Planning for green infrastructure:

Analysing the suitability of scientific knowledge on pollination services for collaborative planning processes



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Abstract

The aim of this paper is to evaluate the extent to which available scientific studies provide suitable knowledge on pollination services that can be applied into collaborative planning processes. Pollination services are provided by foraging organisms that depend on the spatial distribution of suitable habitat areas, resources and the locations where the pollination services are provided. The management of pollination services requires consideration of 3 interconnected components that are also incorporated into the concept of the structure-function-value chain: spatially explicit landscape structures, level of ecosystem function, and the resulting pollination value. Relevant scientific studies are evaluated from a collaborative planning perspective, including the three components of the structure-function-value chain. To guide this process, 5 evaluation criteria are used: (1) structure-function component (2) function-value component (3) nature of scientific information (4) level of spatial scale (5) applicability. Furthermore, the scientific literature is divided into two categories: disciplinary and interdisciplinary literature. An evaluative case study is used to determine the applicability of the gathered studies and what kind of scientific knowledge is still missing. The results indicate that disciplinary studies generate very specific knowledge that cannot be applied to various contexts. On the other hand, these results can be gathered and synthesized into suitable general frameworks that can be used in collaborative planning processes. Lastly, by placing the structure-function-value chain in both practical and theoretical contexts, knowledge gaps and research priorities can be determined, contributing to the further integration of pollination services into collaborative planning processes.

1. Introduction

The focus of this research will be briefly discussed in this chapter, including the background of the problem, followed by the problem description, research objective, focus of the research and summary.

1.1 Background of the problem

Throughout history, human needs have been, and continue to be, supported by nature through ecosystem services. Ecosystem services are a set of ecosystem functions that are useful to humans, many of which are critical to our survival. Examples of such services are natural pest control, carbon sequestration, pollination, air purification, climate regulation and water supply (Kremen et al., 2005). Human domination has rapidly altered the structure, composition and function of ecosystems so that the capacity of these systems to provide services has been eroded (Kremen et al, 2005). Several studies have demonstrated the functional relationship between biodiversity and the provision of ecosystem services, which includes reliability and the effectiveness of ecosystem services (Worm et al., 2006 ; Balvanera et al., 2006). The degree of loss of biodiversity is directly related to different land use intensities and land use change. Biodiversity is declining a thousand times faster than rates that were derived from the fossil record. (De Groot et al., 2010). This has raised concerns about the loss of such for ecosystem functioning and human well-being. Initially, such concerns were limited to the science community. However, with the publication of the Millennium Assessment these concerns have moved beyond the science community to the stakeholder community (Worm, et al., 2006). Investments in sustainable ecosystems are increasingly seen as a win-win situation for both the environment and society because sustainable and diverse ecosystems generate considerable economic, social and ecological benefits (De Groot et al., 2010). There is also an increasing consensus that global climate change is likely to have considerable consequences for the functioning of ecosystems. Management of ecosystem services is included in the array of possible human responses to climate change. (Harris Et Al., 2006). The concept of ecosystem services could therefore provide a relevant framework for sustainable landscape development and management.

1.2 Problem description

Despite the growing amount of scientific literature on ecosystem services and the evident socio-economic and ecological benefits, still many challenges remain regarding the structural integration of knowledge on ecosystem services into spatial planning practice. (De Groot et al., 2010) These challenges constitute of the implementation of spatial structures that support ecological processes and level of biodiversity into landscapes. As was stated previously, the level of ecosystem functioning and biodiversity influences the effectiveness and reliability of the provisioning of ecosystem services. The process of linking spatial structures to the level of biodiversity and the reliability and effectiveness of the provisioning of ecosystem services can be visualized as a structure-function-value chain (see figure 1 below). Note that spatial structures, level of biodiversity and reliability and effectiveness of ecosystems services correspond to ‘structure’, ‘function’ and ‘value’.

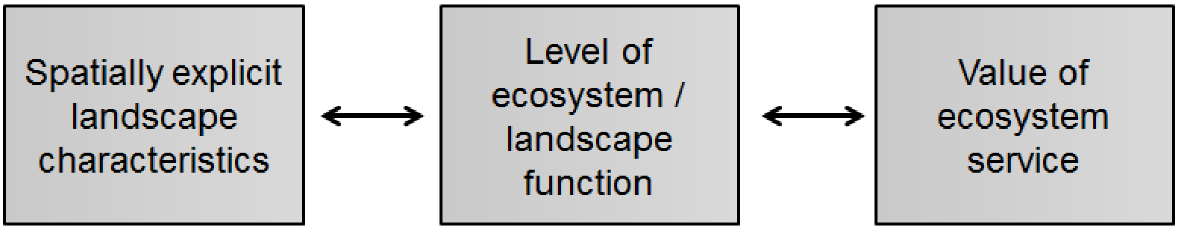

Figure 1: Visualisation of the structure-function-value chain (modified after: Termorshuizen & Opdam, 2009)

The first component of the chain, or ‘structure’, includes spatially explicit elements as part of a spatial concept that promote functioning of ecosystems and a higher level of biodiversity. However, there has been a limited development of spatial concepts that successfully promote this process (Opdam & Steingröver, 2008). Ecological networks are an example of spatial concept which can potentially support these processes. Ecological networks can be described as heterogeneous networks in which different functions, e.g. food production or housing, are connected and intertwined by a network of (semi) natural longitudinal and small-patch shaped elements (Opdam, 2013). The spatial configuration of ecological networks influences functioning of ecosystems and the level of biodiversity, which influences the effectiveness and reliability of the provisioning of ecosystem services. Therefore, incorporating ecological networks into the spatial-function-value chain may provide a relevant framework for the integration of ecosystem services into spatial planning practice.

The integration of the structure-function-value chain into spatial planning practice has proved difficult because of several reasons. One of the major reasons regards the recent changes in the decision-making context of planning processes. State-led planning is giving way to governance models. Hence, decision-making in landscapes involves various groups of actors on local, regional higher geographical scales. This poses an unstructured problem to scientists and practitioners as the context in which spatial planning processes become increasingly complex and dynamic. This recent trend in spatial planning is often credited as ‘collaborative planning’ and denotes the increasing involvement of various stakeholders in the planning process (Termorshuizen & Opdam, 2009). Moreover, there is a discrepancy between ecological processes and relevant spatial patterns as it is difficult for ecologist to formulate guidelines that include a wide variety of species traits (biodiversity) and the range of spatial scale at which these ecological features interact. On the contrary, spatial planners tend to focus on ecologically- relevant spatial patterns instead (Opdam & Steingröver 2008). Consequently, formulating the components of the structure-function-value chain on the basis of scientific knowledge is not a straightforward process as discrepancies between ecological processes and relevant spatial patterns still exist. The components of the structure-function-value chain are not as connected in practice as theory may suggest. Hence, the question remains what kind of relationship exists between the three components of the structure-function-value chain and to what extent this scientific knowledge is suitable for collaborative planning practice.

It is beyond the scope of this thesis to explore the structure-function-value for all possible types of ecosystem services which ranges from provisioning, cultural, supporting and regulating services, including specific ecosystem services in each category (Kremen et al., 2007). Therefore, emphasis is placed on one particular type of regulating services: pollination services. Pollination is a service that is provide by animal pollinators such as bees (both feral and domesticated), birds and small mammals (Ricketts et al., 2008). Animal pollination plays a role in food production as this type of ecosystem services is critically important to human needs (health, wellness) due to the large number of crop species, 75% to be more precise, that rely on animal pollinators to produce seeds, fruits (either partially or completely) and essential nutrients. It is estimated that pollination services worldwide are valued at €153 billion per year, which is approximately $216 billion per year. That is 9.5% of the annual global crop value (Chaplin et al. 2011).

For centuries, farmers have imported colonies of European honey bees (Apis mellifera) for pollination services in orchards and fields. Consequently, we have been dependent entirely on the European honey bee, which is a generalist pollinator, to support the bulk of agricultural pollination (Meffe, 1998). However, there has been a significant decline in managed honey bee populations in the last few decades (Shuler et al., 2005). A number of studies have demonstrated that agricultural intensification and other factors such as increased pesticide use and environmental change, jeopardized bee communities and their ability to provide pollination services (Klein et al. 2007 ;Rickett et al. 2008). These declines in managed honey bee populations have raised interest in the potential of other wild animal pollinators to provide pollinator services (Shuler et al, 2005). Some studies have found that diversity among bees, both domesticated and feral, is essential for sustaining the service as there is year-to-year variation in community composition and weather conditions, which strongly refers to the ‘value’ component of the chain (Kremen et al., 2002). Furthermore, conservation and restoration of bee habitat provide potentially viable win-win situations for both conservationists, developers and agricultural entrepreneurs (Kremen Et Al., 2002).

Therefore, expanding upon the structure-function-value chain as an applicable concept for the further implementation of pollination services into the landscape remains a relevant scientific and societal challenge. The question arises to what extent the available scientific literature offers suitable information on the structure-function-value chain concerning pollination services

1.3 Research objective

Following from the previous sections, the objective of this research is to bridge the gap between scientific knowledge and collaborative planning practice by investigating to what extent scientific literature offers suitable knowledge on the relationships between the components of the structure-function-value chain regarding pollination services for collaborative planning practice.

1.4 Research questions

Following from the problem description and research objective, general and specific research questions can be formulated:

General research question:

- *To what extent provide available scientific studies suitable knowledge on the relationships between the components of the structure-function-value chain regarding pollination services for collaborative planning practice?*

In order to answer the general research question, four specific research questions are posed.

Specific research questions:

1. *What is the relationship between spatial configuration of ecological networks and the level of biodiversity of animal pollinators?*

2. *What is the relationship between the level of biodiversity of animal pollinators and the effectiveness and reliability of pollination services?*

3. *To what extent is this scientific knowledge (specific research question1+2) suitable for collaborative planning practice?*

The first specific research question refers to the relationship between spatial configuration of ecological networks and biodiversity, which corresponds to the ‘structure’ and ‘function’ components of the structure-function-value chain. The second research question includes the relationship between the ‘function’ and ‘value’ components, namely the relationship between the level of biodiversity and effectiveness and reliability of pollination services. Lastly, the third question regards the extent to which the whole structure-function-value chain) is covered.

1.5 Summary of contents

In this section, a brief overview of the contents will be provided. This research has a descriptive and explorative nature. Therefore, secondary sources such as scientific literature, papers, books, news articles, websites, maps and other written or visual material will be used. After a quick scan of relevant scientific literature, a conceptual framework will be constructed. Then, two data collection methods will be employed in order to answer the sub-research questions: (1) a scientific literature review and (2) evaluative case study i.e. the case study is used as a framework to evaluate the results from the scientific literature review. Lastly, the results from the scientific literature review and case study will be synthesized into a final discussion.

2.Conceptual framework

This conceptual framework, based on a preliminary literature review, constitutes of two categories: definitions of relevant concepts and core concepts. The former refers to broad concepts that are relevant to the general research question, but require further specification in order to avoid ambiguity in the following chapters. The latter category includes essential scientific concepts that form the basis for scoping relevant information from scientific literature in order to answer the research questions.

2.1 Conceptual framework: definitions of relevant concepts

Ecosystem services

Ecosystem services can be described as a set of ecosystem functions that can be valued by humans, many of which are critical to our survival (Kremen et al., 2005). The concept of ecosystem services appeared in the scientific literature around the 1970's but with the publication of the Millenium Ecosystem Assessment report the concept gained momentum from the 1990s onwards. Since then, efforts to operationalize the concept have increased significantly. In the Millennium Ecosystem Assessment report, a distinction is made between provisioning, regulating, cultural and supporting ecosystem services (de Groot et al., 2010). This research will focus on regulating services. A considerable amount of synonymous terms for ecosystem services is used in scientific literature. For example, landscape services or environmental services. These terms have in common that the services provided by nature are the result of a connection between physical systems (ecosystems or landscapes) and human values i.e. landscape or ecosystem functioning can be translated into ecosystem services when these functions are valued by humans. In this research, the term of ecosystem services will henceforth be used in order to avoid confusion.

Sustainable landscape development

Sustainable landscape development is widely accepted as a strategic framework for land-use planning. To achieve sustainable development when making land-use decisions, several conditions need to be met. Landscape development must achieve a condition of stability in both social and physical systems by accommodating the needs of the present generations without compromising the ability of future generations to meet their needs. This notion implies the need of a land-use planner to consider long-term ecological, social and economic functions to ensure the conservation of essential resources of prime importance to future generations. Hence, a requirement of sustainable landscapes is that, even over longer periods of time, the potential of landscapes to deliver ecosystem services and values to present and future generation remains intact (Opdam & Steingröver, 2008). Therefore, the requirements of sustainable landscape development can guide the integration of the structure-function-value chain into practices of land-use planning practice.

Biodiversity

Biodiversity plays a considerable role in the functioning of ecosystems and provisioning of ecosystem services. Beside the major role the biodiversity components plays in interactions between the different components of ecosystems, biodiversity can be a final ecosystem service itself: a good for conservation, human health and recreation purposes or a regulator of fundamental ecosystem processes that promote the effectiveness and reliability of ecosystem services (Mace et al., 2012). Despite being mentioned regularly in the available scientific literature on ecosystem services, biodiversity remains an obscure concept. Many people have associations with species variety as a fundamental unit of biodiversity. This corresponds to the definition of biodiversity as proposed by Magurran, in which biodiversity is defined as *'the variety and abundance of species in a defined unit of study'* (Magurran, 2004). This term can be applied to diversity of animal pollinators that provide pollination services.

Ecological networks

Ecological networks can be defined as heterogeneous networks in the landscape in which different functions are connected and intertwined by a network of (semi) natural longitudinal and small-patch shaped elements that support ecosystem functioning (Opdam, 2013). Thus, ecological networks strongly refer to the 'structure' component of the chain. In the literature, similar terms for ecological networks are mentioned e.g. greenways. As opposed to ecological networks, greenways contain exclusively linear elements (Opdam et al., 2008). To avoid ambiguity, heterogeneous networks that support ecosystem services are hereafter referred to as ecological networks. In the next paragraphs, the key roles and the key features of ecological networks will be discussed.

Under the definition of sustainable landscape development, disappearance of a species is only acceptable when that particular species can re-colonise the region when flexibility in landscape structures allow that. This is an implication for ecological networks as these networks may be ecologically unsustainable at a local scale, but sustainable at higher spatial scales as a result of re-colonisation. If such re-colonisations are more frequent compared to local extinction rates, the ecological network allows population processes to be resilient enough to withstand environmental perturbations, stochastic demographic processes and climate change. (see figure 2 below) (Opdam et al., 2008). As figure 4 may imply, ecological networks need to include spatial features to serve as robust conservation networks that support essential processes of ecosystem services. These spatial features will be discussed in the next paragraph.

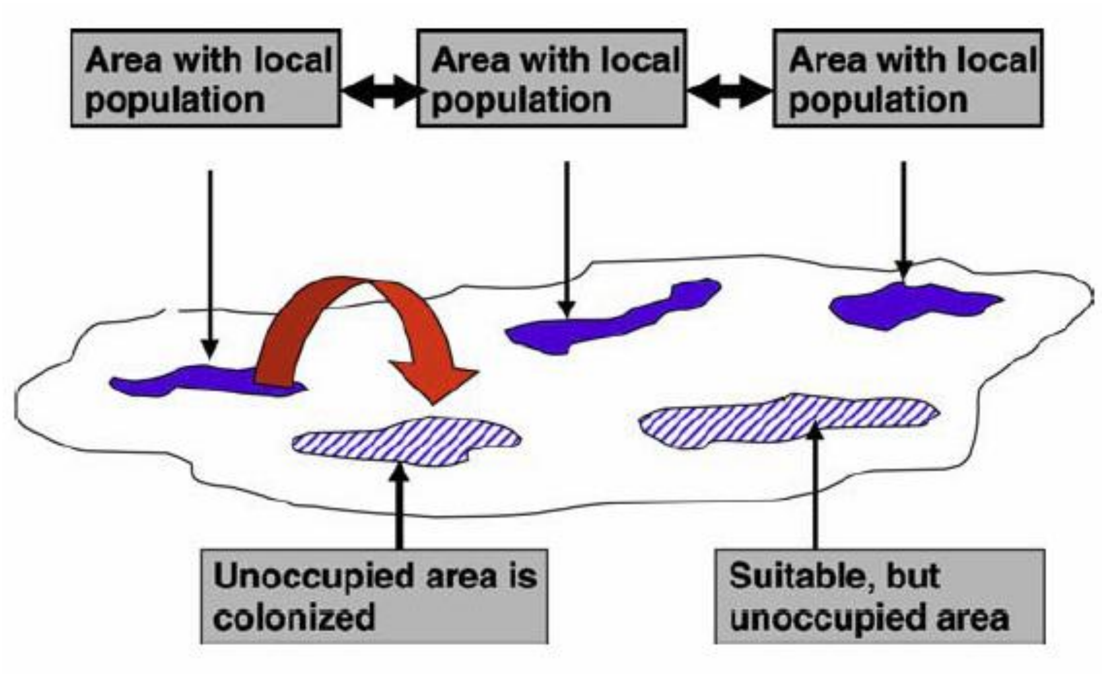

Figure 2: Visualization of re-colonisation processes in ecological networks (Source: Termorshuizen & Opdam, 2009)

Ecological networks can have different shapes and sizes, but can be characterized by four basic spatial features: network density, total network area, quality of network patches and permeability of the network matrix. These features promote spatial coherence of ecological networks within the landscape. The realised pattern of an ecological network is influenced by the characteristics of the planning area, as well as the desired level of biodiversity. Figure 3 shows a 'spatial cohesion generator', in which each key feature of ecological networks is represented by a knob. Additionally, a key patch lever (on the upper right of the figure) indicates the absence or presence of a key patch. By turning each knob according to the characteristics of the planning area and desired level of biodiversity, the four components of the spatial cohesion generator interact to generate a set of sustainable alternatives, introducing flexibility into the planning process. However, generating a series of alternative ecosystem patterns efficiently requires a reference guide for using the cohesion generator e.g. which knob to turn first. This implies the need to an iterative learning process of implementing and evaluating different practical solutions. (Opdam et al., 2008). Hence, the spatial generator can be used to generate alternative spatial configurations of ecological networks, aiding the collaborative planning process.

