterizing effects of landscape and morphometric factors on water quality of reservoirs using a self-organizing map. Environmental Modelling & Software 55 (2014) 214-221. doi:10.1016/j.envsoft.2014.01.031

Parkyn, S. M., R. J. Davies-Colley, Halliday, N.J., et al. (2003) Planted riparian buffer zones in New Zealand: Do they live up to expectations?. Restoration Ecology 11(4): 436-447.

Peng, Y., Guizhu Chen, Shiyu Li, Yu Liu & John C. Pernetta (2013) Use of degraded coastal wetland in an integrated mangrove–aquaculture system: a case study from the South China Sea. Ocean & Coastal Management 85 (2013) 209-213. doi:10.1016/j.ocecoaman.2013.04.008

Qiu, D. R., Z. B. Wu, Liu, B. Et al. (2001) The restoration of aquatic macrophytes for improving water quality in a hypertrophic shallow lake in Hubei Province, China. Ecological Engineering 18(2): 147-156.

Rashin, E. B., C. J. Clishe, Loch, A.T., et al. (2006) Effectiveness of timber harvest practices for controlling sediment related water quality impacts. Journal of the American Water Resources Association 42(5): 1307-1327.

Reed, T., and S. R. Carpenter. (2002) Comparisons of P yield, riparian buffer strips, and land cover in six agricultural watersheds. Ecosystems 5:568-577.

Rodrigo, María A, Miguel Martín, Carmen Rojo, Sara Gargallo, Matilde Segura and Núria Oliver (2013) The role of eutrophication reduction of two small man-made Mediterranean lagoons in the context of a broader remediation system: Effects on water quality and plankton contribution. Ecological Engineering 61: 371–382. doi:10.1016/j.ecoleng.2013.09.038

Scholz, M., A. J. Sadowski, Harrington, R., et al. (2007) Integrated Constructed Wetlands assessment and design for phosphate removal. Biosystems Engineering 97(3): 415-423.

Seilheimer, Titus S., Patrick L. Zimmerman, Kirk M. Stueve and Charles H. Perry (2013) Landscape-scale modeling of water quality in Lake Superior and Lake Michigan watersheds: How useful are forest-based indicators?. Journal of Great Lakes Research 39: 211–223. doi:10.1016/j.jglr.2013.03.012

Sliva, L. And D. D. Williams (2001) Buffer zone versus whole catchment approaches to studying land use impact on river water quality. Water Research 35(14): 3462-3472.

Sooknah, R. D. and A. C. Wilkie (2004) Nutrient removal by floating aquatic macrophytes cultured in anaerobically digested flushed dairy manure wastewater. Ecological Engineering 22(1): 27-42.

Stewart, B. A. (2011) An assessment of the impacts of timber plantations on water quality and biodiversity values of Marbellup Brook, Western Australia. Environmental Monitoring and Assessment 173(1-4): 941-953.

Swaine, M. D., J. Adomako, Ameka, G. Et al. (2006) Forest river plants and water quality in Ghana. Aquatic Botany 85(4): 299-308.

Sweeney, B.W., Bott, T.L., Jackson, J.K., Kaplan, L.A., Newbold, J.D., Standley, L.J., Hession, W.C. & Horwitz, R.J. (2004) Riparian deforestation, stream narrowing, and loss of stream ecosystem services. PNAS, 101, 14132-14137.

Tomimatsu, H., Nakano, K., Yamamoto, N. & Suyama, Y. (2014) Effects of genotypic diversity of Phragmites australis on primary productivity and water quality in an experimental wetland. Oecologia (2014) 175:163–172. DOI 10.1007/s00442-014-2896-8

Verhoeven, J. T. A., B. Arheimer, Yin, C. et al. (2006) Regional and global concerns over wetlands and water quality. Trends in Ecology & Evolution 21(2): 96-103.

Vought, L. B. M., G. Pinay, Fuglsang, A., et al. (1995) Structure and function of buffer strips from a water-quality perspective in agricultural landscapes. Landscape and Urban Planning 31(1-3): 323-331.

Wang, X. H., C. Q. Yin, Shan, B.Q. (2005) The role of diversified landscape buffer structures for water quality improvement in an agricultural watershed, North China. Agriculture Ecosystems & Environment 107(4): 381-396.

Weisner, S. E. B. And G. Thiere (2010) Effects of vegetation state on biodiversity and nitrogen retention in created wetlands: a test of the biodiversity-ecosystem functioning hypothesis. Freshwater Biology 55(2): 387-396.

Wu, C. Y., C. M. Kao, et al. (2010) Using a constructed wetland for non-point source pollution control and river water quality purification: a case study in Taiwan. Water Science and Technology 61(10): 2549-2555.

Pollination

Albrecht, M., Duelli, P., Mueller, C., Kleijn, D. and Schmid, B. (2007) The Swiss agri-environment scheme enhances pollinator diversity and plant reproductive success in nearby intensively managed farmland. Journal of Applied Ecology, 44(4), 813-822.

Allsopp, M.H., De Lange, W.J., Veldtman, R. (2008) Valuing Insect Pollination Services with Cost of Replacement. PLoS ONE, 3 (9): e3128.

Ashworth, L., Quesada, M., Casas, A., Aguilar, R., Oyama, K. (2009) Pollinator-dependent food production in Mexico. Biological Conservation, 142: 1050-1057.

Badano, E.I. and Vergara, C.H. (2011) Potential negative effects of exotic honey bees on the diversity of native pollinators and yield of highland coffee plantations. Agricultural and Forest Entomology. 13. 365-372.

Balvanera, P., Kremen, C. and Martinez-Ramos, M. (2005) Applying community structure analysis to ecosystem function: Examples from pollination and carbon storage. Ecological Applications, 15(1), 360-375.

Batary, P., Baldi, A., Saropataki, M., Kohler, F., Verhulst, J., Knop, E., Herzog, F. and Kleijn, D. (2010) Effect of conservation management on bees and insect-pollinated grassland plant communities in three European countries. Agriculture Ecosystems & Environment, 136(1-2), 35-39.

Biesmeijer, J.C. et al. (2006) Parallel Declines in Pollinators and Insect-pollinated Plants in Britain and the Netherlands. Science, 313: 351-354.

Blanche, R., Cunningham, S.A. (2005) Rain forest provides pollinating beetles for Atemoya crops. Journal of Economis Entomology, 98 (4): 1193-1201.

Bommarco, R., Lundin, O., Smith, H.G., Rundlof, M. (2011) Drastic historic shifts in bumble-bee community composition in Sweden. Proceedings of the Royal Society of Biological Sciences,279: 309-315.

Breeze, T.D., Bailey, A.P., BAlcombe, K.G., Potts, S.G. (2011) Pollination services in the UK: How important are honeybees?. Agriculture, Ecosystems and Environment, 142: 137-143.

Brittain, C., Bommarco, R., Vighi, M., Settele, J. and Potts, S. G. (2010) Organic farming in isolated landscapes does not benefit flower-visiting insects and pollination. Biological Conservation, 143(8), 1860-1867.

Carvalheiro, L. G., Seymour, C. L., Veldtman, R. and Nicolson, S. W. (2010) Pollination services decline with distance from natural habitat even in biodiversity-rich areas. Journal of Applied Ecology, 47(4), 810-820.

Carvalheiro, L.G., Seymour, C.L., Veldtman, R., Nicolson, S.W. (2010) Pollination services decline with distance from natural habitat even in biodiversity-rich areas. Journal of Applied Ecology, 47: 810-820.

Cranmer, L., D. McCollin and J. Ollerton (2012) Landscape structure influences pollinator movements and directly affects plant reproductive success. Oikos 121: 562-568. doi: 10.1111/j.1600-0706.2011.19704.x

da Silva, C. I., N. G. Bordon, L. C. da Rocha Filho and C. A. Garofalo (2012) The importance of plant diversity in maintaining the pollinator bee, Eulaema nigrita (Hymenoptera: Apidae) in sweet passion fruit fields. Revista De Biologia Tropical 60: 1553-1565.

Dauber, J., Biesmeijer, J. C., Gabriel, D., Kunin, W. E., Lamborn, E., Meyer, B., Nielsen, A., Potts, S. G., Roberts, S. P. M., Sober, V., Settele, J., Steffan-Dewenter, I., Stout, J. C., Teder, T., Tscheulin, T., Vivarelli, D. and Petanidou, T. (2010) Effects of patch size and density on flower visitation and seed set of wild plants: a pan-European approach. Journal of Ecology, 98(1), 188-196.

Diekotter, T., Kadoya, T., Peter, F., Wolters, V., Jauker, F. (2010) Oilseed rape crops distrot plant-pollinator interactions. Applied Ecology, 47: 209-214.

Farwig, N., Bailey, D., Bochud, E., Herrmann, J. D., Kindler, E., Reusser, N., Schueepp, C. and Schmidt-Entling, M. H. (2009) Isolation from forest reduces pollination, seed predation and insect scavenging in Swiss farmland. Landscape Ecology, 24(7), 919-927.

Fontaine, C., Dajoz, I., Meriguet, J. and Loreau, M. (2006) Functional diversity of plant-pollinator interaction webs enhances the persistence of plant communities. Plos Biology, 4(1), 129-135.

Garibaldi, L.A., et al. (2011) Stability of pollination services decreases with isolation from natural areas despite honey bee visits. Ecology Letters, 14: 1062-1072.

Garibaldi, Lucas A., Ingolf Steffan-Dewenter, Rachael Winfree, Marcelo A. Aizen, Riccardo Bommarco et al (2014) Wild Pollinators Enhance Fruit Set of Crops Regardless of Honey Bee Abundance. Science 339:1608-11.

Gemmill-Herren, B., Ochieng, A. O. (2008) Role of native bees and natural habitats in eggplant (Solanum melongena) pollination in Kenya. Agriculture Ecosystems & Environment, 127(1-2), 31-36.

Gomez, J.M., Bosch, J., Perfectti, F., Fernandez, J. and Abdelaziz, M. (2007) Pollinator diversity affects plant reproduction and recruitment: the tradeoffs of generalization. Oecologia 153:597–605. DOI 10.1007/s00442-007-0758-3

Greenleaf, S.S., Kremen, C. (2006) Wild bee species increase tomato production and respond differently to surrounding land use in Northern California. Biological Conservation, 33: 81-87.

Greenleaf, S.S., Kremen, C. (2006) Wild Bees Enhance Honey Bee's Pollination of Hybrid Sunflower. Proceedings of the National Academy of Sciences of the United States of America, 103 (37): 13890-13895.

Hoehn, P., Tscharntke, T., Tylianakis, J.M., Steffan-Dewenter, I. (2008) Functional Group Diversity of Bee Pollinators Increases Crop Yield. Proceedings: Biological Sciences, 275 (1648): 2283-2291.

Holzschuh, A., Dormann, C. F., Tscharntke, T. and Steffan-Dewenter, I. (2011) Expansion of mass-flowering crops leads to transient pollinator dilution and reduced wild plant pollination. Proceedings of the Royal Society B-Biological Sciences, 278(1723), 3444-3451.

Holzschuh, A., J.-H. Dudenhoeffer and T. Tscharntke (2012) Landscapes with wild bee habitats enhance pollination, fruit set and yield of sweet cherry. Biological Conservation 153: 101-107. doi/10.1016/j.biocon.2012.04.032

Holzschuh, A., Steffan-Dewenter, I., Kleijn, D. and Tscharntke, T. (2007) Diversity of flower-visiting bees in cereal fields: effects of farming system, landscape composition and regional context. Journal of Applied Ecology, 44(1), 41-49.

Jauker, F., Diekoetter, T., Schwarzbach, F. and Wolters, V. (2009) Pollinator dispersal in an agricultural matrix: opposing responses of wild bees and hoverflies to landscape structure and distance from main habitat. Landscape Ecology, 24(4), 547-555.

Jaukerm, F., Bondarenko, B., Becker, H.C., Steffan-Dewenter, I. (2012) Pollination efficiency of wild bees and hoverflies provided to oilseed rape. Agricultural and Forest Entomology, 14: 81-87.

Klein, A.M.,Steffan-Dewenter, I., Tscharntke, T. (2003) Fruit Set of Highland Coffee Increases with the Diversity of Pollinating Bees. Proceedings: Biological Sciences, 270 (1518): 955-961.

Kohler, F., Verhulst, J., van Klink, R. and Kleijn, D. (2008) At what spatial scale do high-quality habitats enhance the diversity of forbs and pollinators in intensively farmed landscapes?. .

Kohler, F., Verhulst, J., van Klink, R. and Kleijn, D. (2008) At what spatial scale do high-quality habitats enhance the diversity of forbs and pollinators in intensively farmed landscapes?. Journal of Applied Ecology, 45(3), 753-762.

Kremen, C., Williams, N.M., Thorp, R.W. (2002) Crop pollination from native bees at risk from agricultural intensifications. Proceedings of the National Academy of Sciences of the United States of America, 99 (26): 16812-16816.

Krishnan, S., C. G. Kushalappa, R. U. Shaanker and J. Ghazoul (2012) Status of pollinators and their efficiency in coffee fruit set in a fragmented landscape mosaic in South India. Basic and Applied Ecology 13: 277-285. doi:10.1016/j.baae.2012.03.007

Lazaro, A., A. Jakobsson and O. Totland (2013) How do pollinator visitation rate and seed set relate to species' floral traits and community context?. Oecologia 173: 881-893.

Lonsdorf, E., Kremen, C., Rcketts, T., Winfree, R., Willams, N., Greenleaf, S. (2009) Modelling pollinaiton services across agricultural landscapes. Annals of Botany, 103:1589-1600.

Mandelik, Y. and Roll, U. (2009) Diversity patterns of wild bees in almond orchards and their surrounding landscape. Israel Journal of Plant Sciences, 57(3), 185-191.

Martins, D.J., Johnson, S.D. (2009) Distance and quality of natural habitat influence hawkmoth pollination of cultivated papaya. International Journal of Tropical Insect Science, 29 (3): 114-123.

Memmott, J., Waser, N. M. and Price, M. V. (2004) Tolerance of pollination networks to species extinctions. Proceedings of the Royal Society B-Biological Sciences, 271(1557), 2605-2611.

Munoz, A. A., Cavieres, L. A. (2008) The presence of a showy invasive plant disrupts pollinator service and reproductive output in native alpine species only at high densities. Journal of Ecology, 96(3), 459-467.

Munyuli, T.M.B. (2012) Micro, local, landscape and regional drivers of bee biodiversity and pollination services delivery to coffee (Coffea canephora) in Uganda. International JournaL of Biodiversity Science, Ecosystem Services and Management, 8, 190-203.

Munyuli, T.M.B. (2013) Socio-ecological drivers of the economic value of pollination services delivered to coffee in Uganda. International JournaL of Biodiversity Science, Ecosystem Services and Management.

Potts, S.G., et al. (2006) Plant-pollinator biodiveristy and pollination services in a complex Mediterranean landscape. Biological conservation, 129: 519-529.

Rader, R., Howlett, B.G., Cunningham, S.A., Westcott, D.A., Edwards, W. (2012) Spatial and temporal variation in pollinator effectiveness: do unmanaged insects provide consistent pollination services to mass flowerering crops?. Journal of Applied Ecology.

