Ecosystem services in agroforestry systems of Europe

A systematic map

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Contents

List of Tables

List of Figures

List of Abbreviations

Abbreviation	Explanation
AGF	Agroforestry systems
Ac	Alley cropping
CEE	Collaboration for Environmental Evidence
CICES	Common International Classification of Ecosystem Services
CS	Cultural service
Co	Cherry orchard
De	Dehesa
ES	Ecosystem services
EU	European Union
MEA	Millennium ecosystem assessment
Mo	Montado
O	Orchard
Oo	Olive orchard
PS	Provisioning service
RS	Regulating service
SS	Supporting service
SLR	Systematic literature review
SM	Systematic map
Sa	Silvoarable system
Sp	Silvopastoral system
UN	United nation
W	Woodland
Wp	Woodpasture
Oth	undefined agroforestry systems

”Rarely will the money to be made by protecting nature match the money to be made by destroying it.
Nature offers low rates of return by comparison to other investments.
If we allow the discussion to shift from values to value – from love to greed –
we cede the natural world to the forces wrecking it.”
[Monbiot, 2016]

Abstract

Agroforstsysteme sind prägende Elemente der europäischen Kulturlandschaft [McAdam and McEvoy, 2009]. Sie liefern mannigfaltige Ökosystemdienstleistungen und sind zur gleichen Zeit ökologisch sinnvoll und auch ökonomisch profitabel [Jose, 2009; Bjorklund et al., 2013]. Ökosystemdienstleistungen in Agroforstsystemen wurden jedoch bis dato noch nicht umfassend erforscht und auch die Aussagekraft der bisherigen Studien ist unklar [Fagerholm et al., 2016]. Das Ziel dieser Arbeit ist den aktuellen Stand des Wissens bezüglich Ökosystemdienstleistungen in Europäischen Agroforstsystemen darzustellen und einen Teil der Studien hinsichtlich ihrer Qualität kritisch zu beurteilen. Zu diesem Zweck wurde eine systematische Literaturzusammenfassung erstellt, welche sich auf die Richtlinien der Collaboration for Environmental Evidence (CEE) bezieht. Durchsucht nach relevanten Studien wurden hierfür die wissenschaftliche Datenbank ISI Web of Knowledge sowie die Suchmaschinen Google und Google scholar mit Hilfe von vordefinierten Suchbegriffen. Die Recherche wurde auf deutsche und englische Artikel beschränkt, die seit 1929 veröffentlicht wurden. Die extrahierten Artikel wurden mit Hilfe eines zweistufigen Prozesses auf ihre Relevanz geprüft. Dieser Prozess bestand aus einer Prüfung von Titel und Zusammenfassung und darauffolgend aus Zusammenfassung und Volltext durch vordefinierte Kriterien, die über Ausschluss oder Einbeziehung der Studien in die systematisch Literaturzusammenfassung entschieden. Die finalen 110 Studien wurden mit Hilfe der Software R. qualitativ ausgewertet und ein Teil der Studien wurde mit Hilfe des Qualitätsbewertungsschlüssel von Mupepele et al. [2015] kritisch beurteilt. Die Gruppe der regulatorischen und der versorgenden Ökosystemdienstleistungen ist unter den 110 finalen Studien am häufigsten vertreten. Zudem liegt der Fokus primär auf Dehesa und Silvopastoralen Systemen, welche insbesondere in warmen, mediterranen Gebieten vorkommen. Agroforstsysteme und dazugehörigen Ökosystemdienstleistungen, die in temperaten Klimaten beheimatet sind, wurden bis jetzt noch unzureichend erforscht. Die Qualitätsprüfung fand heraus, dass ein Großteil der Studien auf dem gleichen Evidenz Niveau bleibt oder sie nur um 0.5 Evidence Niveaus herunter gestuft werden. Diese Arbeit soll einen Anfangspunkt der Ökosystemdienstleistungsforschung in Agroforstsystemen in Europa darstellen. Desweitern sollen die Ergebnisse als Referenz für Forscher/innen, Praktiker/innen, Naturschützern/innen und politische Entscheidungsträgern/innen für geplante Agroforstprojekte dienen.

Abstract

Agroforestry systems are defining elements of the European countryside [McAdam and McEvoy, 2009] that are viewed as part of a working landscape and provide ecosystem services, environmental benefits and economic commodities [Jose, 2009] [Björklund et al., 2013]. However, agroforestry systems in Europe are not very well explored in terms of ecosystem services and their evidence basis [Fagerholm et al., 2016]. The current state of knowledge, as well as the gaps in the research into ecosystem services in agroforestry systems in Europe, will be identified and a subset of studies will be critically appraised, centred upon the quality of the literature. A systematic literature map, following the guidelines established by the Collaboration for Environmental evidence (CEE) Collaboration for Environmental Evidence [2009] was therefore conducted. The ISI web of knowledge database and the search engines, such as Google and Google scholar, were systematically surveyed for relevant studies on the topic. These searches were limited to English and German articles, published since 1929. The search results were assessed for relevance in a two step process of comparing title and abstract, as well as abstract and the full text against stipulated and/or designated criteria for both inclusion and exclusion. The remaining 110 articles were then qualitatively evaluated using the software R. As a second step, the quality of a subset of the final articles was critically appraised using the quality assessment tool established by Mupepele et al. [2015]. We found amongst the 110 studies included that regulation maintenance and provisioning services are the most investigated ecosystem services categorize in the literature. A major part of the literature focuses on dehesa and silvopastoral systems located mainly in the Mediterranean region. The Nemorales zonobiome (temperate climate) have not so far been researched extensively regarding ecosystem services in agroforestry systems. The findings also show distributions of the the studies concerning the study design and the main message and/or implications of the articles. The evidence assessment generally revealed that many studies remained either at the same level of evidence or are downgraded only to approximately 0.5 of a level. To conclude, this work can be seen as the point of commencement in ecosystem services for agroforestry systems research in Europe. It can be used by researchers, practitioners, conservationists and policy-makers as reference for prospective agroforestry projects.

Chapter 1

Introduction

1.1 Agroforestry systems

Agroforestry systems are defining elements of the European countryside [McAdam and McEvoy, 2009]. They are *"systems that include sustainable land management practices, and comprise at least two components that interact with each other, one woody (tree /shrub) and one herbaceous (grass /crop including forage), they may also involve livestock as a third component"* [Griffith et al., 2015; Björklund et al., 2013]. The Neolithic period, that beginning about 10,200 before Christ and ended between 4,500 and 2,000 before Christ, constitutes the point of origin of agroforestry practices in Europe [P K R Nair, 2012]. At that time forests were used as a source of nutrients in order to maintain soil fertility on agricultural land [Bergmeier et al., 2010]. During the twentieth century the growing population demanded increased food supplies as well as productivity intensification in the agricultural sector. There was no emphasis placed on the environmental benefits of integrated tree and agricultural systems as a course of policy and farmers regarded widely spaced trees in croplands as a hindrance to the efficiency of the crop areas [Graves et al., 2007]. This development led to the disappearance of traditional agroforestry systems. Since that time multiple research projects have been established to investigate traditional agroforestry systems in an effort to prove the negative impact their loss would have on the environment [P K R Nair, 2012], as well as the economic, environmental and social benefits arising from them [Sibbald et al., 2001; Burgess et al., 2003, 2005; Mosquera-Losada et al., 2010]. In order to understand the negative consequences of high-input agriculture on soil, water quality etc. modern agroforestry systems have been developed that draw on modern farming practices but are nevertheless based on traditional systems [Nerlich et al., 2013].

There are different ways to classify agroforestry systems. Commonly they are classified according to their components [McAdam and McEvoy, 2009; Nerlich et al., 2013]. The following defined agroforestry systems by McAdam and McEvoy [2009]; Smith [2010] as well as Nerlich et al. [2013] are the most common in Europe (Table 1.1, below)

Table 1.1: Definitions of the most common agroforestry practices in Europe

Agroforestry practice	Definition
Silvoarable systems	Trees are planted in single or multiple rows with arable or horticultural crops between the rows
Silvopastoral systems	Trees are combined with forage and livestock production including high (forest or woodland grazing) and low density (open forest trees) stands
Orchard intercropping	Fruit tree systems on arable land or grassland mixed with grazing animals (special agroforestry system)
Forest farming	Utilization of forested areas for producing or harvesting natural or cultivated specialty crops for medical, ornamental or culinary uses
Riparian buffer strips	Perennial vegetation (grass, shrubs, trees) is planted in strips between arable land or pastures and bodies of surface water in order to enhance and protect aquatic resources (streams, lakes) from the negative effects of agricultural practices
Windbreaks	Rows of trees are planted around farms and fields to protect crops, animals and soil from wind

Additionally, agroforestry systems can be readily characterized by the time they have been established or at least by the time they have become part of the normal cultural landscape [Smith, 2010; Nerlich et al., 2013]. The papers of Nerlich et al. [2013] and Smith [2010] offer an overview of both traditional and modern agroforestry systems (see Table 1.2 and 1.3).

Table 1.2: Traditional agroforestry systems

Agroforestry system	Definition	Location
Montado/Dehesa	Agrosilvopastoral systems characterized by oak trees and their savanna-like physiognomy [Vicente and Alés, 2006]	Portugal, Spain
Streuobst/pre verger	Various fruit tree species combined with various arable crops or grassland (in some cases with animals)	Germany, Austria, France
Grazed forests	Widely spaced stands with diverse underbrush vegetation providing forage for livestock and wildlife[Salmon et al., 2012]	Swizerland Hungary
Pollarding	Cutting back trees to product a close rounded head of young branches with dense foliage	Norway, Great Britain
Woodland grazing and wood-pasture	Pasturing in woodland is one of the oldest land use practices in human history. In northern Europe, mature woodland provided shelter to cattle and sheep during the winter months, while in Mediterranean regions woodland provided browsing, foraging and shade during early summer drought periods.	Europe

Table 1.3: Modern agroforestry systems

Agroforestry system	Definition	Location
Buffer strip	Woody strips planted to stabilize sloping soils	Italy, Spain, Greece, France
Alley cropping	Utilizing of planted rows of crops or pastures in alleys formed by single or multiple rows of trees or shrubs**?**	France, Germany
Riparian buffer	Lands adjacent to streams where vegetation is strongly influenced by the presence of water**?**	Ukraine, Estonia, Spain

The third and last frequently used classification is dependent on the particular agroecological zone. The different zones have specific climatic and ecological conditions governing the structure of the agroforestry system [McAdam and McEvoy, 2009], although these can in turn influence the local climate [P K R Nair, 2012]. Micro-climatic conditions can be modified by a certain type of agroforestry system (less sunlight, temperature and dryness) which favours the cultivation of agroforestry systems in the southern part of Europe.

The agroforestry systems surveyed in this work are sometimes expressed in different terms, although they consist of the same forestry and agricultural components, e.g silvopastoral systems and wood pasture having equal tasks (see section 2.1.5, scope search generating search terms).

Aside from the baseline information concerning agroforestry systems (history and classifications), their key advantages and implications compared to separate agricultural and tree systems [Graves et al., 2007; Dupraz et al., 2005] are clear. On the one hand, they simultaneously increase land resource efficiency and productivity on the same piece of land [Fagerholm et al., 2016], while on the other hand they serve as biodiversity hot spots, providing animal habitats, improving the micro climate, capturing carbon and acting as a nutrient and water pump from the deeper layers of the subsoil [Björklund et al., 2013; McAdam and McEvoy, 2009; Varah et al., 2013]. In general, agroforestry systems are viewed as part of a working landscape that provide ecosystem services, environmental benefits and economic commodities [Jose, 2009; Björklund et al., 2013]. However, currently institutional and policy support is still too weak and ineffective for agroforestry practices in most European countries [P K R Nair, 2012], even though their advantages and various environmental, economic and social benefits are widely known. The concept of ecosystem services could help to highlight beneficial quantitative and qualitative mechanisms of nature to convince policy-makers and practitioners to support agroforestry practices.

1.2 Ecosystem services

Ecosystem services have been defined by Daily [1997] in the introductory chapter of "Nature's Services: Societal Dependence on Natural Ecosystems" as *"the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life"* [Daily, 1997]. The origin of the modern history of ecosystem services can be traced back to the late 1970s [Gómez-Baggethun et al., 2010], when the general public first became more aware of biodiversity conservation [Westman, 1977; Ehrlich and Ehrlich, 1981]

Also science got more interested in the concept of ecosystem services, that time, [Ehrlich and Ehrlich, 1981] and a dedicated research branch arose concentrating on ecosystem services. This was strongly and actively supported by the Beijer Institute's Biodiversity program (early 1990s), and also by an increased number of literature publications [Costanza et al., 1997; Daily, 1997] as well as by wider interest in the development of methods of estimating the economic value of ecosystem services [Costanza et al., 1997]. In the following decade, policy-makers paid increasing attention to the ecosystem service concept due to the release of the "Ecosystem Approach" (adopted by the United nations environment program - Convention on biological diversity, 2000) and the Global Biodiversity Assessment. The Millennium Ecosystem Assessment (MEA) [Arico et al., 2005] in 2005 was a milestone in ecosystem services history, as it located the concept at the heart of policy making and led to increasing interest on the topic amongst scientists. The use of the concept has increasingly widened from *"the original emphasis on ecosystem services as a pedagogical concept designed to raise public interest for biodiversity conservation"* [Gómez-Baggethun et al., 2010]. Today the emphasis lies on the trading of ecosystem services on different markets.

In 2005 the Millennium Ecosystem Assessment was published and includes a classification that divides ecosystem services into four main categories [Gómez-Baggethun et al., 2010; Eiter and Stokstad, 2015]. The report (MEA) and the categorization (see Table 1.4) builds on the work of

Groot et al. [2002]; McAdam and McEvoy [2009]

Table 1.4: Ecosystem services divided into four main categories

Ecosystem services category	Definition
Provisioning services	Goods, such as food or freshwater, that ecosystems provide and humans consume or use.
Regulatory services	Services, such as flood reduction and water purification, that can be provided by healthy natural systems, such as wetlands.
Cultural services	Intangible benefits, such as aesthetic enjoyment or religious inspiration.
Supporting services	Basic processes and functions, such as soil formation and nutrient cycling, that are critical to the provision of the first three types of ecosystem services.

During the following years influential voices called for a standardized ecosystem services classification system [Boyd and Banzhaf, 2007]. The European Environment Agency responded to these needs and established the common international classification of ecosystem services [Group et al., 2013; Potschin and Haines-Young, 2013]. The goal of the Common international classification of ecosystem services (CICES) (Scheme saved on CD) [Group et al., 2013] is to combine the framework of the United nation (UN) System of Environmental-Economic Accounts [United Nations, 2014] with the European union (EU) process on the mapping and assessment of ecosystems and their services. The scheme is divided into three main categories [CEE, 2013]. In contrast to the MEA [Arico et al., 2005] the category of supporting services is no longer included and the definition of services is far more stringent than it was before [Eiter and Stokstad, 2015].