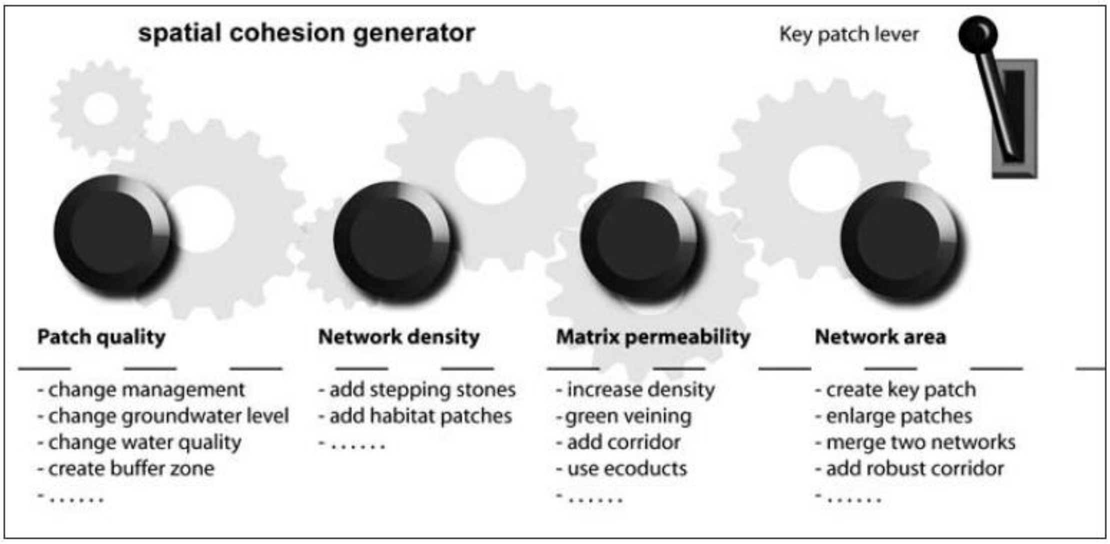

Figure 3: the relationship between the four characteristics of ecological networks and possible corresponding measures in the planning area (Opdam et al. 2008)

2.2 Conceptual framework: core concepts

2.2.1 The structure – function – value chain

The functioning of landscapes is the result of the interaction between physical structures in the landscape, which form the basis for human use and natural processes. In this view, landscapes are human-ecological systems that provide deliver a wide range of ecosystem services that can be valued by humans because of ecological, economic or social reasons (Termorshuizen & Opdam, 2009). The structure-function-value chain connects spatially explicit landscape characteristics to the level of biodiversity, in this case diversity of animal pollinators, which in turn influences the usefulness (effectiveness and reliability) of ecosystem services to humans (see figure 4 below).

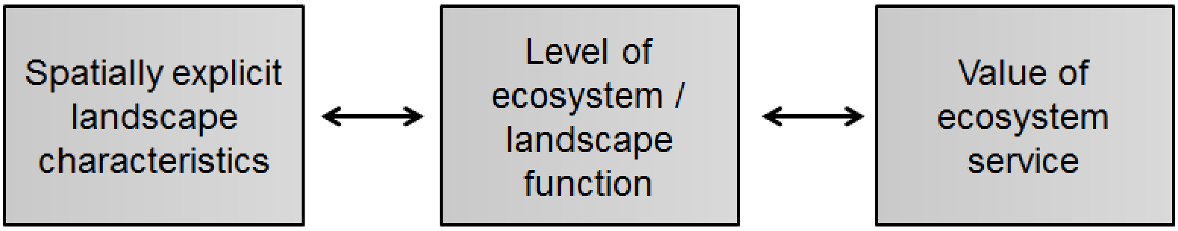

Figure 4: Visualisation of the structure-function-value chain (modified after: Opdam & Termorshuizen, 2009)

As was stated in the problem definition, there exists a discrepancy between different disciplines. As a result, the whole structure-function-value chain is hardly ever investigated. For example: the structure-function part may include ecological or geographical knowledge, while the function-value part may be the domain of economics and sociology. This implies that for each part of the structure-function-value chain, quite a lot of information on bits and pieces, obtained in different landscapes and on varying levels of geographical scale, are scattered throughout the literature. It can therefore be said that the structure-function-value chain is an overarching concept that facilitates scientists from various disciplines to coordinate their research towards the production of more integrated knowledge that is suitable for trans-disciplinary and sustainable landscape development (Termorshuizen & Opdam 2009). The structure-function-value chain can be modified by linking the network characteristics and spatial patterns of ecological networks to the 'structure' component of the chain (Termorshuizen & Opdam, 2009). Additionally, by narrowing down ecosystem services to pollination services, the structure-function-value chain can be visually represented as follows (see figure 5 below)

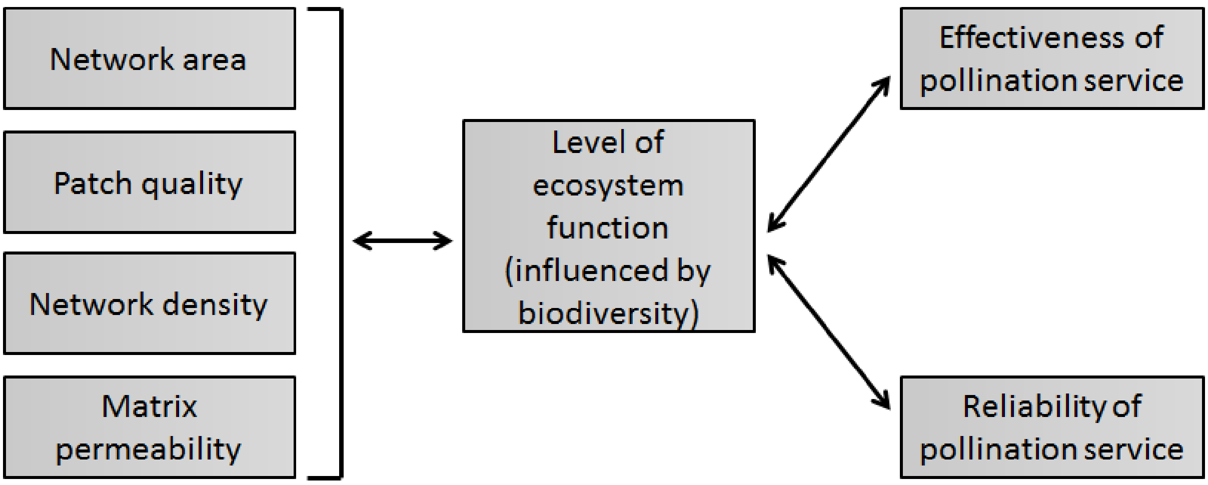

Figure 5: More specific structure-function-value chain that is synthesised with the concept of ecological networks (modified after Termorshuizen & Opdam, 2009)

In figure 5, the 'structure' component consists of the four basic features of ecological networks: network area, patch quality, network density and matrix permeability. The third component of the chain, or 'value' is expressed by the terms 'effectiveness of pollination service' and 'reliability of pollination service'. It is beyond the scope of this article to investigate various methods to measure and value the effectiveness of pollination services to humans, mainly because this would require considerable research as there is no scientific consensus on this issue yet (Winfree et al., 2011). Instead, this research focuses on the relationship between the configuration of landscape elements, the level of biodiversity and the provisioning of pollination services.

2.2.2 Collaborative planning and the structure-function-value chain

Land-use planning practice has changed considerably over the last decades. Recent developments in spatial planning have indicated that state-led planning is giving way to collaborative planning, which involves a more diverse group (local) stakeholders. The aim of local actors is to change the landscape in order to obtain added value that corresponds to their beneficiaries (Steingröver et al,. 2010; Termorshuizen & Opdam, 2009) In this perspective, the landscape is a result from the enduring interaction between humanity and the biophysical system. Humans have been adjusting landscapes for better performance e.g. increased provisioning of ecosystem services. The interdependency between the biophysical system and humans is two-way; use and valuation: humans value the landscape for its benefits and its potential to deliver useful services and secondly, this valuation by humans leads to intentional sustainable landscape change. Humans intervene in the biophysical system, directed toward improved benefits and provisioning of ecosystem services (Opdam, 2013). Hence, social processes play a significant role in how landscapes are changed for human benefit.

To explore how the structure-function-value chain (see figure 3) could facilitate collaborative planning processes, a conceptual framework needs to be designed. The concept of social-ecological landscape has the potential to serve as such a framework (see figure 4). Biophysical landscape processes, as indicated on the left of the figure, can be valued from

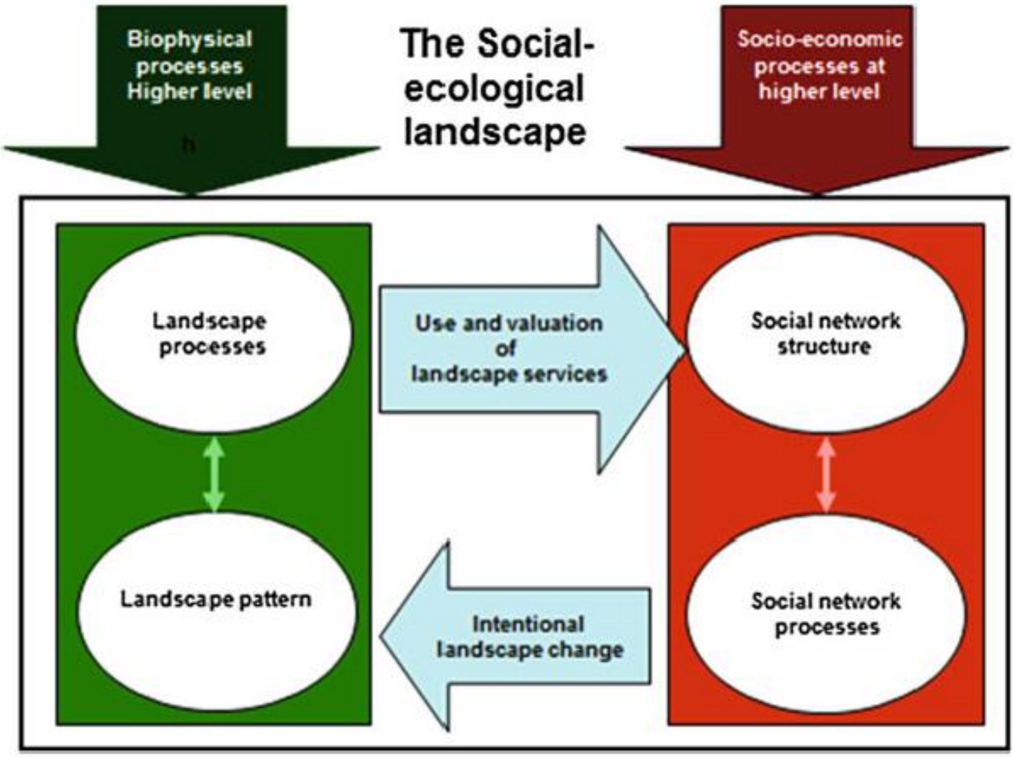

Figure 6: Schematic representation of the social-ecological landscape, consisting of a biophysical and socio-economic component, each including a spatial structure- process relationship (Source Opdam, 2013).

an individual or a common perspective. For example, hedgerows can potentially increase animal pollination, generating benefits for individual farmers. Additionally, the presence of hedgerows may also influence the attractiveness of the landscape to human visitors. The process of valuing ecosystem services is a community process in which individual and common values are established and negotiated. Various (local) actors constitute a social network that is characterized by formal or informal structures, as is presented on the right of the figure. The outcome of (local) valuation processes can form a motive for intentional landscape change, as is depicted in the lower middle of figure 6 (Opdam, 2013). Local actors make choices regarding which ecosystem services the landscape must provide, e.g. pollination services, while taking area-specific aspects such as available space and space quality into account. On top of that, each type of ecosystem services operates on a different spatial scale. For instance, micro-organisms and nitrogen-fixing plants that provide soil generation services operate on a local scale, whereas forests contribute to climate regulation across multiple levels of scale (local, regional, global) (Kremen, 2005). The level of effectiveness and reliability of ecosystem services can be negotiated by (local) actors. The design process and goal setting must result in a adequate landscape structure i.e. an ecological network which is suitable to the desired landscape functions and a provides level of ecosystem functioning that corresponds to the effectiveness and reliability of pollination services aimed for. Communicating vessels, as depicted in figure 7, can serve as a metaphor for the functional connection between the aspiration level of biodiversity and provisioning of ecosystem services e.g. pollination services and the required physical conditions of ecological networks in the landscape. During the design and goal-setting process, it is of key importance to set clear goals regarding the components of the structure-function-value chain. Hence, scientific information on the three entities of the chain (structure, function and value) need to be represented by quantitative indicators that are more verifiable, negotiable and reproducible than qualitative ones. (Termorshuizen and Opdam, 2009). (Termorshuizen & Opdam, 2009).

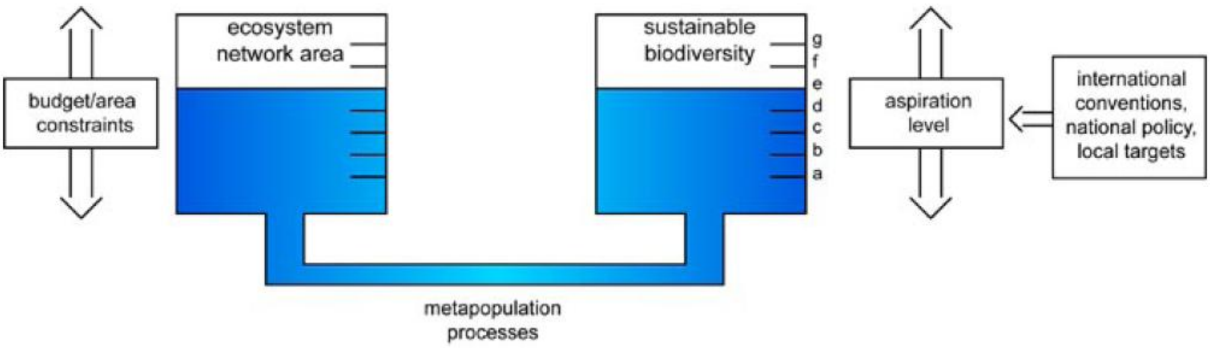

Figure 7: Communicating vessels as a metaphor for the functional relationship between biodiversity goal setting and spatial patterns in the landscape. The vertical arrows represent negotiations among stakeholders with opposing interests (Source: Opdam et al., 2008).

Figure 6 and 7 imply that there a strong need for exploration and incorporation of the complete structure-function-value chain into collaborative planning processes. Scientific knowledge is essential when intentionally changing landscapes to support ecosystem services and providing human benefits. There is also a need for the integration of suitable scientific knowledge into collaborative planning processes that aid landscape- and socioeconomic systems.

In summary, based on the previous sections, the collaborative planning perspective constitutes of (Steingröver et al., 2010; Termorshuizen & Opdam, 2009);

- **Covering the complete structure-function-value chain:** in order to achieve the integration of pollination services into the collaborative planning process, the complete chain needs to be discussed.
- **Integrating knowledge from various scientific disciplines:** (Local) actors negotiate the aspiration level of biodiversity and ecosystem services. The outcome of these negotiations influence the spatial requirements of ecological networks and the other components of the chain. Integrated knowledge on different components of the

chain e.g. ecology or sociology is needed in order to make sound statements regarding desired outcomes.

- **Introducing flexibility into the design**: it is of key importance that scientific knowledge can be applied into a wide variety of collaborative planning contexts, introducing flexibility in the design process. Hence, scientific knowledge needs to be comprehensive, transparent, quantitative (verifiable, reproducible and negotiable) and understandable as scientific information is also applied by stakeholders. Moreover, visualized information can efficiently guide collaborative planning processes.
- **Considering different levels of spatial scale**: Understanding the influence of spatial scales on the functioning of ecosystem services will be essential to developing conservation- and landscape management plans. For instance, if a farmer decides to implement pollination services, the different levels on which ecological networks operate, e.g. local and landscape scale, need to be considered if the ecological network is to efficiently support the pollinator species that provide pollination services. Hence, pollination networks may be ecologically unsustainable at the local scale, but sustainable at a landscape scale as a result of pollinator movements.

In the next chapter, the scientific literature review is conducted by evaluating scientific literature from a collaborative point of view, using the information as presented in this section.

3. Research method

In this chapter, the research method will be briefly discussed. The research method can roughly be divided into two components: a scientific literature review and a case study. The findings from both methods are synthesized into a final conclusion. In the following sections, both the methodology of the scientific literature review and the case study will be further elaborated upon.

3.1 Scientific literature review

The scientific literature review has two objectives. The first, to scope scientific sources for relevant information regarding each component of the structure-function-value chain (specific research question 1 and 2). The second, to evaluate the suitability of this scientific knowledge for collaborative planning (specific research question 3).

A list of 'evaluation criteria' is compiled in order to evaluate the selected scientific literature from a planning perspective. The criteria correspond to either to specific research questions 1 and 2 (evaluation criteria 1+2) or specific research question 3 by using the summary of the collaborative planning practice that was presented in chapter 2.2.2 (evaluation criteria 3-5).

Evaluation criteria regarding knowledge on components of the structure-function-value chain

1. The relationship between spatial configuration of elements and level of biodiversity
2. The relationship between level of biodiversity and reliability and effectiveness of pollination service

Evaluation criteria regarding the suitability of knowledge for collaborative planning

3. The nature of the scientific information (quantitative or qualitative)
4. The level of geographical scale that the scientific information refers to (local, regional, or even higher levels of scale)
5. Suitability of scientific knowledge for collaborative planning processes: Why is scientific knowledge applicable or not? This evaluation criterion is based on three aspects: (1) extent to which the whole structure-function-value chain is covered (2) the extent to which knowledge from different disciplines is integrated (3) The extent to which the scientific information can flexibly applied into various collaborative planning contexts.

Not all relevant scientific studies can be detected and evaluated within the limited time available. Thus, a selection of scientific literature will be made by scanning the available scientific literature on the basis of search criteria. These search criteria consists of key words that are relevant to the evaluation criteria and specific research questions. Synonymous or similar terms are attributed to each search criteria. For example: green-infrastructure is a synonymous term for ecological networks.

Search criteria (keywords) for selecting relevant scientific literature

- <u>Regarding 'structure' component of the chain</u>: Ecological networks or green infrastructure or green-blue networks, (Network) area / patch (quality) / matrix (permeability) / network density/ (semi) natural habitat - patches

- <u>Regarding 'function' component of the chain:</u> Level of ecosystem functioning / level of landscape functioning / bio(logical)diversity / species richness or diversity / pollinator richness

- <u>Regarding 'value' component of the chain:</u> Social or economic or ecological value to humans, level of (ecosystem or pollination) services, reliability and stability or effectiveness of services, reliable and/or stable services, sustaining (pollination) services

The content of each scientific source will be elaborated upon by describing to what extent and how the evaluation criteria are covered (1 until 6). To conclude the scientific literature review, an overview of the results will be briefly presented in a table.