Ricketts, T.H., Regetz, J., Steffam-Dewemter, I., et al. (2008) Landscape effects on crop pollination services: are there general patterns?. Ecology Letters, 11: 499-515.

Samnegard, U., Persson, A. S. and Smith, H. G. (2011) Gardens benefit bees and enhance pollination in intensively managed farmland. Biological Conservation, 144(11), 2602-2606.

Sande, S.O., Crewe, R.M., Raina, S.K., Nicolson, S.W., Gordon, I. (2009) Proximity to forest leads to higher honey yield: Another reason to conserve. Biological Conservation, 142: 2703-2709.

Shavit, O., Dafni, A., Ne´eman, G. (2009) Competition between honey bees (Apis mellifera) and native solitary bees in the Mediterranean region of Israel - Implications for conservation. Israel Journal of Plant Sciences, 57(3), 171-183.

Steffan-Dewenter, I. and T. Tscharntke (1999) Effects of habitat isolation on pollinator communities and seed set. Oecologia 121: 432-440.

Taki, H., K. Okabe, Y. Yamaura, T. Matsuura, M. Sueyoshi, S. i. Makino and K. Maeto (2010) Effects of landscape metrics on Apis and non-Apis pollinators and seed set in common buckwheat. Basic and Applied Ecology 11: 594-602. doi:10.1016/j.baae.2010.08.004

Tscheulin, T., Neokosmidis, L., Petanidou, T. and Settele, J. (2011) Influence of landscape context on the abundance and diversity of bees in Mediterranean olive groves. Bulletin of Entomological Research, 101(5), 557-564.

Vamosi, J.C. et al. (2006) Pollination Decay in Biodiversity Hotspots. Proceedings of the National Academy of Sciences of the United States of America. 103 (4): 956-961

Vergara, C.H., Badano, E.I. (2009) Pollinator diversity increases fruit production in Mexican coffee plantations: the importance of rustic management systems. . Agriculture, Ecosystems and Environment, 129(1-3), 117-123.

Watson, J. C., Wolf, A. T. and Ascher, J. S. (2011) Forested Landscapes Promote Richness and Abundance of Native Bees (Hymenoptera: Apoidea: Anthophila) in Wisconsin Apple Orchards. Environmental Entomology, 40(3), 621-632.

Winfree, R., Kremen, C. (2009) Are ecosystem services stabilized by differences among species? A test using crop pollination. Proceedings of the Royal Society Biological Sciences Series B, 276(1655), 229-237.

Winfree, R., Williams, N. M., Gaines, H., Ascher, J. S. and Kremen, C. (2008) Wild bee pollinators provide the majority of crop visitation across land-use gradients in New Jersey and Pennsylvania, USA. Journal of Applied Ecology, 45(3), 793-802.

Winfree, R., Williams, N.M., Dushoff, J., Kremen, C. (2007) Native bees provide insurance against ongoing honey bee losses. Ecology Letters, 10: 1105-1113.

Yamamoto, M., C. I. da Silva, S. C. Augusto, A. A. Almeida Barbosa and P. E. Oliveira (2012) The role of bee diversity in pollination and fruit set of yellow passion fruit (Passiflora edulis forma flavicarpa, Passifloraceae) crop in Central Brazil. Apidologie 43: 515-526. DOI: 10.1007/s13592-012-0120-6

Pest regulation

Anderson, Annette, Tim Carnus, Alvin J. Helden, Helen Sheridan and Gordon Purvis (2013) The influence of conservation field margins in intensively managed grazing land on communities of five arthropod trophic groups. Insect Conservation and Diversity (2013) 6, 201–211. doi: 10.1111/j.1752-4598.2012.00203.x

Bianchi, F.J.J.A., A. Honek, W. van der Werf (2007) Changes in agricultural land use can explain population decline in a ladybeetle species in the Czech Republic: evidence from a process-based spatially explicit model. Landcape Ecology 22: 1541-1554. 10.1007/s10980-007-9145-z

Bianchi, F.J.J.A., C.J.H. Booij and T. Tscharntke (2006) Sustainable pest regulation in agricultural landscapes: a review on landscape composition, biodiversity and natural pest control. Proc. R. Soc. B. 273: 1715-1727. 10.1098/rspb.2006.3530

Bianchi, F.J.J.A., N.A. Schellhorn, Y.M. Buckley, H.P. Possingham. (2010) Spatial variability in ecosystem services: simple rules for predator-mediated pest suppression. Ecological applications 20: 2322-2333. 10.1890/09-1278.1

Bianchi, F.J.J.A., P.W. Goedhart, J.M. Baveco. (2008) Enhanced pest control in cabbage crops near forest in the Netherlands. Landscape Ecology 23: 595-602. 10.1007/s10980-008-9219-6

Blauuw, B. and Isaacs, R. (2012) Larger wildflower plantings increase natural enemy density, diversity, and biological control of sentinel prey, without increasing herbivore density. Ecological Entomology (2012), 37, 386–394. DOI: 10.1111/j.1365-2311.2012.01376.x

Boccaccio, L., R. Petacchi (2009) Landscape effects on the complex of Bactrocera olear parasitoids and implications for conservation biological control. BioControl 54: 616. 10.1007/s10526-009-9214-0

Castañé, C., J.Arnó, R. Gabarra, O. Alomar. (2011) Plant damage to vegetable crops by zoophytophagous mirid predators. Biological Control 59: 22-29. 10.1016/j.biocontrol.2011.03.007

Casula, Paolo and Mauro Nannini (2013) Evaluating the Structure of Enemy Biodiversity Effects on Prey Informs Pest Management. ISRN Ecology Volume 2013, Article ID 619393, 15 pages. http://dx.doi.org/10.1155/2013/619393

Chaplin-Kramer, R., C. Kremen. (2012) Pest control experiments show benefits of complexity at landscape and local scales. Ecological applications 22: 1936-1948. 10.1890/11-1844.1

Colloff, Matthew J., Elizabeth A. Lindsay, David C. Cook (2013) Natural pest control in citrus as an ecosystem service: Integrating ecology, economics and management at the farm scale. Biological Control 67 (2013) 170–177. doi:10.1016/j.biocontrol.2013.07.017

Crowder, D.W., T.D. Northfield, M.R. Strand, W.E. Snyder. (2010) Organic agriculture promotes evenness and natural pest control. Nature 466: 109-113. 10.1038/nature09183

Daghela Bisseleua HB, Fotio D, Yede, Missoup AD, Vidal S (2013) Shade Tree Diversity, Cocoa Pest Damage, Yield Compensating Inputs and Farmers’ Net Returns in West Africa. PLoS ONE 8(3): e56115. doi:10.1371/journal.pone.0056115

Drapela, T., D. Moser, J.G. Zaller and T. Frank. (2008) Spider assemblages in winter oilseed rape affected by landscape and site factors. Ecography 31: 254-262. 10.1111/j.0906-7590.2008.5250.x

Drapela, T., T. Frank, X. Heer, D. Moser, J.G. Zaller. (2011) Landscape structure affects activity density, body size and fecundity of Pardosa wolf spiders (Araneae: Lycosidae) in winter oilseed rape. Eur. J. Entomol. 106: 609-614. 10.14411/eje.2011.079

Drinkwater, L.E., D.K. Letourneau, F. Worknes, A.H.C. van Bruggen, S. Shennan. (1995) Fundamental differences between conventional and organic tomato agroecosystems in California. Ecological Applications 5: 1098-1112. 10.2307/2269357

Geiger, F., J. Bengtsson, F. Berendse, W.W. Weisser, M. Emmerson, M.B. Morales, P. Ceryngier, J. Liira, T. Tscharntke, C. Winqvist, S. Eggers, R. Bommarco, T. Part, V. Bretagnolle, M. Plantegenest, L.W. Clement, C. Dennis, C. Palmer, J.J. Onate, I. Guerrero, V. Hawro, T. Aavik, C. Thies, A. Flohre, S. Hanke, C. Fischer, P.W. Goedhart, P. Inchausti (2010) Persistent negative effects of pesticides on biodiversity and biological control potential on European farmland. . 10.1016/j.baae.2009.12.001

Iperti, G. (1999) Biodiversity of predateous coccinellidae in relation to bioindication and economic importance. Ecol Res 25: 1141-1149. 10.1016/S0167-8809(99)00041-9

J.J. González-Fernández, F. de la Peña, J.I. Hormaza, J.R. Boyero, J.M. Vela, E. Wong, M.M. Trigo and M. Montserrat (2009) Alternative food improves the combined effect of an omnivore and a predator on biological pest control. A case study in avocado orchards. Bulletin of Entomological Research 99: 433-444. 10.1017/S000748530800641X

Kamo, T., Y. Tokuoka, M. Miyazaki (2010) Influence of aphid-host plant pairs on the survivorship and the development of the multicolored Asian ladybird beetle: implications for the management of vegetation in rural landscapes. . 10.1007/s11284-010-0739-6

Kellermann, J.L., Johnson, M.D. , Stercho, A.M., Hackett. S.C. (2007) Ecological and economic services provided by birds on Jamaican Blue Mountain coffee farms. Conservation Biology 22: 1177-1185. 10.1111/j.1523-1739.2008.00968.x

Koh, L.P. (2008) Birds defend oil palms from herbivorous insects. Ecological Applications 18: 821-825. 10.1890/07-1650.1

Krauss, J., Gallenbergen, I., Steffan-Dewenter, I. (2011) Decreased functional diversity and biological pest control in conventional compared to organic crop fields. PLoS ONE 6(5): e19502. 10.1371/journal.pone.0019502

Kromp, B. (1999) Carabid beetles in sustainable agriculture: a review on pest control efficacy, cultivation impacts and enhancement. Agriculture, Ecosystems and Environment 74: 187-228. 10.1016/S0167-8809(99)00037-7

Kunz, T.H., E. Braun de Torrez, D. Bauer, T. Lobova, T.H. Fleming. (2011) Ecosystem services provided by bats. Annals of the New York Academy of Sciences. 10.1111/j.1749-6632.2011.06004.x

Lee, Y.-F., G.F. McCracken. (2005) Dietary variation of Brazilian free-tailed bats links to migratory populations of pest insects. Journal of Mammalogy 86: 67-76. http://dx.doi.org/10.1644/1545-1542(2005)086<0067:DVOBFB>2.0.CO;2

Legrand, A., C. Gaucherel, J. Baudry, J.-M. Meynard. (2011) Long-term effects of organic, conventional and integrated crop systems on Carabids. Agronomy Sust. Developm.,31:515-524. 10.1007/s13593-011-0007-3

Letourneau, Deborah K., Sara G. Bothwell Allen and John O. Stireman III (2012) Perennial habitat fragments, parasitoid diversity and parasitism in ephemeral crops. Journal of Applied Ecology 2012, 49, 1405–1416. doi: 10.1111/jpe.12001

Macfadyen, S., R. Gibson, A. Polaszek, R.J. Morris, P.G. Craze, R. Planqué, W.O.C. Symondson, J. Memmot. (2009) Do differences in food web structure between organic and conventional farms affect the ecosystem service of pest control?. Ecol Lett 12: 229-238. 10.1111/j.1461-0248.2008.01279.x

Macfayden, S., S.A. Cunningham, A.C. Costamagna, N.A. Schellhorn. (2012) Managing ecosystem services and biodiversity conservation in agricultural landscapes: are the solutions the same?. Journal of Applied Ecology 49: 690-694. 10.1111/j.1365-2664.2012.02132.x

Mody, K., C. Spoerndli, S. Dorn (2011) Within-orchard variability of the ecosystem service 'parasitism': Effects of cultivars, ants and tree location. Basic and Applied Ecology 12: 456-465. 10.1016/j.baae.2011.05.005

Nash, M.A., Thomson, L.J., Hoffmann, A.A. (2008) Effect of remnant vegetation, pesticides, and farm management on abundance of the beneficial predator Notonomus gravis (Chaudor) (Coleoptera: Carabidae). Biological Control 46: 83-93. 10.1016/j.biocontrol.2008.03.018

Öberg, S. (2007) Diversity of spiders after spring sowing - influence of farming system and habitat type. Journal of Applied Entomology 131: 524-531 (species 1). 10.1111/j.1439-0418.2007.01173.x

Öberg, S. (2007) Diversity of spiders after spring sowing - influence of farming system and habitat type. Journal of Applied Entomology 131: 524-531 (species 2). 10.1111/j.1439-0418.2007.01173.x

Oelbermann, K., S. Scheu. (2009) Control of aphids on wheat by generalist predators: effects of predator density and the presence of alternative prey. Entomologia Experimentalis et Applicata 132: 225-231. 10.1111/j.1570-7458.2009.00876.x

Olson, D.M., F.L. Wäckers. (2007) Management of field margins to maximize multiple ecological services. Journal of Applied Ecology 44: 13-21. 10.1111/j.1365-2664.2006.01241.x

Pérez-Lachaud, G., I.C.W. Hardy, J.-P. Lachaud. (2002) Insect gladiators: competitive interactions between three species of bethylid wasps attacking the coffee berry borer, Hypothenemus hampei (Colepoptera: Scolytidae). Biological Control 25: 231-238. 10.1016/S1049-9644(02)00103-2

Perovic, D.J., G.M. Gurr, A. Raman, H.I. Nicol (2010) Effect of landscape composition and arrangement on biological control agents in a simplified agricultural system: a cost-distance approach. Biol. Control 52: 263-270. 10.1016/j.biocontrol.2009.09.014

Rand, T., T. Tscharntke (2007) Contrasting effects of natural habitat loss on generalist and specialist aphid natural enemies. Oikos 116: 1353-1362 (generalists). 10.1111/j.0030-1299.2007.15871.x

Rand, T., T. Tscharntke (2007) Contrasting effects of natural habitat loss on generalist and specialist aphid natural enemies. Oikos 116: 1353-1362 (specialists). 10.1111/j.0030-1299.2007.15871.x

Rezende, M.Q., M. Venzon, A.L. Perez, I.M. Cardoso, Arne Janssen (2013) Extrafloral nectaries of associated trees can enhance natural pest control. Agriculture, Ecosystems and Environment 188 (2014) 198–203. doi:10.1016/j.agee.2014.02.024

Roschewitz, I. M. Hücker, T. Tscharntke, C. Thies. (2005) The influence of landscape context and farming practices on parasitism of cereal aphids. Agriculture Ecosystems & Environment 108: 218-227. 10.1016/j.agee.2005.02.005

Roubah, A. Lassere-Joulin, F., Amiaud, B. and Plantureux, S. (2014) Emergent effects of ground beetles size diversity on the strength of prey suppression. Ecological Entomology (2014), 39, 47–57. DOI: 10.1111/een.12064

Rusch, A. Valantin-Morison, M., Roger-Estrade, J., Sarthou, J.P. (2012) Using landscape indicators to predict high pest infestations and successful natural pest control at the regional scale. Landscape and Urban Planning 105: 62-73. 10.1016/j.landurbplan.2011.11.021