Under CICES the ecosystem services are classified into three main categories [Group et al., 2013]:
1. Provisioning ecosystem services
2. Regulation and Maintenance ecosystem services
3. Cultural ecosystem services

The CICES classification [Group et al., 2013] is used in this work with just one exception: biodiversity is considered to be an ecosystem service, such as is performed in the economics of ecosystems and biodiversity (TEEB) and MEA reports [TEEB, 2008; Arico et al., 2005].

1.3 Ecosystem services of agroforestry system in Eurpe

So far only a small number of studies have been published that summarize the literature on ecosystem services in Europe's agroforestry systems (e.g McAdam and McEvoy [2009]; Trybush et al. [2012]; Fagerholm et al. [2016]). These studies do not systematically consider the whole extent of agroforestry and ecosystem services literature in Europe, aside from the recent published systematic map by Fagerholm et al. [2016] (see section 1.4: Aims and objectives). It is known, that agroforestry systems serve multiple ecosystem services, *"combining the provision of agricultural and forestry products with non commodity outputs, such as climate, water and soil regulation, and recreational, aesthetic and cultural heritage values"* [McAdam and McEvoy, 2009]. These services and benefits provided by agroforestry systems occur over a wiede range of spatial and temporal scales [Jose, 2009]. So far researchers have focused mainly on single ecosystem services and concentrated on tropical regions where these practices are already well established [Jose, 2009]. Nevertheless, the focus of interest in such systems is shifting slowly to temperate areas, where [Smith et al., 2012] investigations into agroforestry practices can balance *"productivity and environmental protection through multiple ecosystem services"*. At a time when European societies in particular are becoming more environmentally aware, while at the same time the consumption of wood and agricultural products is increasing, the promotion of agroforestry systems can be beneficial. It is able to deliver a number of ecosystem services and represents a sustainable alternative to traditional farming that could form an integral part of a multifunctional working landscape [Jose, 2009]. Additionally, there is the ongoing debate concerning mitigation of the effects of climate change and the reduction of greenhousegas emissions. Agroforestry systems have a high potential for capturing carbon [Jose, 2009] and thus could constitute a carbon sink, helping to reduce adverse global climate change [Griffith et al., 2015; Bernard Nsiah, 2010]. Highly productive modern agroforestry systems, [Björklund et al., 2013] (see section: 1.1) can help to meet the rising demand for wood. These systems are at both more profitable than separate tree and cropping systems [Björklund et al., 2013] and beneficial to the environment in terms of *"increased carbon capture, improved soil fertility and enhanced biodiversity on marginal lands"* [Tsonkova et al., 2012; Quinkenstein et al., 2009]. These points underpin the potential and relevance that agroforestry ecosystem services could have in the European context. In the past the lack of hard evidence has hindered the progress of agroforestry and its acceptance by practitioners, farmers and policy makers. Rivest et al. [2013] claim that management options as well as knowledge already exist, but that *"farmers need to be supported by relevant policies"*.

1.4 Evidence based science

Farmers indeed need to be supported not only by relevant policies but also by science based on hard evidence in order to guarantee the reliability of the study results that have been, and still are, published. These results do have some influence on the management decisions that practitioners make. Because of this, a critical appraisal of a subset of studies included in the systematic map will be conducted. This will achieved by applying a tool designed from Mupepele et al. [2015]

to assess the strength of evidence of ecosystem services and conservation studies (see, Methods: 2.2). Historically, Archie Cochrane, the founder of evidence-based medicine, pointed out the importance of *"randomised controlled studies to provide evidence on which health care is based"* [Eboptometry, 2013]. His committed work and the establishment of the Cochrane centre [Association, 2013] in 1993 encouraged other research branches to become more critical concerning their scientific work. The first step towards evidence-based practice in conservation was taken 15 years ago. Following that the 'Collaboration for Environmental Evidence' began to promote evidence based science, establishing guidelines on systematic reviews in which a strong level of evidence should be achievable. Mupepele et al. [2015] stated that: *"Evidence is the 'ground for belief' or 'the available body of information indicating whether a belief or proposition is true or validly extracted"*. Conservation practice are sometimes based on anecdotal evidence and myth rather than upon a systematic appraisal of the hard evidence [Sutherland et al., 2004], especially the evidence base that ought to *"describe the knowledge behind a statement and expresses how solid recommendations are"* [Mupepele et al., 2015]. Interventions that aim to increase the provision of ecosystem services are generally [Nature.blog, 2014], although there are voices which critically reflect on evidence-based practice in conservation [gateway, 2012]. Evidence-based practice has considerable legitimacy in science-based ecosystem services research in which people start to make money from natural services and dynamics. Thus the studies constituting the baseline for monetary calculations of given ecosystem services (e.g. biomass, biodiversity, carbon capturing etc.) should be tested for credibility and reliability in order to guarantee an appropriate and reasonable level of evidence (see, Methods: 2.2.1, Evidence-based practice)

1.5 Aims and objectives

In order to contribute to the improvement and promotion of ecosystem services research in agroforestry system this work focuses on a two-step approach: a systematic literature map followed by an evidence assessment of the articles.

1.5.1 Systematic literature map

In the most recent reviews, fragments of ecosystem service research in AGF have been summarized with a view to depicting the current state of knowledge and to identify gaps, but at insufficient. The recent paper from Fagerholm et al. [2016] has systematically summarized all investigations relating to this topic. The authors concentrate on qualitative publications and do not include single ecosystem services (e.g.Fagerholm et al. [2016]) This work aims to complement and refine the work of Fagerholm et al. [2016] by compiling a systematic literature map of quantitative and qualitative studies of categories and single ecosystem services in European agroforestry systems, and to bridge the gap in the current state of knowledge.
Two research questions were designed following the PICO or PECO [CEE, 2013] structure, targeting the research objective:

1. What is the state of the art in ecosystem services research in agroforestry systems of Europe?

2. What is the overarching aim of these studies?

One paragraph in the methods section (Development of research/review question), is dedicated to a detailed description of the research question development following the PICO or PECO structure.

1.5.2 Evidence-based practice

The introduction the quality assessment of the studies included in the systematic maps is a crucial and often neglected process. The second aim of this study is therefore to critically evaluate the quality of all the studies located in temperate Europe, and to gain an overview of the study quality. This has been achieved by applying an "Evidence based practice tool" conceptualized by Mupepele et al. [2015], with the goal of determining the level of evidence for the publications.

Chapter 2

Material and Methods

2.1 Systematic map

The aim of the systematic map (see subsubsection 1.1.3) is to provide an overview of the ecosystem services of agroforstry systems in Europe. Quantitative and qualitative studies published since 1929 have been compiled and surveyed. In the following section the design and execution of the systematic map is described. The systematic map follows the guidelines for conducting a systematic literature map established by the collaboration for environmental evidence (CEE) Collaboration for Environmental Evidence [2009] and the book : *Handbook of Meta-analysis in Ecology and Evolution* by [Koricheva and Gurevitch, 2013].

2.1.1 General information

The origins of systematic maps in ecological research can be traced back to conservation biology [Pullin et al., 2013; Stewart et al., 2005]. In 2010 the CEE established guidelines for systematic mapping in environmental management [Pullin and Stewart, 2006; Fazey et al., 2004] and defined them as *"methodical overviews of the quantity and quality of evidence in relation to a broad (open) question of policy or managment relevance"*. It is distinguishable from a systematic review in that it does not attempt to conduct an evidence synthesis, and because a critical appraisal of the evidence, while encouraged, is not mandatory.
The implementation of a systematic map involves a set of options. It objectively summarizes the whole content and existing knowledge on a research topic and helps to cover research areas with a wide publication spectrum [Kitchenham and Charters, 2007].
The CEE provides decision criteria that help to decide if a systematic map is the appropriate methodology to investigate a certain case [CEE, 2013]. The criterion that best suits the case investigated is the following:
There is a need to know how much research has been conducted on a specific question. This statement is the basis on which the decision has been made to conduct this map. The strength of a systematic map, taking different articles and offering small insights into a problem in which a clearer and more consistent picture will or can emerge [Hemingway and Brereton, 2009], is

applied. It will finally help to *"significantly improve the identification and provision of evidence"* [Pullin and Stewart, 2006] in the field of ecosystem services science in the agroforestry systems of Europe.

2.1.2 Study area

The study area covers the whole of Europe [Maplandia.com, 2015].

2.1.3 Development of research/review question

A precise, focused and clearly defined research question is crucial for a systematic map. Two criteria should be followed:

1. 1. The question must be answerable using scientific methodology; otherwise relevant primary studies are unlikely to have been conducted.

2. 2. The question should be, as yet, unanswered (i.e. the review team should search for other related systematic reviews and specify what their own will contribute)

In agroforestry research their does not exist any systematic literature map dealing with quantitative and qualitative studies as well as single ecosystem services and ecosystem services categorize. At the beginning of 2016 the paper of Fagerholm et al. [2016] systematically reviewed ecosystem services in agroforestry systems. However, they did not included single ecosystem services (for example. wood, berries etc.) and focused only on qualitative papers. According to Fagerholm et al. [2016]: "The use of single ecosystem service types (e.g. nutrient cycling) as search words would have yielded an extensive amount of results but we were interested in those studies that were clearly linked to ecosystem services research. Hence, we covered only studies that defined themselves as ecosystem services research, in line with the literature researches applied by Martínez-Harms".

So far the present work is the first systematic map of ecosystem services in the agroforestry systems of Europe covering the whole data spectrum.
To develop a closed-framed question containing all the necessary elements, the PICO or PECO [CEE, 2013] structure was applied.
Table 2.1 shows the theoretical setup [CEE, 2013; Pullin and Stewart, 2006] of the question as well as the application of the elements of the case under investigation for the purpose of designing a research question.

The formulated questions for the purpose of this systematic map are as follows:

Table 2.1: Design of research question; PICO structure

Question element	**Investigated case**
Population(of subjects)	Ecosystem services
Intervention	Agroforestry system
Comparator	Conventional forestry or agriculture
Comparator	Increases or decrease of ecosystem services

1. What is the state of the art of ecosystem services research in agroforestry systems of Europe?

2. What is the overarching aim of these studies?

2.1.4 Planning the systematic map

The systematic map was undertaken according to the guidelines for conducting such a map established by the collaboration for environmental evidence (CEE)[Collaboration for Environmental Evidence, 2009] and according to the book : *Handbook of Meta-analysis in Ecology and Evolution* by Koricheva and Gurevitch [2013]. The proceedings, described below (see the process of systematic map), follow the structure of the original systematic map closely, with one exception.
1. The literature search will be/is solely executed in ISI Web of science and Google.

2.1.5 The process of systematic mapping (SM)

The core systematic mapping process involves commonly multiple predefined stages (Figure 2.1) [CEE, 2013] that have been adopted to the case being investigated. In the following the stages are theoretically explained as well as executed.

Figure 2.1: Basic steps in conducting a systematic map adopted from CEE [2013]

Searches for literature

A search has been conducted for papers written and published in English and German in order to guarantee the accessibility of every detail of the text for the reviewer.

Scope search generating search terms

Initially, a scoping search (Appendix A1, Scope search for search terms) to assess search terms for the final search string was executed in Google/Google scholar from the 16-24 of October 2015. The terms extracted from the papers were compared with each other in order to become familiar with the most relevant search terms (Appendix A2, Catchwords scope search). Two stakeholders were questioned about the relevant ecosystem services of agroforestry systems and their suggestions compared with the preliminary search term. These additional terms supplemented the preliminary term and thus the final search terms for the literature search string have been determined.

The Boolean operator 'OR' was used to combine the search terms within each of the categories ('Intervention', 'population' and 'study area') below. For the final search string (see, Search string), the categories were then aggregated by using Boolean operator 'AND'. The asterisks (*) placed behind a term are 'wild-cards' that represent any group of characters, including no character at all [Web of ScienceTM, 2015]. The application of the below stated terms, for the final search string, is considered to be capable of identifying an acceptable share of meaningful studies. They are grouped into three categories: Intervention, population (of subject), study area.

Intervention

The search terms, related to the intervention (i.e. agroforestry practice) used for the search string sometimes have the same or slightly different meanings. For example, wood-pasture and silvopastoral systems are terms sharing agricultural and forest components equally: the grazing of animals, agricultural component, beneath trees, forest component, all occur. The difference is in the origin: silvopastoral systems are schematically planted for a targeted purpose, whereas wood-pastures are based on already established mature forest stands that *"provided shelter to cattle and sheep during the winter months"* [Smith, 2010]. In Smith [2010] a more detailed description of different agroforestry practices and their fine distinctions can be found (see also Introduction). (Agroforestry OR "Agroforestry system*" OR "Integrated land use system*" OR "Integrated land use management" OR "Integrated land use" OR "Multifunctional management" OR "Multifunctional management system*" OR "silvopastoral system*" OR "silvopastoral" OR "Tree pasture system*" OR "silvoarable system*" OR "silvoarable" OR "climate-smart agriculture" OR Windbreak* OR dehesa OR "alley cropping" OR "short rotation" OR "short rotation system" OR "Kurzumtriebsplantage*" OR "short rotation poplar" OR "short rotation coppice" OR Streuobst OR Hauberg OR "Grazed forest*" OR hedgerow* OR "wood pasture" OR "buffer strip" OR piantata OR joualle OR Pomaradas OR "pré-vergers" OR "forest grazing system*")

Population(of subjects)

("Ecosystem service*" OR "Ökosystemdienstleistung*" OR "Ecosystem function*" OR "Environmental service*" OR "Provisioning service*" OR "genetic diversity" OR "agricultural use" OR "soil retention" OR "soil fertility" OR "fruit*" OR "oil*" OR "nut*" OR "timber" OR "firewood" OR "cork" OR "fodder" OR "grain" OR "forage production" OR "forage" OR "seed production" OR "soft fruit*" OR fruit* OR vegetable* OR "bio fuel" OR fodder OR "Mechanical energy" OR "Regulating service*" OR "flood control" OR "water quality control" "water quality" OR "carbon storage" OR "climate regulation" OR "disease regulation" OR pollination OR "shelter belt*" OR "Cultural service*" OR "scenic beauty" OR education OR recreation OR tourism OR "traditional use" OR "cultural heritage" OR "landscape enhancement" OR "Supporting service*" OR "Maintenance service*" OR "pest control" OR "nutrient cycling" OR "Habitat diversity" OR "Species diversity" OR "soil conservation" OR "soil protection" OR "water conservation" OR "nutrient storage" OR "nutrient leaching" OR "carbon sequestration")

Study area:

(Europe OR temperate)

The ecosystem service terms extracted from the major studies were likened to the classification by Group et al. [2013] to ensure topicality of the terms and the general recognition in the ecosystem services science community.

Search string

A comprehensive literature search, capturing all relevant studies, was conducted. This progressed through an incremental-vise creation of the search string. The stringing together of the search terms began on a narrow view for example: (Ecosystem service*)AND(Agroforestry) AND Europe, till a broader view ensued (Appendix A3, Literature search) on the topic, until a final search string was produced. Searches of academic databases and search engines were performed between the 24th October until the 3rd of November 2015. In what follows the searches utilizing different search engines are described.