3.2 Case study

The results of the scientific literature review will be evaluated by using a case study of the Hoekse Waard as a framework. The Hoekse Waard is an agricultural area in the Netherlands in which a green-blue network for natural pest control was designed and implemented. The case study has two objectives. The first, to provide further insights into the applicability of the obtained scientific information, namely (1) by determining to what extent the scientific information is useful for designing an ecological network in the Hoekse Waard (2) gain further knowledge of how the scientific knowledge can be applied in (agricultural) areas. The second, to identify further scientific challenges and knowledge gaps as not all relevant information could be detected through a scientific literature review within the short timeframe of this study.

It is beyond the scope of this research to provide spatially-tailored solutions or provide a detailed account of the of the case study. This case study is seen as a framework to further evaluate the results of the scientific literature review, instead of means for gaining further knowledge albeit the case study can provide relevant insights on how the scientific knowledge can be used to design green ecological networks in the landscape that support pollination services. Therefore, the case study is used as a means to determine which knowledge is applicable when designing a pollination network in the Hoekse Waard and what kind of scientific knowledge is still missing.

4. Scientific literature review

The goal of this scientific literature review is to scope relevant information from scientific literature and evaluate this information from a planning perspective, as was described in chapter 2.2.2. The aim is to be comprehensive, knowing that not all relevant studies can be detected within the time available. Hence, a few articles are selected followed by a brief argumentation. Then, the scientific studies are evaluated and an overview of the main findings will be presented in a table.

4.1 Arguments for chosen literature

Due to limited resources a limited number of scientific articles can be scoped for information. Therefore, an effective strategy to filter out the most relevant scientific studies is to set a minimum of criteria that need to be met: in this case at least two out of three search criteria need to be fulfilled.

The chosen scientific literature is divided into two categories: disciplinary or interdisciplinary scientific literature. As was stated in the problem definition, there exists a discrepancy between different scientific disciplines as bits and pieces of scientific information on each part of the structure-function-value chain, obtained in different landscapes and on varying levels of geographical scale, are scattered throughout literature. After a quick scan of the chosen articles, some articles seemed to have succeeded – to a varying degree - in integrating knowledge from different disciplines and relate this knowledge with pollination services. Therefore, comparing both categories may provide relevant insights into the extent to which scientific literature offers suitable knowledge for collaborative planning processes.

An overview of the scientific literature – of both categories - is presented in tables (see next two pages), in which search criteria that apply to each scientific article are ticked off, including relevant key words that were found in each article. Note that these tables only give a first impression of which topics are included in each scientific article. The extent to which these topics are discussed and linked to one another is of higher importance when evaluating the suitability of this knowledge for collaborative planning. The scientific articles will be thoroughly evaluated in the next subchapter.

Disciplinary literature

- Brittain, C., Kremen, C., & Klein, A. M. (2013). Biodiversity buffers pollination from changes in environmental conditions. *Global change biology*, *19*(2), 540-547.
- Kremen, C., Williams, N. M., Bugg, R. L., Fay, J. P., & Thorp, R. W. (2004). The area requirements of an ecosystem service: crop pollination by native bee communities in California. *Ecology letters*, *7*(11), 1109-1119.
- Ricketts, T. H., Regetz, J., Steffan-Dewenter, I., Cunningham, S. A., Kremen, C., Bogdanski, A., ... & Viana, B. F. (2008). Landscape effects on crop pollination services: are there general patterns?. Ecology letters, 11(5), 499-515.
- Olschewski, R., Tscharntke, T., Benítez, P. C., Schwarze, S., & Klein, A. M. (2006). Economic evaluation of pollination services comparing coffee landscapes in Ecuador and Indonesia. *Ecology and Society*, *11*(1), 7.
- Winfree, R., & Kremen, C. (2009). Are ecosystem services stabilized by differences among species? A test using crop pollination. *Proceedings of the Royal Society B: Biological Sciences*, *276*(1655), 229-237.

Reference of article	**Search criteria ('structure' component):** Ecological networks or green infrastructure or green-blue networks, (network) area / patch (quality) / matrix (permeability) / network density/ (semi) natural habitat - patches	**Search criteria ('function' component):** Level of ecosystem functioning / level of landscape functioning / bio(logical)diversity / species richness or diversity / pollinator richness	**Search criteria ('value' component):** Social/economic/ ecological value, level of (ecosystem or pollination) services, reliability and stability or effectiveness of services, reliable and/or stable services, sustaining (pollination) services
Brittain et al., 2013	✗	✓ **species diversity, species richness, ecosystem functioning**	✓ **sustaining pollination services**, buffer **pollination services**
Kremen et al., 2004	✓ **Networks** to conserve biodiversity	✓ **Biodiversity**	✓ **Economic value, stability of pollination services**
Ricketts et al., 2008	✓ Patch of **natural habitat**	✓ **Biodiversity, pollinator richness**	✓ **Stable pollination services**
Olschewski et al., 2006	✓ **Natural habitats, natural patches, matrix**	✓ **Biodiversity**	✓ **Value** of pollination services, **economic** effect **of pollination services**
Winfree et al., 2009	✗	✓ **Biological diversity, species richness, species' abundances, ecosystem functioning**	✓ **Stable services** over space and time, increasing **level of services**,

Interdisciplinary literature

- Kremen, C., Williams, N. M., Aizen, M. A., Gemmill-Herren, B., LeBuhn, G., Minckley, R., ... & Ricketts, T. H. (2007). Pollination and other ecosystem services produced by mobile organisms: a conceptual framework for the effects of land-use change. *Ecology Letters*, *10*(4), 299-314.

- Kremen, C., & Miles, A. (2012). Ecosystem services in biologically diversified versus conventional farming systems: benefits, externalities, and trade-offs. *Ecology and Society*, *17*(4), 40.

Reference of article	**Search criteria ('structure' component):** Ecological networks or green infrastructure or green-blue networks (Network) area / patch (quality) / matrix (permeability) / network density / (semi) natural habitat – patches	**Search criteria ('function' component):** Level of ecosystem functioning / level of landscape functioning / bio(logical)diversity / species richness or diversity / pollinator richness	**Search criteria ('value' component):** Social or economic or ecological value to humans, level of (ecosystem) services, reliability and stability or effectiveness of services, reliable and/or stable services, sustaining (pollination) services
Kremen et al., 2012	✓ **Natural areas**, **patch**es of natural vegetation	✓ **Species abundance** and **richness of** plants and **pollinators**, **biodiversity**	✓ **Effectiveness** of ecosystem providers, **level of** pest suppression
Kremen et al., 2007	✓ **Patch**es, meta population **networks, quality** of the **matrix, natural habitat area**	✓ **Biodiversity, species richness, natural habitat**	✓ **Economic value of pollination services, value to humans,** pollinator **effectiveness, reliability of pollination services**

4.2 Analysis of disciplinary literature

In this section, an analysis of the chosen disciplinary literature will be presented and evaluated using the evaluation criteria. A brief summary of each study is provided.

Article 1: Brittain et al. (2013). Biodiversity buffers pollination from changes in environmental conditions.

This study investigates how pollinator diversity contributes to the reliability and effectiveness of pollination services through spatial complementarity and response diversity to varying wind speeds. The study was conducted in the Californian almond orchards; in the Colusa and Yolo counties in the Sacramento Valley in Northern California from 2008 - 2010. Data to investigate preferences in foraging location of pollinators within the tree were collected in 23 almond orchards that were stocked with honey bee hives during the period of almond bloom.

Key words: Keywords: climate change, Ecosystem services, Global change, Insurance, Orchard crop, Pollinators, Spatial complementarity, Wild bees, Wind speed (Brittain et al., 2013)

Evaluation criterion 1: The relationship between spatial configuration of landscape elements and level of biodiversity

A quick scan in the article demonstrates that none of the terms regarding spatial elements in the landscape are mentioned. The term 'spatial' is used for describing the spatial dimensions of foraging behaviour of bees rather than spatially explicit landscape elements.

Evaluation criterion 2: The relationship between level of biodiversity and reliability and effectiveness of pollination service

This study focuses on the complementarity between functional groups of pollinators and the effects of this relationship on the provisioning of pollination services. The results showed that honey bee populations demonstrated a preference for the top sections of the tree. Wild pollinators demonstrated spatial complementarity to honey bees by visiting the bottom tree sections more frequently. As wind speed increased, honey bees demonstrated a shift in spatial preference and moved to the bottom tree sections. As for other species, their foraging behaviour deviated from those of the honey bees during changing wind speeds (see figure 8). The wild bee *Andrena cerasifolii* (Cockerel) was especially abundant at times of high wind speeds; 37% of all visits took place under high wind speeds. This is in contrast with the visit

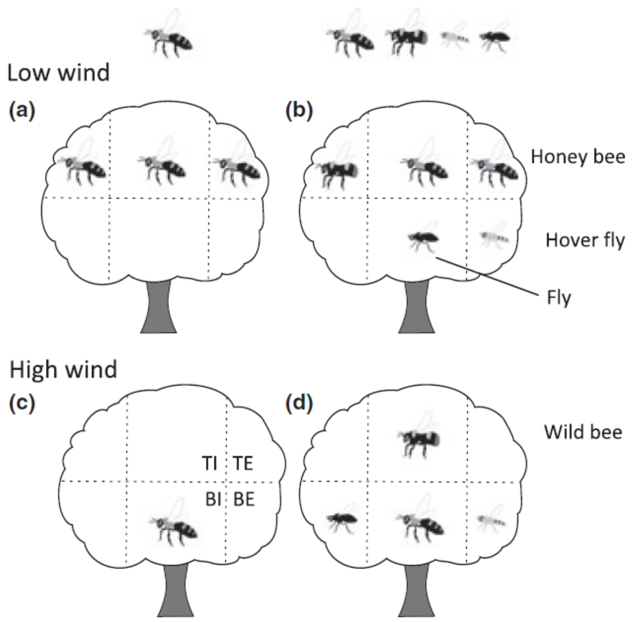

Figure 8: visual representation of flower visitation in different parts of the Californian almond tree (Source: Brittain et al., 2013)

rate (7%) under low wind speeds in the same orchards. During times of high wind speed (> 2.5 m/s), orchards with low pollinator diversity i.e. managed honey bees were the only pollinator species present, visitation rates decreased drastically, leading to almost no flower visits. In orchards with high pollination diversity, visitation rates declined to a lesser extent. Pollination was buffered from changes in environmental conditions as feral bee and wild pollinator visitation was unaffected by high wind speed (Brittain et al., 2013). These findings relate to the 'function-value' components of the chain.

Evaluation criterion 3: The nature of the scientific information (quantitative or qualitative)

After a quick scan of the article, it can be concluded that this article has a quantitative nature. The data collection method employed included field observations, spatial partitioning and statistical data analysis. The results were presented in tables, containing statistical argumentation (see figure 9 below). These data were visualized using bar graphs, but also vector models (see figure 10). This is a clear indication of quantitative data analysis methods.

	Honey bees		Wild bees	Hover flies		All-others	
Location within tree	219.9***		6.5	26.1***		17.3***	
BE:BI	10.3**	BE		3.0		0.0	
TI:BI	82.3***	TI		18.0***	BI	12.1***	BI
TE:BI	82.5***	TE		18.6***	BI	5.3*	BI
TI:BE	52.2***	TI		6.8***	BE	11.4***	BE
TE:BE	49.1***	TE		6.8**	BE	4.7*	BE
TE:TI	1.1			0.0		1.9	
Wind speed	2.4		0.8	0.9		0.4	
Location × wind	9.4*		5.1	6.1		2.7	

The table gives χ^2 values (*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$) from the log likelihood comparison of models before and after the removal of a variable. The table also indicates which sections received significantly higher visitation in any given contrast.

Figure 9: data results from fieldwork study (Source: Brittain et al., 2013)

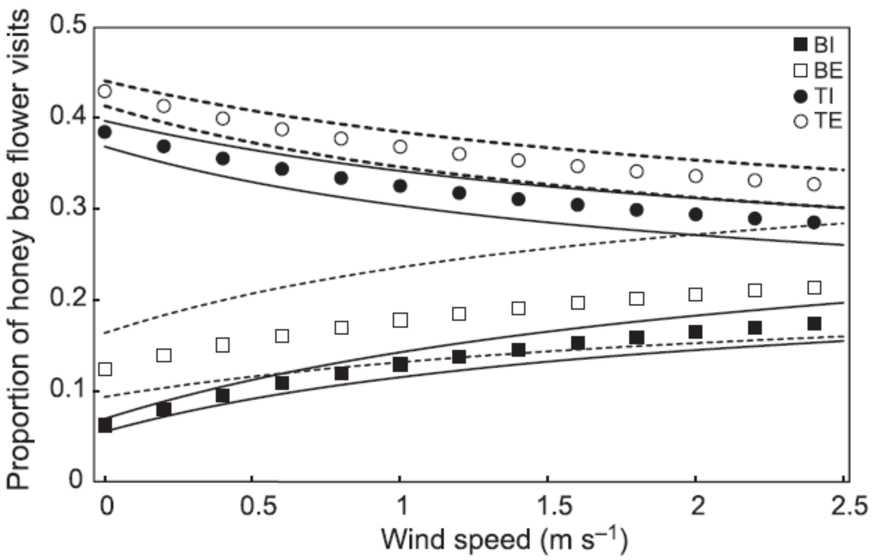

Figure 10: Vector model of the relationship between proportion of honey bee flower visits and wind speed, based on data from figure 11. (Source: Brittain et al., 2013)

Evaluation criterion 4: The level of geographical scale that the scientific information refers to (local, regional, or even higher levels of scale)

The results of this study focus on the specific parts of a tree and the specific spatial behaviour that bees demonstrate on a micro-scale. It can therefore be said that this research was conducted at a local or even 'micro' level of scale.

Evaluation criterion 5: Applicability of knowledge by local stakeholders (understandable, comprehensive). Why or why not applicable?

The extent to which the whole structure-function-value chain is discussed

This study clearly focuses on a single component of the structure-function-value chain. While the article provides valuable insights into the function-value component of the chain, the study contains no findings regarding the 'structure-function' component of the chain.

The extent to which knowledge from different scientific disciplines is integrated

Although this study successfully relates the provisioning of pollination services with foraging behaviour of various bee species, the focus of this study remains disciplinary.. The majority of the references originates from disciplinary journals mainly focused on life sciences such as biology and entomology: *Nature* (4 references), *Proceedings of the Royal Society B-Biological Sciences* (4 references), Ecological Entomology (2 references). A quick scan of the reference list demonstrated one hit for 'Ecological Economics', which is a journal that traditionally focuses on the economic dimension of the 'function-value' component of the chain.

The extent to which the information is flexible and can be applied by stakeholders in various contexts

While the data-collection methods may be beyond the understanding of some (local) stakeholders, this study provides very specific, but useful information on the 'function-value' component. For example, figure 10 provides a visual representation of the spatial complementarity between different bee species. Such graphs can be used in collaborative planning processes since visual information can be comprehended relatively easy by different stakeholders. The main conclusion of the article states that a conservation of pollinator diversity is recommended to help sustain the provisioning of pollination services in the future (Brittain et al., 2013), which is a clear message to stakeholders.

In summary

This study provides an important, albeit incomplete picture of the processes that drive pollination services. The scientific knowledge needs to be further synthesized with interdisciplinary knowledge into a general framework. Moreover, the question remains to what extent the results that were presented in this article apply to types of tree other than almond trees or different pollinator species.

Article 2: Kremen et al., (2004). The area requirements of an ecosystem service: crop pollination by native bee communities in California

This study focuses on how pollination services provided by animal pollinators varied along a gradient of distance from natural habitat. The latter variable includes the proportion of upland natural habitat close to farm sites. The fieldwork was conducted in 22 watermelon fields located in Yolo, Sacramento and Solane counties of California from June to August 2002.

Key words of the article: 'Agriculture, Apis mellifera, Apoidea, bee community, bee foraging distance, conservation planning, landscape ecology, pollination service, scale effects.' (Kremen et al., 2004)

Evaluation criterion 1: The relationship between spatial configuration of landscape elements and level of biodiversity (structure-function components)

This study demonstrates how pollination services vary on a gradient of isolation from natural habitat. For example, ground-nesting bees near sunflower farms demonstrated a decrease in abundance with increasing distance from natural habitat, but also showed more variability with increasing patchiness of nesting resources at different sites. Moreover, the provisioning of pollination services from feral bees were significantly, positively related to the proportion of natural habitat in the immediate surroundings of farm sites (Kremen et al., 2004). However, this study does not explicitly relate the spatial configuration of landscape elements with the diversity of pollinators.

Evaluation criterion 2: The relationship between level of biodiversity and reliability and effectiveness of pollination service (function-value components)

No explicit findings regarding the 'function-value' component are discussed. However, instead of investigating the 'function' component of the chain empirically, the authors seem to agree with the scientific consensus regarding the positive influence of pollinator richness on the provisioning of pollination services: *'...the aggregate, pollination function is more stable than the populations of individual bee species...' (from Kremen et al., 2004)*

Further statements regarding the 'value' component indicate that a robust relationship between natural habitat area and pollination services exists over space and time, allowing a reliable prediction of the natural habitat area needed to produce a given level of pollination services within landscapes. This consistency also indicates that in aggregate pollination communities, pollination deposition is more stable than in the populations of individual bee species. Pollination services provided by native bee species were less variable among farm sites surrounded by higher proportional areas of upland area (see figure 11 below) (Kremen et al., 2004).

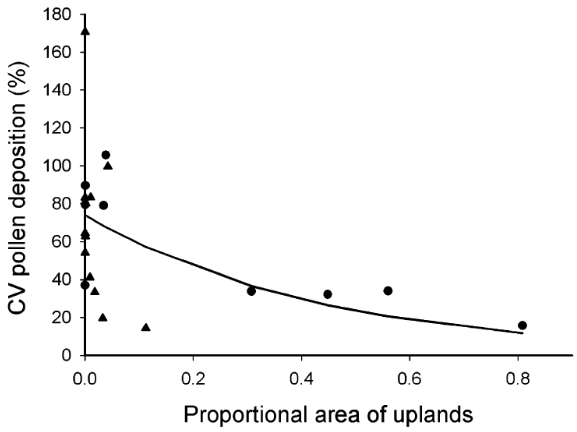

Figure 11 : the relationship between the variability of pollen deposition by native bee species ('CV pollen deposition' on the x-axis) and the proportional area of uplands within 2.4 km of a farm site (Source: Kremen et al., 2004)

Evaluation criterion 3: The nature of the scientific information (quantitative or qualitative)
Quantitative data collection methods were employed to extract results from the fieldwork data. For example, the main pollen deposition by native bees per flower was measured in 10 minutes at each fields, using a standardized quotation.

$$\sum v_{is} e_{is}$$

Further quantitative data collection and analysis methods consisted of: spatial autocorrelation analysis methods, regression methods and statistical methods that were carried out in STATA. In the chapter 'Results' the outcomes of the study sites were expressed in quantitative terms and graphs (e.g. figure 9):

'Regressions of native bee abundance....were non-significant at 600 m (Bonferonni-adjusted a¢ ¼ 0.01, P ¼ 0.06), but were consistently significant (P < 0.001) and explained a similar level of variation (0.3 < r 2adj < 0.34)....' (from Kremen et al., 2004)

These methods are a clear indication for the quantitative nature of this study.