Rusch, Adrien, Riccardo Bommarco, Mattias Jonsson, Henrik G. Smith and Barbara Ekbom (2013) Flow and stability of natural pest control services depend on complexity and crop rotation at the landscape scale. Journal of Applied Ecology 2013, 50, 345–354. doi: 10.1111/1365-2664.12055

Rush, A., M. Valantin-Morison, J-P. Sarthou, J. Roger-Estrade (2010) Biological control of insect pest in agroecosystems: effects of crop management, farming systems and seminatural habitats at the landscape scale: a review. Ch. 6 of .... Advances in Agronomy, volume 109. 10.1016/B978-0-12-385040-9.00006-2

Schmidt, M.H., A. Lauer, T. Purtauf, C. Thies, M. Schaefer, T. Tscharntke (2003) Relative importance of predators and parasitoids for cereal aphid control. Proceedings: Biological Sciences 270: 1905-1909. 10.1098/rspb.2003.2469

Schmidt. M.H., U. Thewes, C.Thies, T. Tscharntke (2004) Aphid suppression by natural enemies in mulched cereals. Entemologia Experimentalis et Applicata 113: 87-93. 10.1111/j.0013-8703.2004.00205.x

Steingröver, E.G., W. Geertsema, W.K.R.E. van Wingerden (2010) Designing agricultural landscapes for natural pest control: a transdisciplinary approach in the Hoeksche Waard (the Netherlands). Landscape Ecology 25: 825-838. 10.1007/s10980-010-9489-7

Tscharntke, T., Y. Clough, S. A. Bhagwat, D. Buchori, H. Faust, D. Hertel, D. Holscher, J. Juhrbandt, M. Kessler, I. Perfecto, C. Scherber, G. Schroth, E. Veldkamp, T. Wanger (2011) Multifunctional shade-tree management in tropical agroforestry landscapes- a review. Journal of Applied Ecology 48: 619-629. 10.1111/j.1365-2664.2010.01939.x

Vinatier, F., M. Gosme, M. Valantin-Morison. (2012) A tool for testing integrating pest management strategies on a tritophic system involving pollen beetle, its parasitoid and oilseed rape at the landscape scale. Landscape Ecology 27: 1421-1433. 10.1007/s10980-012-9795-3

Vollhardt, Ines M.G., Felix J.J.A. Bianchi, Felix L. Wackers, Carsten Thies, Teja Tscharntke. (2010) Spatial distribution of flowers vs. Honeydew resources in cereal fields may affect aphid parasitism. Biological Control 53: 204-213. 10.1016/j.biocontrol.2009.12.011

Wackers, F. L., P. C.J. van Rijn, G. E. Heimpel. (2008) Honeydew as a food source for natural enemies: Making the best of a bad meal?. Biological Control 45. 176-184. 10.1016/j.biocontrol.2008.01.007

Wilby, A. and M. B. Thomas. (2002) Natural enemy diversity and pest control: patterns of pest emergence with agricultural intensification. Ecology Letters 5: 353-360. 10.1046/j.1461-0248.2002.00331.x

Wilby, A., L. P. Lan, K. L. Heong, N. P. D. Huyen, N. H. Quang, N. V. Minh and M.B. Thomas. (2006) Arthropod diversity and community structure in relation to land use in the Mekong Delta, Vietnam. Ecosystems 9:538-549. 10.1007/s10021-006-0131-0

Wilby, A., S.C. Villareal, L.P. Lan, K.L. Heong and M.B. Thomas. (2005) Functional benefits of predator species diversity depend on prey identity. Ecological Entomology 30. pp 497-501. 10.1111/j.0307-6946.2005.00717.x.

Woodcock, Ben A., Collin Harrower, John Redhead, Mike Edwards, Adam J. Vanbergen, Matthew S. Heard, David B. Roy and Richard F.Pywell (2014) National patterns of functional diversity and redundancy in predatory ground beetles and bees associated with key UK arable crops. Journal of Applied Ecology 2014, 51, 142–151. doi: 10.1111/1365-2664.12171.

Xu, Q., S. Fujiyama and H. Xu (2011) Biological pest control by enhancing populations of natural enemies in organic farming systems. Journal of Food, Agriculture & Environment Vol. 9 (2): 455-463.

Xu, Q., S. Fujiyama and H. Xu (2012) Pest control by enriching natural enemies under artificial habitat management along sidewalls of greenhouse in organic farming systems. Journal of Food, Agriculture & Environment Vol. 10 (2): 449-458. 10.1007/s10526-014-9579-6.

Zhang, W., W. van der Werf and S. M. Swinton (2010) Spatially optimal habitat management for enhancing natural control of an invasive agricultural pest: Soybean aphid. Resource and Energy Economics 32: 551-565. 10.1016/j.reseneeco.2010.04.006.

Freshwater fishing

Acuna, Vicenc; Ramon Diez, Jose; Flores, Lorea; et al. (2013) Does it make economic sense to restore rivers for their ecosystem services?. Journal of Applied Ecology 50, 988–997. doi: 10.1111/1365-2664.12107

Adamowicz, W., Louviere, J., Williams, M. (1994) Combining revealed and stated preference methods for valuing environmental amenities. Journal of environmental economics and management, 26: 271-292.

Beamish, R. J., R. M. Sweeting, C. M. Neville, K. L. Lange, T. D. Beacham, D. Preikshot (2012) Wild chinook salmon survive better than hatchery salmon in a period of poor production. Environ Biol Fish 94:135–148. DOI 10.1007/s10641-011-9783-5

Beardmore, Ben, Malte Dorow, Wolfgang Haider, Robert Arlinghaus (2011) The elasticity of fishing effort response and harvest outcomes to altered regulatory policies in eel (Anguilla anguilla) recreational angling. Fisheries Research 110:136–148. 10.1016/j.fishres.2011.03.023

Birkeland, C., Dayton, P.K. (2005) The importance in fishery management of leaving the big ones. TRENDS in Ecology and Evolution, 20(7): 356-358.

Boukal, D.S., M. Jankovsky, J. Kubeckad and M. Heino (2012) Stock-catch analysis of carp recreational fisheries in Czech reservoirs: Insights into fish survival, water body productivity and impact of extreme events. Fisheries Research. 119-120: 23-32.

Carey, M. P. and D. H. Wahl (2011) Determining the mechanism by which fish diversity influences production. Oecologia 167: 189-198. DOI 10.1007/s00442-011-1967-3

Connelly, N.A., Knuth, B.A., Brown, T.L. (2001) An angler typology based on angler fishing preferences. Transactions of the American Fisheries Society, 130(1): 130-137.

Colotelo, Alison H., Graham D. Raby, Caleb T. Hasler, Tim J. Haxton, Karen E. Smokorowski, Gabriel Blouin-Demers, Steven J. Cooke (2013) Northern pike bycatch in an inland commercial hoop net fishery: Effects of water temperature and net tending frequency on injury, physiology, and survival. Fisheries Research 137: 41-49. http://dx.doi.org/10.1016/j.fishres.2012.08.019

Craig, J.F., A.S. Halls, J.J.F. Barr, C.W. Beand (2004) The Bangladesh floodplain fisheries. Fisheries Research 66: 271–286. 10.1016/S0165-7836(03)00196-6

De Silva, S.S. (2003) Culture-based fisheries: an underutilised opportunity in aquaculture development. Aquaculture, 221: 221-243.

De Silva, S.S., Lin, Y., Tang, G. (1992) Possible yield-predictive models based on morphometric characteristics and stocking rates for three groups of Chinese reservoirs. Fisheries Research, 13: 369-380.

Dos Santos, M.J.M., Valenti, W.C. (2002) Production of Nile Tilapia Oreochromis niloticus and Freshwater Prawn Macrobrachium rosenbergii stocked at different densities in polyculture systems in Brazil. Journal of the World Aquaculture Society, 33(3): 369-376.

Downing, J.A., Plante, C., Lalonde, S. (1990) Fish production correlated with primary productivity, not the morphoedaphic index. Can. J. Fish. Aquat. Sci. 47:1929-1936.

Dugan, Patrick J., Chris Barlow, Angelo A. Agostinho, Eric Baran, Glenn F. Cada, Daqing Chen, Ian G. Cowx, John W. Ferguson, Tuantong Jutagate, Martin Mallen-Cooper, Gerd Marmulla, John Nestler, Miguel Petrere, Robin L. Welcomme, Kirk O. Winemiller (2010) Fish Migration, Dams, and Loss of Ecosystem Services in the Mekong Basin. AMBIO, 39:344-348. 10.1007/s13280-010-0036-1

Ficke, Ashley D., Christopher A. Myrick, Lara J. Hansen (2007) Potential impacts of global climate change on freshwater fisheries. Reviews in Fish Biology and Fisheries, 17:581-613. 10.1007/s11160-007-9059-5

Frei, M., Becker, K. (2005) A greenhouse experiment on growth and yield effects in integrated rice-fish culture. Aquaculture, 255: 119-128.

Gherardi, F., J. R. Britton, K. M. Mavuti, N. Pacini, J. Grey, E. Tricarico and D. M. Harper (2011) A review of allodiversity in Lake Naivasha, Kenya: Developing conservation actions to protect East African lakes from the negative impacts of alien species. Biological Conservation 144: 2585-2596. doi:10.1016/j.biocon.2011.07.020

Hai Yen, N. T., K. Sunada, S. Oishi, Y. Sakamoto, K. Ikejima and T. Iwata (2008) The spatial distribution of fish species catches in relation to catchment and habitat features in the floodplain lot fisheries of Tonle Sap Lake, Cambodia. Journal of Fisheries and Aquatic Sciences 3: 213-227.

Hickley, Phil, Robert Arlinghaus, Richard Tyner, Miran Aprahamian, Ken Parry, Matthew Carter (2004) Rehabilitation of urban lake fisheries for angling by managing habitat: general overview and case studies from England and Wales. Vol. 4, Ecohydrology & Hydrobiology, No 4, 365-378.

Hilborn, Ray, Thomas P. Quinn, Daniel E. Schindler, and Donald E. Rogers (2003) Biocomplexity and fisheries sustainability. PNAS 100: 6564–6568 . doi:10.1073pnas.1037274100

HOEINGHAUS, D. J., AGOSTINHO, A. A., GOMES, L. C., PELICICE, F. M., OKADA, E. K., LATINI, J. D., KASHIWAQUI, E. A. L. and WINEMILLER, K. O. (2009) Effects of River Impoundment on Ecosystem Services of Large Tropical Rivers: Embodied Energy and Market Value of Artisanal Fisheries. Conservation Biology, Volume 23, No. 5, 1222–1231. doi: 10.1111/j.1523-1739.2009.01248.x

Holmlund C.M, Hammer M. (1999) Ecosystem services generated by fish populations. Ecological Economics, 29: 253-268.

Hunt, C.P., Bettoli, P.W. (2007) Preferences, specialization and management attitudes of trout anglers fishing in Tennessee tailwaters. North American Journal of Fisheries Management, 27(4): 1257-1267.

Lapointe, N. W. R., S. J. Cooke, J. G. Imhof, D. Boisclair, J. M. Casselman, R. A. Curry, O. E. Langer, R. L. McLaughlin, C. K. Minns, J. R. Post, M. Power, J. B. Rasmussen, J. D. Reynolds, J. S. Richardson and W. M. Tonn (2014) Principles for ensuring healthy and productive freshwater ecosystems that support sustainable fisheries. Environmental Reviews 22: 110-134. dx.doi.org/10.1139/er-2013-0038

Lavrentyeva, G.M., Lavrentyev, P.J. (1996) The relationship between fish yield and primary production in large European freshwater lakes. Hydrobiologia, 322: 261-266.

Lawrie, A. H. (1978) The fish community of Lake Superior. Journal of Great Lakes Research, (3-4): 513-549.

Li, J. (1999) An appraisal of factors constraining the success of fish stock enhancement programmes. Fisheries Management and Ecology, 6: 161-169.

Lorenzen (1995) Population dynamics and management of culture-based fisheries. Fisheries Management and Ecology, 2: 61-73.

Lorenzen, K. (2000) Allometry of natural mortality as a basis for assessing optimal release size in fish-stocking programmes. Canadian Journal of Fisheries and Aquatic Sciences, 57(12) 2374-2381.

Lorenzen, K. (2001) Using population models to assess culture-based fisheries: A brief review with an application to the analysis of stocking experiments. Reservoir and culture-based fisheries: Biology and management. ACIAR Proceedings, 98: 257-265. Canberra, Australia.

Maceina, M.J., Reeves, W.C. (1996) Relations between submersed macrophyte abundance and largemouth bass tournament success on two Tennessee River impoundments. J. Aquat. Plant Manage., 34: 33-38.

Matsuzaki, S.-I. S., N. Takamura, K. Arayama, A. Tominaga, J. Iwasaki and I. Washitani (2011) Potential impacts of non-native channel catfish on commercially important species in a Japanese lake, as inferred from long-term monitoring data. Aquatic Conservation-Marine and Freshwater Ecosystems 21: 348-357. DOI: 10.1002/aqc.1198

Michaletz, P.H. (2009) Variable responses of channel catfish populations to stocking rate: Density-dependent and lake productivity effects. North American Journal of Fisheries Management, 29: 177-188.

Milstein, A. (1992) Ecological aspects of fish species interactions in polyculture ponds. Hydrobiologia, 231: 177-186.

Milstein, A., Hulata, G., Wohlfarth, G.W. (1988) Canonical correlation analysis of relationships between management inputs and fish growth and yields in polyculture. Aquaculture and Fisheries Management, 19: 13-24.

Mollot, R., Phothitay, C., & Kosy, S. (2003) Hydrology, habitat and livelihoods on the floodplains of southern Lao. PDR. On Mekong Fisheries, 155.

Nguyen, S.H., Bui, A.T., Le, L.T., Nguyen, T.T.T., De Silva, S.S. (2001) The culture-based fisheries in small, farmer-managed reservoirs in two Provinces of northern Vietnam: an evaluation based on three production cycles. Aquaculture Research, 32: 975-990.

Nolan, K. S., N. N Fabre and V. S. Batista (2009) Landscape variables affecting fishery yield in lake systems of the Central Amazon region, Brazil. Journal of Applied Ichthyology 25: 294-298. doi: 10.1111/j.1439-0426.2008.01122.x

Oláh, J., Sinha, V.R.P., Ayyappan, S., Purushothaman, C.S., Radheyshyam, S. (1986) Primary production and fish yields in the fish ponds under different management practices. Aquaculture, 58: 111-122.

Papoutsoglou, S.E., Petropoulos, G., Barbieri, R. (1992) Polyculture rearing of Cyprinus carpio (L.) and Oreochromis aureus (St.) using a closed circulated system. Aquaculture, 103: 311-320.

Parkinson, Eric A., John R. Post, Sean P. Cox (2004) Linking the dynamics of harvest effort to recruitment dynamics in a multistock, spatially structured fishery. Canadian Journal of Fisheries and Aquatic Sciences, 61(9): 1658-1670,. 10.1139/f04-101

Quiros, R., Mari, A. (1999) Factors contributing to the outcome of stocking programmes in Cuban reservoirs. Fisheries Management and Ecology, 5: 241.254.