1. Academic database *"ISI web of knowledge"*:

For the main literature search only the ISI web of knowledge was surveyed. The number of databases, that comprises the web of knowledge, depends only on the subscription of the University of Freiburg. For this reason, 10 out of a possible 15 databases were searched. The decision to survey, only one academic database was due to, a limited time schedule for the literature search, and also the fact that Scopus, the second largest academic database, does not carry references before 1996 [Aghaei Chadegani et al., 2013]. These were the determining factors for only scanning the web of knowledge. The final search string was executed as a topic search, as were the others, and this was refined by:

1. COUNTRIES/TERRITORIES:

(UK OR SPAIN OR AUSTRIA OR NORTH IRELAND OR GERMANY OR FRANCE OR HUNGARY OR ROMANIA OR ITALY OR CROATIA OR SWEDEN OR SCOTLAND OR NETHERLANDS OR NORWAY OR BULGARIA OR ENGLAND OR BELGIUM OR SLOVENIA OR PORTUGAL OR DENMARK OR SWITZERLAND OR WALES OR GREECE OR SLOVAKIA OR FINLAND OR LATVIA OR POLAND OR CZECH REPUBLIC OR LITHUANIA OR ESTONIA OR IRELAND OR WEST GERMANY OR UKRAINE) PORTUGAL OR DENMARK OR SWITZERLAND OR WALES OR GREECE OR FINLAND OR POLAND OR IRELAND OR WEST GERMANY OR UKRAINE)

2. LANGUAGES: ENGLISH OR GERMAN

The final search string reads as follows:

("Ecosystem service*" OR "Ökosystemdienstleistung*" OR "Ecosystem function*" OR "Environmental service*" OR "Provisioning service*" OR "genetic diversity" OR "agricultural use" OR "soil retention" OR "soil fertility" OR "fruit*" OR "oil*" OR "nut*" OR "timber" OR "firewood" OR "cork" OR "fodder" OR "grain" OR "forage production" OR "forage" OR "seed production" OR "soft fruit*" OR fruit* OR vegetable* OR "bio fuel" OR fodder OR "Mechanical energy" OR "Regulating service*" OR "flood control" OR "water quality control" "water quality" OR "carbon storage" OR "climate regulation" OR "disease regulation" OR pollination OR "shelter belt*" OR "Cultural service*" OR "scenic beauty" OR education OR recreation OR tourism OR "traditional use" OR "cultural heritage" OR "landscape enhancement" OR "Supporting service*" OR "Maintenance service*" OR "pest control" OR "nutrient cycling" OR "Habitat diversity" OR "Species diversity" OR "soil conservation" OR "soil protection" OR "water conservation" OR "nutrient storage" OR "nutrient leaching" OR "carbon sequestration") AND (Agroforestry OR "Agroforestry system*" OR "Integrated land use system*" OR "Integrated land use management" OR "Integrated land use"

OR ”Multifunctional management” OR ”Multifunctional management system*” OR ”silvopastoral system*” OR ”silvopastoral” OR ”Tree pasture system*” OR ”silvoarable system*” OR ”silvoarable” OR ”climate-smart agriculture” OR Windbreak* OR dehesa OR ”alley cropping” OR ”short rotation” OR ”short rotation system” OR ”Kurzumtriebsplantage*” OR ”short rotation poplar” OR ”short rotation coppice” OR Streuobst OR Hauberg OR ”Grazed forest*” OR hedgerow* OR ”wood pasture” OR ”buffer strip” OR piantata OR joualle OR Pomaradas OR ”pré-vergers” OR ”forest grazing system*”) AND (Europe OR temperate)
The final number of hits accounts for 718 papers.
Details of the development of the final search string can be found in Appendix A3, literature search.

2. Search engine Google and Google scholar:
To obtain an overview of the grey literature published on the internet concerning 'ecosystem services research in agroforestry systems of Europe' a brief review was undertaken. Only one article, from Smith [2010], could be retrieved by doing the search.
Details of the development of the search can be found in Appendix A4, literature search.

In order to proceed with the screening process the 719 final articles including title and abstract, received from the first literature search (24 October until 3 of November 2015), were downloaded and saved as an Excel document (see CD, lit data 3_ 11).

Estimating the comprehensiveness of the search
For the purpose of checking the comprehensiveness of the Google grey literature search an additional Google search entering the term ”ecosystem services of agroforestry systems in Europe” was conducted on the 8th of January. Through this the systematic map of Fagerholm et al. [2016], at that time only available on the internet, was encountered. The paper has the same methodological target (systematic map) and inherent objectives of the present work, the mapping of ecosystem services of agroforestry systems in Europe. It was duly conducted and the results delineated in a distinct way (see Introduction). Nevertheless the final search string of the Fagerholm et al. [2016] paper and of the present work were opposed, compared and thus a check for comprehensiveness was performed. It was found that 14 expressions (see, literature search: agrosilvopastoral OR ”farm woodland*” OR ”forest farming*” OR ”isolated trees” OR ”scattered tree*” OR ”tree outside forest*” OR ”farm tree*” OR woodlot* OR ”timber tree system” OR ”olive tree*” OR ”orchard intercropping” OR parkland* OR ”fodder tree*” OR pannage) for varying agroforestry terms were not included in this search string, although it did show several more ecosystem services. The missing terms (see above) were inserted into the final search string and then fed into the academic database ISI web of knowledge, which resulted in a final number of 1090 hits of papers (see, search terms Appendix A3, 8th_ January and data spreadsheet on CD). The two final literature search Excel files (lit data 3_ 11 and 8th_ January) were fed into R (see R script ex_ round_ 1 title 8th of January on CD) to compare and check them for duplications beneath the papers.

Screening of literature

Screening process

The evaluation for inclusion of the publications searched (see CD, lit data 3_ 11) was undertaken in a two-stage process, comprising: title- and abstract- , abstract- and full-text level. The excluded articles did not proceed to the next stage, and the reason for the exclusion was documented for all articles surveyed at every stage. A single reviewer undertook the whole assessment, who in case of an uncertain paper chose inclusion rather than exclusion.

The first examination round, title and abstract, was conducted from the 3rd - 12th of November. The order of the final number of papers (see CD, lit data 3_ 11secondround) was randomized (see CD, R script, ex_ round_ 1, Randomize data table R.data). It was guaranteed that the second examination was undertaken in an unbiased way, because of the random screening of the listed papers.

Next, each article found to be potentially relevant on the basis of title and abstract was assessed for inclusion by one reviewer, who studied the abstract and the full text from the 13th of November until the 14th of December. The full text was searched via Google Scholar and downloaded into Mendeley. Based on the limited time available and the large amount of data, abstracts were surveyed very precisely again and screening of the full text was done only if information needed for the final data base was missing in the abstract. During the process additional articles were found (i.g important citations in papers) and were then entered in the screening process. The Excel spreadsheet contains 392 (lit data 3_ 11secondround) rather than 388 papers.

Based on the comprehensiveness search, performed on the 8th of January (see above, Estimating the comprehensiveness of the search), and the detection of the Fagerholm paper [Fagerholm et al., 2016], all the stages already described were repeated. Only those papers that were retrieved after the duplication check, beneath the two Excel spreadsheets: lit data 3_ 11 (first search) and 8th_ January (comprehensiveness search), were screened again. In total 372 studies were found. In total (dat_ ges) the results of the second round, abstract and the full text screening revealed 110 papers included in the systematic map and 366 excluded papers.

Based on the experiences and observations made during the screening, some of the inclusion criteria were specified further (see below, Inclusion criteria).

Article retrieval

A total of ten articles, during/after the abstract-full text search could not be obtained in full text either digitally or in print!

Inclusion or exclusion criteria

Articles were screened and included/excluded according to criteria relevant for the particular stage (1. Title and abstract; 2. Abstract and full text). The criteria are as follows:

- Relevant subject: Agroforestry systems in Europe

General:

As an approximation of the extent of Europe [Maplandia.com, 2015] was used. Studies included in the systematic map had to be located within the defined region (see, study area).

1. Title and abstract:

The agroforestry system treated in the work had to fall within a definition from Nerlich et al. [2013]. If the study just elaborated on, for example " a group of trees in the landscape " then a clear definition has not been stated.

2. Abstract and full text:

During the first evaluation process of title and abstract it became clearly recognizable that the inclusion criterion needed to be specified. At first, short rotation coppices without an agricultural component could no longer be seen as agroforestry systems, so they were excluded. Secondly, hedgerows, buffer strips and vineyards are not entirely closed systems. Such as e.g silvoarable system, in which trees interact with the surrounding area. The influence of the planted tree strip or hedgerow on the agricultural crop depends on the height of the trees [agroforestry Center, 2012] and can be negligibly small. These two separate systems, forests and agricultural system, which have mainly been planted detached from each other, inhabit solely beneficial edge effects for the adjacent system. In this work the previously mentioned landscape elements (e.g. hedgerows buffer strips etc.) are not looked upon as agroforestry systems.

- Relevant types of study design

Papers of various kinds of study designs [Mupepele et al., 2015] are targeted and therefore no exclusion criterion exists.

- Relevant intervention(s): Ecosystem services

1. Title and abstract:

In general a conjunction between the ecosystem service (single or group of services) and the agroforestry system has to be present, e.g. the ecosystem service has been measured, an respectively quantified within the agroforestry system.

2. Abstract and full text:

The connection needs to be fully described, must be understandable and should be underpinned with ex-tractable data, if not the paper was excluded.

Table 2.2: Abbreviations for the exclusion criteria used during the screening process

Component	Content	Exclusion criterion
Relevant subject	Study region	nEu
Relevant subject	Agroforestry system	nAgro
Relevant subject	Agroforestry system	Shor
Relevant intervention	Ecosystem services	nRela
Relevant intervention	Ecosystem services	nDat

Effect modifiers/sources of heterogeneity

Prior to the screening process a sample of the effect-modifying variables were set up.

Effect modifying variables:

- Focus on multiple or single ecosystem services
- Monetary evaluation
- Implication on_ Main message
- Implication on_ Main message

Coding and data extraction

Some meta-data information was filtered from the paper during the full-text evaluation. All the data was extracted from the study according to the framework described in table 2.3 below. The final quantitative data fact sheets containing information was filtered according to the framework (Table 2.3) depicted below, which are included on the CD (dat_ ges).

Table 2.3: Data variables extracted from the final papers and included in the systematic map

Data	Description
Title	Source article title
Author	Source article author
Year	Source article publication year
Extraction date	Source article date of extraction data
Agroforestry system	Agroforestry system the study focus is on
Country	Country in which the study was conducted
Climatic zone	Climatic zone study region location
Focus on multiple or single ecosystem service	Intrinsic focus of the study: on single or multiple ecosystem services
Regulation and Maintenance services	Ecosystem service category assessed in the study. Also subcategories are stated in the framework
Provisioning services	Ecosystem service category assessed in the study.
Supporting services	Ecosystem service category assessed in the study.
Cultural services	Ecosystem service category assessed in the study.
Monetary evaluation	Occurrence of monetary evaluation
Implication on_ Main message	Main message delivered by the study
Research design	Research design of the source article

Study quality assessment

Elaboration on the quality assessment of the final studies can be found in the section: Evidence based practice.

2.2 Evidence based practice

An important part of a systematic map often underestimated and neglected is the quality assessment resulting in an critical appraisal of the studies. It is not an easy task to carry out a critical appraisal because of the varying criteria for each systematic map_ review [Mupepele et al., 2015; Stewart and Schmid, 2015]. To bridge this gap the evidence-based practice tool from Mupepele et al. [2015] was conceptualized and is used in this work to assess the study quality.

2.2.1 Study area

It was not possible, due to time constraints, to undertake a critical appraisal for the whole study area, investigated in the SM. Therefore a subset was taken and only those studies covering the nemorales zonobiom [Walter and Breckle, 1991] were critically appraised.

2.2.2 Data selection

Only a subset of the final literature survey data set was checked with the evidence-assessment tool. It contains only those papers located within the defined study area (see, 2.2.1). This reduction has been undertaken because of the large final volume of data and the lack of available time for the execution of this step (see CD, Ebes_ ges).
Further information on data selection proceedings can be found on the CD (R script).

2.2.3 Evidence-assessment tool

The evidence-assessment tool is designed to assess the strength of evidence of ecosystem services and conservation studies [Mupepele et al., 2015]. The core of the evidence assessment is the evaluation of the reliability of a study that is characterized by its study design and the quality of its implementation.

Theoretical framework

The main structure of the tool for critical appraisal can be divided into two parts. The first part concerns the determination of the study design which refers to a weak or a strong evidence level. For the purpose of estimating the reliability of the study, *"study designs can be ranked hierarchically according to a level-of-evidence scale"* [Mupepele et al., 2015] depicted in an evidence hierarchy pyramid (see, Figure 2.2).

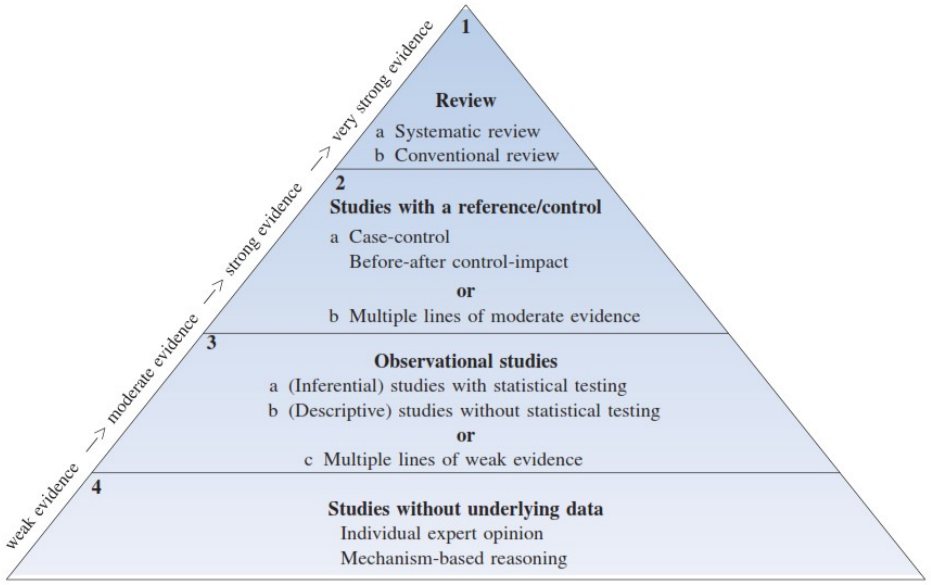

Figure 2.2: Evidence hierarchy pyramide adopted from Mupepele et al. [2015]

The previously designated level-of-evidence, based on the study design, constitutes the baseline for the critical appraisal. By accomplishing a critical appraisal the study design, particularly its methodological quality, and its realization as well as the reporting are measured. Conclusively, it *"may lead to a downgrading in the evidence hierarchy"* [Mupepele et al., 2015]. This was done by executing the first quality checklist for conservation and ecosystem services, that contains 43 targeted questions (see CD, Ebes out eins - fünf and paper .