Evaluation criterion 4: The level of geographical scale that the scientific information refers to (local, regional, or even higher levels of scale)
In the first chapter of the article, one of the research questions put forth is *'What is the appropriate spatial scale for the landscape analysis of pollination services?'*. The authors found that crop pollination occurred on a relatively local scale as native bee species strongly relied on the proportion of natural upland habitat within 1 – 2.5 km of the farm sites. This local spatial scale corresponds well with the predicted maximal foraging ranges for both native and similar bee species (Kremen et al., 2004). However, the results are not linked to other levels of scale e.g. the landscape scale.

Evaluation criterion 5: Applicability of knowledge by local stakeholders (understandable, comprehensive). Why or why not applicable?

The extent to which the whole structure-function-value chain is discussed
Interestingly, while the chain as a whole is not explicitly investigated in this study, aspects of each component of the chain are included. For example, the main focus of this study is the variation of pollination services ('value component') along a gradient of isolation from natural habitat (aspect of 'structure' component). In this study, however, only a specific aspect of the 'structure' component is discussed as this study focuses on the isolation from natural habitat. Based on a scientific literature review, the 'function' component is seen as an intermediary link between them.

The extent to which knowledge from different scientific disciplines is integrated
The results of this study are mainly gained through quantitative, ecological methods. Thus, this study takes a strong disciplinary perspective. Strikingly, in the final chapter 'Final Discussion' the results of the study are synthesized and discussed from a more economic perspective, as will be elaborated upon in the following paragraph.

The extent to which the information is flexible and can be applied by stakeholders in various contexts
In the last chapter, the authors elaborate on how the results presented can be useful for farmers - who can be potential stakeholders - in two ways. First, the authors argue that there

will be an economic optimum at which maximum gains in crop productivity are realized as a result of increased animal pollination. This maximum necessarily occurs at intermediate levels of natural habitat surrounding farm sites as each unit of land reserved for pollination services is then no longer available for agricultural use. Conservation efforts for pollination services can even be realized on farms which are far from natural habitat, if farmers were willing to convert the non-farmed portions of their land into suitable habitat for native bee species and other beneficial animal pollinators. This is a vital insight that is highly applicable in collaborative planning processes. Moreover, the authors stress the need for farmers to diversify their sources for pollination services. Conservation and management of natural habitat near farms could allow farmers to lower their dependence on managed honey bee species, and thereby securing food production for society and supporting species richness and abundance of beneficial animal pollinators near farmlands. Second, the results indicate that there exists a predictive relationship between habitat area and the provisioning of pollination services (see figure 9 on page 21). This relationship could aid land-use planners to establish conservation targets that are generally applied in ecological networks (described as 'planning networks of protected areas to conserve biodiversity' in this study). Once targets for pollination services are established, they could be realized through public and private efforts (Kremen et al., 2004). Lastly, the statistical methods used are most likely beyond comprehension for the majority of stakeholders. However, the results meet the requirements of transparency, negotiability and reproducibility. For example: *'....their farms would need to be situated in areas containing ‡ 40% of natural habitat within a 2.4 km radius as natural habitat...' (from Kremen et al., 2004)* These numbers are established through empirical evidence and provide a clear guideline for land-use management practices. Hence, these quantitative results can be useful in planning processes.

<u>In summary</u>
While the scientific jargon may be unclear to stakeholders and laymen and provided the fact that not the complete structure-function-value chain is covered, his article provides applicable and comprehensive knowledge. Some of the graphs express clear rules of thumb (see figure 9) and the results are discussed from a farmers' perspective, which adds to the applicability of the knowledge. However, the results needs to be complemented with further information on ecological networks and scientific jargon needs to be 'translated' into comprehensible terms.

Article 3: Ricketts et al., (2008). Landscape effects on crop pollination services: are there general patterns?

This study focuses on the relationship between the level of pollination by native bee species and distance from (semi-) natural habitats. Emphasis is placed on how observed patterns differ between social and solitary bees, and tropical and temperate crops. Literature searches were used to gather studies that relate pollination services with isolation from habitat. The results of 23 studies – representing 16 crops on five continents – were analysed using Bayesian techniques. In all but three studies, the pollinator group consisted of bee species (Ricketts et al., 2008).

Key words: Agriculture, bees, ecosystem services, habitat fragmentation, hierarchical Bayesian model, land use, pollinators (Ricketts et al., 2008).

Evaluation criterion 1: The relationship between spatial configuration of landscape elements and level of biodiversity

The authors have found strong exponential declines in both species (pollinator) richness and native visitation with increasing distance from natural habitat, as is represented in figure 12 below:

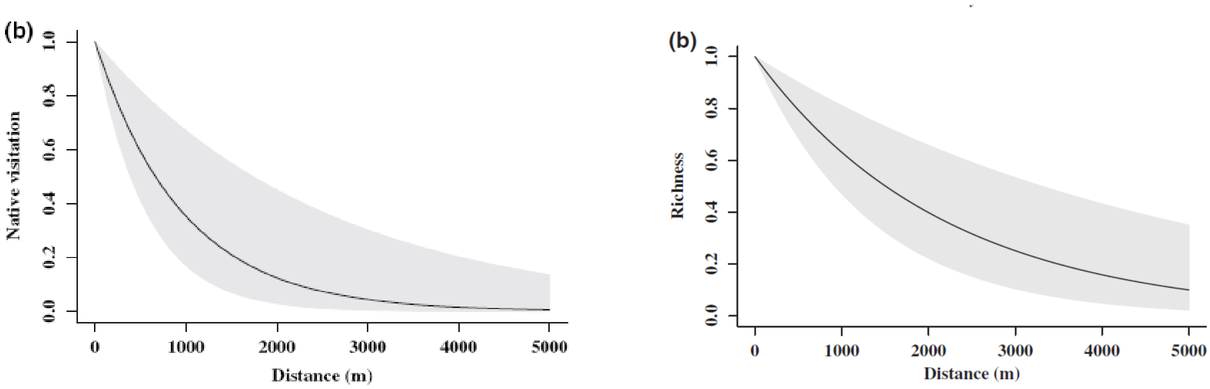

Figure 12: Relationship between native bee visitation and isolation from natural habitat (left) and the relationship between native bee richness and isolation from natural habitat (right) (Source: Ricketts et al., 2008)

Visitation rates showed a more steep decline, dropping to half of its measured maximum at 0.6 km from natural habitat, compared to 1.5 km species richness. However, the authors acknowledge that the spatial dimension of pollination services consists of more than just isolation from natural habitat:*'... our synthesis.. focused on isolation of crops from natural habitat, but more information is needed on the effects of habitat size and quality' (from Ricketts et al., 2008)*

Furthermore, the social system of bees is an indicator for susceptibility to environmental change. Social bees demonstrated a more steeply drop in visitation rate than solitary bees. Therefore, a decline in tropical may occur when pollination by social bees fails as a result of habitat loss (Ricketts et al., 2008).

Evaluation criterion 2: The relationship between level of biodiversity and reliability and effectiveness of pollination service

Bees are central-place foragers i.e. bees return to fixed nest sites after foraging. Hence, the proximity of suitable habitats for bee nesting relative to agricultural lands is a variable of critical importance to bee-pollinated crops, whether in tropical or temperate regions. Therefore, farms within close range of suitable habitats for bee nesting sites may benefit from enhanced pollination services. Moreover, the authors state that a high level of biodiversity in pollinator communities provides more stable pollination services over time, buffering services against populations fluctuations and stochastic environmental conditions (Ricketts et al., 2008). This indicates that the 'function' component (level of biodiversity) is assumed to fulfil and intermediary link between the 'structure' and 'value' component.

Evaluation criterion 3: The nature of the scientific information (quantitative or qualitative)
The use of exponential decay models, comparative analyses and hierarchical Bayesian techniques indicate the quantitative nature of this research. General relationships between bee pollination and the distance from (semi-) natural habitats are expressed in graphs (e.g. figure X on the previous page), box plots (see figure 12 on the next page) and tables.

Evaluation criterion 4: The level of geographical scale that the scientific information refers to (local, regional, or even higher levels of scale)
The graphs show distances from 0 to 5000 meters, which is a clear indication that the scientific information refers to a more local geographical scale. Moreover, the article states that maintaining pollination services requires local management of resources for wild bee populations close to agricultural landscapes. The resources mentioned include management techniques which refer to a more local scale: create suitable soil substrates as well as providing sufficient floral resources e.g. nectar and pollen.

Evaluation criterion 5: Applicability of knowledge by local stakeholders (understandable, comprehensive). Why or why not applicable?

<u>The extent to which the whole structure-function-value chain is discussed</u>
As figure X on the previous page may imply, this study relates the 'structure' component (distance to natural habitat) with both the 'function' (bee richness) and 'value' (visitation rates). However, it cannot be said that the complete chain is covered. Only one specific aspect of the 'structure' component is discussed, namely the distance to natural habitat. The authors acknowledged that more information is needed on the effects of habitat size and quality.

<u>The extent to which knowledge from different scientific disciplines is integrated</u>
The authors used literature searches to gather relevant studies. The majority of those studies were articles, published in journals focusing on ecological or conservation themes. The content of the paper reflects this ecological focus. Further clues regarding the disciplinary perspective can be found in the article: *'...distilling general patterns from recent research is important and informative for both <u>ecology and conservation</u>. From <u>an ecological perspective</u>, such a synthesis can provide a predictive understanding...' (from Ricketts et al., 2008)* Despite the seemingly dominant ecological perspective of this study, references are made to the relevance of the results for spatial planning practice: *'...it can inform <u>land use planners</u> who seek to balance the needs of both biodiversity and farmers by ensuring adequate habitat protection and sustainable ecosystem service production...' (from Ricketts et al., 2008)* This statement clarifies that resources i.e. financial resources simply do not exist to conduct separate case studies for every landscape. Therefore, rules of thumb that are based on syntheses of current work are needed to guide planning efforts. This could result in more complete cost-benefit analyses, benefiting stakeholders e.g. farmers.

<u>The extent to which the information is flexible and can be applied by stakeholders in various contexts</u>
General rules of thumb are distilled from raw empirical data. These rules of thumb can be relatively easily applied in collaborative planning processes. For example, the generalized relationship between distance and bee richness (figure 13 on the next page) is derived from a raw, quantitative data set which includes data of 23 different studies. The generalized relationship can be informative for planning practice, as it is clear that bee richness and

visitation rates strongly decline with distance from natural habitat. Moreover, this study included valuable numbers that can be used in collaborative planning processes. For example: *'The distance at which pollinator richness drops to half of its maximum value (i.e. at distance = 0) is 1507 m..' (from Ricketts et al., 2008)* These numbers can guide land-use management when spatially-tailored solutions are required.

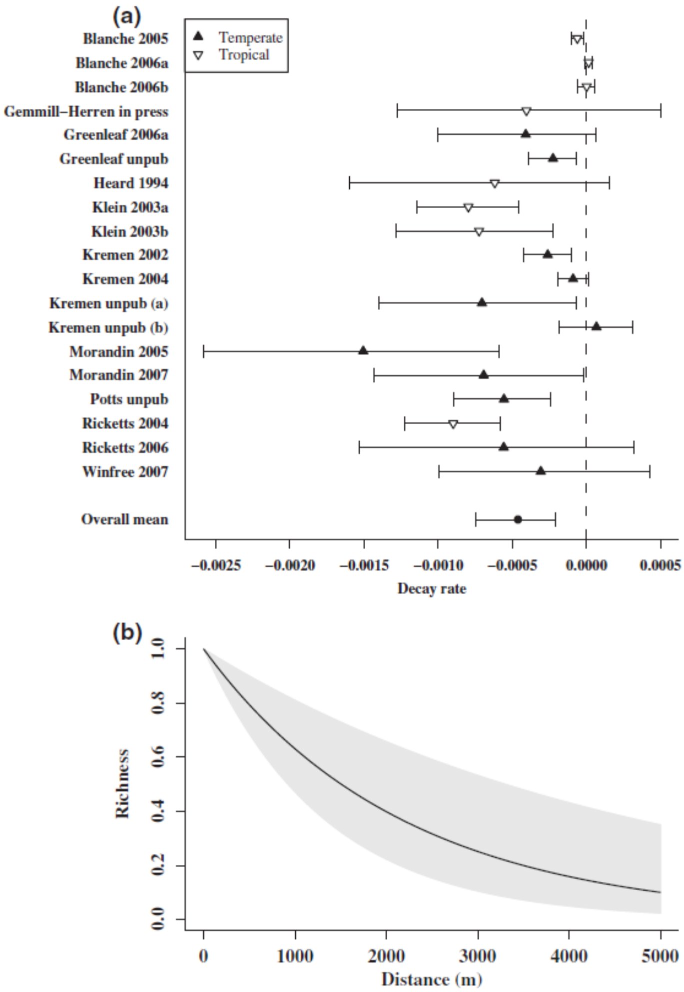

Figure 13: generalized relationship between distance from natural habitat and pollinator richness (below), derived from the data gathered from 23 different studies shown in the boxplosts above (Source: Ricketts et al., 2008)

<u>In summary</u>
This study includes useful knowledge for collaborative planning processes. The structure-function-value chain is discussed to a large extent, though it needs to be stressed that information on certain aspects of the structure component in particular are needed to complete the chain. Although this study takes an ecological perspective, the potential applicability of the information for land-use planning is taken into account.

Article 4: Olschewski et al., (2006). Economic evaluation of pollination services comparing coffee landscapes in Ecuador and Indonesia.

Biodiversity conservation through landscape management on private land has gained considerable attention as an urgent environmental policy issue. Olschewski et al. (2006) conducted an economic evaluation of pollination by bees in two distinct coffee-producing regions in the tropics: an area of low human intervention with natural forests surrounding agro-forestry in Indonesia; and an area of high human intervention with little remaining natural habitat in Ecuador. Two novel approaches were used: (1) examining how coffee net revenues depend on pollination services; (2) define net welfare effects of land-use changes.

Key Words: biodiversity conservation; certified shaded coffee; environmental services; pest management

Evaluation criterion 1: The relationship between spatial configuration of landscape elements and level of biodiversity

The structure-function component is included in this study, albeit few explicit statements are made. Olschewski et al., (2006) conclude that pollinator activity and coffee fruit set is higher in agro-forestry sites adjacent to remnants of forests. Following from this, one can argue that natural forest ecosystems within landscape matrices play a vital role in maintaining bee pollination services

Evaluation criterion 2: The relationship between level of biodiversity and reliability and effectiveness of pollination service

The empirical data of the number of flower-visiting bees showed that open pollination by bees was positively and significantly correlated to coffee fruit set; average coffee fruit set and coffee berry weight also decreased with increasing distance to natural forests (see figure 14 below). At a maximum distance of 1500 m from natural forests, the annual coffee yield per hectare diminished by 45%. Even self-fertile species, such as the highland coffee Coffea Arabica L., demonstrated an increase in fruit set and berry weight as a result of bee pollination, whereas the occurrence of pea berries was reduced. No explanation has been offered for this difference in pollinator-plant interaction. The empirical data showed that this resulted in a 45% of gross revenues and net revenues declined by 47%. Additionally, Olschewski et al. (2006) determined that the main marginal (net) revenue decrease of yields (estimated at 55% of the overall reduction) took place within a distance of 400m from bordering forests. Consequently, increased distances to forests result in a considerably reduced attractiveness of coffee production.

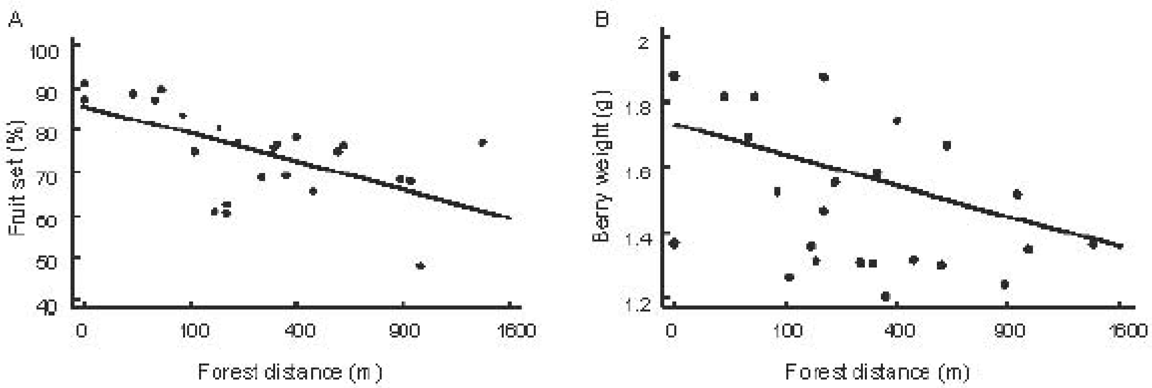

Figure 14: relationship between forest distance and fruit set (see figure on the left) and average berry weight (see figure on the right). (Source: Olschewski et al., 2006)

The impacts of alternative deforestation scenarios on pollination services are presented. In figure 15 below Forests provide natural habitat for bee population, hence, the value of population services can be determined by comparing alternative forest deforestation scenarios with a reference situation, as was done in figure 15. Deforestation initially leads to a the marginal net welfare effect, however, this effect decreases as more forest is converted to farmland (Olschewski et al., 2006). Note that, as figure 14 and 15 may indicate, the empirical data are interpreted according to the structure (deforestation patterns) and the value component. The ‘function’ component of the chain is seen as an intermediary component that connects both.