Rahman, M.M., Verfegem, M., Wahab, M.A. (2008) Effects of tilapia (Oreochromis niloticus L.) stocking and artificial feeding on water quality and production in rohu-common carp bi-culture ponds. Aquaculture Research 39-15:1579-1587.

Roos, N., M. A. Wahab, M. A. Reza Hossain and S. H. Thilsted (2007) Linking human nutrition and fisheries: Incorporating micronutrient-dense, small indigenous fish species in carp polyculture production in Bangladesh. Food and Nutrition Bulletin 28: S280-S293.

Rosenfeld, J. S., E. Raeburn, P. C. Carrier and R. Johnson (2008) Effects of side channel structure on productivity of floodplain habitats for juvenile coho salmon. North American Journal of Fisheries Management 28: 1108-1119. DOI: 10.1577/M07-027.1

Rutten, M, J.M., Bovenhuis, H., Komen, H. (2005) Genetic parameters for fillet traits and body measurements in Nile tilapia (Oreochromis niloticus L.). Aquaculture 246: 125-132.

Schindler, D. E., R. Hilborn, B. Chasco, C. P. Boatright, T. P. Quinn, L. A. Rogers and M. S. Webster (2010) Population diversity and the portfolio effect in an exploited species. Nature 465: 609-612. doi:10.1038/nature09060

Senanayake, F. R. & Peter B. Moyle (1982) Conservation of freshwater fishes of Sri Lanka. Biological Conservation 22:181-195.

Siemer, W.F., Brown, T.L. (1994) Motivations and satisfactions of Lake Ontario boating salmonid anglers. J. Great Lakes Res. 20(2): 457-470.

Sierszen, M. E., J. A. Morrice, A. S. Trebitz and J. C. Hoffman (2012) A review of selected ecosystem services provided by coastal wetlands of the Laurentian Great Lakes. Aquatic Ecosystem Health & Management 15: 92-106. DOI:10.1080/14634988.2011.624970

Silvano, R.A.M., Begossi, A. (2001) Seasonal dynamics of fishery at the Piracicaba River (Brazil). Fisheries Research 51: 69-86.

Silvano, R. A. M., G. Hallwass, P. F. Lopes, A. R. Ribeiro, R. P. Lima, H. Hasenack, A. A. Juras and A. Begossi (2014) Co-management and Spatial Features Contribute to Secure Fish Abundance and Fishing Yields in Tropical Floodplain Lakes. Ecosystems 17: 271-285. DOI: 10.1007/s10021-013-9722-8

Smith, J.A., Baumgartner, L.J., Suthers, I.M., Ives, M.C., Taylor, M.D. (2012) Estimating the stocking potential of fish in impoundment by modelling supply and steady-state demand. Freshwater Biology, 57: 1482-1499.

Sugunan, V.V., Katiha, P.K. (2004) Impact of stocking on yield in small reservoirs in Andhra Pradesh, India. Fisheries Management and Ecology, 11: 65-69.

Teppo Vehanen, Jouni Aspi (1996) Classification of northern Finnish lakes and the suitability for the stocking for brown trout (Salmo trutta (L.) m. Zacustris). Fisheries Research 27: 37-49.

Tolonen, K. T., H. Hamalainen, A. Lensu, J. J. Merilainen, A. Palomaki and J. Karjalainen (2014) The relevance of ecological status to ecosystem functions and services in a large boreal lake. Journal of Applied Ecology 51: 560-571. doi: 10.1111/1365-2664.12245

Trzebiatowski, R., Filipiak, J., Jakubowski, R. (1981) Effect of stock density on growth and survival of rainbow trout (Salmo gairdneri Rich.). Aquaculture, 22: 289-295.

Wahab, M.A., Rahman, M.M., Milstein, A. (2002) The effect of common carp, Cyprinus carpio (L.) and mrigal, Cirrhinus mrigala (Hamilton) as bottom feeders in major Indian carp polycultures. Aquaculture Research, 33: 547-556.

Watson, Dwight J. (1982) Subsistence fish exploitation and implications for management in the baram river system, Sarawak, Malaysia. Fisheries Research 1:299-310.

Timber production

Adame, P., T. J. Brandeis and M. Uriarte (2014) Diameter growth performance of tree functional groups in Puerto Rican secondary tropical forests. Forest Systems 23: 52-63. doi: http://dx.doi.org/10.5424/fs/2014231-03644

Amoroso M. and Turnblom E. (2006) Comparing productivity of pure and mixed Douglas-fir and western hemlock plantations in the Pacific Northwest. Can. J. For. Res. 36: 1484-1496.

Amoroso M. and Turnblom E. (2006) Comparing productivity of pure and mixed Douglas-fir and western hemlock plantations in the Pacific Northwest. Can. J. For. Res. 36: 1484-1496.

Bauhus J., van Winden A., Nicotra A. (2004) Aboveground interactions and productivity in mixed-species plantations of Acacia mearnsii and Eucalyptus globulus. Can. J. For. Res. 34: 686 - 694.

Belote R.T., Aplet G.H. (2014) Land protection and timber harvesting along productivity and diversity gradients in the Northern Rocky Mountains. Ecosphere 5 (2) 1-19.

Bristow M., Vanclay J., Brooks L., Hunt M. (2006) Growth and species interactions of Eucalyptus pellita in a mixed and monoculture plantation in the humid tropics of north Queensland. Forest Ecology and Management 233, 285 - 294.

Chen H., Klinka K. (2003) Aboveground productivity of western hemlock and western red cedar mixed-species stands in southern coastal British Columbia. Forest Ecology and Management 184, 55 - 64.

Chen H., Klinka K., Mathey A.-H., Wang X., Varga P., Chourmouzis C. (2003) Are mixed-species stands more productive than single-species stands: an empirical test of three forest types in British Columbia and Alberta. Can. J. For. Res. 33: 1227-1237.

Chen H., Klinka K., Mathey A.-H., Wang X., Varga P., Chourmouzis C. (2003) Are mixed-species stands more productive than single-species stands: an empirical test of three forest types in British Columbia and Alberta. Can. J. For. Res. 33: 1227-1237.

Chen H., Klinka K., Mathey A.-H., Wang X., Varga P., Chourmouzis C. (2003) Are mixed-species stands more productive than single-species stands: an empirical test of three forest types in British Columbia and Alberta. Can. J. For. Res. 33: 1227-1237.

Collet, C., F. Ningre, I. Barbeito, A. Arnaud and A. Piboule (2014) Response of tree growth and species coexistence to density and species evenness in a young forest plantation with two competing species. Annals of Botany 113: 711-719. doi:10.1093/aob/mct285

Donoso, Pablo J. & Lusk, Christopher H. (2007) Differential effects of emergent Nothofagus dombeyi on growth and basal area of canopy species in an old-growth temperate rainforest. Journal of Vegetation Science 18: 675-684.

Donoso, Pablo J. & Lusk, Christopher H. (2007) Differential effects of emergent Nothofagus dombeyi on growth and basal area of canopy species in an old-growth temperate rainforest. Journal of Vegetation Science 18: 675-684.

Erskine P., Lamb D., Bristow M. (2006) Tree species diversity and ecosystem function: Can tropical multi-species plantations generate greater productivity?. Forest Ecology and Management 233, 205-210.

Firn, J., Erskine, P. D. and Lamb, D. (2007) Woody species diversity influences productivity and soil nutrient availability in tropical plantations. Oecologia, 154 3: 521-533.

Forrester D., Bauhus J., Khanna P. (2004) Growth dynamics in a mixed-species plantation of Eucalyptus globulus and Acacia mearnsii. Forest Ecology and Management 193, 81-95.

Garcia-Gonzalo, J., H. Peltola, A. Z. Gerendiain and S. Kellomaki (2007) Impacts of forest landscape structure and management on timber production and carbon stocks in the boreal forest ecosystem under changing climate. Forest Ecology and Management 241: 243-257. doi:10.1016/j.foreco.2007.01.008

Harrington, T. B., R. A. Slesak and S. H. Schoenholtz (2013) Variation in logging debris cover influences competitor abundance, resource availability, and early growth of planted Douglas-fir. Forest Ecology and Management 296: 41-52. doi:10.1016/j.foreco.2013.01.033

Healy, C., N. J. Gotelli and C. Potvin (2008) Partitioning the effects of biodiversity and environmental heterogeneity for productivity and mortality in a tropical tree plantation. Journal of Ecology 96: 903-913. doi: 10.1111/j.1365-2745.2008.01419.x

Hynynen J., Repola J., Mielikäinen K. (2011) The effects of species mixture on the growth and yield of mid-rotation mixed stands of Scots pine and silver birch. Forest Ecology and Management 262, 1174-1183.

Jacob M. ,Leuschner C., Thomas F. (2010) Productivity of temperate broad-leaved forest stands differing in tree species diversity. Ann. For. Sci. 67, 503.

Kelty M. (1989) Productivity of New England Hemlock/Hardwood stands as affected by species composition and canopy structure. Forest Ecology and Mangement 28, 237-257.

Khanna P. (1997) Comparison of growth and nutrition of young monocultures and mixed stands of Eucalyptus globulus and Acacia mearnsii. Forest Ecology and Management 94, 105-113.

Kirui B.,Kairo J., Skov M., Maurizio Mencuccini M.,Huxham M. (2012) Effects of species richness, identity and environmental variables on growth in planted mangroves in Kenya. Mar Ecol Prog Ser Vol. 465: 1–10.

Klang F., Ekö P.-M. (1999) Tree properties and yield of Picea abies planted in shelterwoods. Scand. J. For. Res. 14, 262-269.

Kunert N., Schwendenmann L., Potvin C., Hölscher D. (2012) Tree diversity enhances tree transpiration in a Panamanian forest plantation. Journal of Applied Ecology, 49, 135-144.

Lei X., Wang W., Peng C. (2009) Relationships between stand growth and structural diversity in spruce-dominated forests in New Brunswick, Canada. Can. J. For. Res. 39: 1835-1847.

Liang J., Buongiomo J., Monserud R., Kruger E., Zhou M. (2007) Effects of diversity of tree species and size on forest basal area growth, recruitment, and mortality. Forest Ecology and Management 243, 116-127.

Linden M. Agestam E. (2003) Increment and yield in mixed and monoculture stands of Pinus sylvestris and Picea abies based on an experiment in Southern Sweden. Scand. J. For. Res. 18: 155-162.

Lusk, C. and Ortega, A. (2003) Vertical structure and basal area development in second-growth Nothofagus stands in Chile. Journal of Applied Ecology 40, 639-645.

Merganic, J., R. Marusak, K. Merganicova, R. Stolarikova and L. Tipmann (2013) Relation between selected indicators of forest stand diversity and quality of timber production in young stands aged up to 40 years. Journal of Forest Science (Prague) 59: 503-513.

Morris, D. M., D. E. B. Reid, M. Kwiaton, S. L. Hunt and A. M. Gordon (2014) Comparing growth patterns of jack pine and black spruce in mixed natural stands and plantations. Ecoscience 21: 42644. DOI 10.2980/21-1-3646

Neufeld, B. A., D. M. Morris, N. Luckai, D. E. B. Reid, F. W. Bell, C. Shahi, W. L. Meyer and S. Adhikary (2014) The influence of competition and species mixture on plantation-grown white spruce: Growth and foliar nutrient response after 20 years. Forestry Chronicle 90: 70-79.

Nguyen H., Herbohn J.,Firn J.,Lamb D. (2012) Biodiversity-productivity relationships in small-scale mixed-species plantations using native species in Leyte province, Philippines. Forest Ecology and Management 274, 81-90.

Olschewski, R., A.-M. Klein and T. Tscharntke (2010) Economic trade-offs between carbon sequestration, timber production, and crop pollination in tropical forested landscapes. Ecological Complexity 7: 314-319. doi:10.1016/j.ecocom.2010.01.002

Opuni-Frimpong, E., S. M. Opoku, A. J. Storer, A. J. Burton and D. Yeboah (2013) Productivity, pest tolerance and carbon sequestration of Khaya grandifoliola in the dry semi-deciduous forest of Ghana: a comparison in pure stands and mixed stands. New Forests 44: 863-879. DOI 10.1007/s11056-013-9376-6

Paquette A. and Messier C. (2011) The effect of biodiversity on tree productivity: from temperate to boreal forests. Global Ecology and Biogeography (Global Ecol. Biogeogr.) 20, 170-180.

Parrotta J. (1999) Productivity, nutrient cycling, and succession in single- and mixrd-species plantations of Casuarina equisetifolia, Eucalyptus robusta, and Leucaena leucocephala in Puerto Rico. Forest Ecology and Management 124, 45-77.

Petit B., Montagnini F. (2006) Growth in pure and mixed plantations of tree species used in reforesting rural areas of the humid region of Costa Rica, Central America. Forest Ecology and Management 233, 338-343.

Petit, B. and F. Montagnini (2004) Growth equations and rotation ages of ten native tree species in mixed and pure plantations in the humid neotropics. Forest Ecology and Management 199: 243-257. doi:10.1016/j.foreco.2004.05.039

Piotto D., Craven D., Montagnini F., Alice F. (2010) Silvicultural and economic aspects of pure and mixed native tree species plantations on degraded pasturelands in humid Costa Rica. New Forests 39: 369-385.

Piotto D., Viquez E., Montagnini F., Kanninen M. (2004) Pure and mixed forest plantations with native species of the dry tropics of Costa Rica: a comparison of growth and productivity. Forest Ecology and Management 190, 359 - 372.

Piotto, D. (2007) Growth of native tree species planted in open pasture, young secondary forest and mature forest in humid tropical Costa Rica. Journal of Tropical Forest Science 19: 92-102.

Piotto, D. (2008) A meta-analysis comparing tree growth in monocultures and mixed plantations. Forest Ecology and Management 255: 781-786. doi:10.1016/j.foreco.2007.09.065

POTVIN C., DUTILLEUL P. (2009) Neighborhood effects and size-asymmetric competition in a tree plantation varying in diversity. Ecology, 90(2), pp. 321–327.

Potvin C. and Gotelli N. (2008) Biodiversity enhances individual performance but does not affect survivorship in tropical trees. Ecology Letters 11: 217–223.

Riedel J., Dorn S., Plath M., Potvin C., Mody K. (2013) Time matters: Temporally changing effects of planting schemes and insecticide treatment on native timber tree performance on former pasture land. Forest Ecology and Management 297, 49-56.

SAPIJANSKAS J. ,POTVIN C., LOREAU M. (2013) Beyond shading: Litter production by neighbors contributes to overyielding in tropical trees. Ecology, 94(4), pp. 941–952.

Sayyad E., Hosseini S.M., Mahdavi R., Jalali S.G., Akbarinia M., Tabari M. (2006) Comparison of growth, nutrition and soil properties of pure and mixed stands of Populus deltoides and Alnus subcordata. Silva Fennica 40 (1) 27 - 35.