A more detailed description on the theoretical setup of the critical appraisal framework can be found in the paper by Mupepele et al. [2015].

Application

The quality assessment framework was applied to 25 studies (see CD, Ebes out eins - fünf).

Chapter 3

Results

In the following section the results based on the 110 final studies for the systematic map are shown. Due to the large volume of data, all 110 studies are included in a table and attached to this work (see CD Ebes_ ges). In order to more easily understand the graphs, frequently used abbreviations for agroforestry systems and ecosystem services are explained in advance (see below, Table 3.1). Olive orchards as well as cherry orchards are frequent agroforestry types among the studies surveyed and are found below the orchard category. Thus they are displayed in separate sub categorize (Oo and Co). For further indications of different agroforestry practices, see Methods, 2.1.5 and 1.4

Table 3.1: Abbreviations used in the results section

(a) Agroforestry systems

Abbreviation	Definition
1. Ac	Alley cropping
2. Co	Cherry orchard
3. De	Dehesa
4. Mo	Montado
5. O	Orchard
6. Oo	Olive orchard
7. Sa	Silvoarable system
8. Sp	Silvopastoral system
9. W	Woodland
10. Ww	Woodpasture
11. Oth	Undefined agroforestry systems

(b) Ecosystem services categories

Abbreviation	Definition
1. RM	Regulating and maintenance service
2. PS	Provisioning service
3. CS	Cultural service
4. SS	Supporting service

3.1 Systematic map

3.1.1 Literature searches and screening

The flow chart (Figure 3.1) shows the different levels of inclusion and exclusion as well as the search dates of the publications. The first literature search (search 1) was conducted between the 24th and the 30t of October 2015 (see Methods for the exact search string) and resulted in 718 hits. An additional brief grey literature search was executed from the 28th October to the 3rd of November (n=1). These two searches returned 719 articles. After the first screening (search 1) of titles and abstracts, 327 papers were excluded. The first search string was updated and checked for comprehensiveness (search 2) on the 8th of January (n=1090). After the duplication check between searches 1 and 2, 372 articles remained. Screening was based on title and abstract. Search 2, left 84 articles that were still considered potentially relevant. Through the eligibility check of 392 (search 1) and 84 (search 2) studies a total number of 110 papers were found and included in the systematic map. Data on each of these studies are available in an Excel file (see CD dat_ ges).

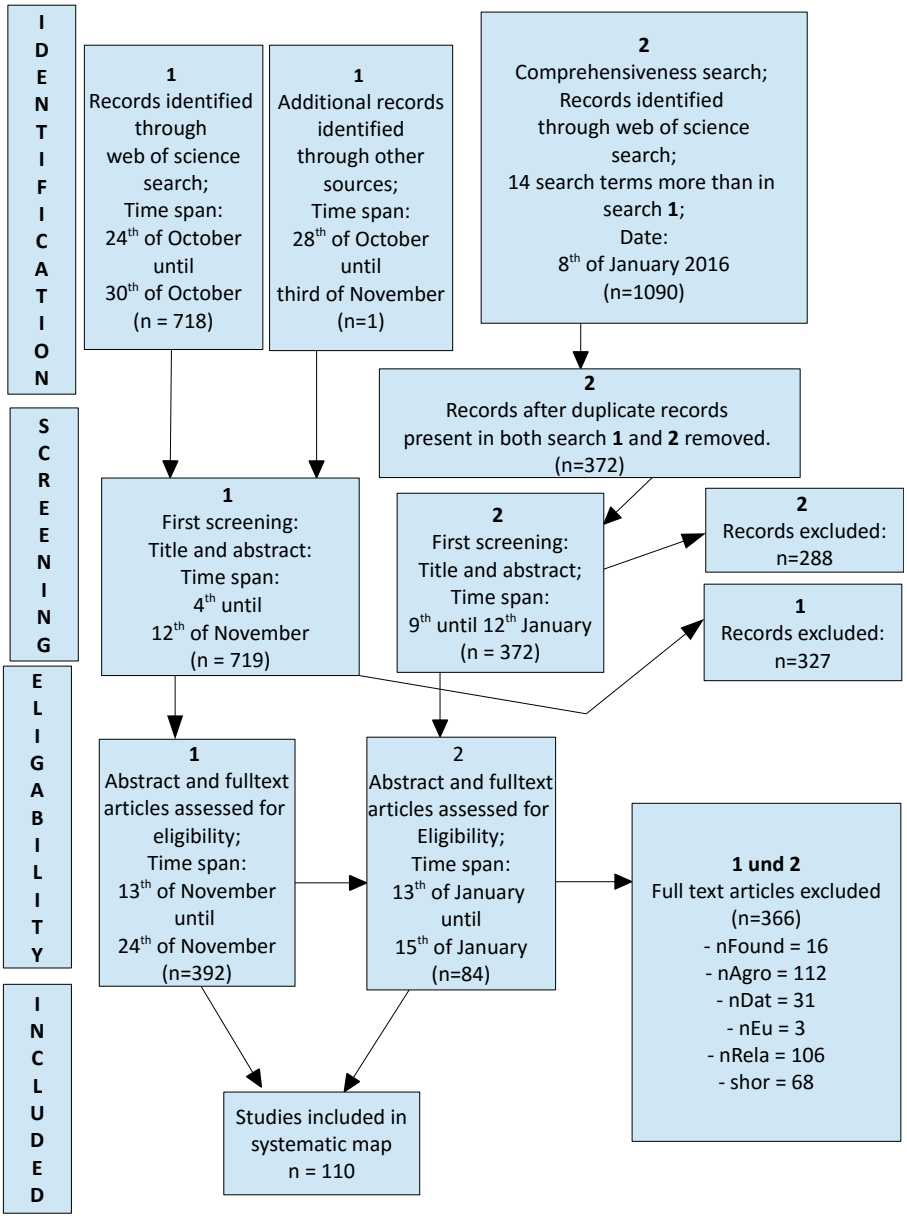

Figure 3.1: Flow diagram showing the inclusion and exclusion processes for the systematic map as well as the date of the search; Abbreviations: nFound = papers that were not found through the serach, nAgro = no defined agroforestry system, nDat = not enough available extractable data, nEu = study area not located in Europe, nRela = Ecosystem service not directly related to agroforestry system, shor = short rotation coppice without agricultural component

3.1.2 Ecosystem services of agroforestry systems in Europe

As shown in the trend line, Figure 3.2 below, the number of annual publications on ecosystem services in agroforestry systems in Europe has increased more than 15 times over the last 25 years. Nevertheless, before 1996 interest in this topic was minimal; since then however aca-

demic involvement has been continually rising.

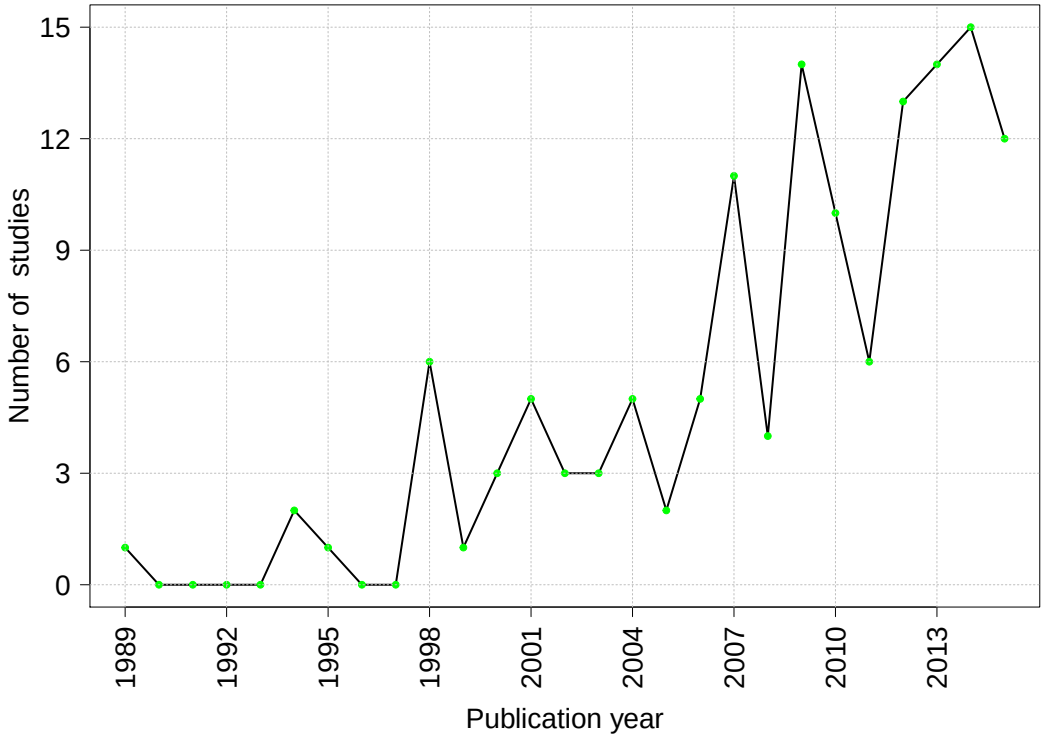

Figure 3.2: Number of studies included in the systematic map per year

Ecosystem services categories within different agroforestry systems are shown (Figure 3.3), giving an overview on the major research question:
What is the state of the art of ecosystem services research in agroforestry systems in Europe?
It can be clearly seen that a large part of the literature focuses on dehesa and silvopastoral systems. The ecosystem service category that accounts for the largest proportion of dehesa and silvopastoral systems amongst all the studies is that of provisioning services. It is followed by regulation and maintenance services, which are on a par with cultural services. The so called modern agroforestry systems of alley cropping, as well as cherry orchards, montados and woodlands have yet to be thoroughly researched.

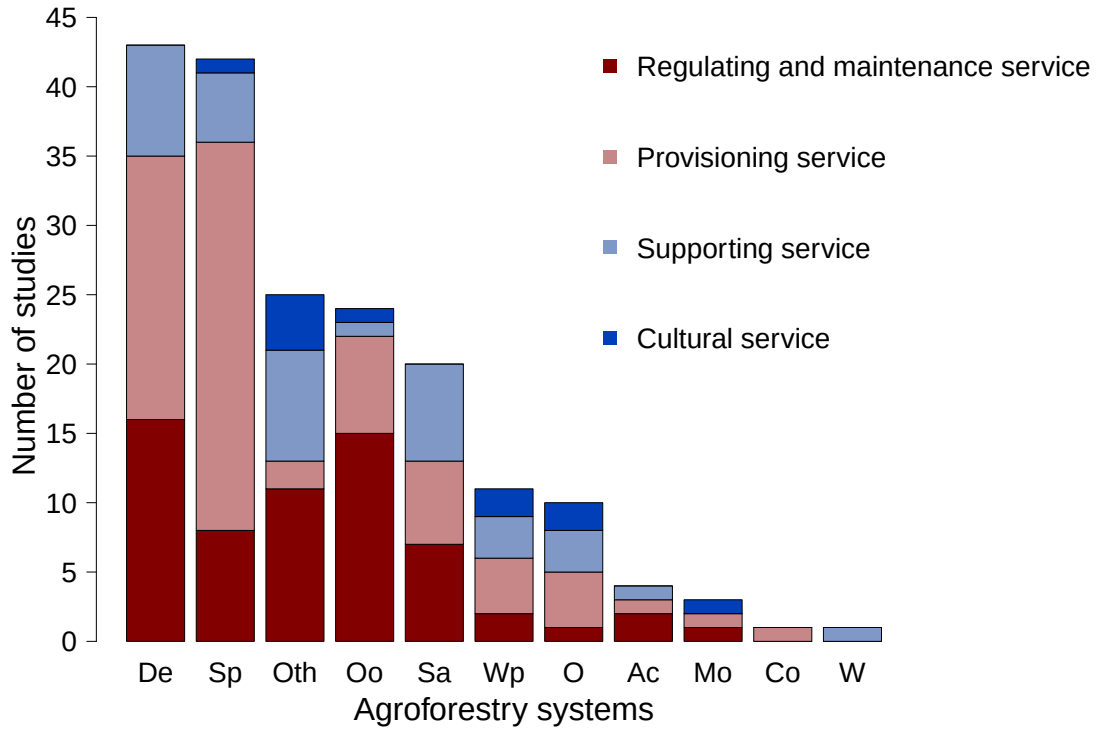

Figure 3.3: The graph depcits the amount of ecosystem service categories in different agroforestry systems

According to the following figures (Figure 3.4 until 3.6) the data distribution confirms the data pattern shown in the overview display (Figure 3.3, above). Dehesa systems, as well as other systems (those not defined in the papers) take the lead followed by silvopastoral and silvoarable systems.

Regulating and maintaining ecosystem services have mainly been investigated in Dehesa (22 studies), others (24 studies) and silvoarable systems (Figure 3.4). Soil formation and carbon sequestration constitute a major share of the ecosystem services literature in all the systems, but especially in dehesa, silvoarable, silvopastoral and other systems. Orchard studies (16) constitute, in terms of ecosystem services distribution/existence, an exception under the very well investigated agroforestry systems such as e.g. dehesa silvoarable, silvopastoral and other systems. They also have their research focus on the ecosystem services: hydro logical cycle and pollination. In terms of regulation and maintenance services, none of the other agroforestry practices have been studied in depth.

The category of provisioning services (Figure 3.5) represented 42 percent of all the studies, and depicts a distinct distribution of ecosystem services in agroforestry systems compared to other ecosystem services categories (e.g.Regulation and maintenance, Supporting services and cultural services). Silvopastoral systems (34 studies) and dehesa systems (23 studies) exhibit twice as much literature than other agroforestry systems (e.g. Sa(ten), O(seven), Ac(six)). The two leading agroforestry systems (silvopastoral and dehesa) have their focus on different single ecosystem services beneath the biomass groups. The ES group Biomass occurs, according to the CICES classification [Group et al., 2013], in the ecosystem service category provision services of different divisions (e.g Nutrition, Materials, Energy). In each of these divisions (Nutrition, Materials, Energy) a biomass group is included that can be broken up again into single ecosystem services (e.g. classes) such as biomass _ meat, biomass _ materials, biomass _ crops. The largest share of the publications on silvopastoral systems included biomass _ meat, whereas literature about dehesa systems concentrates on biomass _ materials. Additionally, the ecosystem service biomass _ crops account for the same part (8 studies) in dehesa and silvopastoral systems and is present in almost all agroforestry systems. Studies on biomass_ herbs are very uncommon.

Despite the fact that literature about cultural and supporting services is generally not that common in agoroforestry research, dehesa (11) and other (14) agoroforestry systems have been very thoroughly investigated (Figure 3.6). Research into biodiversity has a higher proportion of publications released among the agroforestry systems than does species richness, but at the same time biodiversity is explored in fewer agroforestry systems than is species richness. Only biodiversity and species richness are distinguishable from each other among studies based on the denomination of names.