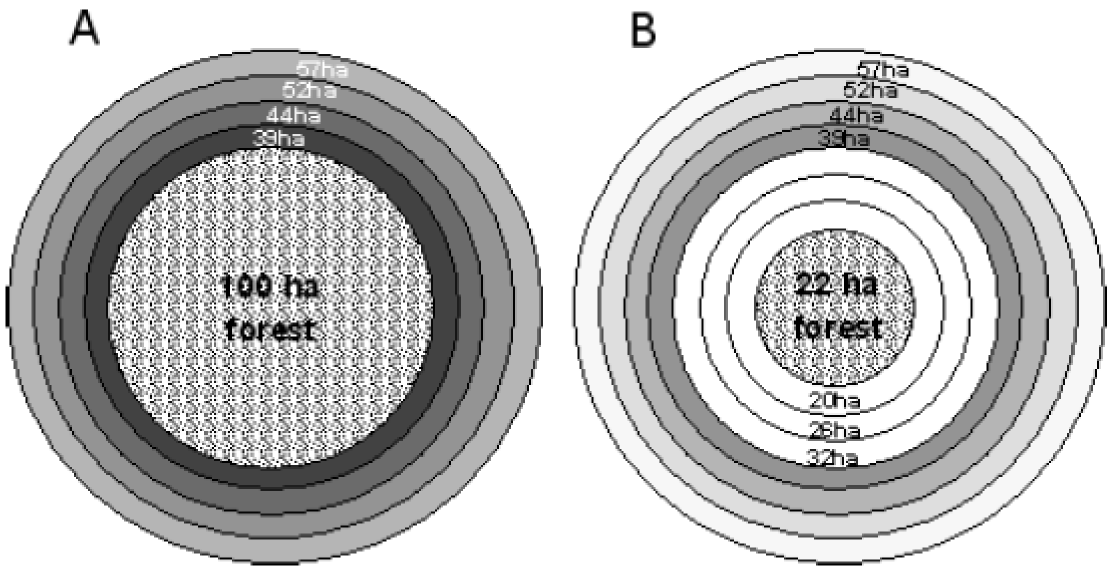

Figure 15: Visual representation of two coffee-growing area and deforestation scenarios; a comparison of scenario A (100 ha forest remnants) and B (22 ha forest remnants). The surrounding circular areas – the width of one ring is 100 m - illustrate increasing distance to the central forest area. The extent of gray shading reflects the decrease in effectiveness of pollination services (intense gray illustrates a relative high delivery of pollination services), while the white areas in scenario B indicate cleared patches of forest for alternative cropping. (Source: Olschewski et al., 2006)

Evaluation criterion 3: The nature of the scientific information (quantitative or qualitative)

Two different methods were used to generate results for both the study areas in Indonesia and Ecuador. For the study area in Indonesia, the ecological data were collected in 24 agro-forestry systems in Central Sulawesi. In each system, the number of flower-visiting bee species and fruit sets after open pollination were determined. For the economic analysis of the Indonesian case, a household survey – consisting of standardized, formal questionnaires - was conducted to collect data on yields, coffee prices and production costs. The economic analysis for the study area in Ecuador was based on published findings and an analysis of the local coffee markets in the regions (Olschewski et al., 2006). Based on the ecological results, scenarios were used to determine regional net welfare effects as a result of converting forests to farmlands.

As a result, it can be concluded that the scientific information that was presented has a quantitative nature, which can be explained by the focus on economic aspects of pollination services.

Evaluation criterion 4: The level of geographical scale that the scientific information refers to (local, regional, or even higher levels of scale)

This study looks at pollination services from different levels of geographical scale. Provided that bees a central-place foragers, figure 16 and 17 indicate that emphasis is placed on a more local scale. Olschewski et al. (2006) argue that bee pollination services can only be addressed properly if the local landscape management is considered from landscape composition on a larger-scale i.e. from the context of the surrounding habitat matrix. Additionally, the regional net welfare effect of land-use changes was considered i.e. coffee trade at regional and even global scale. Although this obviously does not apply to a spatial scale, pollination services are also placed within a framework that transcends the local scale.

Evaluation criterion 5: Applicability of knowledge by local stakeholders (understandable, comprehensive). Why or why not applicable?

<u>The extent to which the whole structure-function-value chain is discussed</u>

The whole structure-function-value chain was discussed, although a few remarks need to be made. Interestingly, emphasis was placed on the relationship between deforestation practices (structure component) and the effectiveness of pollination services (value component), which in turn influences annual crop yield. The ‘function’ component of the chain is seen as an intermediary link between landscape characteristics and effectiveness, but is not as elaborately discussed as the other two component of the chain. Instead, general statements regarding the ‘function’ component are deduced from empirical data and literature reviews.

<u>The extent to which knowledge from different scientific disciplines is integrated</u>

Provided that this study’s main focus is the economic and ecological evaluation of pollination services, the following paragraphs show the determination of the authors to provide a fairly integrated approach to the valuation of pollination services. However, notably, while the regional and local welfare effects of alternative coffee-systems were discussed, relatively few attention was paid to the social value of pollination services to humans. Nevertheless, Olschewski et al. (2006) looked pollination services at different perspectives e.g. regional net welfare effects of pollination services, relationship between ecological and biotic characteristics of a landscape mosaic and effectiveness of pollination services.

<u>The extent to which the information is flexible and can be applied by stakeholders in various contexts</u>

As a result of the quantitative nature of this study, valuable number concerning the economic and ecological value of pollination services. The results were mostly described in quantitative terms, but were also visually represented as was done in figure 17. Additionally, ecological results were linked to economic evaluations i.e. sketching the impact of alternative deforestation scenarios on the effectiveness of pollination services. These findings were expressed by visual means (see figure 16, 17) or in quantitative numbers that express net revenue gains or losses. This information presents a valuable source for collaborative planning processes, as these numbers are reproducible, transparent and negotiable.

<u>In summary</u>

This study provides useful information for collaborative planning processes. To begin with, his study took an integrative approach towards the ecological and economic valuation of pollination services. However, a few side remarks can be made. First, the whole structure-function-value chain is covered, although emphasis is placed on the ‘structure’ and ‘value’ components. Furthermore, this study strongly focuses on the relationship between the economic and ecological dimensions of pollination services. Lastly, the results are highly contextual, since they refer to tropical regions.

Article 5: Winfree & Kremen (2009). Are ecosystem services stabilized by differences among species? A test using crop pollination.

Ecological theory predicts that when an ecosystem service, i.e. pollination services, is provided by various species, it will be stabilized against stochastic conditions through an array of stabilizing mechanisms. This theory forms the focus of this article. The objective of this research is to investigate whether stabilizing mechanisms for pollination services occur in real landscapes affected by human disturbance. Two datasets on crop pollination by wild native bees were screened for differences among three stabilizing mechanisms: density compensation, response diversity and cross-scale resilience. Data were collected at 21 watermelon farms in a 90 x 60 area of central New Jersey and eastern Pennsylvania (Winfree & Kremen, 2009).

Keywords: biodiversity-ecosystem function; cross-scale resilience; density compensation; numerical compensation; response diversity; redundancy

Evaluation criterion 1: The relationship between spatial configuration of landscape elements and level of biodiversity

As the preliminary scope for search criteria demonstrated that there were zero hits for the search criteria in the category of 'structure' components. 'Native vegetation' is mentioned, however, but this term refers to 'proportion of native habitat cover' as a variable that can be used when measuring the stability of pollination services.

Evaluation criterion 2: The relationship between level of biodiversity and reliability and effectiveness of pollination service

In this article, emphasis is placed on the 'function-value' component of the chain. Three mechanisms that can potentially stabilize pollination services against change in environmental conditions are presented and tested: density compensation, response diversity and cross-scale resilience. Density compensation takes place when the abundance of one (pollinator) species increases as a consequence of decreases in the abundance of another species. The second stabilizing mechanism is response diversity, which occurs when populations of species demonstrate varying response to environmental change. The third stabilizing mechanism – cross scale resilience - occurs when species' abundances are affected by changes in environmental conditions at different spatial or temporal scales (Winfree & Kremen, 2009).

Firstly, no evidence of density compensation as a stabilizing mechanism was found. Instead, the abundances of different bee species turned out to be positively correlated. Secondly, data analysis showed that response diversity had indeed occurred. However, it needs to be stressed that some bee species demonstrated a positive – and others a negative – response to environmental conditions e.g. native vegetation loss. Thirdly, cross-scale resilience occurred in both the New Jersey and Pennsylvania datasets as various, but not all, bee species demonstrated a strong response to native habitat loss at different spatial scales, ranging from a 200 m to 3000 m radius around the study site. Lastly, the authors argue that outcomes regarding the loss of pollination services under various scenarios of biodiversity can be utterly different depending on the strength of each stabilizing mechanism (Winfree & Kremen, 2009).

Evaluation criterion 3: The nature of the scientific information (quantitative or qualitative)

Field data were gathered in a systematic manner e.g. study farms were clustered along a gradient of decreasing natural habitat in the landscape. Statistical methods – e.g. pair wise correlation coefficients and variance ratio test - were used to analyse the data for density compensation, response diversity and cross-scale resilience (Winfree & Kremen, 2009). The graphs and results that were distilled have a quantitative nature.

Evaluation criterion 4: The level of geographical scale that the scientific information refers to (local, regional, or even higher levels of scale)

The analysis of the fieldwork data took place on the landscape scale. The authors proclaimed, that as far as they are aware, this study is the first investigation of stabilizing mechanisms for pollination services at the landscape scale. However, the landscape scale should not be confused with a regional scale. Proportions of native vegetation cover that were measured fell within radii of 200, 500, 1000, 1500, 2000, 2500 and 3000 m from the study sites, indicating that the measurement scale transcends the local scale, but does not refer to a regional scale.

Evaluation criterion 5: Applicability of knowledge by local stakeholders (understandable, comprehensive). Why or why not applicable?

<u>The extent to which the whole structure-function-value chain is discussed</u>

This article focuses on the 'function-value' component of the chain. 'Natural vegetation' is mentioned in the article, though this refers to 'proportion of native habitat cover' as a variable indicating environmental change. Thus, it can be concluded that this study is limited as only the 'function' and 'value' component are related with one another.

<u>The extent to which knowledge from different scientific disciplines is integrated</u>

The majority of the scientific references are published in disciplinary journals such as Ecology Letters, Ecology, Conservation Biology and Applied ecology. The article takes an ecological perspective. The following quote supports this statement: *" ....and there is widespread interest among <u>ecologists</u> in the relationships between human disturbance, biodiversity loss and the loss of ecosystem functioning or services' (from Winfree et al., 2009)*. Thus, it can be concluded that knowledge from differing scientific disciplines was integrated to a lower extent.

<u>The extent to which the information is flexible and can be applied by stakeholders in various contexts</u>

The results were reproducible and transparent as a result of clear data and analysis methods that were employed. However, relatively frequent use of scientific jargon (cross-scale resilience, density compensation and response diversity) may not be understood by local stakeholders. An example of such jargon can be found in figure 16 below:

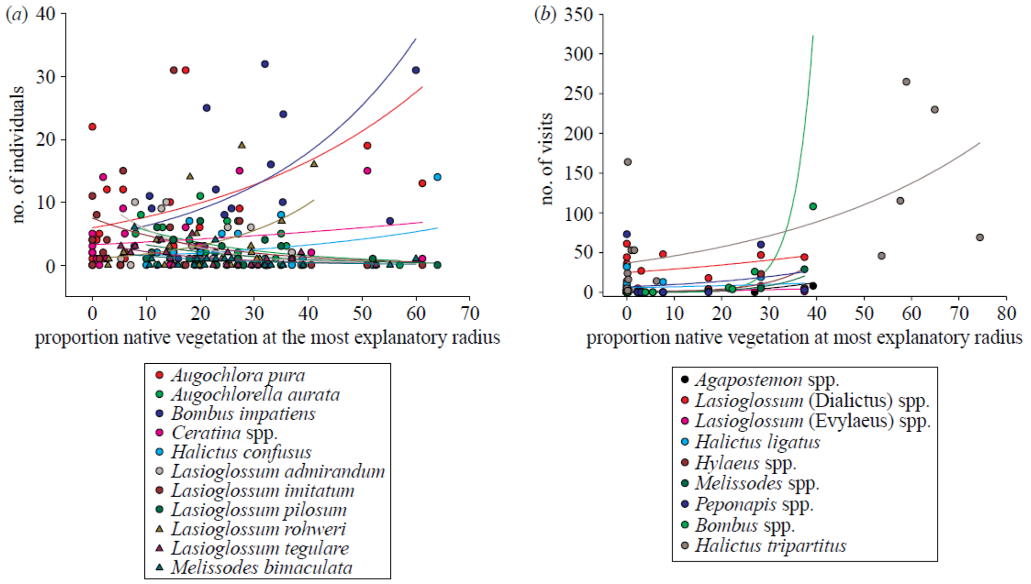

Figure 16: Relationship between proportion of native vegetation and number of individual bees (left) and relationship between proportion of native vegetation and number of bee visits (right) (Source: Winfree et al., 2009)

Terms as ‘explanatory radius’ and Latin terms for bee species e.g. ‘Auglochlora pura’ are used, which may confuse stakeholders and laymen who are less familiar with ecological jargon. Although the coloured lines indicate that efforts have been made to derive general relationships from the data, it is neither comprehensive nor understandable to stakeholders. Thus, provided the fact that not the whole structure-function-value chain is covered, this study is narrow in scope.

In summary

This study provides specific and useful information regarding the function-value components of the chain, but is not very suitable for collaborative planning processes in general. Scientific jargon needs to be filtered out of the information and the results of this study need to be placed within a general framework. This is a crucial step before the information, which provides useful insights into the workings behind stabilizing mechanisms for pollination services, can be applied in collaborative planning processes.

4.3 Analysis of interdisciplinary literature

In this section, an analysis of the chosen interdisciplinary literature will first be presented and evaluated on the basis of the five evaluation criteria.

Article 6: Kremen et al., (2007). Pollination and other ecosystem services produced by mobile organisms: a conceptual framework for the effects of land-use change.

Some ecosystem services e.g. pollination services and seed dispersal are provided at a local scale by mobile organisms that forage within or between different habitat. Kremen et al. (2007) developed a conceptual model for exploring how pollination services – an example of mobile-based ecosystem services or MABES – are affected by landscape changes. The model includes the following aspects: biology of the organisms involved, interactions and feedbacks among land-use policies and market forces. Finally, the results are generalized to other mobile-based ecosystem services (MABES).

Key words: Conservation biology, ecosystem service, habitat loss, landscape ecology, mobile link, natural resource management, pollinator (from Kremen et al., 2007)

Evaluation criterion 1: The relationship between spatial configuration of landscape elements and level of biodiversity

Changes in land-use and landscape structures influence the abundance and richness of pollinators, plants and their interactions at the individual, population and community level. In the MABES conceptual framework (see figure 17 on the next page), alterations in pollinator communities are closely connected with land-use changes. Box B and box C and D from the left until in the middle of the figure indicate a relationship exists between the 'structure' and 'function' component of the chain. Spatial structures in the landscape consist of different types of (semi-) natural and anthropogenic habitats. These structures influence the spatial and temporal availability of resources critical to the survival of pollinators such as foraging, nesting and overwintering sites, but also richness and abundance of plant communities. Among the whole animal pollinator community, bee species in particular are vulnerable to landscape change because of the nature of their foraging behaviour. Bees are central-place foragers, which means that individual foraging movements are anchored to just one particular nesting site. Although it needs to be stressed that this sensitivity to environmental change differs with each bee species as bee populations and communities demonstrate a wide range of responses to fragment size, including positive, negative and neutral responses (Kremen et al., 2007).

Furthermore, the quality of the landscape matrix has a significant influence on individual pollinator movements i.e. an adequately large matrix that is devoid of flowering plants acts as a barrier, while a matrix that includes mass-flowering plants can support connectivity between habitat patches and provide access to rich patches during floral scarcity in the original habitat remnants (Kremen et al., 2007). This statement strongly refers to one of the basic features of ecological networks, namely 'patch quality'. Moreover, this study elaborates upon another study conducted by Moradin & Winston (2006). This suggests that farmers could maximize their profits by converting 30% of their land into suitable habitat for animal pollinators, so as to benefit from higher yields on the remaining 70% (Kremen et al., 2007).

Evaluation criterion 2: The relationship between level of biodiversity and reliability and effectiveness of pollination service

The function-value link of the chain is represented by Box C, D and F of the MABES conceptual framework (see figure 17 on the next page). The interaction between the plants species and their pollinators leads to the pollination service value, as is depicted as connecting arrows between Box C and D. Any target plant species that relies on animal pollination is visited by only a subdivision of species from the entire community. There exists a positive relationship between abundance and the richness of flowering plant species, which can be a crop or a wild species of plant, and pollinator abundance and richness (Kremen et al., 2007).

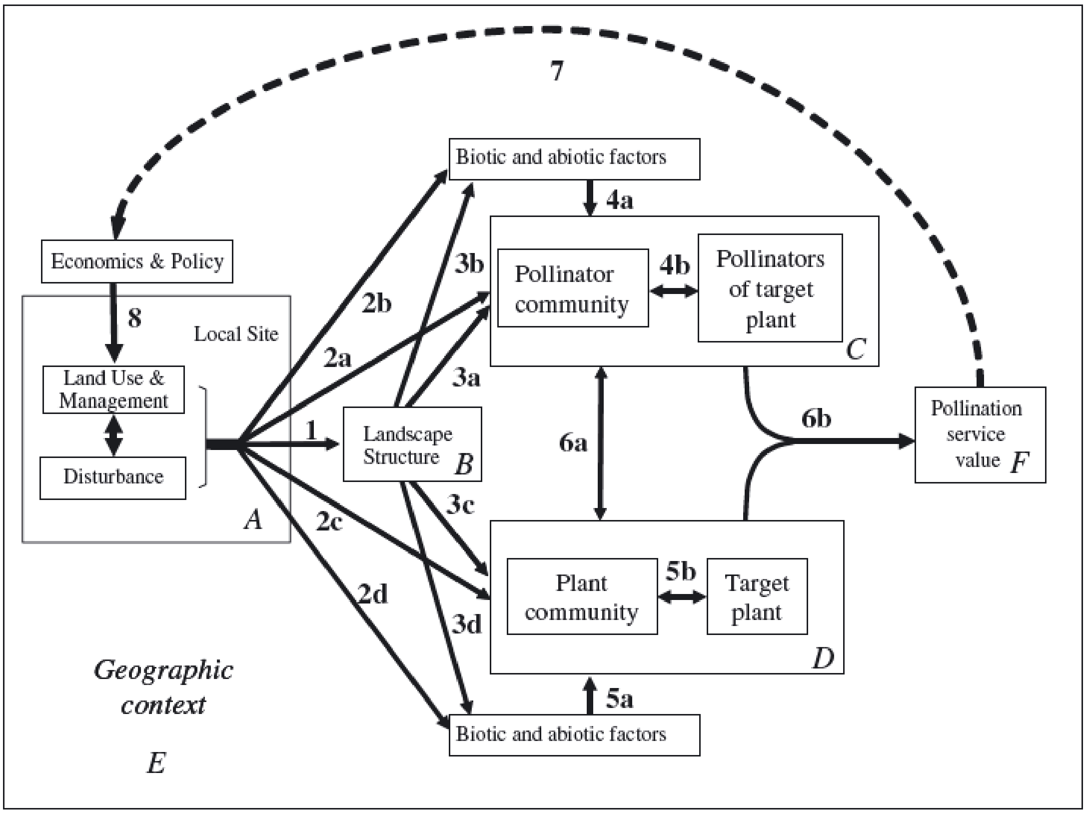

Figure 17: MABES conceptual framework, including the impacts of land-use change on pollinator and plant communities (Box A - D), market-based forces and the biology of pollinators and plants. Note: letters refers to boxes; numbers refer to arrows. (Source: Kremen et al., 2007)

Greater floral diversity generates a wider variety of foraging niches for a more diverse functional group of animal pollinators, and in turn, target plant communities are sustained by a wide variety of pollinators. This is a result of interspecific facilitation and complementarity i.e. different species may augment the effectiveness of other species as pollinators through behavioural interaction or by occupying a specific niche. Kremen et al., (2007) illustrated this by presenting the results from a relevant study by Moradin & Winston (2006). The results of this study demonstrated that flowers near natural habitat areas produce greater seed yields as a result of a more diverse and abundant feral bee community. Additionally, shifting compositions in either the pollinator or recipient (plant) community bring about alterations in the effectiveness of individual pollinator species in differing community contexts (Kremen et al., 2007).