Seiwa, K., Y. Eto, M. Hishita and K. Masaka (2012) Effects of thinning intensity on species diversity and timber production in a conifer (Cryptomeria japonica) plantation in Japan. Journal of Forest Research 17: 468-478. DOI 10.1007/s10310-011-0316-z

Tang, G., K. Li, C. Zhang, C. Gao and B. Li (2013) Accelerated nutrient cycling via leaf litter, and not root interaction, increases growth of Eucalyptus in mixed-species plantations with Leucaena. Forest Ecology and Management 310: 45-53. http://dx.doi.org/10.1016/j.foreco.2013.08.02

Vilà M., Vayreda J., Comas L., Ibanez J., Mata T. and Obon B. (2007) Species richness and wood production: a positive association in Mediterranean forests. Ecology Letters 10: 241-250.

Vilà M., Vayreda J., Gracia C., Ibáiiez J. (2003) Does tree diversity increase wood production in pine forests?. Oecalagia 135:299-303.

Vilà M., Carrillo-Gavilan, J. Vayreda, H. Bugmann, J. Fridman, W. Grodzki, J. Haase, G. Kunstler, M. Schelhaas and A. Trasobares (2013) Disentangling Biodiversity and Climatic Determinants of Wood Production. Plos One 8: e53530. doi:10.1371/journal.pone.0053530

Yang, L., P. Wang and C. Kong (2010) Effect of larch (Larix gmelini Rupr.) root exudates on Manchurian walnut (Juglans mandshurica Maxim.) growth and soil juglone in a mixed-species plantation. Plant and Soil 329: 249-258. DOI 10.1007/s11104-009-0149-0

Zhang Y, Chen HYH, Reich PB (2012) Forest productivity increases with evenness, species richness and trait variation: a global meta-analysis. Journal of Ecology 100: 742–749. doi: 10.1111/j.1365-2745.2011.01944

Food production (crops)

Alam, M.Z., Braun, G., Norrie, J. and Hodges, D.M. (2014) Ascophyllum extract application can promote plant growth and root yield in carrot associated with increased root-zone soil microbial activity. Can. J. Plant Sci. 94: 337348. doi:10.4141/CJPS2013-135

Anderson, R.L. (2009) Rotation Design: A Critical Factor for Sustainable Crop Production in a Semiarid Climate: A review. E. Lichtfouse (ed.), Organic Farming, Pest Control and Remediation of Soil Pollutants, Sustainable Agriculture Reviews 1. DOI 10.1007/978-1-4020-9654-9 7

Bayala, J., G.W. Sileshi, R. Coe, A. Kalinganire, Z. Tchoundjeu, F. Sinclair and D. Garrity (2012) Cereal yield response to conservation agriculture practices in drylands of West Africa: A quantitative synthesis. Journal of Arid Environments 78:13-25. doi:10.1016/j.jaridenv.2011.10.011

Bayala, J., J Sanou, Z Teklehaimanot, A Kalinganire and SJ Ouedraogo (2014) Parklands for buffering climate risk and sustaining agricultural production in the Sahel of West Africa. Current Opinion in Environmental Sustainability 6:28–34. http://dx.doi.org/10.1016/j.cosust.2013.10.004

Bedoussac, L. and Justes, E. (2010) The efficiency of a durum wheat-winter pea intercrop to improve yield and wheat grain protein concentration depends on N availability during early growth. Plant Soil 330:19–35. DOI 10.1007/s11104-009-0082-2

Bell, Lindsay A., Andrew D. Moore and John A. Kirkegaard (2014) Evolution in crop–livestock integration systems that improve farmproductivity and environmental performance in Australia. Europ. J. Agronomy 57:10–20. doi/10.1016/j.eja.2013.04.007

Benites, J.R., R.E. McCollum and G.C. Naderman (1993) Production efficiency of intercrops relative to sequentially-planted sole crops in a humid tropical environment. Field Crops Res., 30: 1-18. 0378-4290/92/$05.00

Bouws, H. and M. R. Finckh (2008) Effects of strip intercropping of potatoes with non-hosts on late blight severity and tuber yield in organic production. Plant Pathology 57: 916–927. Doi: 10.1111/j.1365-3059.2008.01860.x

Chavas, Jean-Paul and Salvatore Di Falco (2012) On the Productive Value of Crop Biodiversity: Evidence from the Highlands of Ethiopia. Land Economics, 88(1): 58-74. DOI: 10.1353/lde.2012.0009

Cowger, Christina and Randy Weisz (2008) Winter Wheat Blends (Mixtures) Produce a Yield Advantage in North Carolina. Agronomy Journal 100:169–177. doi:10.2134/agronj2007.0128

Davis AS, Hill JD, Chase CA, Johanns AM, Liebman M (2012) Increasing Cropping System Diversity Balances Productivity, Profitability and Environmental Health. PLoS ONE 7(10): e47149. doi:10.1371/journal.pone.0047149

de la Fuente, Elba B, Susana A. Suárez, Adriana E. Lenardis, Santiago L. Poggioc (2014) Intercropping sunflower and soybean in intensive farming systems: Evaluating yield advantage and effect on weed and insect assemblages. NJAS - Wageningen Journal of Life Sciences 70–71:47–52. doi/10.1016/j.njas.2014.05.002

di Falco, S. and Chavas, J-P. (2006) Crop genetic diversity, farm productivity and the management of environmental risk in rainfed agriculture. European Review of Agricultural Economics 33 (3) :289–314. doi:10.1093/erae/jbl016

Di Falco, Salvatore and Jean-Paul Chavas (2008) Rainfall Shocks, Resilience, and the Effects of Crop Biodiversity on Agroecosystem Productivity. Land Economics 84 (1): 83–96.

di Falco, Salvatore, Jean-Paul Chavas and Melinda Smale (2007) Farmer management of production risk on degraded lands: the role of wheat variety diversity in the Tigray region, Ethiopia. Agricultural Economics 36:147–156.

Di Falco, Salvatore, Melinda Smale and Charles Perrings (2008) The role of agricultural cooperatives in sustaining the wheat diversity and productivity: the case of southern Italy. Environ Resource Econ 39:161–174. DOI 10.1007/s10640-007-9100-0

Di Falco, Salvatore, Mintewab Bezabih and Mahmud Yesuf (2010) Seeds for livelihood: Crop biodiversity and food production in Ethiopia. Ecological Economics 69: 1695–1702. doi:10.1016/j.ecolecon.2010.03.024

Ebanyat, P., N. de Ridder, A. de Jager, R. J. Delve, M. A. Bekunda and K. E. Giller (2010) Impacts of heterogeneity in soil fertility on legume-finger millet productivity, farmers' targeting and economic benefits. Nutr Cycl Agroecosyst 87:209–231. DOI 10.1007/s10705-009-9329-9

Hadgu, Kiros M., Walter A. H. Rossing, Lammert Kooistra & Ariena H. C. van Bruggen (2009) Spatial variation in biodiversity, soil degradation and productivity in agricultural landscapes in the highlands of Tigray, northern Ethiopia. Food Sec. 1:83–97. DOI 10.1007/s12571-008-0008-5

Hauggaard-Nielsen, Henrik, Bjarne Jørnsgaard, Julia Kinane and Erik Steen Jensen (2008) Grain legume–cereal intercropping: The practical application of diversity, competition and facilitation in arable and organic cropping systems. Renewable Agriculture and Food Systems: 23(1); 3–12. doi:10.1017/S1742170507002025

Himanen, Sari J., Elise Ketoja, Kaija Hakala, Reimund P. Rötter, Tapio Salo and Helena Kahiluoto (2013) Cultivar diversity has great potential to increase yield of feed barley. Agron. Sustain. Dev. 33:519–530. DOI 10.1007/s13593-012-0120-y

Huang, Chong, Zhenyu Sun, Haiguang Wang, Yong Luo and Zhanhong Ma (2012) Effects of wheat cultivar mixtures on stripe rust: A meta-analysis on field trials. Crop Protection 33: 52e58. doi:10.1016/j.cropro.2011.11.020

Jones, Andrew D., Aditya Shrinivas and Rachel Bezner-Kerr (2014) Farm production diversity is associated with greater household dietary diversity in Malawi: Findings from nationally representative data. Food Policy 46: 1–12. doi/10.1016/j.foodpol.2014.02.001

Kaut, A.H.E.E., Mason, H.E., Navabi, A., Donovan, J.T. and Spaner, D. (2009) Performance and stability of performance of spring wheat variety mixtures in organic and conventional management systems in western Canada. Journal of Agricultural Science, 147, 141–153. doi:10.1017/S0021859608008319

Kiær, Lars P. Ib M. Skovgaard and Hanne Østergard (2009) Grain yield increase in cereal variety mixtures: A meta-analysis of field trials. Field Crops Research 114: 361–373. doi:10.1016/j.fcr.2009.09.006

Leblanc, H.A. and McGraw, R.L. (2004) Evaluation of Inga edulis and I. samanensis for firewood and green mulch production in an organic maize alley-cropping practice in the humid tropics. Trop. Agric. (Trinidad) 81: 1-8.

Li , Qiuhong, Fengzhi Wu , Yang Yang & Xuezheng Wang (2009) Effects of rotation and interplanting on soil bacterial communities and cucumber yield. Acta Agriculturae Scandinavica, Section B — Soil & Plant Science, 59:5, 431-439. DOI 10.1080/09064710802342319

Li C, He X, Zhu S, Zhou H, Wang Y, et al. (2009) Crop Diversity for Yield Increase. PLoS ONE 4(11): e8049. doi:10.1371/journal.pone.0008049

Liebman, Matt; Helmers, Matthew J.; Schulte, Lisa A. and Chase, Craig A. (2013) Using biodiversity to link agricultural productivity with environmental quality: Results from three field experiments in Iowa. Renewable Agriculture and Food Systems: 28(2); 115–128. doi:10.1017/S1742170512000300

Mallikarjuna Swamy, B.P. and N. Sarla (2008) Yield-enhancing quantitative trait loci (QTLs) from wild species. Biotechnology Advances 26:106–120. doi:10.1016/j.biotechadv.2007.09.005

Mugendi, D.N., Nairi, P.K.R., Mugwe, J.N., O'Neill, M.K. and Woomer, P.L. (1999) Alley cropping of maize with calliandra and leucaena in the subhumid highlands of Kenya. Agroforestry Systems 46: 39–50.

Newton, A.C. and D.C. Guy (2009) The effects of uneven, patchy cultivar mixtures on disease control and yield in winter barley. Field Crops Research 110: 225–228. doi:10.1016/j.fcr.2008.09.002

O’Reilly, Kelsey A., Darren E. Robinson, Richard J. Vyn, and Laura L. Van Eerd (2011) Weed Populations, Sweet Corn Yield, and Economics Following Fall Cover Crops. Weed Technology 25:374–384. DOI: 10.1614/WT-D-10-00051.1

Omer, Amani, Unai Pascual and Noel P. Russell (2007) Biodiversity Conservation and Productivity in Intensive Agricultural Systems. Journal of Agricultural Economics, 58 :308–329.

Ortiz-Ceballos, Angel I., Carlos Fragoso and George G. Brown (2007) Synergistic effect of a tropical earthworm Balanteodrilus pearsei and velvetbean Mucuna pruriens var. utilis on maize growth and crop production. Applied Soil Ecology 35: 356–362. doi:10.1016/j.apsoil.2006.07.009

Osonubi, O., M.O. Atayese and K. Mulongoy (1995) The effect of vesicular-arbuscular mycorrhizai inoculation on nutrient uptake and yield of alley-cropped cassava in a degraded Alfisol of southwestern Nigeria. Biol Fertil Soils 20:70-76.

Ostergard, H., Kristensen, K. and Jensen, J. (2005) Stability in variety mixtures of spring barley. Organic plant breeding strategies and the use of molecular markers 28:30.

Palmer, M. W. and K. A. Chandler-Ezell (2001) Effects of initial plant species richness in microcosms: preliminary results. COMMUNITY ECOLOGY 2(1): 41-49.

Qin, An-zhen, Gao-bao Huang, Qiang Chai, Ai-zhong Yu and Peng Huang (2013) Grain yield and soil respiratory response to intercropping systems on arid land. Field Crops Research 144: 1–10 2013. doi/10.1016/j.fcr.2012.12.005

Rahman, MM, MA Awal, A Amin, MR Parvej (2009) Compatibility, growth and production potentials of mustard/lentil intercrops. Int. J. Bot 5:100-106. DOI10.3923/ijb.2009.100.106

Reynolds, M. P., K. D. Sayre and H. E. Vivar (1994) Intercropping wheat and barley with N-fixing legume species: a method for improving ground cover, N-use efficiency and productivity in low input systems. Journal of Agricultural Science, Cambridge, 123: 175-183.

Rutunga, Venant, Nancy K. Karanja and Charles K.K. Gachene (2008) Six month-duration Tephrosia vogelii Hook.f. and Tithonia diversifolia (Hemsl.) A.Gray planted-fallows for improving maize production in Kenya. Biotechnol. Agron. Soc. Environ.12(3): 267-278.

Schröder, Daniela and Ulrich Köpke (2012) Faba bean (Vicia faba L.) intercropped with oil crops – a strategy to enhance rooting density and to optimize nitrogen use and grain production?. Field Crops Research 135: 74–81. doi/10.1016/j.fcr.2012.07.007

Schroth G. and Lehmann J. (1995) Contrasting effects of roots and mulch from 3 agroforestry tree species on yields of alley cropped maize, *Agriculture, Ecosystems and Environment* **54**: 89-101.

Sharma A. R. and U. K. Behera (2009) Recycling of legume residues for nitrogen economy and higher productivity in maize (Zea mays)–wheat (Triticum aestivum) cropping system. Nutr Cycl Agroecosyst 83:197–210. DOI 10.1007/s10705-008-9212-0

Sileshi, G. and P.L. Mafongoya (2006) Long-term effects of improved legume fallows on soil invertebrate macrofauna and maize yield in eastern Zambia. Agriculture, Ecosystems and Environment 115: 69–78. doi:10.1016/j.agee.2005.12.010

Sileshi, Gudeta, Festus K. Akinnifesi, Legesse K. Debusho, Tracy Beedy, Oluyede C. Ajayi and Simon Mong'omba (2010) Variation in maize yield gaps with plant nutrient inputs, soil type and climate across sub-Saharan Africa. Field Crops Research 116:1–13. doi:10.1016/j.fcr.2009.11.014

Sileshi, Gudeta, Festus K. Akinnifesi, Oluyede C. Ajayi & Frank Place (2008) Meta-analysis of maize yield response to woody and herbaceous legumes in sub-Saharan Africa. Plant Soil 307:1–19. DOI 10.1007/s11104-008-9547-y

Smith,Richard G., Katherine L. Gross and G. Philip Robertson (2008) Effects of Crop Diversity on Agroecosystem Function: Crop Yield Response. Ecosystems 11: 355–366. DOI: 10.1007/s10021-008-9124-5

Smithson, J.B. and J.M. Lenne (1996) Varietal mixtures: a viable strategy for sustainable productivity in subsistence agriculture. Ann. appl. Biol.128:127-158.