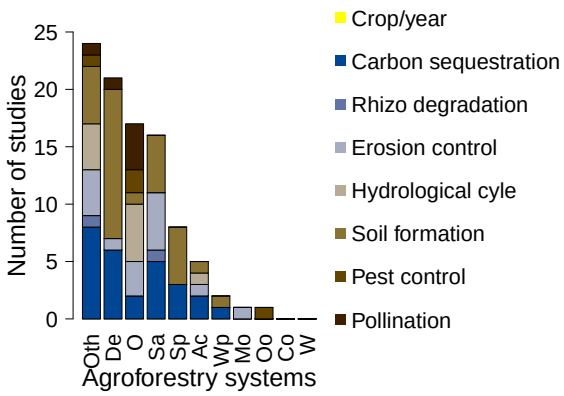

Figure 3.4: Agroforestry system versus RM-services

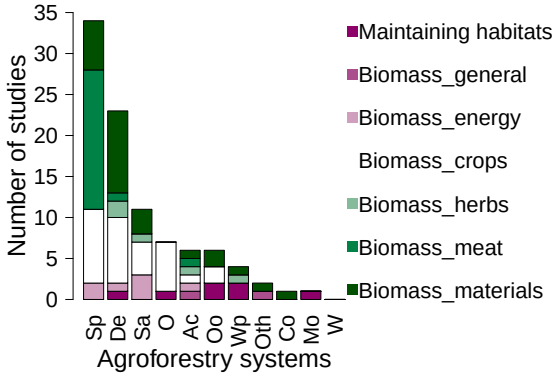

Figure 3.5: Agroforestry system versus Provisioning services

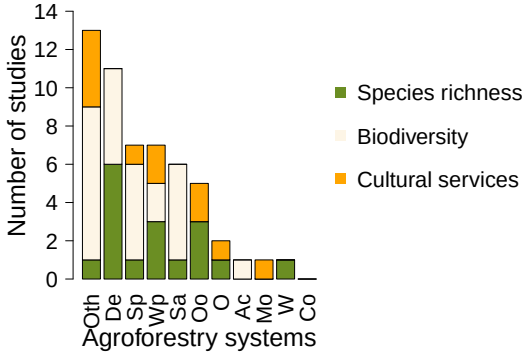

Figure 3.6: Agroforestry system versus Supporting and Cultural services

For a greater understanding of the data structure, the most common agroforestry systems in climatic zones were selected to show the distribution of their ecosystem service categories and associated single ecosystem services (Table 3.2). The bulk of the study areas of the literature on ecosystem services in agroforestry systems is located in the Mediterranean area (n=89). The

records of the Nemorales zonobiome, characterized by a temperate climate, are around a third less (n=53) than for the Mediterranean zone. Studies without a defining limitation of the study area, named Europe (see, Table 3.2), are also imprecise in their declarations of frequently occurring agroforestry systems. In the Nemorales and the Mediterranean zonobiome agroforestry practices, which traditionally originate from these regions (e.g. the Mediterranean: dehesa, olive orchards) are the most reported. These systems also show similarities in the focus on ecosystem service categories, because regulation and maintenance services, as well as provisioning services, have the highest number of publications. At a deeper level in the ecosystem service hierarchy the prevalent focus is on single ecosystem services such as: provisioning services e.g. Biomass_ meat; Biomass_ crops, followed by supporting services such as biodiversity and species richness.

Table 3.2: The table represents the literature divided by the climatic zones of Europe and grouped by the most common agroforestry systems within the zones. Further it contains the number of ecosystem services; AGF = Agroforestry systems; ES = Ecosystem services; RM = Regulation and Maintenance services

Climatic zone	Nr of studies in Climatic zone	Agroforestry system	Nr of studies in AGF	Ecosystem service category	Nr of studies in ES-category	Ecosystem service	Nr of studies in ES
1. Europe	10						
		Others	12	RM	7		
				Provisioning	1		
				Supporting	7	Biodiversity	7
				Cultural	2		
2. Nemorales zonobiome	53						
		Silvopastoral systems	22	RM	1		
				Provisioning	20	Biomass_ Meat	14
				Supporting	2		
				Cultural	1		
		Silvoarable systems	12	RM	6		
				Provisioning	5	Biomass_ Crops	3
						Biomass_ Wood	3
				Supporting	6	Species richness	3
				Cultural	0		
							3
3. Mediterranean zonobiome	89						
		Dehesa	35	RM	15		
				Provisioning	18	Biomass_ Wood	11
						Biomass_ Crops	9
				Supporting	8		
				Cultural	0		
		Olive-Orchard	23	RM	15		
				Provisioning	7	Biomass_ Crops	5
				Supporting	1		
				Cultural	0		

Studies have investigated agroforestry system with the help of different study designs. Study design is an important indicator for identifying the reliability of the study results. A highly heterogeneous allocation of ecosystem services related to study design over all agroforestry systems is displayed (Figure 3.7 and 3.8). In general qualitative studies (e.g. 1b and 3b) take up a smaller proportion, whereas quantitative studies occur very frequently in some agroforestry systems, such as dehesa and silvopastoral systems. These are equipped with many provisioning service case-control studies (PS_ 2a) as well as regulation and maintenance service case-control studies (RM_ 2a). Literature about provisioning services with a case-control design comprise is an especially large and striking part of the study design division. These combinations, PS_ 2a and RM_ 2a, can be found in nearly all agroforestry systems. Another noticeable illustration is the bar others, where more than half consists of RM_ 1b studies (Figure 3.7) and in the Figure 3.8 of SS_ 1b studies.

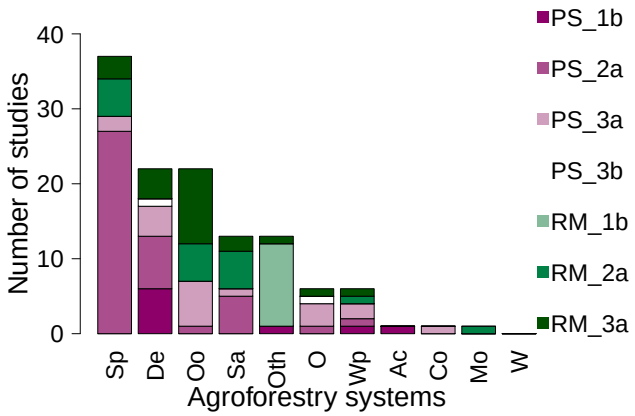

Figure 3.7: Study design combined with provisioning services and regulation and maintenance services in different agroforestry systems)

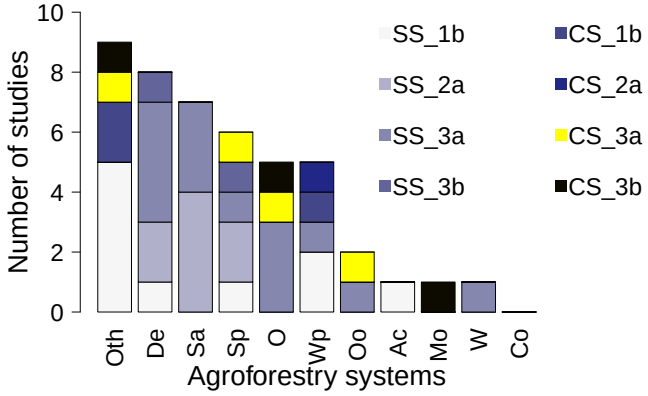

Figure 3.8: Study design combined with supporting services and cultural services in different agroforestry systems

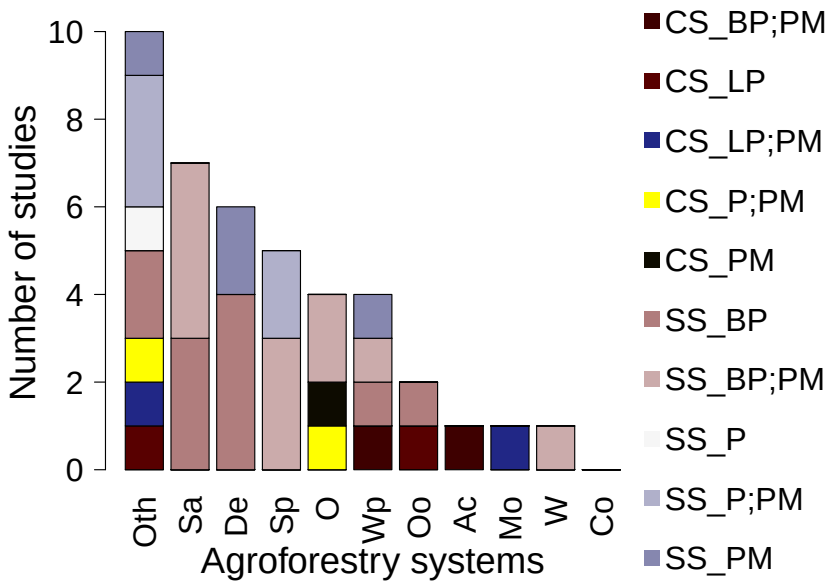

Figure 3.9: Literature on cultural and supporting services in agroforestry systems with their main message. P=Policy, BP=Biophysical, PM=Practical application management, LP=Local participation

To conclude the summary on the mapping of the ecosystem service in agroforestry systems in Europe, the main messages of the studies is divided between the ecosystem service categories displayed in three graphs. The second research question (see Methods, research question) concerning the overarching aim of the studies has been answered.

Considering graph in Figure 3.9, it can be seen that the literature on cultural services concentrates more on local participation, whereas publications on supporting services tend to focus on biophysical limitations (see Figure 3.9). Supporting services with biophysical and practical application_management or solely biophysical intentions exhibit the largest share over the whole range of agroforestry systems. The agroforestry systems frequently represented under the supporting and cultural services category are dehesa and silvoarable systems. They are similar to each other regarding the ecosystem services and their concomitant main message. Dehesa systems mainly attend to main messages about supporting services with biophysical or practical application_management and silvoarable systems attend to main messages about supporting services with biophysical or practical application_management and biophysical implications.

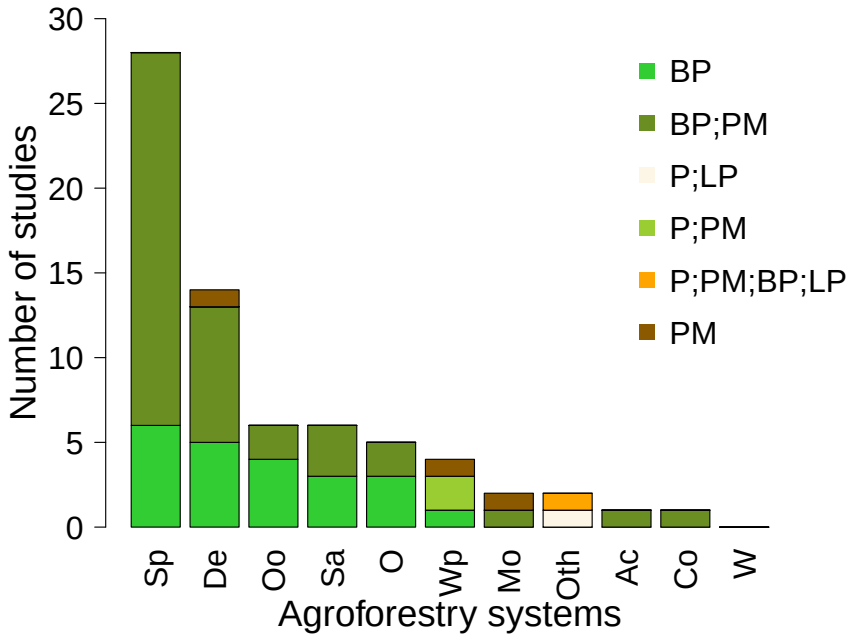

Figure 3.10: Literature on provisioning services in agroforestry systems with their main message; P=Policy, BP=Biophysical, PM=Practical application management, LP=Local participation

The allocation of the main messages beneath the provisioning services is distinct (Figure 3.10). Regarding all agroforestry systems, dehesa and silvopastoral systems present once again the largest in publications. However, biophysical combined with practical application_management intentions are seen to have the largest proportion over all systems followed by biophysical intentions. Studies conveying political or practical application_management messages do exist, but are seldom seen.

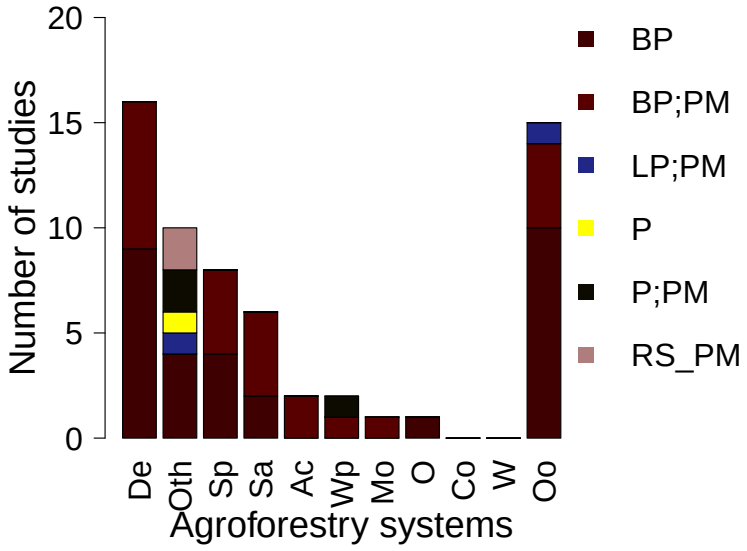

Figure 3.11: Literature on regulating and maintenance services in agroforestry systems with their main message; P=Policy, BP=Biophysical, PM=Practical application management, LP=Local participation

Figure 3.11 shows that biophysical and practical application_management implications take up the highest rate of main messages throughout regulation and maintenance services publications. The other main messages are small enough to overlook.

An evaluation of the monetary value of ecosystem services in agorofrestry systems of Europe has so far only rarely been conducted (see CD Appendix dat_ ges, column: Monetary evaluation).

3.2 Evidence based practice

In following section the results of the evidence assessment obtained by the application of the quality framework [Mupepele et al., 2015] are represented.