Evaluation criterion 3: The nature of the scientific information (quantitative or qualitative)

The MABES conceptual framework was constructed on the basis of a scientific literature review. The relevant results of each study were synthesized into a generalized framework. No quantitative data collection methods were presented. Hence, the scientific information has a qualitative nature.

Evaluation criterion 4: The level of geographical scale that the scientific information refers to (local, regional, or even higher levels of scale)

Several spatial scales are related to one another as pollination services are provided at a local scale by mobile pollinators foraging within or between habitats, but managing pollinators and the services they deliver goes beyond the local scale. The individual behaviour of pollinators and their population- and community dynamics are influenced by processes on a larger, landscape scale e.g. distribution of resources. Therefore, it can be stated that the MABES concept is distinct in the scale of production, which is set primarily by the mobility of animal pollinators that deliver the services (Kremen et al., 2007).

Evaluation criterion 5: Applicability of knowledge by local stakeholders (understandable, comprehensive). Why or why not applicable?

The extent to which the whole structure-function-value chain is discussed

The whole structure value chain is covered and each component is elaborately discussed and related to other components of the chain. For example, the MABES conceptual framework includes both plant- and pollinator communities in the 'function' component of the chain, providing a broad ecological understanding of the processes that determine the interactions between the abundance and richness of both pollinators and plants and their interdependencies. Moreover, the MABES concept expands upon the structure-function-value chain by including other aspects: economics & politics, land-use & management and human disturbance of the landscape. The value of pollination services may trigger a feed-back response through market-based forces to influence land-use policies, which in turn influences land management practices that initiate landscape changes- and structures (Kremen et al., 2007). Hence, the MABES model includes a strong anthropogenic aspect. The value of pollination services (economic, ecological, social and economic factors) in turn may influence land-use policies. Land-use policies may influence the persistence of pollinator communities, which in turn influences pollination services, through the effects of policies on landscape structures and habitat quality from agricultural fields (local scale) to agricultural regions (see link between box A and B of figure 17).

The extent to which knowledge from different scientific disciplines is integrated

Literature from different scientific disciplines, mainly ecological and biological disciplines, was synthesized to determine the response of each component of the MABES conceptual model to land-use change. Lastly, the authors stress the need for identifying further knowledge gaps in order to establish research priorities and targeting interventions that could be applied in adaptive land-use management (which is a strong reference to collaborative planning).

The extent to which the information is flexible and can be applied by stakeholders in various contexts

The scientific knowledge that was presented is applicable and comprehensive because of several reasons: (1) the MABES conceptual includes the complete structure-function-value chain and expands upon it (2) Disciplinary knowledge was applied into the conceptual framework (3) The MABES conceptual framework includes a anthropogenic component, which makes this study particularly valuable to collaborative planning processes. Last but not least, knowledge from the MABES conceptual framework is generalized to other mobile-agent based ecosystem services (see figure 18 on the next page), which could provide a strong scientific basis for collaborative planning processes when the conservation and management of other mobile-based ecosystem services are aimed for.

In summary

This article provides relevant and suitable information for collaborative planning processes. The generalized knowledge that is presented in the MABES framework (figure 17) and the generalized model for ecosystem services (figure 18) can be used in various situations and planning contexts. It needs to be stressed, however, that designing ecological networks for pollination services requires further knowledge of local conditions such as local wildlife, policies, land-use management and crop markets.

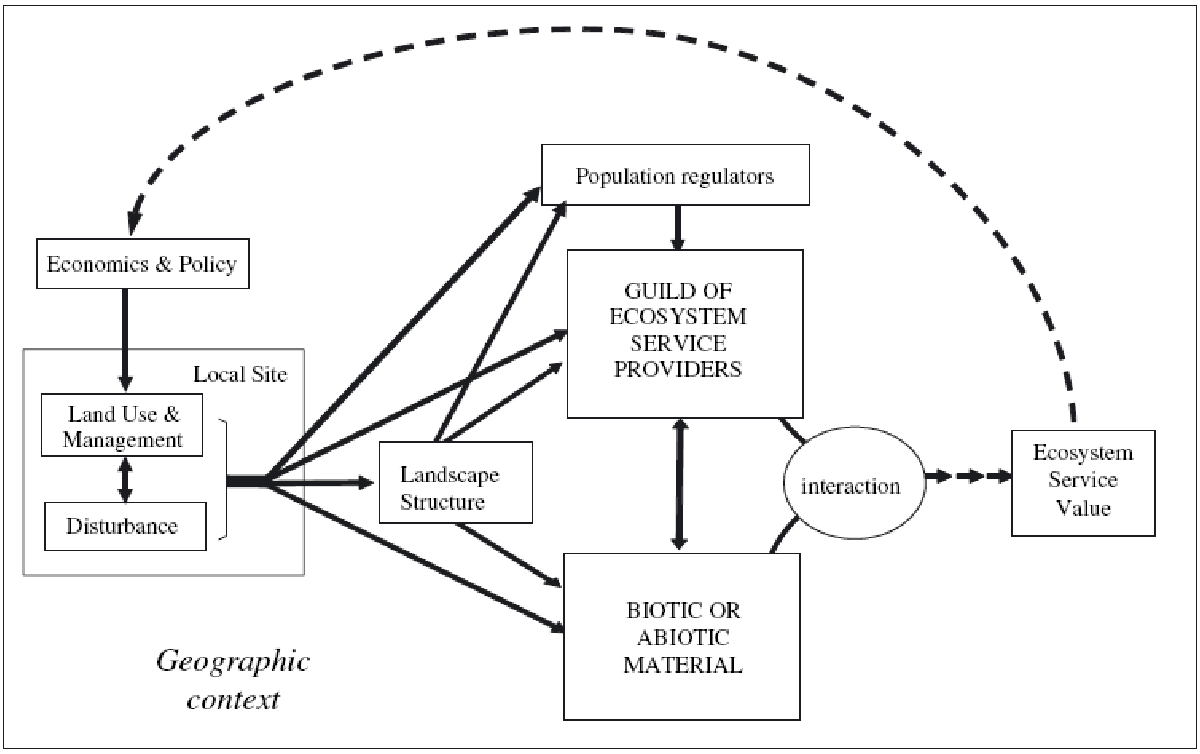

Figure 18: Generalised MABES conceptual framework for other ecosystem services that rely on mobile organisms (Source: Kremen et al., 2007)

Article 7: Kremen & Miles (2012). Ecosystem services in biologically diversified versus conventional farming systems: benefits, externalities, and trade-offs.

Kremen & Miles (2012) hypothesize that species richness across ecological, temporal and spatial scales supports and maintains ecosystem services that provide vital inputs to humans. The main objective of this research is to identify the benefits, externalities and trade-offs of diversified farming systems compared to conventional systems. Diversified farming systems take a more holistic and integrated approach to the management of ecosystem services through mechanisms for sustaining biotic and a-biotic interactions. The ecological performance of diversified and conventional farming systems was assessed across 12 key ecosystem services.

Key Words: agricultural food production; agricultural intensification; agrobiodiversity; agroecology; biodiversity; conventional agriculture; conventional farming systems; diversified farming systems; ecosystem services; land-sharing; landsparing; organic agriculture; sustainable agriculture; sustainable intensification

Evaluation criterion 1: The relationship between spatial configuration of landscape elements and level of biodiversity

An effective management technique for enhancing pollinator diversity and abundance includes planting hedgerows, flower-rich hedgerows, grassy borders and insectary strips along farming fields. Multi-region studies from Europe have demonstrated the negative influence of landscape simplification – across multiple spatial scales – and isolation from natural habitat on the diversity of (wild) pollinator communities. The stability of pollination services demonstrated a 9-16% decline respectively at 1-km isolation of wild pollinator communities from natural habitat. On the other hand, non-crop plantings surrounding agricultural lands promote biodiversity across spatial scales. Across the whole field, land use structures e.g. hedgerows, grass strips and border plantings enhance biodiversity dynamically e.g. support pollinator richness. These structures are incorporated into multiple fields at the landscape-to-regional scale. In addition to the effect of landscape structures across spatial scale, increasing the proportion of (semi-) natural habitats surrounding farm fields from 5 to 20% further increased pollinator abundance and richness by 60% or more on both organic and conventional farms (Kremen & Miles, 2012).

Evaluation criterion 2: The relationship between level of biodiversity and reliability and effectiveness of pollination service

Kremen et al. (2012) state that maintaining pollinator diversity across scales enhances the ecosystem services provided by different organisms, but also promotes their resilience in the face of stochastic environmental conditions or environmental disturbances e.g. drought or floods. However, no further statements regarding this evaluation criterion are made.

Evaluation criterion 3: The nature of the scientific information (quantitative or qualitative)

The results of this study were gained through a scientific literature study, using search terms in a Web of Science. The following types of studies were included in the literature review of this study (in descending order): (1) meta-analyses or quantitative syntheses; (2) studies of long-term systems; (3) review articles that provide a qualitative summary of multiple studies.

Notably, despite the fact that quantitative syntheses and meta-analyses were prioritized as scientific sources, this study by Kremen et al. (2012) has a qualitative nature. Firstly, the main purpose of quantitative meta-analyses and syntheses is to derive general trends, which are valuable to qualitative research when interpreting general patterns of a phenomenon e.g. effectiveness of pollination services. Secondly, the results from quantitative studies and replicated multi-region studies were ‘translated’ into effective management techniques for diversified farming systems.

Furthermore, no graphs or tables that included quantitative data were included into the paper, indicating that this study is a product of synthesizing and deriving qualitative results from the chosen scientific literature.

Evaluation criterion 4: The level of geographical scale that the scientific information refers to (local, regional, or even higher levels of scale)
This study covers various levels of scale, which can be explained by the wide variety of ecosystem services that were included in this study. Concerning the issue of pollination services, however, this study mainly refers to the local and landscape scale as pollination services operate on lower levels of spatial scale (Kremen & Miles, 2012).

Evaluation criterion 5: Applicability of knowledge by local stakeholders (understandable, comprehensive). Why or why not applicable?

<u>The extent to which the whole structure-function-value chain is discussed</u>
The complete structure-function-value chain was covered. However, while the structure-function link was elaborated upon, relatively few statements were made regarding the function-value function. For instance, quantitative numbers and a relatively elaborate description of the mechanisms behind the relationship between richness and abundance of pollinator communities and landscape elements across different spatial scales were presented. The function-value link, however, was mentioned in the light of scientific consensus i.e. based on other studies, the authors assumed that a high diversity and abundance was positively correlated with higher effectiveness and reliability of pollination services.

<u>The extent to which knowledge from different scientific disciplines is integrated</u>
Diversified agriculture is looked at from a holistic, sustainable view that includes ecological and social aspects besides the economic incentives of agriculture. Furthermore, ecosystem services as a concept was not narrowed down to one particular type, as was done in disciplinary studies. Instead, pollination services was included within this study as one of many ecosystem services (see table 3). The differences and similarities of each ecosystem services regarding area requirements and management techniques were discussed, but more importantly, these ecosystem services were incorporated into the framework of diversified farm systems, adding to the integrative nature of this study.

<u>The extent to which the information is flexible and can be applied by stakeholders in various contexts</u>
As was mentioned in the previous paragraph, pollination services are being discussed looking from an integrative framework. The article contains a relatively low proportion of scientific jargon. Instead, effective management techniques for ecosystem services – synthesized from both quantitative and qualitative studies -are discussed. A key characteristic of diversified farming systems is the diversification of ecosystem services across ecological, spatial and temporal scales that serve as the mechanism for maintaining biotic interactions between organisms, and in turn, ecosystem services – e.g. pest control and pollination – that provide vital inputs for agriculture. This is a relevant framework for collaborative land-use processes that concern landscape management in agricultural regions.

<u>In summary</u>
This study provides applicable and suitable information on pollination services for collaborative planning processes, albeit a few side-notes need to be made. To begin with, the whole chain was covered, however, emphasis was placed on the ‘structure’ and ‘value’ components of the chain. Additionally, no explicit references to the basic features of ecological networks were not explicitly related to management techniques. Lastly, a limited amount of scientific information was presented on pollination services, as a considerable number of ecosystem services was discussed (see table 3).

Ecosystem service	Compost or manure	Intercrop	Agroforestry	Insectary strip	No till or low till	Rotation	Cover crop or green manure	Fallow	Border planting	Riparian buffers	Woodlots, meadows, forests
Biodiversity (above and below ground)	x	x	x	x	x	x	x	x	x	x	x
Soil quality	x	x	x		x	x	x	x		x	x
Nutrient management	x					x	x		x	x	x
Water-holding capacity	x		x		x		x	x			
Weed control		x	x			x	x				
Disease control	x	x	x			x	x				
Pest control		x	x	x		x	x	x	x	x	x
Pollination		x	x	x		x	x	x	x	x	x
Carbon sequestration	x		x		x		x	x	x	x	x
Energy-use efficiency	x	x	x	x		x	x		x		
Resilience to drought	x		x		x		x	x		x	
Resilience to hurricanes/ heavy rains	x	x	x		x	x	x	x	x	x	x
Productivity/ yield	x	x	x	x	x	x	x	x			
Scale	Within-field				Field				Perimeter	Landscape	

Table 3: Relationship between diversified farming systems and the provisioning of various ecosystem services (Source: Kremen et al., 2012)

4.4 Major findings

In this section, a summary of the major findings is presented, using a table that includes the main findings of each evaluation criterion.

In the column on the right – *'Suitability of scientific knowledge for collaborative planning? (evaluation criterion 5)'* – number 1,2,3 are included that correspond to the respective aspects included in evaluation criterion 5 (see chapter 4.1):

- 1) corresponds 'extent to which the complete structure-function-value is covered'
- 2) corresponds to 'integrated knowledge'
- 3) corresponds to 'applicable and comprehensive knowledge'

Scientific article or source	Relevant scientific regarding the structure-function component ? (evaluation criterion 1)	Relevant scientific information regarding the function-value component ? (evaluation criterion 2)	Nature of the scientific information? (evaluation criterion 3)	Level of geographical scale? (evaluation criterion 4)	Suitability of scientific knowledge for collaborative planning? (evaluation criterion 5)
Article 1: Brittain et al., (2013)	No results were presented	*Wild bee species demonstrated spatial complementarity to honey bees by visiting different sections of the tree during high winds *In orchards with high pollinator diversity, flower visitation rates were more stable	Quantitative	Local or micro level of scale	The article provides useful knowledge, however, this information needs to be 'translated' for collaborative planning: **1)**Only the 'function-value' component of the chain is discussed **2)**Article focuses on the ecological dimension of the chain (strongly disciplinary) **3)**Specific information was visually presented (e.g. figure 10), but might not apply to other types of trees than almond
Article 2: Kremen et al. (2004)	*Ground-nesting bees demonstrated more variability with increasing patchiness of nesting resources at different sites *However, no explicit findings regarding the structure-function component were presented	*Value component is linked to 'distance to natural habitat area' instead of pollinator diversity (e.g. figure 9)	Quantitative	Local scale	The information is valuable for further understanding between the balance between land use and pollination services, but not suitable for planning; **1)**Information on each component of the chain is included, but only the 'structure' and 'value' components are investigated and linked. **2)**Study is based on disciplinary knowledge, mainly ecological and biological disciplines **3)**Article contains scientific jargon, which makes the information less applicable

Scientific article or source	Relevant scientific regarding the structure-function component (evaluation criterion 1)?	Relevant scientific information regarding the function-value component (evaluation criterion 2)	Nature of the scientific information? (evaluation criterion 3)	Level of geographical scale? (evaluation criterion 4)	Suitability of scientific knowledge for collaborative planning (evaluation criterion 5)
Article 3: Ricketts et al. (2008)	*Species richness drops to half of its measured maximum at 1.5 from natural habitat *Bees are central-place foragers i.e. proximity of suitable habitats is of vital importance	*Social bees demonstrated to be more susceptible to environmental change than solitary bees *Based on a literature review, the positive relationship between species richness and abundance and pollination services is confirmed	Quantitative	Local scale	The scientific information that was presented is partly suitable for collaborative planning; **1)**Structure component (distance from natural habitat) is mainly linked to the value component. Based on literature reviews, the function component is seen as an intermediary link between those two **2)**Article has a disciplinary nature **3)**Results are interpreted from both an ecological and planning perspective to generate rules of thumb
Article 4: Olschewski et al. (2006)	*Natural forest ecosystems within landscape matrices play a vital role in maintaining bee pollination services *Annual coffee yields showed a 45% decrease at a distance of 1500 m from natural habitat	*Average fruit set and coffee berry weight were positively correlated to abundance of bee species *Deforestation initially leads to a marginal welfare effect. This effect decreased as more forest was converted to farmland	Quantitative	*Multiple levels of scale: local scale, landscape scale. But also, regional and global dynamics behind coffee markets	The information is largely suitable for collaborative planning; **1)**Only the ‘structure’ and ‘value’ components were elaborately discussed. **2)**The study considered economic and ecological evaluation of pollination services, but not social aspects. Additionally, this study focused on deforestation scenarios in tropical areas, which is not applicable to a variety of contexts. **3)**The results are reproducible, transparent and negotiable