Snapp, Sieglinde S, Malcolm J. Blackie, Robert A. Gilbert, Rachel Bezner-Kerr and George Y. Kanyama-Phiri (2010) Biodiversity can support a greener revolution in Africa. PNAS 107(48): 20840–20845. doi/10.1073/pnas.1007199107

Snapp, Sieglinde S., Lowell E. Gentry and Richard Harwood (2010) Management intensity – not biodiversity – the driver of ecosystem services in a long-term row crop experiment. Agriculture, Ecosystems and Environment 138: 242–248. doi:10.1016/j.agee.2010.05.005

STAUDACHER, Karin, NIKOLAUS SCHALLHART, BETTINA THALINGER, CORINNA WALLINGER, ANITA JUEN AND MICHAEL TRAUGOTT (2013) Plant diversity affects behavior of generalist root herbivores, reduces crop damage, and enhances crop yield. Ecological Applications, 23(5): 1135–1145.

Tian, G., B.T. Kang, G.O. Kolawole, P. Idinoba and F.K. Salako (2005) Long-term effects of fallow systems and lengths on crop production and soil fertility maintenance in West Africa. Nutrient Cycling in Agroecosystems 71: 139–150. DOI 10.1007/s10705-004-1927-y

Tonitto, C., M.B. David and L.E. Drinkwater (2006) Replacing bare fallows with cover crops in fertilizer-intensive cropping systems: A meta-analysis of crop yield and N dynamics. Agriculture, Ecosystems and Environment 112: 58–72. doi:10.1016/j.agee.2005.07.003

Vesterager, Jens M., Niels E. Nielsen and Henning Høgh-Jensen (2008) Effects of cropping history and phosphorus source on yield and nitrogen fixation in sole and intercropped cowpea–maize systems. Nutr Cycl Agroecosyst 80:61–73. DOI 10.1007/s10705-007-9121-7

WU, FENGZHI, HUIYING YU, GAOBO YU, KAI PAN & JING BAO (2011) Improved bacterial community diversity and cucumber yields in a rotation with kidney beancelerycucumber. Acta Agriculturae Scandinavica Section B Soil and Plant Science, 61: 122-128. DOI: 10.1080/09064710903555322

Xuan, Do Thi & Vo Thi Guong & Anna Rosling & Sadhna Alström & Benli Chai & Nils Högberg (2011) Different crop rotation systems as drivers of change in soil bacterial community structure and yield of rice, Oryza sativa. BIOLOGY AND FERTILITY OF SOILS · SEPTEMBER 2011. DOI: 10.1007/s00374-011-0618-5

Zhang, Fusuo & Long Li (2003) Using competitive and facilitative interactions in intercropping systems enhances crop productivity and nutrient-use efficiency. Plant and Soil 248: 305–312.

Zhu, Youyong , Hairu Chen, Jinghua Fan, Yunyue Wang, Yan Li, Jianbing Chen, JinXiang Fan, Shisheng Yang, Lingping Hu, Hei Leung, Tom W. Mew, Paul S. Teng, Zonghua Wang & Christopher C. Mundt (2000) Genetic diversity and disease control in rice. NATURE 406: 718-722.

Water supply

Baral, H., Keenan, R. J., Fox, J. C., Stork, N. E., & Kasel, S. (2013) Spatial assessment of ecosystem goods and services in complex production landscapes: A case study from south-eastern Australia. Ecological Complexity, 13, 35-45. 10.1016/j.ecocom.2012.11.001

Benegas, L., U. Ilstedt, O. Roupsard, J. Jones, A. Malmer (2014) Effects of trees on infiltrability and preferential flow in two contrasting agroecosystems in Central America. Agriculture, Ecosystems and Environment 183: 185–196. http://dx.doi.org/10.1016/j.agee.2013.10.027

Blumenfeld, S., C. Lu, Christophersen, T., et al. (2009) Water, wetlands and forests: a review of ecological, economic and policy linkages. CBD Technical Series(47): 38 pp.

Bosch, J.; Hewlett, J. (1982) A review of catchment experiments to determine the effect of vegetation changes on water yield and evapotranspiration. Journal of Hydrology 55: 3-23. 10.1016/0022-1694(82)90117-2

Brauman, K. A., D. L. Freyberg, Daily, G.C. (2010) Forest structure influences on rainfall partitioning and cloud interception: A comparison of native forest sites in Kona, Hawai. Agricultural and Forest Meteorology 150(2): 265-275. 10.1016/j.agrformet.2009.11.011

Brauman, K.A., Freyberg, D.L., Daily, G.C. (2012) Potential evapotranspiration from forest and pasture in the tropics: A case study in Kona, Hawai. Journal of Hydrology 440-441, 52-61. 10.1016/j.jhydrol.2012.03.014

Bren, L., Hopmans, P. (2007) Paired catchments observations on the water yield of mature eucalypt and immature radiata pine plantations in Victoria, Australia. Journal of Hydrology, 336, 416- 429. 10.1016/j.jhydrol.2007.01.018

Bruijnzeel, L.A. (2004) Hydrological functions of tropical forests: not seeing the soil for the trees?. Agriculture, Ecosystems and Environment 104: 185-228. 10.1016/j.agee.2004.01.015

Buytaert, W., V. Iniguez, De Bievre, B. (2007) The effects of afforestation and cultivation on water yield in the Andean paramo. Forest Ecology and Management 251(1-2): 22-30. 10.1016/j.foreco.2007.06.035

Cavaleri, M.A., Sack, L. (2010) Comparative water use of native and invasive plants at multiple scales: a global meta-analysis. Ecology, 91(9) 2705-2715. 10.1890/09-0582.1

Chan, K.M.A., Shaw, M.R., Cameron, D.R., Underwood, E.C., Daily, G.C. (2006) Conservation planning for ecosystem services. PLOS Biology, 4(11) 2138-2152. 10.1371/journal.pbio.0040379

Cornish, P.M.; Vertessy, R.A. (2001) Forest age-induced changes in evapotranspiration and water yield in a eucalypt forest. Journal of Hydrology 242: 43-63. 10.1016/S0022-1694(00)00384-X

Dierick, D. Hölscher, D. (2009) Species-specific tree water use characteristics in reforestation stands in the Philippines. Agricultural and Forest Meteorology 149, 1317-1326. 10.1016/j.agrformet.2009.03.003

Duncan, M.J. (1995) Hydrological impacts of converting pasture and gorse to pine plantation, and forest harvesting, Nelson, New Zealand. Journal of Hydrology (NZ) 31(1) 15-41.

Egoh, B., Reyers, B., Rouget, M., Bode, M. & Richardson, D.M. (2009) Spatial congruence between biodiversity and ecosystem services in South Africa. Biological Conservation, 142, 553-562. 10.1016/j.biocon.2008.11.009

Egoh, B., Reyers, B., Rouget, M., Richardson, D.M., Le Maitre, D.C. & van Jaarsveld, A.S. (2008) Mapping ecosystem services for planning and management. Agriculture Ecosystems & Environment, 127, 135-140. 10.1016/j.agee.2008.03.013

Everson, C. S., P. J. Dye, M. B. Gush and T. M. Everson (2011) Water use of grasslands, agroforestry systems and indigenous forests. Water SA 37: 781-788. http://dx.doi.org/10.4314/wsa.v37i5.15

Fahey, B.; Jackson, R. (1997) Hydrological impacts of converting native forests and grasslands to pine plantations, South Island, New Zealand. Agricultural and Forest Meteorology 84: 69-82. 10.1016/S0168-1923(96)02376-3

Fahey, B.D.; Watson, A.J. (1991) Hydrological impacts of converting tussock grassland to pine plantation, Otago, New Zealand. Journal of Hydrology, New Zealand 30: 1-15.

Farley KA, Jobbagy EG, Jackson RB. (2005) Effects of afforestation on water yield: a global synthesis with implications for policy. Global Change Biology 11: 1565-1576. 10.1111/j.1365-2486.2005.01011.x

Garmendiaa,E., Marielc, P., Tamayod, I., Aizpurud, I, Zabaletae, A. (2012) Assessing the effect of alternative land uses in the provision of water resources: Evidence and policy implications from southern Europe. Land Use Policy, 29(4): 761–770. 10.1016/j.landusepol.2011.12.001

Gomez-Peralta, D.; Oberbauer, S.F.; McClain, M.E.; Philippi, T.E. (2008) Rainfall and cloud-water interception in tropical montane forests in the eastern Andes of Central Peru. Forest Ecology and Management 255: 1315-1325. 10.1016/j.foreco.2007.10.058

Hamilton, L. S. (1995) Mountain cloud forest conservation and research - a synopsis. Mountain Research and Development 15(3): 259-266.

Holdsworth, D.K.; Mark, A.F. (1990) Water and nutrient input: output budgets: effects of plant cover at seven sites in upland snow tussock grasslands of eastern and central Otago, New Zealand. Journal of the Royal Society of New Zealand 20: 1-24. 10.1080/03036758.1990.10426730

Hornbeck, J.W.; Adams, M.B.; Corbett, E.S.; Verry, E.S.; Lynch, J.A. (1993) Long-term impacts of forest treatments on water yield: a summary for northeastern USA. Journal of Hydrology 150: 323-344. 10.1016/0022-1694(93)90115-P

Huang, M.; Zhang, L.; Gallichand, J. (2003) Runoff responses to afforestation in a watershed of the Loess Plateau, China. Hydrological Processes 17: 2599-2609. 10.1002/hyp.1281

Ilstedt, U., A. Malmer, E. Verbeeten, D. Murdiyarso (2007) The effect of afforestation on water infiltration in the tropics: A systematic review and meta-analysis. Forest Ecology and Management 251: 45–51. doi:10.1016/j.foreco.2007.06.014

Jayasuriya, M.D.A., Dunn, G., Benyon, R., O'Shaughnessy, P.J. (1993) Some factors affecting water yield from mountain ash (Eucalyptus regnans) dominated forests in south-east Australia. Journal of Hydrology, 150, 345-367. 10.1016/0022-1694(93)90116-Q

Kagawa, A., Sack L., Duarte, K., James, S. (2009) Hawaiian native forest conserves water relative to timber plantation: Species and stand traits influence water use. Ecological Applications, 19(6) 1429-1443.

Komatsu H, Kume T, Otsuki K. (2008) The effect of converting a native broad-leaved forest to a coniferous plantation forest on annual water yield: a paired-catchment study in northern Japan. Forest Ecology and Management 255: 880-886. 10.1016/j.foreco.2007.10.010

Le Maitre, D.C.; van Wilgen, B.W.; Gelderblom, C.M.; Bailey, C.; Chapman, R.A.; Nel, J.A. (2002) Invasive alien trees and water resources in South Africa: case studies of the costs and benefits of management. Forest Ecology and Management 160: 143-159. 10.1016/S0378-1127(01)00474-1

Licata, Julian A., Javier E. Gyenge, Maria Elena Fernandez, Tomas M. Schlichter, Barbara J. Bond (2008) Increased water use by ponderosa pine plantations in northwestern Patagonia, Argentina compared with native forest vegetation. Forest Ecology and Management 255: 753–764. doi:10.1016/j.foreco.2007.09.061

Locatelli, B. and Vignola, R. (2009) Managing watershed services of tropical forests and plantations: Can meta-analyses help?. Forest Ecology and Management 258:1864–1870. doi:10.1016/j.foreco.2009.01.015

Mitchell, P.J., Benyon, R.G., Lane, P.N.J. (2012) Responses of evapotranspiration at different topographic positions and catchment water balance following a pronounced drought in a mixed species eucalypt forest, Australia. Journal of Hydrology 440–441 (2012) 62–74. 10.1016/j.jhydrol.2012.03.026

Muller, J. (2009) Forestry and water budget of the lowlands in northeast Germany - consequences for the choice of tree species and for forest management. Journal of Water and Land Development(13a): 133-148. 10.2478/v10025-010-0024-7

Nie, W. Yuan, Y., Kepner, W., et al. (2011) Assessing impacts of Landuse and Landcover changes on hydrology for the upper San Pedro watershed. Journal of Hydrology 407 (2011) 105-114. 10.1016/j.jhydrol.2011.07.012

Nie, W., Y. Yuan, Kepner, W., et al. (2012) Hydrological impacts of mesquite encroachment in the upper San Pedro watershed. Journal of Arid Environments 82: 147-155. 10.1016/j.jaridenv.2012.02.008

Nosetto, M.D.; Jobbagy, E.G.; Paruelo, J.M. (2005) Land-use change and water losses: the case of grassland afforestation across a soil textural gradient in central Argentina. Global Change Biology 11: 1101-1117. 10.1111/j.1365-2486.2005.00975.x

Petheram, C., Walker, G., Grayson, R., Thierfelder, T., Zhang, L. (2002) Towards a framework for predicting impacts of land-use on recharge: 1. A review of recharge studies in Australia. Australian Journal of Soli Research, 40, 397-417.

Putuhena, W.M., Cordery, I. (2000) Some hydrological effects of changing forest cover from eucalypts to Pinus radiata. Agricultural and Forest Meteorology, 100, 59-72. 10.1016/S0168-1923(99)00086-6

Rey Benayas, J. M., Martins, A., Nicolau, J.M., et al. (2007) Abandonment of agricultural land: an overview of drivers and consequences. CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources 2(057): 14 pp. 10.1079/PAVSNNR20072057

Rowe, L.K., Pearce, A.J. (1994) Hydrology and related changes after harvesting native forest catchments and establishing Pinus radiata plantations. part 2. The native forest water balance and changes in streamflow after harvesting. Hydrological Processes. 10.1002/hyp.3360080402

Ruprecht, J.K., Stoneman, G.L. (1996) Water yield issues in the jarrah forest of south-western Australia. Journal of Hydrology, 150, 369-391.

Ruprecht, J.K.; Schofield, N.J. (1989) Analysis of streamflow generation following deforestation in southwest Western Australia. Journal of Hydrology 105: 1-17.