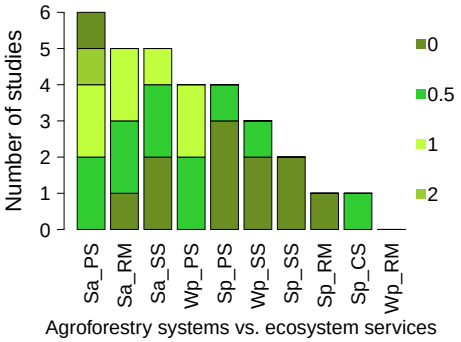

Figure 3.12: Agroforestry system with ES categorize versus level of downgrade

Graph 3.12 outlines the level of study downgrades that are determined by the final quality scores of the quality assessment framework (see CD Methods Ebes out 1 bis 5) related to agroforestry systems with the ecosystem services categorize. It offers a rough overview of the distribution of the evidence structure. The silvoarable system studies exhibit the highest rate on downgrades compared to silvo-pastoral system studies. The downgrades, expressed as percentages over all the studies, are as follows: 37% no downgrade, 34% 0.5 downgraded levels, 27% 1 downgraded levels, 2% 2 downgraded levels.
Because of its size, a spreadsheet including all the studies used for the evidence assessment can be found on the CD (see Results, EBES_ Vor_ Nach). In this spreadsheet following points are illustrated:
Individual number (number related to papers of or in table dat_ ges on CD), AGF, ES-category, study design, level of evidence.

Table 3.3: Before (stuy design) and after (Level of evidence) the application of the evidence assessment tool

Study design	Individual number	Level of evidence	Number of downgrades
1. 1b	13	1b	1
	16, 16 (Quali)	2b	2
2. 2a	49,1,1,3.1.1,24,24	2a	6
	10, 36, 42, 110	2b	4
	57, 69, 69, 105, 105	3a	5
	29	3c	1
3. 3a	16, 16 (Quanti)	3a	2
	61, 17, 50, 108, 108, 109	3b	6
	12	4	1
4. 3b	4	3b	1

The table 3.3 above shows the study design depicting the baseline situation and the resulting level of evidence estimated using the tool. It supplements the previous graph (Figure 3.12), showing both the study design and the level of evidence. It can be seen that many studies remained either at the same level of evidence or are only downgraded to approximately 0.5 level. In particular, studies having a case-control design (2a) are not very downgraded.

Table 3.4, constitutes a subset of the complete data-spreadsheet (see CD, EBES_ ges), outlines of the completed quality framework that was applied to 25 studies. As shown in Table 3.3 most of the studies are only downgraded by 0.5 levels and almost all do not meet the general criterion: uncertainty and attrition bias (abbreviation in table above = Combination). No clear trend can be detected concerning to the corresponding agroforestry systems and ecosystem services of the publications.
However, there are differences between case-control and observational literature among exclusion criteria.
Case-control (see table 3.4, Design aspect) designed studies often lack random or probability sampling, an adequate description of the statistical method employed (General criteria) and, relating to design aspects, the allocation bias is given. The focus aspect frequently missing from all examples is that of quantification and temporal change of quantities.
Observational studies (see table 3.4, Design aspect) often have two main characteristics in contrast to case-control studies (Quantification and management). They illustrate in these cases deficiencies regarding the framework criteria temporal changes, as well as quantities measured concerning the side effects on ecosystem services. The study design requires the only listed item: the confounding factor. Additionally, the general set of criteria sometimes lacks all appropriate data collection description or information on the magnitude of the effects.

Table 3.4: The table is showing a subset (complete data spreadsheet, see Appendix B1) of the informations about the studies being investigated by the quality appraisal framework as well as criterion that are not met in the quality appraisal framework; Abbreviations: Id_ nr = Individual number (see CD Methods, dat_ ges), Down. = Downgrading, Combination = Critirion uncertainty and attrition bias, Alloca. = Allocation bias

Id_nr	AGF	ES	Down.	Scores max	achieved	General criteria	Design aspects	Focus aspects
16 Quali	WP	PS	1	28	26	4 of 16; Combination	Review, 5 of 8	2 of 5; Management
10	SA	PS	0.5	32	25	4 of 16; all analysis questions	1 of 5; Case-control, alloca.	1 of 5; Management
36	SA	RS	0.5	27	20	4 of 16; Combination	1 of 5; Case-control, alloca.	1 of 2; Quantification
42	SP	PS	0.5	30	23	5 of 16; Combination	2 of 5; Case-control, alloca.	0; Quantification; management
110	WP	PS	0.5	27	25	2 of 16; Combination	0; Case-control	0; Quantification
57	SA	PS	1	25	18	6 of 16; Combination	1 of 5; Case-control, alloca.	1 of 2; Quantification
69	SA	RS	1	25	18	6 of 16; Combination	1 of 5; Case-control, allocation bias	1 of 2; Quantification, temporal change quantity's measured
105	SA	RS, PS	1	28	19	6 of 16	1 of 5; Case-control, alloca.	1 of 2; Quantification
29	SA	PS	2	23	15	5 of 16; Combination	1 of 1; Observational studies	1 of 2;Quantification
61	WP	PS	0.5	27	23	1 of 16	1 of 1; Observational studies	1 of 2;Quantification; 1 of 5; Management
17	SA	PS	0.5	27	19	4 of 16; Combination	1 of 1; Observational studies	1 of 2;Quantification; 1 of 5; Management
50	SA	SS	0.5	23	18	3 of 16; Combination	1 of 1; Observational studies	0;Quantification
108	SA	RS,SS	0.5	21	18	0	1 of 1; Observational studies	1 of 5; Management
109	SP	CS	0.5	23	19	2 of 16	1 of 1; Observational studies	0; Quantification
12	WP	PS	1	22	16	4 of 16; Combination	1 of 1; Observational studies	1 of 2; Quantification

Chapter 4

Discussion

This systematic map shows that substantive research has been conducted on ecosystem services in the agroforestry systems of Europe.
The results of the systematic map will now be discussed and critically evaluated with reference to the initial research questions, which are as follows:

1. What is the state of the art of ecosystem services research in agroforestry systems of Europe?

2. What is the overarching aim of these studies?

4.1 Overall completeness and applicability of evidence

The interest in the topic of ecosystem services in agroforestry systems began gradually in 1996. With the release of the Millennium Ecosystem Assessment report, awareness was raised concerning the concept of ecosystem services [Arico et al., 2005], and the amount of published literature on the subject increased significantly.
The goal of the first research question was to summarize all the literature that has so far been conducted on this topic in order to evaluate the state of the art. It was generally found that this question could be answered in a sufficient way. It was also possible to obtain a clear picture of the data structure, even though the number of published studies (n=137) included in the systematic map was not very large. This led to the conclusion that little research had been done on the topic of ecosystem services in agroforestry systems up to the point, and that this branch of research is only at the beginning of its development [Fagerholm et al., 2016].

Several authors agreed on a characterization of silvopastoral systems based on their components. To this end silvopastoral systems have at least four components: man, trees (wood vegetation), sward and animals [San Miguel-Ayanz, 2005]. As can be seen in the classification of silvopastoral systems from San Miguel-Ayanz [2005], dehesa systems are a special type of silvopastoral system

which appear in the semi-arid, Mediterranean regions of Spain and Portugal [McEvoy J., 2002]. In this region dehesa systems constitute the only land use practice that is *"rational, productive and sustainable "* [Olea and Miguel-Ayanz, 2006] at the same time.
In this research area a high proportion of studies focus on dehesa and silvopastoral systems, which are of economic interest and currently profitable for farmers [Olea and Miguel-Ayanz, 2006]. Thus, the provisioning services, exploring mainly biomass (Figure 3.3 and 3.5), constitute the most frequently investigated category. Biomass_ meat takes up the vast majority of ES in silvopastoral systems, due to the animal grazing agricultural component used for meat production in the agroforestry system [Nerlich et al., 2013]. Dehesa systems, which are also made up of an animal agricultural components, do not just focus on meat from grazed sheep, cattle and pigs (Jamón Ibérico [Company, 2004]). The initial and still ongoing emphasis is placed on cork oak and acorn production [Joffre et al., 1999] (see Figure 3.5, biomass_ materials and biomass_ crops). However, regulation and maintenance services also play an important role in dehesa systems (Figure 3.3 and 3.4), soil_ formation and carbon sequestration especially were researched in depth. This is perhaps because of researchers objectivity and practitioners keen interest to explore further and to understand the impact that grazing animals have on soil dynamics or mechanisms [Joffre et al., 1999; Peco et al., 2006]. In addition, orchard systems were thoroughly checked regarding RM-services, and it was discovered that their focus compared to other AGF, is also on the hydro-logical cycle and on pollination. Orchards dependent upon reliable pollination to guarantee their fruit harvest and yield. That lead to an increased incident of studies covering this subject [Bosch et al., 2002; Holzschuh et al., 2012].
Cultural and supporting services comprised the least surveyed category amongst all agroforestry practices. It can be assumed that supporting services in agroforestry systems will gain in importance in the near future based on the growing environmental consciousness of the population [Jana Rückert-John, 2013] and therefore wider research activities will be employed. As already mentioned dehesa and silvopastoral systems are studied mainly in regard to ecosystem services. For this reason the most of the studies on ecosystem services in agroforestry systems are located in Mediterranean climates, where the dehesa system originates. Dehesa and olive orchards clearly require warmer climates, which occur very frequently in this zone (Table 3.2).
When discussing the study design (Figure 3.7) of the literature included in the systematic map a highly heterogeneous picture emerges. Generally speaking, qualitative studies seldom appear compared to quantitative studies. Having a majority of quantitative studies can probably be traced back to the prevailing ecosystem service categorizes of PS and RM. These hold single ecosystem services which are mainly measurable and or quantifiable (see Figures 3.3 until 3.6).

The preceding paragraph discussed the results of the systematic map, leaving aside the second research question concerning the overarching aim of the included studies. Some revealing information regarding this concerns the statement Rivest et al. [2013] claimed. He claimed that management option as wells as knowledge does already exist but that *"farmers need to be supported by relevant policies"* mainly in the category of PS and RM services. That categorize offer essential information (e.g. biomass_ meat, biomass_ materials, soil formation etc.) for the es-

tablishment of agroforestry systems, as well as political implications and opportunities for local participation, which have as yet not been researched in depth. The finding underpins this approach [Rivest et al., 2013] demonstrating that scientific knowledge and management options (categories: biophysical and practical application_ management) are already well known but that promotion and implementation through local participation as well as political support is missing.

4.1.1 Restrictions of the study

Because of the missing data some evaluations could not be performed and the overall message of the systematic map is not as precise and comprehensive as it could have been. In the following sentences missing data and possible associated evaluations that could have been performed are described.
For a large proportion of studies it was difficult to obtain the exact agroforestry system definition. In order not to leave them out of the evaluation a category called "other agroforestry systems" was designed. Approximately a quarter to a fifth (see, Figure 3.3) of the studies fell into this category (Others). It is likely that some of these poorly-defined studies also cover Dehesa or Silvopastoral systems. They could not be considered in the analysis as they may have influenced the comprehensiveness of the results. Information on the monetarization of ecosystem services in agroforestry systems was not given in the literature. It was thus not possible to discuss this topic based on extracted information.

4.2 Quality of the evidence

Studies conducted in Central Europe, defined by the boundaries of a Nemorales zonobiom, were investigated in more detail and critically appraised (see, Appendix? EBES_ ges).
The evidence assessment provides the first estimation of the study quality and the reliability of the results in central European agroforestry systems. Similar results and analyses would be desirable for other parts of Europe and the rest of the world. The results of the evidence tool showed that a major part of the studies remained at the same level of evidence or were downgraded only by 0.5 of a level. Studies especially having a case-control design are not downgraded very often (see results, Table 3.3). This outcome might be attributable to the number of released studies on the topic of ecosystem services in agroforestry systems. It was discovered, that not many studies have yet been conducted on this topic yet. It is therefore surprising that those few studies are not only descriptive and qualitative, but they also use a case-control design which are much more complex to implement and they also attempt to reveal causal relationships.
A deeper examination of the quality assessment framework reveals some interesting facts. First of all, no clear trend can be detected concerning the corresponding agroforestry systems and ecosystem services from the publications. Due to the very new research branch of ecosystem services in agroforestry systems, criteria guidelines or standards on methodological setups for surveying correlations between ecosystem services and agroforestry systems have rarely not

been designed. This is why no clear trend could be detected amongst the studies.
Case-control and observational studies display some distinctions in their evidence structures, that are not solely attributable to the different study designs. One notable example is the dissimilarity concerning the point "main implications" of the evaluation tool. Where case-control studies mainly have one implication, observational studies attempt to convey two implications in one publication. This might be because the descriptive character of observational studies takes a broader view of a topic than usual, with the intention of imparting a set of implications or main messages. Case control studies, however, take mainly a narrow view of a topic, having just one focal research point that is investigated throughout the surveys. This results in only one main implication. It cannot be adequately judged weather it is better or worse for the explanatory power of a study having one or more main messages / implications. Generally, it must fit the case being investigated, and should be underpinned with valid results.

4.3 Limitations of the map

The map is limited to those studies the author was able to locate using the detected, extracted and defined search terms, databases and languages. It is certain that some important studies were not found and thus not fed into the systematic map. In particular, grey literature, such as reports from governments or literature published in books or non scientific as well as scientific magazines/journals that are not covered by the ISI web of knowledge subscription from the university of Freiburg or located via google, could have been missed. Because of the novelty of the research area it can be assumed that (see Methods, Figure 3.2) not many books and non-scientific literature have been written on this topic. Ideas first have to be discovered, investigated and discussed amongst scientific communities before reach the wider population.
General literature published in other languages, most notably French and Spanish, could easily have been missed. France and Spain are European countries that have a long tradition in the establishment and cultivation of agroforestry systems. It is likely that there exists some relevant research published in French and Spanish. Additionally, there were hardly any English search terms translated into German and included into the search string. German expressions were only inserted into the search string if the English term would have distorted the original meaning. Expressions were also included if it could be expected that a certain German term would based on information from the literature, receive many hits. Even though, the language specification tool bar in the ISI web of knowledge was used to locate terms exclusively in English and German, the translation of each of the search terms included in the search string would probably have resulted in a greater number of final hits (studies).
The final limitation of the systematic map concerns the completeness of the literature, and is due to the the exclusion of agroforestry systems. One of these systems is the hedgerow system which is already widely explored [UK, 2016; Baudry et al., 2000] and some literature on it does exist. Nevertheless, as already explained hedgerow systems are not entirely closed systems and their influence on planted crops can be negligibly able small [agroforestry Center, 2012]. The inclusion

of these search terms would clearly have resulted in a greater number of hits but nevertheless this would not have influenced and reflected the conviction of the author.

Chapter 5

Conclusion

5.1 Implication for research and management

The systematic map is based on a comprehensive and screening of all the available literature on ecosystem services in different agroforestry systems across Europe. It summarizes and determines the basic knowledge from quantitative and qualitative statements and from the data of ecosystem services in agroforestry systems.
The scientific branch of ecosystem services in the agroforestry systems of Europe is largely unexplored [Fagerholm et al., 2016] and the results of this systematic map can be considered as a baseline for forthcoming research. Missing knowledge has been indicated throughout this work, and such gaps represent signposts for researchers getting to know uninvestigated fields.
Agroforestry systems located within the Nemorales zonobiome (temperate climate) (see Results Table 3.2), have yet to be investigated in any depth, although they have distinct potential for becoming increasingly important in the future. This is commensurate with a changing mid-European society that is gaining an increasing awareness of environmental issues, particularly as the lifestyles and behaviour of western consumers impinges so much upon the global environment [Jana Rückert-John, 2013]. This of course is combined with the fact that agroforestry systems are not only beneficial for the environment but at the same time economically profitable [Dupraz et al., 2005; Graves et al., 2007; McEvoy J., 2002]. It might therefore be a good investment to set the focus of research onto temperate climatic zones in order to support the establishment of agroforestry systems and to close this gap in our knowledge (see, Table 3.2).
Another weakness of the systematic map is that many publications do not accurately define the agroforestry system that the study deals with. All of these publications, with their undefined agroforestry systems, have been included in the category of 'Others'. If this inaccuracy could be corrected by scientific research then the message of the systematic map might be so much more precise.