Scientific article or source	Relevant scientific regarding the structure-function component (evaluation criterion 1)?	Relevant scientific information regarding the function-value component (evaluation criterion 2)	Nature of the scientific information? (evaluation criterion 3)	Level of geographical scale? (evaluation criterion 4)	Suitability of scientific knowledge for collaborative planning (evaluation criterion 5)
Article 5: Winfree & Kremen (2009)	No results were presented	*Abundances of different bee species were positively correlated *Bee species demonstrated various responses to environmental changes and cross-scale resilience	Quantitative	Landscape, local scale	The concept of stabilizing mechanisms provides valuable insights, however, the information presented is not entirely suitable for planning practice: **1)**Not the whole chain is discussed, only the 'function-value' component is investigated **2)**The article takes a strong ecological perspective **3)**Frequent use of scientific jargon (e.g. cross-scale resilience) may not be understood by local stakeholders
Article 6: Kremen et al. (2007)	*Spatial structures influence spatial and temporal availability of resources e.g. nesting sites for bees *landscape matrix that includes mass flowering plants can support connectivity between habitat patches	*Interspecific facilitation and complementarity buffers the provisioning pollination services *Abundance and richness of flowering plant species e.g. crops is positively related to biodiversity of animal pollinators	Qualitative	Multiple levels of scale: local and landscape scale	The MABES concept is very suitable for collaborative planning practice: **1)**The MABES concept even expands on the complete chain by including further aspects (economics & policy and land use management) **2)**Knowledge from various scientific disciplines is integrated within the MABES concept **3)**The MABES concept is translated into a generalized model for ecosystem services

Scientific article or source	**Relevant scientific regarding the structure-function component (evaluation criterion 1)?**	**Relevant scientific information regarding the function-value component (evaluation criterion 2)**	**Nature of the scientific information? (evaluation criterion 3)**	**Level of geographical scale? (evaluation criterion 4)**	**Suitability of scientific knowledge for collaborative planning (evaluation criterion 5)**
Article 7: Kremen & Miles (2012)	*At the local scale, non-crop plantings e.e. hedgerows bordering agricultural lands promote pollinator diversity	*Based on a literature review, Kremen et al. (2007) confirm that maintaining pollinator diversity enhances the stability and effectiveness of pollination services	Qualitative	Multiple levels of scale: local geographical scale, landscape-to-regional scale	The knowledge presented is largely suitable for collaborative planning: **1)**The whole chain was covered, however, the 'function' component is seen as an intermediary link between the 'structure' and 'value' component **2)**Diversified agriculture is looked from a holistic perspective that includes ecological, economic and social aspects. Additionally, pollination was included in this study as one of many ecosystem services. **3)**Scientific knowledge is placed in an integrative, general framework

4.5 Points of attention

While searching for relevant studies and evaluating the scientific articles for relevant information, other relevant insights that did not directly appeal to the specific research questions became evident. These insights can potentially contribute to answering the general research question. Thus, these insights will be briefly discussed in this section.

Several interpretations of pollination networks as a concept

A quick scan in a Web of Science – after entering 'pollination networks' as one of the search terms – demonstrated that pollination network as a concept has different meanings across scientific disciplines. Looking from a land-use planning perspective, pollination networks are ecological networks that support pollination services. However, pollination services is a vastly different concept in disciplinary literature focusing on biological issues. For example, Olesen et al. (2007) describe pollination networks as an often organized non-random network which shows distinct and repeated complex patterns in natural communities. Dupont et al. (2009) argue that pollination networks are representations of interactions between plants and their pollinators at a given site. In this sense, an ecological network consists of strongly connected species instead of spatial structures in the landscape. When using the term pollination services in planning processes, this notion needs to be kept in mind in order to avoid ambiguity and confusion.

Scientific bias towards bee species as animal pollinators

The majority of the scientific articles focuses on one single type of pollinator: domesticated or feral, native bee species. For example, in the study of Ricketts et al. (2008), gathered studies that relate crop pollination services with isolation from natural habitat. The aim was to be comprehensive and synthesize the knowledge obtained into general rules of thumb. In 20 out of 23 studies pollinators were bees (Ricketts et al, 2008). This indicates a strong scientific bias towards bee species, both feral and domesticated. Provided the fact that bees are the predominant and economically most important group of pollinators in the majority of geographical regions (Kremen et al., 2007), this finding can be explained. In table 4 below, an overview of the pollinators in each study are presented. Note that in disciplinary articles, the Latin names of bee species are mentioned, as opposed to interdisciplinary articles, where diversity of animal pollinators is more broadly defined.

Scientific article	**Key pollinators**
Brittain et al., (2013)	<u>Bee species</u> • Honey bees (*Apis mellifera*) • Wild bees (Bombus spp., *O.cornuta, Andrena cerasifolii)* <u>Non-bee species</u> • Hover flies • All others
Kremen et al., (2004)	<u>Bee species</u> • Managed honey bees (*Apis mellifera*) • Wild bees (*Bombus spp., Halictus spp.)*
Ricketts et al., (2008)	<u>Bee species</u> • Managed honey bees (*Apis mellifera*) • Wild bees <u>Non-bee species</u>

	Others (e.g. small beetles, Elaeidobius kamerunicus)
Winfree et al., (2009)	<u>Bee species</u> • Wild native bees
Kremen et al., (2007)	<u>Bee species</u> • Honey bees • Wild, native bees Non-bee species • Butterflies • Moths • Flies • Beetles • Wasps • Birds • Mammals (Although the article focuses on bee species)
Kremen & Miles (2012)	<u>Bee species</u> • Honey bees • Wild bee species (although not further specified)
Olschewski et al. (2006)	Bee species • Not further specified than 'flower-visting bees'

Table 4: Overview of the contents of each article regarding diversity of pollination services (Own source)

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5. Evaluation of scientific literature review : Case study

This case study is used as a means to determine which knowledge is applicable when designing a pollination network and what kind of scientific knowledge is still missing. This chapter consists of four parts: (1) a description of the selected case study (2) an overview of which scientific information that was gained through the scientific literature review can be applied to the case study (3) an overview of relevant scientific challenges and knowledge gaps (4) an evaluation of the main insights. Although they may appear similar, 'knowledge gaps' and 'scientific challenges' are not used interchangeably. Knowledge gaps have a twofold connotation. Firstly, the term refers to scientific information that is most likely available, but was not discussed in the literature review as not all relevant scientific articles could be scoped for information in the limited time available. Secondly, knowledge gaps refer to specific information that is crucial to aiding collaborative planning processes, but can hardly be included into the structure-function-value chain or a general framework due to its highly contextual nature. On the other hand, scientific challenges refer to the aspects that need to be included in future studies to complement the available knowledge on the structure-function-value chain and pollination services.

5.1 Selected case study: natural pest control in the Hoekse Waard

Recent changes in national and European water-management legislation provided incentives to further implement regulative ecosystem services into agricultural areas. As a result of the revised EU Water Framework Directive in 2000, amongst other measures, famers and water boards are obliged to meet stringent water qualities. In order to achieve this level of water quality, pesticides need to be removed from surface water. However, this removal involves considerable costs. Thus, it is in the farmer's interest to practice agriculture in a way that involves a reduction in the use of pesticides, yet do not increase the risk of pests damaging crops. Natural pest control is such an alternative to chemical pesticides as this practice involves the exploitation of beneficial insects in the agricultural landscape that suppress pests populations by predation or parasitism. A study was conducted in the Hoekse Waard to explore the ways in which generic scientific knowledge could be applied to design a spatial structure for a green-blue network (similar to ecological networks) that enhances natural pest control. The Hoekse Waard is an agricultural area in the Netherlands that consists of arable fields and a distinct network of dikes, ditches, creeks, fields margins, making it an attractive area in which to implement natural pest control. However, the interests of the local stakeholders showed a wide variety, including nature and landscape conservation, water management and local or regional politics. A team of researchers cooperated with local stakeholders in order to develop spatial norms and design rules for the design of a green-blue networks that effectively supports natural pest control by providing various resources for the survival of beneficial insects. (Steingröver et al., 2010).

The Hoekse Waard provides a suitable case study for this research for several reasons. To begin with, the majority of pollination-related case studies focused on managed honey bee populations, and therefore did not provide a holistic picture of the application of ecosystem services into collaborative processes. Additionally, there are fundamental similarities between pollination services and pest control. Population-based services, such as pest control and crop pollination, are delivered by mobile agents, albeit both services are delivered by different species. Hence, the dispersal and foraging movements made by mobile-organisms greatly influence the provisioning of crop pollination and pest control (Kremen, 2005). Lastly, the Hoekse Waard is one of the few places in which an ecological network that supports ecosystem services was designed through a series of stakeholder workshops. Thus, the landscape-development strategies and management plans for natural pest control are a result of collaborative planning processes.

5.2 Analysis of the case study: applying scientific knowledge from the scientific literature review

In this section, the results from the scientific literature review will be applied to the case study of the Hoekse Waard to evaluate to what extent the results can be applied in agricultural areas. To achieve this, the results from the scientific literature review are synthesized with available information on the case study of the Hoekse Waard.

Finely-meshed network versus robust network

As was concluded in the scientific literature review, individual pollinators provide services at a local scale, albeit depend on processes on a larger scale for the distribution of vital resources (Kremen & Miles, 2012 ; Kremen et al., 2007). The mesh size of the network, which influences the network density and network area of ecological networks, is defined by the distance between fine and robust elements (Steingröver et al., 2010). Semi-natural vegetation shows a wide variety in the Hoekse Waard. These different types can roughly be divided into two categories: fine elements (maximum width 5m) and robust elements (width more than 5 m). The fine elements include ditch banks, field margins and the verges of secondary roads.

Figure 19: Finely-meshed network of field margins (Source: Samenwerkingsorgaan Hoekse Waard, 2012)

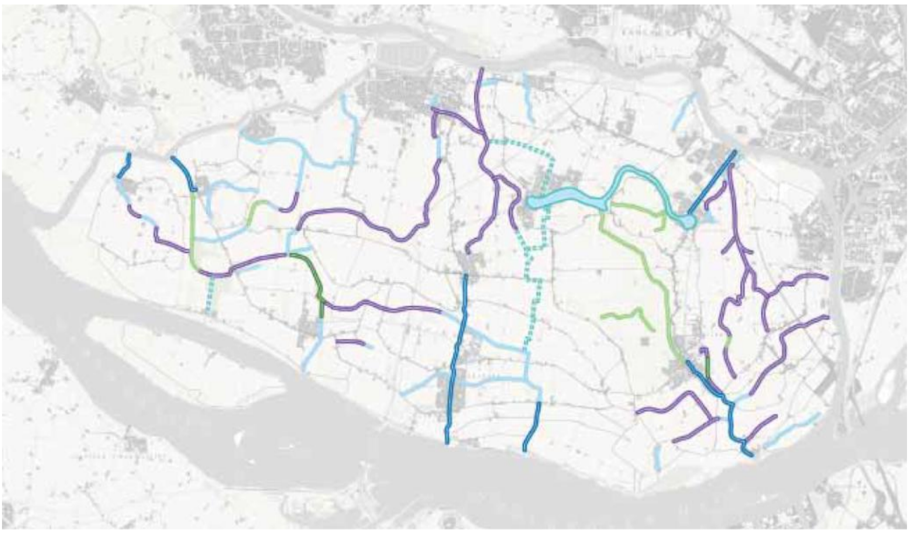

Figure 20: Robust network of creeks (source: Samenwerkingsorgaan Hoekse Waard, 2012)

These elements form a finely-meshed network that entwines around the arable fields of the Hoekse Waard. On the other hand, robust elements consist of creeks, dikes, forest patches and the verges of the main roads. The Hoekse Waard is characterized by the many dikes that are bordered by lines of trees (Steingröver et al., 2010). On figure 19 and 20 on the previous page, examples of such finely-meshed and robust networks are presented. These two types of networks strongly refer to the different levels of geographical scale on which pollination services occur. Note that ‘robust’ networks refer to spatial structures at the landscape scale or a relatively local scale still. The fine and robust elements, albeit small elements, can cover a considerable area. For example, the total area of field margins in the Hoekse Waard adds up to an estimated 140 hectares, stretching over 398 kilometres. (Samenwerkingsorgaan Hoekse Waard, 2012).

High-quality habitat patches

To function for pollination services, finely-meshed and robust networks need to be extended, but must also contain high-quality vegetation. The majority of the road verges, field margins and ditch banks are traditionally managed i.e. the vegetation is kept short due to frequent mowing. As a result, the area is not very suitable for the implementation of pollination services. To effectively support animal pollinators, the management of fine elements should be more focused on providing suitable vegetation structure and habitat. Several management techniques can be applied, such as (1) extensively managing these fine landscape elements through mowing and planting (2) planting willows, which positively influences biodiversity, alongside ditch banks, creeks and hayfields (3) emphasizing on biologically diverse patches of land e.g. botanically-rich hayfields. The management of robust elements should aim at providing suitable conditions for food, shelter and a stable living environment across larger levels of geographical scale. This includes planting rows of flowering trees e.g. fruit trees or willows alongside dikes, forming a robust network that entwines around the fields of the Hoekse Waard and providing high-quality habitat (Samenwerkingsorgaan Hoekse Waard, 2012). To support pollination services, environmental conditions in these robust elements need to be stable and continuous compared to the arable fields, that are characterized by an annual turnover of vegetation (Steingröver et al., 2010). Thus, corridors and patches of (semi)natural habitats need to be in the direct vicinity of farmlands in order to be effective.

5.3 Analysis of the case study: knowledge gaps

So far, much attention has been paid to the spatial configuration of a pollination network in the Hoekse Waard. To design an ecological network that supports pollination services, more aspects need to be included. In this section, the knowledge gaps will be further elaborated upon.

Evaluation mechanisms for pollination services

The scientific literature review demonstrated that relatively much attention has been paid to the structure and value component, while the function chain is seen as an intermediary link. However, there is a scientific consensus that the ‘structure’, ‘function’ and ‘value’ component are positively related to one another. An important part of implementing the chain, which was not discussed in the literate review, is the way in which pollination methods are quantified and valuated. Many studies that focus on valuing pollination services can be found (Winfree et al., 2009; Winfree et al., 2011). Therefore, it is recommended to use this information to estimate the added value of pollination networks in the Hoekse Waard.

Influence of stakeholder processes on the design process

Stakeholders have different interest in ecosystem services that function at different scales. For example, although all stakeholders had a mutual interest in conserving agricultural characteristics of the area and were aiming at more sustainable land-use practices, but each stakeholder had private interests and expectations. For instance, the water board had a great interest in the improvement in water quality as a result from reduced pesticide use, and the nature organisations in the conservation and increase of biodiversity. For farmers, however, the management of natural pest control most not only result in effective control, but also cost-efficient by saving on the costs of chemical pesticides and water purification techniques (Steingröver et al., 2010). If the aim is to successfully implement pollination services on top of natural pest control, the positions and beneficiaries of each stakeholder need to be investigated. Although general models can be used to guide collaborative planning processes, positions and beneficiaries of local stakeholders are highly contextual.

5.4 Analysis of the case study: Scientific challenges

As opposed to the knowledge gaps that were identified in the previous sections, there is no scientific knowledge on particular aspects relevant to the structure-function-value chain. A brief overview of the major challenges, which were distilled from the scientific studies used for the literature review, is provided in the next paragraphs.

Integrating across ecosystem services
An important scientific challenge is to integrate across various ecosystem services in determining tradeoffs and synergies of alternative land-use management schemes. There is a need for integrated studies that determine not only the added value of pollination services, but also the effects of other agricultural inputs, such as pest control or water supply (Kremen et al., 2007). This is an important notion for the case of the Hoekse Waard if multiple ecosystem services are to be incorporated into alternative management schemes. This also provides an implication for the multiple-use of space, which could potentially form an interesting scientific challenge in land-use planning practice.

Evaluating compensatory responses between pollinators and plant-pollinator interactions
A further challenge is to evaluate the extent to which compensatory responses of other (wild) pollinator species can compensate for the loss of managed honey bees as opposed to investigating the relationship pollinator abundance and the provisioning of services. Relatively little is known about pollinator species other than bees. Moreover, there exists a mutual relationship between plants and pollinators. Further research should document the potential misalignments and the reproductive and demographic consequences for plants and pollinators (Kremen et al., 2007). This implies the need for further research on the compensatory responses between various pollinator species in the Hoekse Waard and the relationship between these pollinators and local plants and crops.

Evaluating the effects of alternative land-use schemes
Adopting alternative land-use schemes could potentially reduce the farmer's dependence on managed honey bee populations. Pollination services must be managed over various temporal and spatial scales. An important goal of future studies is not only to predict but also empirically determine the effects of alternative management techniques on pollination services, pollinator communities, crop yields and net revenues (Kremen et al., 2007). For instance, in case of the Hoekse Waard various alternative land-management schemes need to be evaluated for their effectiveness across spatial scales and on the short- and longer term.

5.5 Major insights

A number of valuable insights can be deduced from the case study of the Hoekse Waard. Provided the fact that a number of scientific challenges remain and that knowledge gaps will persist to some degree as social networks are highly contextual, the structure-function-value chain is subject to constant revision. However, one of the major insights of this evaluative case study is the way in which the structure-function-value chain, and associated scientific knowledge, contributes to landscape design in collaborative planning. Strikingly, the structure-function-value is applied differently in each context. For instance, the chain is applied from left to right (see figure 20 on the next page) when assessing spatial plans. In assessments, the extent to which landscape patterns has changed and how this has affected pollinator communities and the provisioning of crop pollination services is evaluated (Opdam, 2013). Hence, one can deduce what the approximate outcome regarding the level and value of pollination services will be by evaluating the configuration of spatial elements in the landscape. Additionally, when scoping the scientific articles for information on pollination services, the structure-function-value chain was applied from right to left.