Saenz, L., Mulligan, M. (2013) The role of Cloud Affected Forests (CAFs) on water inputs to dams. Ecosystem Services, 9pp. 10.1016/j.ecoser.2013.02.005

Sahin, V.; Hall, M.J. (1996) The effects of afforestation and deforestation on water yields. Journal of Hydrology 178: 293-309. 10.1016/0022-1694(95)02825-0

Schume, H., Jost, G. and Hager, H. (2004) Soil water depletion and recharge patterns in mixed and pure forest stands of European beech and Norway spruce. Journal of Hydrology 289: 258-274. doi:10.1016/j.jhydrol.2003.11.036

Scott, D.F., Lesch, W. (1997) Streamflow responses to afforestation with Eucalyptus gruadis and Pinus patula and to felling in the Mokobulaan experimental catchments, South Africa. Journal of Hydrology 199, 360-377. 10.1016/S0022-1694(96)03336-7

Silvio Simonit and Charles Perrings (2013) Bundling ecosystem services in the Panama Canal watershed. Proceedings of the National Academy of Sciences, 110(23), 9326-9331. 10.1073/pnas.1112242110

Singh, S., Mishra, A. (2012) Spatiotemporal analysis of the effects of forest covers on water yield in the Western Ghats of peninsular India. Journal of Hydrology 446-447, 24-34. 10.1016/j.jhydrol.2012.04.021

Stoneman, G.L. (1993) Hydrological response to thinning a small jarrah (Eucalyptus marginata) forest catchment. Journal of Hydrology, 150, 393-407. 10.1016/0022-1694(93)90118-S

Sun G, Zhou G, Zhang Z, Wei X, McNulty SG, Vose JM. (2006) Potential Water Yield Reduction due to forestation across China. Journal of Hydrology 328: 548-558. 10.1016/j.jhydrol.2005.12.013

Takahashi,M., Giambelluca,T.W., Mudd, R.G., DeLay, J.K., Nullet, M.A., Asner, G.P. (2011) Rainfall partitioning and cloud water interception in native forest and invaded forest in Hawaiʻi Volcanoes National Park. Hydrological Processes, 25, 448-464. 10.1002/hyp.7797

Vertessy, R.A., Watson, F.G.R., O'Sullivan, S.K. (2001) Factors determining relations between stand age and catchment water balance in mountain ash forests. Forest Ecology and Management 143, 13-26. 10.1016/S0378-1127(00)00501-6

Waterloo, M.J., Schellekens, J., Bruijnzeel, L.A., Rawaqa, T.T. (2007) Changes in catchment runoff after harvesting and burning of a Pinus caribaea plantation in Viti Levu, Fiji. Forest Ecology and Management 251, 31-44. 10.1016/j.foreco.2007.06.050

Webb, A.A. (2009) Streamflow response to Pinus plantation harvesting: Canobolas State forest, southeastern Australia. Hydrological Processes, 23, 1679-1689. 10.1002/hyp.7301

Webb, A.A., Kathuria, A. (2012) Response of streamflow to afforestation and thinning at Red Hill, Murray Darling Basin, Australia. Journal of Hydrology 412-413, 133-140. 10.1016/j.jhydrol.2011.05.033

Williams, C. A., et al. (2012) Climate and vegetation controls on the surface water balance: Synthesis of evapotranspiration measured across a global network of flux towers. Water Resources Research, 48. 10.1029/2011WR011586

Yao, Y., Cai, T., Wei, X., Mingfang Zhang, M., Cunyong Ju, C. (2012) Effect of forest recovery on summer streamflow in small forested watersheds, Northeastern China. Hydrological Processes, 26, 1208-1214. 10.1002/hyp.8204

Zou, C.B., Breshears, D.D., Newman, B.D., Wilcox, B.P., Gard, M.A., and Rich, P.M. (2008) Soil water dynamics under low-versus high-ponderosa pine tree density: ecohydrological functioning and restoration implications. Ecohydrology, 1, 309-315. 10.1002/eco.17

Recreation (species-based)

Angulo, E., Deves, A.L., Saint Jalmes, M., Courchamp, F. (2009) Fatal attraction: rare species in the spotlight. Proc. Roy. Soc. Lond. B 276, 1331-1337.

Arlinghaus, R. (2006) On the apparently striking disconnect between motivation and satisfaction in recreational angling: the case of catch orientation of German anglers. N. Amer. J. Fish. Manage., 26:592-605 (2006).

Arlinghaus, R., and T. Mehner. (2003) Socio-economic characterization of specialized common carp (Cyprinus carpio L.) anglers in Germany, and implications for inland fisheries management and eutrophication control. Fish. Res., 61: 19-33.

Ballantyne, R., Packer, J., & Sutherland, L. A. (2011) Visitors' memories of wildlife tourism: Implications for the design of powerful interpretive experiences. Tourism Management, 32(4), 770-779.

Booth, J.E., Gaston, K.J., Evans, K.L. & Armsworth, P.R. (2011) The value of species rarity in biodiversity recreation: a birdwatching example. Biological Conservation, 144, 2728-2732.

Bouton, S.N., Frederick, P.C., Rocha, C.D., Barbosa dos Santos, A.T., Bouton, T.C. (2005) Effects of Tourists Disturbance on Wood Stork Nesting Success and Breeding Behavior in the Brazilian Pantanal. Waterbirds, 28: 487-497.

Burger, J., M. Gochfeld, et al. (1995) Ecotourism and birds in coastal New Jersey: Contrasting responses of birds, tourists, and managers. Environmental Conservation 22(1): 56-65.

Butler JRA, Radford A, Riddington G, Laughton R. (2009) Evaluating an ecosystem service provided by Atlantic salmon, sea trout and other fish species in the river Spey, Scotland: the economic impact of recreational rod fisheries. Fisheries Research 96: 259-266.

Butler, J.R.A., Radford, A., Riddington, G., Laughton, R. (2009) Evaluating an ecosystem service provided by Atlantic salmon, sea trout and other fish species in the River Spey, Scotland: The economic impact of recreational rodfisheries. FisheriesResearch 96,259-266.

Carolina Remacha, Javier Pérez-Tris, Juan Antonio Delgado (2011) Reducing visitors group size increases the number of birds during educational activities: Implications for management of nature-based recreation. Journal of Environmental Management, Volume 92, Issue 6, June (2011), Pages 1564-1568.

Cisneros-Montemayor, A.M., Sumaila, U.R. (2010) A global estimate of benefits from ecosystem-based marine recreation: potential impacts and implications for management. Journal of Bioeconomics. 10.1007/s10818-010-9092-7

Cooke, S. J. and C. D. Suski. (2005) Do we need species-specific guidelines for catch- and-release recreational angling to conserve diverse fishery resources?. Biodiversity and Conservation 14: 1195-1209.

Croes, B.M., Funston, P.J., Rasmussen, G., Buij, R., Saleh, A., Tumenta, P.N., Iongh, H.H. (2011) The impact of trophy hunting on lions (Panthera leo) and other large carnivores in the Benuoe Complex, northern Cameroon. Biological Conservation 144: 3065-3072.

Everard M, Kataria G. (2011) Recreational angling markets to advance the conservation of a reach of the Western Ramganga River. Aquatic Conservation: Marine and Freshwater Ecosystems 21: 101-108.

Farr, Marina, Natalie Stoeckl and Rabiul Alam Beg (2014) The non-consumptive (tourism) ‘value’ of marine species in the Northern section of the Great Barrier Reef. Marine Policy 43: 89–103. http://dx.doi.org/10.1016/j.marpol.2013.05.002

Fennel, D.A. (2002) The Canadian ecotourist in Costa Rica: ten years down the road. Int. J. Sustainable development, 5(3): 282-299.

Fennell, D. A., and D. B. Weaver. (1997) Vacation Farms and Ecotourism in Saskatchewan, Canada. Journal of Rural Studies, Vol. 13, No. 4: pp. 467-475.

Gallagher, A. J. and N. Hammerschlag. (2011) Global shark currency: The distribution frequency and economic value of shark ecotourism. Current Issues in Tourism 14(8): 797-812.

Guarnieri, G., Terlizzi, A., Bevilacqua, S., Frashetti, S. (2012) Increasing heterogeneity of sensitive assemblages as a consequence of human impact in submarine caves. Marine Biology, 159: 1155-1164.

Hedblom, M., Heyman, E., Antonsson, H. and Gunnarsson, B. (2014) Bird song diversity influences young people’s appreciation of urban landscapes. Urban Forestry & Urban Greening 13:469–474. http://dx.doi.org/10.1016/j.ufug.2014.04.002

Hussain, A., Zhang, D., Armstrong, J.B. (2004) Willingness to pay for hunting leases in Alabama. Southern Journal of Applied Forestry 28 (1), 21-27.

Hvenegaard, G.T (2002) Birder Specialization Differences in Conservation Involvement, Demographics, and Motivations. Human Dimensions of Wildlife, 7; 21-36.

Isabelle D. Wolf, David B. Croft. (2012) Observation techniques that minimize impacts on wildlife and maximize visitor satisfaction in night-time tours. Tourism Management Perspectives, Volume 4, October (2012), Pages 164-175.

Ityavyar, J.A., Inah,E., Akosim, C. (2012) Assessment of captive management of Nile crocodile, Crocodylus niloticus in three towns of Benue State, Nigeria. Journal of Research in Forestry, Wildlife and Environment 3, 12-23.

KERLEY, G.I.H., GEACH, B.G.S. & VIAL, C. (2003) Jumbos or bust: do tourists’ perceptions lead to an under-appreciation of biodiversity?. South African Journal of Wildlife Research 33:13-21.

Knoche, S., Lupi, F. (2007) Valuing deer hunting ecosystem services from farm landscape. Ecol. Econ. 64, 313-320.

Koniak, G., Sheffer, E., Noy-Meir, I. (2011) Recreation as an ecosystem service in open landscapes in the Mediterranean region in Israel: Public preferences. Israel Journal of Ecology and Evolution, 57: 151-171.

Kunz, T.H., Braun de Torrez, E., Bauer, D., Lobova, T., Fleming, T.H. (2011) Ecosystem services provided by bats. Annals of the New York Academy of Sciences, 1223: 1-38.

Larsen, F.W., Petersen, A.H., Strange, N., Lund, M.P., Rahbek, C. (2008) A qualitative Analysis of Biodiversity and the Recreational Value of Potential National Parks in Denmark. Environmental Management, 41, 685-695.

Lee ,Choong-Ki, Jin-Hyung Lee , Tae-Kyun Kim & James W. Mjelde (2010) Preferences and willingness to pay for birdwatching tour and interpretive services using a choice experiment. Journal of Sustainable Tourism, 18: 695-708. DOI:10.1080/09669581003602333

Lemelin, R.H. (2007) Finding beauty in the dragon: the role of dragonflies in recreation and tourism. Journal of Ecotourism 6, 139-145.

Lewin, W. C., R. Arlinghaus, et al. (2006) Documented and potential biological impacts of recreational fishing: Insights for management and conservation. Reviews in Fisheries Science 14(4): 305-367.

Lindsey, P., Alexander, R., Balme, G., Midlane, N. & Craig, J. (2012) Possible relationships between the South African captive-bred lion hunting industry and the hunting and conservation of lions elsewhere in Africa. SA journal of wildlife research.42:11-22.

Lindsey, P., Alexander, R., Mills, M., Woodroffe, R. & Romañach, S. (2007) Wildlife viewing preferences of visitors to protected areas in South Africa: implications for the role of ecotourism in conservation. J. Ecotourism 6, 19-33.

Lindsey, P.A., Alexander, R., Frank, L. G., Mathieson, A., Romanach, S.S. (2006) Potential of trophy hunting to create incentives for wildlife conservation in Africa where alternative wildlife-based land uses may not be viable. Animal Conservation, 9: 283-291.

Luck, G.W., Davidson, P., Boxall, D. and Smallbone, L. (2011) Relations between Urban Bird and Plant Communities and Human Well-Being and Connection to Nature. Conservation Biology, 25: 816–826. DOI: 10.1111/j.1523-1739.2011.01685.x

McCarthy, J.L., McCarthy, K.P., Fuller, T.K., McCarthy, T.M. (2010) Assessing Variation in Wildlife Biodiversity in the Tien Shan Mountains of Krygzstan Using Ancillary Camera-trap Photos. Mountain Research and Development, 30 (3): 295-301.

Munn, I., Hussain, A., Hudson, D., West, C.B. (2011) Hunting Preferences and Willingness to Pay for Hunting Leases. Forest Science, 57(3): 189- 200.

Muoneke, M.I., Childress, W.M. (1994) Hooking mortality: A review for recreational fisheries. Reviews in Fisheries Science, 2(2): 123-156.

Nahuelhual, L. , Carmona, A., Lozada, P., Jaramillo, A., Aguayo, M. (2013) Mapping recreation and ecotourism as a cultural ecosystem service: An application at the local level in Southern Chile. Applied Geography, 40: 71- 82.

Nyaupane, G.P., Poudel, S. (2011) Linkages among biodiversity, livelihood, and tourism. Annals of Tourism Research, 38 (4): 1344-1366.

Okello, M.M., Manka, S.G. & D'Amour, D.E. (2008) The relative importance of large mammal species for tourism in Amboseli National Park, Kenya. Tourism Management. 29, 751-760.

Parnell, P.E., Dayton, P.K., Fisher, R.A., Loarie, C.C., Darrow, R.D. (2010) Spatial patterns of fishing effort off San Diego: implications for zonal management and ecosystem function. Ecological Applications: Manuscript accepted 18 February 2010.

Parsons, E. C. M., Warburton, C. A., Woods-Ballard, A., Hughes, A., Johnston, P., Bates, H., & Lück M. (2003) Whale-watching tourists in west Scotland. Journal of Ecotourism, 2 (2), 93-113.

Pennisi, L.A., Holland, S.M., Stein, T.V. (2004) Achieving Bat Conservation through Tourism. Journal of Ecotourism, 3 (3): 195-207.

RATZ, H. & THOMPSON, C. (1999) Who is watching whom? Checks for impacts of tourists on Yelloweyed Penguins Megadyptes antipodes. Marine Ornithology 27: 205-210.

Reynolds, P.C., Braithwaite, D. (2001) Towards a conceptual framework for wildlife tourism. Tourism Management 22: 31-42.

RHYNE, J.D., I.A. MUNN., AND A. HUSSAIN. (2009) Hedonic analysis of auctioned hunting leases: A case study of Mississippi 16th Section Lands. Hum. Dimens. Wildl. 14(4):227-239.

Ruiz-Frau, A., H. Hinz, et al. (2012) Spatially explicit economic assessment of cultural ecosystem services: Non-extractive recreational uses of the coastal environment related to marine biodiversity. Marine Policy.

Ryan, C., Hughes, K., Chirgwin, S. (2000) The gaze, spectacle and ecotourism. Annals of Tourism Research, 27:148-163.

Sarı, C., Oban, R., & Erdogan, A. (2011) Ornitho-Tourism and Antalya. Procedia-Social and Behavioral Sciences, 19, 165-172.

Scarpaci, C., Dayanthi, N., Corkeron, P.J. (2003) Compliance with Regulations by "Swim with Dolphins" Operations in Port Phillip Bay, Victoria, Australia. Environmental Management, 31 (3): 342-347.

Smallwood, C. B., L. Beckley, et al. (2006) Shore-based recreational angling in the Rottnest Island Reserve, Western Australia: Spatial and temporal distribution of catch and fishing effort. Pacific Conservation Biology 12(3): 238-251.

Stockin, K.A., Lusseau, D., Binedell, V., Wiseman, N., Orams, M.B. (2008) Tourism affects the behavioural budget of the common dophin Delphinus sp. In the Hauraki Gulf, New Zealand. Marine Ecology Progress Series, 355, 287-295.

Tisdell, C., Wilson, C. (2001) Sea Turtles as non-consumptive tourism resource in Australia. Toursim Management, 22: 279-288.

Uyarra, M., Cote, I., Gill, J., Tinch, R., Viner, D. and Watkinson, A. (2005) Island-specific preferences of tourists for environmental features: implications of climate change for tourism-dependent states. Environmental Conservation 32 (1): 11–19. doi:10.1017/S0376892904001808

Uyarra, M.C., Côté, I.M. (2007) The quest for cryptic creatures: impacts of species focused recreational diving on corals. Biological Conservation 136, 77-84.

Yee, S.H., Dittmar, J.A., Oliver, L.M. (2014) Comparison of methods for quantifying reef ecosystem services: A case study mapping services for St. Croix, USVI. Ecosystem Services.