In general this work can be seen as a point of commencement and a baseline for ecosystem service research in agroforestry systems centred on two factors.
First, in the past the paucity of hard evidence has hindered the progress of agroforestry and its

acceptance by practitioners, farmers and policy makers [Jose, 2009]. The information arising from this work can be used by these (stakeholders) as a decision-making tool and a reference for prospective agroforestry projects in order to advertise agroforestry systems in Europe.
Second, at the current stage of ecosystem service research in agroforestry systems the possible direction for further investigation is very open and unbiased, but is nevertheless also open to influence by interests from different stakeholder groups. That is because of its novelty [Fagerholm et al., 2016], which opens up many possibilities for researchers. In this regard one must remember the impact that scientific discoveries could have on forthcoming policies and on management decisions. It should therefore be emphasized which particular purpose ecosystem services were originally designed for. The concept of ecosystem services was conceptualized as a pedagogical framework in order to raise public awareness of biodiversity conservation [Gómez-Baggethun et al., 2010], and not to use it as an instrument for conveying economic interests. It is for this reason, that researchers should apply their scientific powers to using the concept of ecosystem services for the purpose for which they were originally designed, and to thus promote agroforestry systems in Europe.

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Appendix A

The process of systematic mapping

A.1 Scope search for search terms

Time span: 16-24 of October 2015

Table A.1: Scope search including date of search, search engine and literature found

Search engine	Date	Search term	Literature
Google scholar	16-10-15	history ecosystem services	Daily [1997]
Google	16-10-15	history ecosystem services	Thomson [2012] (1.further literature extracted)
Google	19-10-15	cices.eu	Group et al. [2013]
Google scholar	20.10.2015	Agroforestry in europe	Nerlich et al. [2013] (4.further literature extracted)
Google scholar	20.10.2015	silvoarable systems europe	Eichhorn et al. [2006]
Google scholar	21.10.2015	Agroforestry in europe	Mosquera-Losada et al. [2010]
Google scholar	22-10-2015	Ecosystem services agroforestry systems	Jose [2009] (3. further literature extracted) Power [2010]; Udawatta and Godsey [2010]
Google scholar	23-10-2015	history ecosystem services	Daily [1997]
Google	23-10-2015	agroforestry europe	McAdam and McEvoy [2009]

Further literature:
1. Literature from Thomson [2012]: The Millennium Ecosystem Assessment 2003, 56 – 60; Daily [1997]; Kareiva et al. Natural Capital: Theory and Practice of Mapping Ecosystem Services; Salzmann 2010 and B.H.: Environmental law and politics; Working [2004]
2.Literature from P K R Nair [2012]: Dupraz et al. [2005]
3. Literature from: Hylander and Hylander [2013]
4. Literature from Nerlich et al. [2013]: Smith et al. [2012]

A.2 Catchwords scope search

Time span: 16-24 of October 2015

1. Single ecosystem services in agroforestry systems:
- carbon sequestration, biological control, pollination, nitrogen fixation Hylander and Hylander [2013]
- carbon sequestration, soil enrichment, biodiversity conservation, air and water quality Jose [2009]

2. Single ecosystem services of agroforestry system divided in categories:Group et al. [2013]
2.1 Provisioning services:
- genetic diversity for future agricultural use, soil retention, regulation of soil fertility, fruits, oils, nuts, timber, firewood, cork, fodder grain, seed production, soft fruits and vegetables, bio fuel, fodder, Mechanical energy Power [2010]
2.2 Regulating services:
- flood control, water quality control, carbon storage, climate regulation through greenhouse gas emissions, disease regulation, pollination, and waste treatment (e.g. nutrients, pesticides), shelter belts, Power [2010] Group et al. [2013]
2.3.Maintenance service:
- pest control, nutrient cycling, Habitat diversity, Species diversity, soil conservation, water conservation, nutrient storage, nutrient leaching, carbon sequestration
2.4. Cultural services:
- scenic beauty, education, recreation and tourism, traditional use, cultural heritage, landscape enhancement, recreation Power [2010]
2.5 Supporting services:
- biodiversity can contribute a variety of supporting servicesPower [2010]

3. McAdam and McEvoy [2009] describes functions in agroforestry systems
3.1. Function & Description of function & Examples goods and services
- Production & Creation of biomass & Trees: fruits, oils, nuts, timber, firewood, cork, fodder; Crops: grain and seed production, soft fruits and vegetables, bio fuel and fodder

3.2. Function & Description of function & Examples goods and services
- Habitat & Provision of habitat for conservation and maintenance of biological diversity & Habitat diversity, Species diversity, Shelter for animals, Mechanical support
3.3. Regulation & Maintenance of essential ecological processes and life support systems & Soil and water conservation, Reduced nutrient leaching, Reduced fire risk, Carbon sequestration
- Cultural & Opportunities for reflection, cognitive development and recreation & Cultural heritage, Landscape enhancement, recreation

4. Agroforestry systems stated in Nerlich et al. [2013] :
- Windbreaks
- Silvopastoral systems (tree + fodder crop + animal)
- Silvoarable systems (tree + crop) McAdam and McEvoy [2009]
- Dehesa
- Montado
- Alley cropping
- Short rotation / poplar / coppice
- Joualle
- Forest grazing

5. Overarching/General agroforestry terms from different sources:
- Multifunctional management Smith et al. [2012]
- Integrated land use systemsDixon et al. [1994]
- Tree pasture systems
- Climate-smart agricultureGriffith et al. [2015]
- Piantata Eichhorn et al. [2006]
- Pomaradas Eichhorn et al. [2006]
- Pré-vergersEichhorn et al. [2006]

A.3 Literature search

I. Search in ISI web of knowledge
Zeitraum: 1926 bis 2015
24th Oct. 2015

15
(Ecosystem service*)AND(Agroforesty) AND Europe
topic search;
outcome = 15.
Far to little papers! Enlarge the search term.

54
(”Ecosystem service*” OR ”Ecosystem function*” OR ”Provisioning service*” OR ”Regulating service*” OR ”Cultural service*” OR ”Supporting service*” OR ”Maintenance service*” OR service) AND (Agroforestry OR ”Agroforestry system*” OR ”Integrated land use system*” OR ”Integrated land use management” OR ”Integrated land use” OR ”Multifunctional management” OR ”Multifunctional management system*” OR ”silvopastoral system*” OR ”silvopastoral” OR ”Tree pasture system*” OR ”silvoarable system*” OR ”silvoarable”) AND ((Europe OR ”temperate region*” OR temperate OR ”temperate zone”) NOT (America OR US OR Canada))
topic search;
outcome = 54;
Next search:
search term has to be more specific: first step = include single ecosystem service*;

26th an 27th Oct. 2015
361
(”Ecosystem service*” OR ”Ecosystem function*” OR ”Provisioning service*” OR ”genetic diversity” OR ”agricultural use” OR ”soil retention” OR ”soil fertility” OR ”fruit*” OR ”oil*” OR ”nut*” OR ”timber” OR ”firewood” OR ”cork” OR ”fodder” OR ”grain” OR ”seed production” OR ”soft fruit*” OR fruit* OR vegetable* OR ”bio fuel” OR fodder OR ”Mechanical energy” OR ”Regulating service*” OR ”flood control” OR ”water quality control” ”water quality” OR ”carbon storage” OR ”climate regulation” OR ”disease regulation” OR pollination OR ”shelter belts” OR ”Cultural service*” OR ”scenic beauty” OR education OR recreation OR tourism OR ”traditional use” OR ”cultural heritage” OR ”landscape enhancement” OR ”Supporting service*” OR ”Maintenance service*” OR ”pest control” OR ”nutrient cycling” OR ”Habitat diversity” OR ”Species diversity” OR ”soil conservation” OR ”water conservation” OR ”nutrient storage” OR ”nutrient leaching” OR ”carbon sequestration” OR service) AND (Agroforestry OR ”Agroforestry system*” OR ”Integrated land use system*” OR ”Integrated land use management” OR ”Integrated land use” OR ”Multifunctional management” OR ”Multifunctional management system*” OR ”silvopastoral system*” OR ”silvopastoral” OR ”Tree pasture system*” OR ”silvoarable system*” OR

”silvoarable”) AND ((Europe OR ”temperate region*” OR temperate OR ”temperate zone”) NOT (America OR US OR Canada))
topic search;
outcome = 361;
Next search:
1. countries will be specified, 2. agroforestry systems and German expressions will be defined;
Include: forage production, soil protection, environmental services **?**
Exclude: Australia, ”New Zealand”, ”Cape Verde”, Chile, China, Asia, Africa,

972

(”Ecosystem service*” OR ”Ökosystemdienstleistung*” ”Ecosystem function*” OR ”Environmental service*” OR ”Provisioning service*” OR ”genetic diversity” OR ”agricultural use” OR ”soil retention” OR ”soil fertility” OR ”fruit*” OR ”oil*” OR ”nut*” OR ”timber” OR ”firewood” OR ”cork” OR ”fodder” OR ”grain” OR ”forage production” OR ”forage” OR ”seed production” OR ”soft fruit*” OR fruit* OR vegetable* OR ”bio fuel” OR fodder OR ”Mechanical energy” OR ”Regulating service*” OR ”flood control” OR ”water quality control” ”water quality” OR ”carbon storage” OR ”climate regulation” OR ”disease regulation” OR pollination OR ”shelter belts” OR ”Cultural service*” OR ”scenic beauty” OR education OR recreation OR tourism OR ”traditional use” OR ”cultural heritage” OR ”landscape enhancement” OR ”Supporting service*” OR ”Maintenance service*” OR ”pest control” OR ”nutrient cycling” OR ”Habitat diversity” OR ”Species diversity” OR ”soil conservation” OR ”soil protection” OR ”water conservation” OR ”nutrient storage” OR ”nutrient leaching” OR ”carbon sequestration” OR service) AND (Agroforestry OR ”Agroforestry system*” OR ”Integrated land use system*” OR ”Integrated land use management” OR ”Integrated land use” OR ”Multifunctional management” OR ”Multifunctional management system*” OR ”silvopastoral system*” OR ”silvopastoral” OR ”Tree pasture system*” OR ”silvoarable system*” OR ”silvoarable” OR ”climate-smart agriculture” OR Windbreaks OR dehesa OR ”alley cropping” OR ”short rotation” OR ”short rotation system” OR ”Kurzumtriebsplantage*” OR ”short rotation poplar” OR ”short rotation coppice” OR Streuobst OR Hauberg OR ”Grazed forests” OR hedgerow* OR ”wood pasture” OR ”buffer strip” OR piantata OR joualle OR Pomaradas OR ”pré-vergers” OR ”forest grazing system*”) AND ((Europe OR ”temperate region*” OR temperate OR ”temperate zone”) NOT (America OR US OR Canada OR Australia OR ”New Zealand” OR ”Cape Verde” OR Chile OR China OR Asia OR Africa))
topic search;
outcome = 972 ;
Next search:
refine by Countries/Territories + Languages –¿ only European countries
Refined by: COUNTRIES/TERRITORIES:
(UK OR SPAIN OR AUSTRIA OR NORTH IRELAND OR GERMANY OR FRANCE OR HUNGARY OR ROMANIA OR ITALY OR CROATIA OR SWEDEN OR SCOTLAND OR NETHERLANDS OR NORWAY OR BULGARIA OR ENGLAND OR BELGIUM OR SLOVENIA OR PORTUGAL OR DENMARK OR SWITZERLAND OR WALES OR GREECE OR SLOVAKIA OR FINLAND OR

LATVIA OR POLAND OR CZECH REPUBLIC OR LITHUANIA OR ESTONIA OR IRELAND OR WEST GERMANY OR UKRAINE) PORTUGAL OR DENMARK OR SWITZERLAND OR WALES OR GREECE OR FINLAND OR POLAND OR IRELAND OR WEST GERMANY OR UKRAINE) LANGUAGES: ENGLISH OR GERMAN
Exclude: service

690

(”Ecosystem service*” OR ”Ökosystemdienstleistung*” ”Ecosystem function*” OR ”Environmental service*” OR ”Provisioning service*” OR ”genetic diversity” OR ”agricultural use” OR ”soil retention” OR ”soil fertility” OR ”fruit*” OR ”oil*” OR ”nut*” OR ”timber” OR ”firewood” OR ”cork” OR ”fodder” OR ”grain” OR ”forage production” OR ”forage” OR ”seed production” OR ”soft fruit*” OR fruit* OR vegetable* OR ”bio fuel” OR fodder OR ”Mechanical energy” OR ”Regulating service*” OR ”flood control” OR ”water quality control” ”water quality” OR ”carbon storage” OR ”climate regulation” OR ”disease regulation” OR pollination OR ”shelter belts” OR ”Cultural service*” OR ”scenic beauty” OR education OR recreation OR tourism OR ”traditional use” OR ”cultural heritage” OR ”landscape enhancement” OR ”Supporting service*” OR ”Maintenance service*” OR ”pest control” OR ”nutrient cycling” OR ”Habitat diversity” OR ”Species diversity” OR ”soil conservation” OR ”soil protection” OR ”water conservation” OR ”nutrient storage” OR ”nutrient leaching” OR ”carbon sequestration”) AND (Agroforestry OR ”Agroforestry system*” OR ”Integrated land use system*” OR ”Integrated land use management” OR ”Integrated land use” OR ”Multifunctional management” OR ”Multifunctional management system*” OR ”silvopastoral system*” OR ”silvopastoral” OR ”Tree pasture system*” OR ”silvoarable system*” OR ”silvoarable” OR ”climate-smart agriculture” OR Windbreaks OR dehesa OR ”alley cropping” OR ”short rotation” OR ”short rotation system” OR ”Kurzumtriebsplantage*” OR ”short rotation poplar” OR ”short rotation coppice” OR Streuobst OR Hauberg OR ”Grazed forests” OR hedgerow* OR ”wood pasture” OR ”buffer strip” OR piantata OR joualle OR Pomaradas OR ”pré-vergers” OR ”forest grazing system*”) AND ((Europe OR ”temperate region*” OR temperate OR ”temperate zone”) NOT (America OR US OR Canada OR Australia OR ”New Zealand” OR ”Cape Verde” OR Chile OR China OR Asia OR Africa))
topic search;
outcome = 689
Exclude = NOT (America OR US OR Canada OR Australia OR ”New Zealand” OR ”Cape Verde” OR Chile OR China OR Asia OR Africa)) + temperate zone and temperate region
- I am worried that ISI does not cite papers that mention the countries above = because they are just site remarks and do not depict the study area!
Next search:
refine by Countries/Territories + Languages –¿ only European countries
- Refined by:
1. COUNTRIES/TERRITORIES:
(UK OR SPAIN OR AUSTRIA OR NORTH IRELAND OR GERMANY OR FRANCE OR HUNGARY OR ROMANIA OR ITALY OR CROATIA OR SWEDEN OR SCOTLAND OR NETHERLANDS