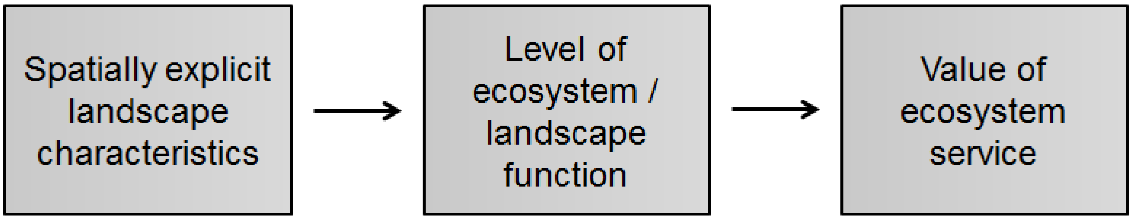

Figure 20: The structure-function-value chain, as applied to in the assessment of spatial plans. (Modified after Termorshuizen & Opdam, 2009)

However, the chain is applied in the reversed order in landscape design (Opdam, 2013), as was done in the Hoekse Waard. The ultimate goal was to design an ecological network that sufficiently supports a desired level of pest control. Looking at the chronological order of the process, the stakeholders first negotiated which type(s) of ecosystem services to aim for and the desired ecosystem value through a series of stakeholder sessions. Spatial norms were defined as minimum measures needed to achieve this set target. These spatial patterns depend on local characteristics of the landscapes and distances between local areas. (Steingröver et al., 2010). Hence, in case of the Hoekse Waard, the starting point consisted of the 'value' component, reverting the order of the original chain. In figure 21, the structure-function-value chain is modified to a reversed version. Note that the figure can still be read from left to right, but that the original 'structure-function-value' chain is reverted to a 'value-function-structure' chain, in which different levels of pollination value and associated pollinator diversity are negotiated by stakeholders, before adjusting local spatial patterns and structures to these targets.

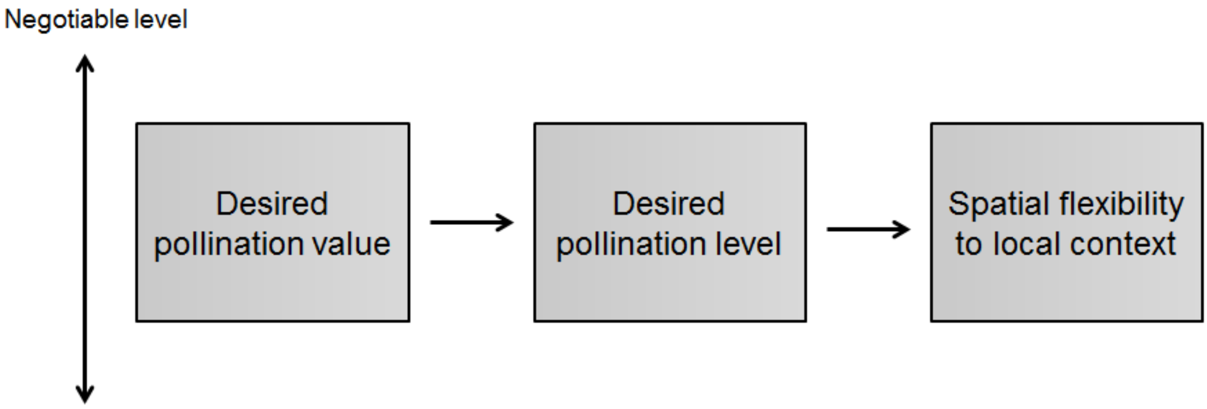

Figure 21: The structure-function-value chain in reverted order, resulting in a value-function-value chain in which desired pollination values and level influence the spatial configuration of ecological networks. (Modified after Termorshuizen & Opdam, 2009 ; Opdam et al., 2008)

Notably, however, the structure-function value chain was applied in both ways during the design process in the Hoekse Waard. The team of researchers developed design rules, by applying the structure-function-function from left to right to assess alternative options (see figure 20), but for the actual application of such rules the involvement of local stakeholders was of vital importance (Steingröver et al., 2010). As was previously stated, the chain is applied in reversed order in the actual landscape design. Hence, there are differences between the theoretical and practical application of the structure-function-value chain as a concept.

Final discussion

The results from the previous chapters will be synthesized to provide an answer to the general research question:

To what extent provide available scientific studies suitable knowledge on the relationships between the components of the structure-function-value chain regarding pollination services for collaborative planning practice?

Both disciplinary and interdisciplinary articles provide useful information on the structure-function-value chain to a varying extent, but differ in the way they do so. Generally speaking, disciplinary are based on methods that involve isolating and investigating two variables (chiefly regarding the 'structure' and 'value' component) e.g. distance from natural habitat and level of pollination services delivered. Emphasis is generally placed on one specific crop or type of plant. Additionally, these studies tended to focus on one group of pollinators, namely bees. Furthermore, disciplinary studies tend to focus on a limited number of specific aspects of pollination services instead of providing a holistic picture of ecosystem services. Hence, disciplinary studies do not provide suitable scientific information that can be applied in a myriad of collaborative planning contexts.

This does not mean, however, that disciplinary studies do not contribute to the development of the structure-function-value chain. By isolating two variables, the workings behind specific ecological processes can be discovered and generalized into rules-of-thumb that can be applied in a wider variety of contexts. Distilling overall trends and combining results from multiple studies is an important step in creating more suitable knowledge for collaborative planning processes. When using the results of various studies, however, one can encounter a few discrepancies. The investigated systems contrast with one another in terms of ecosystem type, land-use intensities or richness in pollinator communities. Not all studies measure the same variables or measure variables in the same manner, resulting in different sample sizes. Furthermore, synthesizing the results of various studies requires considering a difference in geographical scale, location and timeframe. However, the aim of the majority of interdisciplinary studies is not to compare different systems, but to detect general patterns that may occur in each and incorporate those in general frameworks. The reference lists of interdisciplinary studies usually consists of a long list of disciplinary studies, indicating the need to 'transform' this type of information. Therefore, rules-of-thumb that were distilled from disciplinary studies contribute to developing more general frameworks in interdisciplinary studies, such as the MABES conceptual framework as proposed by Kremen et al. (2007.). Therefore, some standardisation among studies is needed, albeit part of the specific scientific information is lost in the process of constructing more holistic frameworks.

General frameworks can aid collaborative planning process to a certain extent as they provide vital guidelines. However, not all relevant information can be captured into a general model as collaborative planning processes are highly contextual. For example, local conditions (stakeholder positions and beneficiaries, local biodiversity, local environmental conditions) influences the spatial configuration of pollination networks and the level of pollination services that is aimed for, despite the myriad of scientific information that is available on pollination services and collaborative planning processes.

A characteristic that disciplinary and interdisciplinary studies do share to an extent, however, with one exception (study by Kremen et al., 2007), is that the four basic features of ecological networks are not explicitly mentioned or discussed. Particular aspects to spatial conditions, chiefly distance to natural habitat, are discussed without including further features of spatially explicit landscape structures. On the other hand, the scientific information that was gained during the literature review could easily be related to the landscape characteristics of the Hoekse Waard and the four key features of ecological landscapes. The case study demonstrated that the concept of ecological networks can be used in a wide variety of landscapes. The density of the network may differ, but the concept of using robust and finely-meshed landscape structures is applicable to almost any landscape. For instance, the Hoekse Waard consists of a network of linear elements in the landscape, which may not be typical of landscapes elsewhere. The robust elements may be more patchy, and hence requires a focus on patchy elements rather than linear structures (Steingröver et al, 2010). Thus, it needs to be stressed that general models provide a solid base for design processes, but need to be adjusted to local characteristics.

A second characteristic that disciplinary and interdisciplinary studies share regards the general consensus regarding the spatial scale on which pollination services operate and how these spatial scales relate to one another. At the local scale, pollinator communities inhabit small patches of habitat and pollinate nearby flowers. Pollination services can also be provided at the landscape scale, where pollination services are provided through large orchards, stretching across the landscape. Biodiversity conservation generally requires large and natural landscapes, but both disciplinary and interdisciplinary studies demonstrated that crop pollination operates at small patches of (semi-) natural patches of habitat within anthropogenic landscapes. This notion need to be kept in mind when communicating with stakeholders, biologists and ecologists as their view of ‘ecological networks’ might include associations with robust nature reserves and corridors, stretching over the landscape. This is an important notion, because understanding the relationship between pollination services and spatial scale will be vital to developing local and landscape-level management strategies and spatial plans. For example, there is no clear scientific answer to the question on how patches of natural habitat should be distributed within agricultural landscapes to provide crop pollination services. As was previously stated, the negotiations between stakeholders will determine how pollination services are protected and managed. Additionally, evaluating pollination services (value component of the chain) can take place on various ‘social’ scales e.g. local markets, regional or national production areas or global markets.

In conclusion, scientific literature offers bits and pieces of suitable information, but requires further moulding into general frameworks. In disciplinary studies, scientific knowledge is generated through the isolation of specific variables and distilling general rules-of thumb from them. On the other hand, interdisciplinary studies show a general trend of placing these general rules-of-thumb into a comprehensive framework, as was successfully done by Kremen et al., (2007). Despite this apparent synergy between these types of studies, there still are still important scientific challenges ahead. To begin with, there is a limited number of interdisciplinary studies that contain suitable information and comprehensive frameworks that are valuable to collaborative planning processes. A further challenge is to integrate across ecosystem services and adapt land-use plans to fit the requirements of various services. The second challenge is to evaluate the extent to which compensatory responses of other pollinators can make up for the loss of managed honey bees. The third challenge consists of evaluating the effects of alternative land-use schemes over temporary and spatial scales in order to sketch informative scenarios for local stakeholders. Last but not least, the methods used to scope the scientific literature for relevant information were based on the characteristics of the structure-function-value chain and collaborative planning processes. It is one of the many ways to effectively distil relevant patterns from scientific literature. Provided the considerable amount and variety of available scientific literature on pollination services, the development of such evaluation methods are required to effectively scope scientific sources for relevant information that can be incorporated into applicable frameworks useful for collaborative planning processes. It also needs to be kept in mind that constructing such evaluation methods is an iterative process and therefore, no straightforward rules apply to this process. By constantly evaluating and putting existing methods to the test through trial-and-error, evaluation methods and the resulting general frameworks can be improved upon, leading to more suitable knowledge for collaborative planning processes. However, one should also acknowledge that knowledge gaps and scientific challenges will pertain and that planners cannot afford to wait with applying scientific knowledge until everything is known as that will never be the case. The following quote from Theobald et al. (2000), therefore, captures the final conclusion of this article:

‘*’We cannot afford waiting with applying our knowledge until we know enough: that will never be the case. Land use decision making will not wait for scientists to get it right (Theobald et al., 2000).’’*

References

Scientific literature

Balvanera, P., Pfisterer, A. B., Buchmann, N., He, J. S., Nakashizuka, T., Raffaelli, D., & Schmid, B. (2006). Quantifying the evidence for biodiversity effects on ecosystem functioning and services. Ecology letters, 9(10), 1146-1156.

Brittain, C., Kremen, C., & Klein, A. M. (2013). Biodiversity buffers pollination from changes in environmental conditions. *Global change biology*, *19*(2), 540-547.

Brosi, B. J., Daily, G. C., & Ehrlich, P. R. (2007). Bee community shifts with landscape context in a tropical countryside. *Ecological Applications*, *17*(2), 418-430.

Chaplin-Kramer, R., Tuxen-Bettman, K., & Kremen, C. (2011). Value of wildland habitat for supplying pollination services to Californian agriculture. *Rangelands*, *33*(3), 33-41.

Cowling, R. M., Egoh, B., Knight, A. T., O'Farrell, P. J., Reyers, B., Rouget, M., ... & Wilhelm-Rechman, A. (2008). An operational model for mainstreaming ecosystem services for implementation. Proceedings of the National Academy of Sciences, 105(28), 9483-9488.

Daily, G. C., Polasky, S., Goldstein, J., Kareiva, P. M., Mooney, H. A., Pejchar, L., ... & Shallenberger, R. (2009). Ecosystem services in decision making: time to deliver. Frontiers in Ecology and the Environment, 7(1), 21-28.

De Groot, R. S., Alkemade, R., Braat, L., Hein, L., & Willemen, L. (2010). Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. Ecological Complexity,7(3), 260-272.

Dupont, Y. L., Padrón, B., Olesen, J. M., & Petanidou, T. (2009). Spatio-temporal variation in the structure of pollination networks. *Oikos*, *118*(8), 1261-1269.

Favila, M. E., & Halffter, G. (1997). THE USE OF INDICATOR GROUPS FOR MEASURING BIODIVERSITY AS RELATED T0 COMMUNITY STRUCTURE AND FUNCTION.

Harris, J. A., Hobbs, R. J., Higgs, E., & Aronson, J. (2006). Ecological restoration and global climate change. *Restoration Ecology*, *14*(2), 170-176.

Klein, A. M., Vaissiere, B. E., Cane, J. H., Steffan-Dewenter, I., Cunningham, S. A., Kremen, C., & Tscharntke, T. (2007). Importance of pollinators in changing landscapes for world crops. *Proceedings of the Royal Society B: Biological Sciences*, *274*(1608), 303-313.

Klein, A. M., Brittain, C., Hendrix, S. D., Thorp, R., Williams, N., & Kremen, C. (2012). Wild pollination services to California almond rely on semi-natural habitat. *Journal of Applied Ecology*, *49*(3), 723-732.

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

Kremen, C. (2005). Managing ecosystem services: what do we need to know about their ecology?. Ecology letters, 8(5), 468-479.

Kremen, C., Williams, N. M., Aizen, M. A., Gemmill-Herren, B., LeBuhn, G., Minckley, R., ... & Ricketts, T. H. (2007). Pollination and other ecosystem services produced by mobile organisms: a conceptual framework for the effects of land-use change. *Ecology Letters*, *10*(4), 299-314.

Kremen, C., Williams, N. M., Bugg, R. L., Fay, J. P., & Thorp, R. W. (2004). The area requirements of an ecosystem service: crop pollination by native bee communities in California. *Ecology letters*, *7*(11), 1109-1119.

Kremen, C., & Miles, A. (2012). Ecosystem services in biologically diversified versus conventional farming systems: benefits, externalities, and trade-offs. *Ecology and Society*, *17*(4), 40.

Mace, G. M., Norris, K., & Fitter, A. H. (2012). Biodiversity and ecosystem services: a multilayered relationship. *Trends in ecology & evolution*, *27*(1), 19-26.

Magurran, A. E. (2004). Measuring biological diversity.

Meffe, G. K. (1998). The potential consequences of pollinator declines on the conservation of biodiversity and stability of food crop yields. *Conservation Biology*, *12*(1), 8-17.

Millennium Ecosystem Assessment (2003). Ecosystems and Human Well-Being: A Framework For Assessment. Island Press, Washington.

Morandin, L. A., & Winston, M. L. (2006). Pollinators provide economic incentive to preserve natural land in agroecosystems. *Agriculture, Ecosystems & Environment*, *116*(3), 289-292.

Olesen, J. M., Bascompte, J., Dupont, Y. L., & Jordano, P. (2007). The modularity of pollination networks. *Proceedings of the National Academy of Sciences*, *104*(50), 19891-19896.

Olschewski, R., Tscharntke, T., Benítez, P. C., Schwarze, S., & Klein, A. M. (2006). Economic evaluation of pollination services comparing coffee landscapes in Ecuador and Indonesia. *Ecology and Society*, *11*(1), 7.

Opdam, P., & Steingröver, E. (2008). Designing Metropolitan Landscapes for Biodiversity Deriving Guidelines from Metapopulation Ecology. Landscape journal, 27(1), 69-80

Opdam, P., Pouwels, R., van Rooij, S., Steingröver, E., & Vos, C. C. (2008). Setting biodiversity targets in participatory regional planning: introducing ecoprofiles. *Ecology and Society*, *13*(1), 20.

Opdam, Paul. "Using ecosystem services in community-based landscape planning: science is not ready to deliver." *Landscape Ecology for Sustainable Environment and Culture*. Springer Netherlands, 2013. 77-101

Opdam, P., Verboom, J., & Pouwels, R. (2003). Landscape cohesion: an index for the conservation potential of landscapes for biodiversity. Landscape ecology,18(2), 113-126.

Ricketts, T. H., Regetz, J., Steffan-Dewenter, I., Cunningham, S. A., Kremen, C., Bogdanski, A., ... & Viana, B. F. (2008). Landscape effects on crop pollination services: are there general patterns?. Ecology letters, 11(5), 499-515.

Schröter, D., Cramer, W., Leemans, R., Prentice, I. C., Araújo, M. B., Arnell, N. W., ... & Zierl, B. (2005). Ecosystem service supply and vulnerability to global change in Europe. *Science*, *310*(5752), 1333-1337.

Steingröver, E. G., Geertsema, W., & van Wingerden, W. K. (2010). Designing agricultural landscapes for natural pest control: a transdisciplinary approach in the Hoeksche Waard (The Netherlands). Landscape Ecology, 25(6), 825-838.

Shuler, R. E., Roulston, T. A. H., & Farris, G. E. (2005). Farming practices influence wild pollinator populations on squash and pumpkin. *Journal of economic entomology*, *98*(3), 790-795.

Termorshuizen, J. W., & Opdam, P. (2009). Landscape services as a bridge between landscape ecology and sustainable development. *Landscape Ecology*, *24*(8), 1037-1052.

Theobald, D. M., Hobbs, N. T., Bearly, T., Zack, J. A., Shenk, T., & Riebsame, W. E. (2000). Incorporating biological information in local land-use decision making: designing a system for conservation planning. *Landscape ecology*,*15*(1), 35-45.

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

Winfree, R., Gross, B. J., & Kremen, C. (2011). Valuing pollination services to agriculture. *Ecological economics*, *71*, 80-88.

Worm, B., Barbier, E. B., Beaumont, N., Duffy, J. E., Folke, C., Halpern, B. S., ... & Watson, R. (2006). Impacts of biodiversity loss on ocean ecosystem services. science, 314(5800), 787-790.

Zhang, W., Ricketts, T. H., Kremen, C., Carney, K., & Swinton, S. M. (2007). Ecosystem services and dis-services to agriculture. *Ecological economics*,*64*(2), 253-260.

Other sources

Samenwerkingsorgaan Hoekse Waard 2012. Landschapsbeheerplan Hoekse Waard [Online available at]
http://www.sohw.org/actueel/70/ [Accessed on] 24-01-2014

Pictures

Biojournaal 2013. Bestuivers [Online available at]
http://www.biojournaal.nl/nieuws/2013/0610/Bestuivers.jpg [Accessed on] 03-12-2013

Netwerk Platteland 2013. Hoekse Waard gaat praktijkervaring opdoen. [Online available at]
http://www.netwerkplatteland.nl/hoeksche-waard-gaat-praktijkervaring-opdoen/ [Accessed on] 03-12-2013

Bijenhouders 2013. Idylle [Online available at]
http://www.bijenhouders.nl/images/pictures/normal/idylle-1.jpg [Accessed on] 03-12-2013