Zhang, J.T., Xiang C., Min, L. (2012) Effects of Tourism and Topography on Vegetation Diversity in the Subalpine Meadows of the Dongling Mountains of Beijing, China. Environmental Management, 49: 403-411.

Zivin, J., Hueth, B.M., Zilberman, D. (2000) Managing a Multiple-Use Resource: The case of Feral Pig Management in California Rangeland. Journal of Environmental Economics and Management, 39: 189-204.

Aesthetic landscapes

A. Kaplan, T. Taskın and A. Önenc (2006) Assessing the visual quality of rural and urban-fringed landscapes surrounding livestock farms. Biosystems engineering, 95(3), 437-448. 10.1016/j.biosystemseng.2006.07.011

Á. Ní Dhubháin, M.-C. Fléchard, R. Moloney and D. O'Connor (2009) Stakeholders' perceptions of forestry in rural areas - Two case studies in Ireland. Land Use Policy. 26: 695-703. 10.1016/j.landusepol.2008.09.003

A. Ruiz-Frau, H.Hinz, G.Edwards-Jones & M.J.Kaiser (2013) Spatially explicit economic assessment of cultural ecosystem services: Non-extractive recreational uses of the coastal environment related to marine biodiversity. Marine Policy 38: 90–98. 10.1016/j.marpol.2012.05.023

A.E. Buijs, B.H.M. Elands and F. Langers (2009) No wilderness for immigrants: Cultural differences in images of nature and landscape preferences. Landscape and Urban Planning. 91: 113-123. 10.1016/j.landurbplan.2008.12.003

A.E. Van den Berg and S.L. Koole (2006) New wilderness in the Netherlands: An investigation of visual preferences for nature development landscapes. Landscape and Urban Planning. 78: 362-372. 10.1016/j.landurbplan.2005.11.006

A.E. van den Berg, C.A.J. Vlek and J.F. Coeterier (1998) Group differences in the aesthetic evaluation of nature development plans: a multilevel approach. Journal of Environmental Psychology. 18: 141-157.

A.J. Thorn, R.C. Daniel, B. Orland and N. Brabyn (1997) Managing forest aesthetics in production forests. New Zealand Forestry. 42: 21-29.

C. Acar and C. Sakıcı (2008) Assessing landscape perception of urban rocky habitats. Building and Environment. 43: 1153-1170. 10.1016/j.buildenv.2006.02.026

C.-F. Lee, H.-I Huang and H.-R. Yeh (2010) Developing an evaluation model for destination attractiveness: sustainable forest recreation tourism in Taiwan. Journal of Sustainable Tourism, 07/2010; 18:811-828. 10.1080/09669581003690478

D. Oğuz, E. D. Diriöz and N. Belkayalı (2010) Tourists' perception of landscape design: The case of resorts in the Belek Specially Protected Area. African Journal of Agricultural Research. 5(10): 1028-1035. 10.5897/AJAR09.106

D.D. Huppert, R.L. Johnson, J. Leahy and K. Bell (2003) Interactions between human communities and estuaries in the Pacific Northwest: trends and implications for management. Estuaries. 26(4B): 994-1009.

Derek B. van Berkel & Peter H. Verburg (2014) Spatial quantification and valuation of cultural ecosystem services in anagricultural landscape. Ecological Indicators 37: 163– 174. 10.1016/j.ecolind.2012.06.025

E. Heyman (2012) Analysing recreational values and management effects in an urban forest with the visitor-employed photography method. Urban Forestry & Urban Greening. 11: 267-277. 10.1016/j.ufug.2012.02.003

Eszter Kelemen, Geneviève Nguyen, Tiziano Gomiero, Eszter Kovács, Jean-Philippe Choisis, Norma Choisis, Maurizio G. Paoletti, László Podmaniczky, Julie Ryschawy, Jean-Pierre Sarthou, Felix Herzog, Peter Dennis, Katalin Balázs (2013) Farmers' perceptions of biodiversity: Lessons from a discourse-baseddeliberative valuation study. Land Use Policy 35: 318– 328. 10.1016/j.landusepol.2013.06.005

F. Kienast, B. Degenhardt, B. Weilenmann, Y. Wäger and M. Buchecker (2012) GIS-assisted mapping of landscape suitability for nearby recreation. Landscape and Urban Planning. 105: 385-399. 10.1016/j.landurbplan.2012.01.015

I. de Aranzabal, M.F. Schmitz and F.D. Pineda (2009) Integrating Landscape Analysis and Planning: A Multi-Scale Approach for Oriented Management of Tourist Recreation. Environmental Management. 44: 938-951. 10.1007/s00267-009-9371-z

I. Liekens, M. Schaafsma, L. De Nocker, S. Broekx, J. Staes, J. Aertsens & R. Brouwer (2013) Developing a value function for nature development and land use policy in Flanders, Belgium. Land Use Policy 30: 549–559. 10.1016/j.landusepol.2012.04.008

J. Black, E.J. Milner-Gulland, N. Sotherton and S. Mourato (2010) Valuing complex environmental goods: landscape and biodiversity in the North Pennines. Environmental Conservation. 37(2): 136-146. 10.1017/S0376892910000597

J. Gómez-Limón and J.V. de Lucío Fernández (1999) Changes in use and landscape preferences on the agricultural-livestock landscapes of the central Iberian Peninsula (Madrid, Spain). Landscape and Urban Planning. 44: 165-175.

J. MIKULEC and M. ANTOUŠKOVÁ (2011) Landscape and tourism potential in the protected landscape areas. Agric. Econ. - Czech. 57 (6): 272-278.

Jason Kreitler, Michael Papenfus, Kristin Byrd and William Labiosa (2013) Interacting Coastal Based Ecosystem Services: Recreation and Water Quality in Puget Sound, WA. PLoS ONE 8(2): e56670. 10.1371/journal.pone.0056670

Koo Ja-Choon, Park Mi Sun and Youn Yeo-Chang (2013) Preferences of urban dwellers on urban forest recreational services in South Korea. Urban Forestry & Urban Greening 12: 200– 210. 10.1016/j.ufug.2013.02.005

Ling Qiu, Stefan Lindberg & Anders Busse Nielsen (2013) Is biodiversity attractive?—On-site perception of recreational and biodiversity values in urban green space. Landscape and Urban Planning 119: 136– 146. 10.1016/j.landurbplan.2013.07.007

M. Czajkowski, A. Bartczak, M. Giergiczny, S. Navrud, T. Żylicz (2014) Providing preference-based support for forest ecosystem service management. Forest Policy and Economics 39: 1–12. 10.1016/j.forpol.2013.11.002

M. García-Llorente, B. Martín-López, I. Iniesta-Arandia et al. (2012) The role of multi-functionality in social preferences toward semi-arid rural landscapes: An ecosystem service approach. Environmental Science & Policy. 19-20: 136-146. 10.1016/j.envsci.2012.01.006

M. Hofmann, J.R. Westermann, I. Kowarik and E. van der Meer (2012) Perceptions of parks and urban derelict land by landscape planners and residents. Urban Forestry & Urban Greening. 11: 303-312. 10.1016/j.ufug.2012.04.001

M.F. Schmitz, I. De Aranzabal and R.D. Pineda (2007) Spatial analysis of visitor preferences in the outdoor recreational niche of Mediterranean cultural landscapes. Environmental Conservation. 34 (4): 300-312. 10.1017/S0376892907004249

M.L. Cocks, T. Dold and S. Vetter (2012) ‘God is my forest’ - Xhosa cultural values provide untapped opportunities for conservation. South African Journal of Science. 108(5/6) Art. #880, 8 pages. 10.4102/sajs.v108i5/6.880

M.S. Tveit (2009) Indicators of visual scale as predictors of landscape preference; a comparison between groups. Journal of Environmental Management. 90: 2882-2888. 10.1016/j.jenvman.2007.12.021

N. Püschel-Hoeneisen and J.A. Simonetti (2012) Forested habitat preferences by Chilean citizens: Implications for biodiversity conservation in Pinus radiata plantations. Revista Chilena de Historia Natural. 85: 161-169.

P. Holgén, L. Mattsson and C.-Z. Li (2000) Recreation values of boreal forest stand types and landscapes resulting from different silvicultural systems: an economic analysis. Journal of Environmental Management. 60: 173-180. 10.1006/jema.2000.0377

P. Horne, P.C. Boxall and W.L. Adamowicz (2005) Multiple-use management of forest recreation sites: a spatially explicit choice experiment. Forest Ecology and Management. 207: 189-199.

P. Howley, C.O. Donoghue and S. Hynes (2012) Exploring public preferences for traditional farming landscapes. Landscape and Urban Planning. 104: 66-74. 10.1016/j.landurbplan.2011.09.006

P. Lindemann-Matthies, R. Briegel, B. Schüpbach and X. Junge (2010) Aesthetic preference for a Swiss alpine landscape: The impact of different agricultural land-use with different biodiversity. Landscape and Urban Planning. 98: 99-109. 10.1016/j.biocon.2009.10.003

P.H. Gobster (2002) Managing urban parks for a racially and ethnically diverse clientele. Leisure Sciences. 24: 143-159.

Peter W. Schuhmann, James F. Casey, Julia A. Horrocks & Hazel A. Oxenford (2013) Recreational SCUBA divers’ willingness to pay for marine biodiversity in Barbados. Journal of Environmental Management 121: 29-36. 10.1016/j.jenvman.2013.02.019

R. Kaplan (2007) Employees’ reactions to nearby nature at their workplace: The wild and the tame. Landscape and Urban Planning. 82: 17-24. 10.1016/j.landurbplan.2007.01.012

R. Kaplan and J.F. Talbot (1988) Ethnicity and preference for natural setting: A review and recent findings. Landscape and Urban Planning. 15: 107-117.

R. Kaplan and M.E. Austin (2004) Out in the country: sprawl and the quest for nature nearby. Landscape and urban planning. 69: 235-243. 10.1016/j.landurbplan.2003.09.006

R.G. Ribe (2006) Perceptions of forestry alternatives in the US Pacific Northwest: Information effects and acceptability distribution analysis. Journal of Environmental Psychology. 26: 100-115. 10.1016/j.jenvp.2006.05.004

R.G. Ribe (2009) In-stand scenic beauty of variable retention harvests and mature forests in the U.S. Pacific Northwest: The effects of basal area, density, retention pattern and down wood. Journal of Environmental Management. 91: 245-260. 10.1016/j.jenvman.2009.08.014

R.P.H. Snep, E.C. van Ierland and P. Opdam (2009) Enhancing biodiversity at business sites: What are the options, and which of these do stakeholders prefer?. Landscape and Urban Planning. 91: 26-35. 10.1016/j.landurbplan.2008.11.007

S. Marzetti, M. Disegna, G. Villani and M. Speranza (2011) Conservation and recreational values from semi-natural grasslands for visitors to two Italian parks. Journal of Environmental Planning and Management. 54 (2): 169-191. 10.1080/09640568.2010.505792

S. Oreszczyn and A. Lane (2000) The meaning of hedgerows in the English landscape: Different stakeholder perspectives and the implications for future hedge management. Journal of Environmental Management. 59: 00-00. 10.1006/jema.2000.0365

S.-C. L. Huang (2013) Visitor responses to the changing character of the visual landscape as an agrarian area becomes a tourist destination: Yilan County, Taiwan. Journal of Sustainable Tourism. 21(1): 154-171. 10.1080/09669582.2012.687739

S.R. Swaffield and R.J. Foster (2000) Community perceptions of landscape values in the South Island high country. A literature review of current knowledge and evaluation of survey methods. Publisher: Department of Conservation, Wellington. 53p.

S.R. Swaffield and R.J. Foster (2000) Community perceptions of landscape values in the South Island high country. A literature review of current knowledge and evaluation of survey methods. Publisher: Department of Conservation, Wellington. 53p.

S.R. Swaffield and R.J. Foster (2000) Community perceptions of landscape values in the South Island high country. A literature review of current knowledge and evaluation of survey methods. Publisher: Department of Conservation, Wellington. 53p.

S.R. Swaffield and R.J. Foster (2000) Community perceptions of landscape values in the South Island high country. A literature review of current knowledge and evaluation of survey methods. Publisher: Department of Conservation, Wellington. 53p.

S.R. Swaffield and R.J. Foster (2000) Community perceptions of landscape values in the South Island high country. A literature review of current knowledge and evaluation of survey methods. Publisher: Department of Conservation, Wellington. 53p.

T. A. Becerra, D. M. Engle, R. Dwayne Elmore and S. D. Fuhlendorf (2013) Contrasting Preference for Grassland Landscapes Among Population Groups in the Central and Southern Great Plains. Rangeland Ecol Manage 66:529–538. 10.2111/REM-D-12-00174.1

T. Bowman, J.C. Tyndall, J. Thompson, J. Kliebenstein and J.P. Colletti (2012) Multiple approaches to valuation of conservation design and low-impact development features in residential subdivisions. Journal of Environmental Management. 104: 101-113. 10.1016/j.jenvman.2012.02.006

T. Bowman, J.C. Tyndall, J. Thompson, J. Kliebenstein and J.P. Colletti (2012) Multiple approaches to valuation of conservation design and low-impact development features in residential subdivisions. Journal of Environmental Management. 104: 101-113. 10.1016/j.jenvman.2012.02.006

T. Pinto-Correia, F. Barroso, D. Surová and H. Menezes (2011) The fuzziness of Montado landscapes: progress in assessing user preferences through photo-based surveys. Agroforest Syst. 82: 209-224. 10.1007/s10457-010-9347-2

T.C. Brown and T.C. Daniel (1986) Predicting scenic beauty of timber stands. Forest Science. 32(2): 471-487.

T.C. Daniel, A. Muhar, A. Arnberger, O. Aznar, J.W. Boyd, K.M.A. Chan, R. Costanza, T. Elmqvist, C.G. Flint, P.H. Gobster, A. Grêt-Regamey, R. Lave, et al. (2012) Contributions of cultural services to the ecosystem services agenda. PNAS. 109: 8812-8819. 10.1073/pnas.1114773109

W.E. Dramstad, M. Sundli Tveit, W.J. Fjellstad and G.L.A. Fry (2006) Relationships between visual landscape preferences and map-based indicators of landscape structure. Landscape and Urban Planning. 76: 465-474. 10.1016/j.landurbplan.2005.12.006

W.L. Hadwen, P.I. Boon and A.H. Arthington (2012) Aquatic ecosystems in inland Australia: tourism and recreational significance, ecological impacts and imperatives for management. Marine and Freshwater Research. 63: 325-340.

Y. Natori and R. Chenoweth (2008) Differences in rural landscape perceptions and preferences between farmers and naturalists. Journal of Environmental Psychology. 28: 250-267. 10.1016/j.jenvp.2008.02.002

Y. Yao, X. Zhu, Y. Xu, H. Yang, X. Wu, Y. Li and Y. Zhang (2012) Assessing the visual quality of green landscaping in rural residential areas: the case of Changzhou. China. Environ Monit Assess. 184: 951-967. 10.1007/s10661-011-2012-z