OR NORWAY OR BULGARIA OR ENGLAND OR BELGIUM OR SLOVENIA OR PORTUGAL OR DENMARK OR SWITZERLAND OR WALES OR GREECE OR SLOVAKIA OR FINLAND OR LATVIA OR POLAND OR CZECH REPUBLIC OR LITHUANIA OR ESTONIA OR IRELAND OR WEST GERMANY OR UKRAINE) PORTUGAL OR DENMARK OR SWITZERLAND OR WALES OR GREECE OR FINLAND OR POLAND OR IRELAND OR WEST GERMANY OR UKRAINE)
2. LANGUAGES: ENGLISH OR GERMAN

30th Oct. 2015

718

(”Ecosystem service*” OR ”Ökosystemdienstleistung*” OR ”Ecosystem function*” OR ”Environmental service*” OR ”Provisioning service*” OR ”genetic diversity” OR ”agricultural use” OR ”soil retention” OR ”soil fertility” OR ”fruit*” OR ”oil*” OR ”nut*” OR ”timber” OR ”firewood” OR ”cork” OR ”fodder” OR ”grain” OR ”forage production” OR ”forage” OR ”seed production” OR ”soft fruit*” OR fruit* OR vegetable* OR ”bio fuel” OR fodder OR ”Mechanical energy” OR ”Regulating service*” OR ”flood control” OR ”water quality control” ”water quality” OR ”carbon storage” OR ”climate regulation” OR ”disease regulation” OR pollination OR ”shelter belt*” OR ”Cultural service*” OR ”scenic beauty” OR education OR recreation OR tourism OR ”traditional use” OR ”cultural heritage” OR ”landscape enhancement” OR ”Supporting service*” OR ”Maintenance service*” OR ”pest control” OR ”nutrient cycling” OR ”Habitat diversity” OR ”Species diversity” OR ”soil conservation” OR ”soil protection” OR ”water conservation” OR ”nutrient storage” OR ”nutrient leaching” OR ”carbon sequestration”) AND (Agroforestry OR ”Agroforestry system*” OR ”Integrated land use system*” OR ”Integrated land use management” OR ”Integrated land use” OR ”Multifunctional management” OR ”Multifunctional management system*” OR ”silvopastoral system*” OR ”silvopastoral” OR ”Tree pasture system*” OR ”silvoarable system*” OR ”silvoarable” OR ”climate-smart agriculture” OR Windbreak* OR dehesa OR ”alley cropping” OR ”short rotation” OR ”short rotation system” OR ”Kurzumtriebsplantage*” OR ”short rotation poplar” OR ”short rotation coppice” OR Streuobst OR Hauberg OR ”Grazed forest*” OR hedgerow* OR ”wood pasture” OR ”buffer strip” OR piantata OR joualle OR Pomaradas OR ”pré-vergers” OR ”forest grazing system*”) AND (Europe OR temperate)
topic search;
outcome = 718

8th of January 2016

Search in google: ecosystem services of agroforestry systems in Europe Complementing “agroforestry” search term above.
Adding/Inserting names of agroforestry systems, from Fagerholm 2016, that haven’t been used in the final literature search run on the 30th of October (see above).

1090

(”Ecosystem service*” OR ”Ökosystemdienstleistung*” OR ”Ecosystem function*” OR ”Environmental service*” OR ”Provisioning service*” OR ”genetic diversity” OR ”agricultural use” OR ”soil

retention" OR "soil fertility" OR "fruit*" OR "oil*" OR "nut*" OR "timber" OR "firewood" OR "cork" OR "fodder" OR "grain" OR "forage production" OR "forage" OR "seed production" OR "soft fruit*" OR fruit* OR vegetable* OR "bio fuel" OR fodder OR "Mechanical energy" OR "Regulating service*" OR "flood control" OR "water quality control" "water quality" OR "carbon storage" OR "climate regulation" OR "disease regulation" OR pollination OR "shelter belt*" OR "Cultural service*" OR "scenic beauty" OR education OR recreation OR tourism OR "traditional use" OR "cultural heritage" OR "landscape enhancement" OR "Supporting service*" OR "Maintenance service*" OR "pest control" OR "nutrient cycling" OR "Habitat diversity" OR "Species diversity" OR "soil conservation" OR "soil protection" OR "water conservation" OR "nutrient storage" OR "nutrient leaching" OR "carbon sequestration") AND (Agroforestry OR "Agroforestry system*" OR "Integrated land use system*" OR "Integrated land use management" OR "Integrated land use" OR "Multifunctional management" OR "Multifunctional management system*" OR "silvopastoral system*" OR "silvopastoral" OR "Tree pasture system*" OR "silvoarable system*" OR "silvoarable" OR "climate-smart agriculture" OR Windbreak* OR dehesa OR "alley cropping" OR "short rotation" OR "short rotation system" OR "Kurzumtriebsplantage*" OR "short rotation poplar" OR "short rotation coppice" OR Streuobst OR Hauberg OR "Grazed forest*" OR hedgerow* OR "wood pasture" OR "buffer strip" OR piantata OR joualle OR Pomaradas OR "pré-vergers" OR "forest grazing system*" OR agrosilvopastoral OR "farm woodland*" OR "forest farming*" OR "isolated trees" OR "scattered tree*" OR "tree outside forest*" OR "farm tree*" OR woodlot* OR "timber tree system" OR "olive tree*" OR "orchard intercropping" OR parkland* OR "fodder tree*" OR pannage) AND (Europe OR temperate)
topic search;

- Refined by:
1. COUNTRIES/TERRITORIES:
(UK OR SPAIN OR AUSTRIA OR NORTH IRELAND OR GERMANY OR FRANCE OR HUNGARY OR ROMANIA OR ITALY OR CROATIA OR SWEDEN OR SCOTLAND OR NETHERLANDS OR NORWAY OR BULGARIA OR ENGLAND OR BELGIUM OR SLOVENIA OR PORTUGAL OR DENMARK OR SWITZERLAND OR WALES OR GREECE OR SLOVAKIA OR FINLAND OR LATVIA OR POLAND OR CZECH REPUBLIC OR LITHUANIA OR ESTONIA OR IRELAND OR WEST GERMANY OR UKRAINE) PORTUGAL OR DENMARK OR SWITZERLAND OR WALES OR GREECE OR FINLAND OR POLAND OR IRELAND OR WEST GERMANY OR UKRAINE)
2. LANGUAGES: ENGLISH OR GERMAN
3. Include agroforestry terms from Fagerholm et al. [2016]:on the 8th_ of January
agrosilvopastoral OR "farm woodland*" OR "forest farming*" OR "isolated trees" OR "scattered tree*" OR "tree outside forest*" OR "farm tree*" OR woodlot* OR "timber tree system" OR "olive tree*" OR "orchard intercropping" OR parkland* OR "fodder tree*" OR pannage

A.4 Grey literature search

Time span: 28th October until third of November 2015
Search engine: Google

1. (Ecosystem service*)AND(Agroforestry) AND Europe
Outcome:
First page:
1.1 THE CONTRIBUTION OF AGROFORESTRY SYSTEMS TO ...
- web page of pdf document:
http://journals.bg.agh.edu.pl/GORNICTWO/2011-03/GG_ 2011_ 3_ 04.pdf
In PDF document: in paragraph Outline reference to citation 3 in Appendix
Citation 3 = Quinkenstein et al. [2009]
To find this document in google you have to insert:
Assessment of ecosystem services provided by agroforestry systems in Europe. World Agroforestry Centre (Hrsg.): Book of Abstracts, 2nd World Congress of Agroforestry, Agroforestry The Future
W̄orld Congress of Agroforestry Nairobi
- Paper: Bernard Nsiah [2010]

Third page:
1.2 Agroforestry - Forestryencyclopedia - Sites - Google
- web page of document:
https://sites.google.com/site/forestryencyclopedia/Home/Agroforestry
- Paper: There is no paper in pdf format available, only web page!

2. Ecosystem service*AND Agroforestry AND Europe
Outcome:
Listed according enumeration/appearance in google:
General:
2.1. Books
first page
2.1.1 Agroforestry in Europe - Current Status and — Antonio
Agroforestry in Europe
Current Status and Future Prospects
Editors: Rigueiro-Rodríguez, Antonio, McAdam, Jim, Mosquera-Losada, María Rosa (Eds.)

5th page
2.1.2 Ecosystem Services from Agriculture and Agroforestry - CIRAD
- Ecosystem Services from Agriculture and Agroforestry
Measurement and Payment
Bruno Rapidel, Fabrice DeClerck, Jean-François Le Coq and John Beer
Earthscan
2011

3.
(”Ecosystem service*” OR ”Ecosystem function*” OR ”Provisioning service*” OR ”Regulating service*” OR ”Cultural service*” OR ”Supporting service*” OR ”Maintenance service*” OR service) AND (Agroforestry OR ”Agroforestry system*” OR ”Integrated land use system*” OR ”Integrated land use management” OR ”Integrated land use” OR ”Multifunctional management” OR ”Multifunctional management system*” OR ”silvopastoral system*” OR ”silvopastoral” OR ”Tree pasture system*” OR ”silvoarable system*” OR ”silvoarable”) AND ((Europe OR ”temperate region*” OR temperate OR ”temperate zone”) NOT (America OR US OR Canada))
Outcome:
Listed according enumeration/appearance in google:
First page:
3.1 Agroforestry - The Future of Global Land Use
Book:
Agroforestry - The Future of Global Land Use
P.K. Ramachandran Nair,Dennis Garrity
Content: Definition of different ecosystem services in agroforestry systems, but in a global context not only temperate regions!
3.2 Forestry NRCS - Natural Resources Conservation Service
web page:
http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/landuse/forestry/
Content:
Explanatory papers about different agroforestry systems, like windbreak, silvopastoral systems, alley cropping etc.!

Second page:
3.3 Service functions of agroforestry systems
Content is only given on a web page. Its about ecosystem services in agroforestry systems.
web page of document:
http://www.fao.org/docrep/article/wfc/xii/ms20-e.htm

4. Agroforestry Environment:
First page:
Reconciling Production with Protection of the Environment
paper:Smith [2010]

5. Search in German:
Ökosystemdienstleistung*UND Agroforstwirtschaft UND Europa
Outcome:
Listed according enumeration/appearance in google:
First page:
Agroforstwirtschaft in der europäischen Forschung ... - FNR
paper: Zehlius-Eckert [2010]
Content:
Enumeration of ecosystem services of agroforestry systems in Europe + negative impacts of agroforestry systems on ecosystem services

Appendix B

Results supplement

B.1 Criterion not met in the quality appraisal framework

Table B.1: The table is depicting the criterion that are not met in the quality appraisal framework

Id_nr	AGF	ES	Downgrad	Scores		General criteria	Design aspects	Focus aspects
				max	achieved			
16 Quali	WP	PS	1	28	26	4 of 16;random./prob samp., original data evaluation, responses given	Review, 5 of 8	2 of 5; Management, long and short term effects, outcome measure
10	SA	PS	0.5	32	25	4 of 16; all analysis questions	1 of 5; Case-control, allocation bias	1 of 5; Management, side effects on ES
36	SA	RS	0.5	27	20	4 of 16; random./prob samp., uncertainty, attrition bias, description statistic methods	1 of 5; Case-control, allocation bias	1 of 2; Quantification, temporal change
42	SP	PS	0.5	30	23	5 of 16; random./prob samp., uncertainty, attrition bias, description statistic methods, focused question	2 of 5; Case-control, allocation bias, replicates treatment	0; Quantification and management
110	WP	PS	0.5	27	25	2 of 16; uncertainty, attrition bias	0; Case-control	0; Quantification
57	SA	PS	1	25	18	6 of 16; random./prob samp., uncertainty, attrition bias,description statistic methods, choice statistic method	1 of 5; Case-control, allocation bias	1 of 2; Quantification, temporal change quantity's measured
69	SA	RS	1	25	18	6 of 16; random./prob samp., uncertainty, attrition bias,description statistic methods, choice statistic method	1 of 5; Case-control, allocation bias	1 of 2; Quantification, temporal change quantity's measured
105	SA	RS, PS	1	28	19	6 of 16; random./prob samp., attrition bias, data collection, all analysis	1 of 5; Case-control, allocation bias	1 of 2; Quantification, temporal change quantity's measured

Table B.2: The table is depicting the criterion that are not met in the quality appraisal framework

Id_nr	AGF	ES	Downgrad.	Scores max	achieved	General criterion	Design aspects	Focus aspects
29	SA	PS	2	23	15	5 of 16; random./prob samp.,uncertainty, attrition bias, data collection, origin. data evaluation	1 of 1; Observational studies, confounding factors	1 of 2;Quantification, temporal change quantity's measured
61	WP	PS	0.5	27	23	1 of 16; uncertainty	1 of 1; Observational studies, confounding factors	1 of 2;Quantification, temporal change quantity's measured; 1 of 5; Management, side effects on ES
17	SA	PS	0.5	27	19	4 of 16; uncertainty, attrition bias, study pretested, description statistic methods	1 of 1; Observational studies, confounding factors	1 of 2;Quantification, temporal change quantity's measured; 1 of 5; Management, side effects on ES
50	SA	SS	0.5	23	18	3 of 16; uncertainty, attrition bias, magnitude of effects	1 of 1; Observational studies, confounding factors	0;Quantification
108	SA	RS,SS	0.5	21	18	0	1 of 1; Observational studies, confounding factors	1 of 5; Management, side effects on ES
109	SP	CS	0.5	23	19	2 of 16; Attrition bias, magnitude of effects	1 of 1; Observational studies, confounding factors	0; Quantification
12	WP	PS	1	22	16	4 of 16; Attrition bias, uncertainty, data collection, variables given	1 of 1; Observational studies, confounding factors	1 of 2; Quantification, temporal change quantity's measured

Selbstständigkeitserklärung

Erklärung

Ich versichere hiermit, dass ich die vorliegende Arbeit ohne fremde Hilfe selbstständig verfasst und nur die angegebenen Quellen und Hilfsmittel benutzt habe. Wörtlich oder dem Sinn nach aus anderen Werken entnommene Stellen habe ich unter Angabe der Quellen kenntlich gemacht.

(I hereby declare that I have composed this document unassistedly and that I only used the sources and devices I declared. Passages taken verbatim or in meaning from other sources are identified as such and the sources are acknowledged and cited.)

Freiburg, 28. April 2016