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Full Length Article

Stakeholder perceptions of agricultural landscape services, biodiversity, and drivers of change in four European case studies

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ABSTRACT

Many studies have explored farmers' perspectives on biodiversity and ecosystem services, but fewer qualitative and cross-country comparisons exist. We develop a socio-ecological system to analyse agricultural landscape services, biodiversity, and drivers that have affected these services in recent decades. Via a systematic stakeholder mapping and 49 semi-structured interviews, we identify stakeholder perceptions of this system. We compare the perceptions across four regional case studies (Austria, Estonia, Germany, Switzerland), and two stakeholder groups (land managers and administrators). The case studies share certain commonalities in perceptions (e.g., provisioning and regulating services discussed in all of them) but also show differences (e.g., changes in biodiversity and landscape services more often perceived in the Swiss and German cases, but less in the Austrian and Estonian case studies). Across all case studies, typical land use change can be attributed to multiple drivers of various strengths, with climate change being the most often perceived driver directly affecting landscape services, followed by policies and market-based drivers, which affect services and biodiversity indirectly via land use. Compared to the administrators (e.g., decision-makers, scientists), the managers (e.g., farmers, NGOs) discuss more often the drivers, like various biodiversity and landscape service categories, as well as climate change, markets, and technologies. However, the administrators focus more on cultural services, policies as drivers, and consider more often links between drivers and landscape services and/or biodiversity. Hence, both of the groups' (administrators and managers) perceptions partly complement each other. Since policy making should be based on the best knowledge of different stakeholder groups, active knowledge exchange between managers and administrators should be supported and outcome considered in decision making. The resulting regional differences in stakeholder perceptions of the drivers and their respective impact on

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agricultural landscapes suggest that future agricultural policies need regional targeting and the consideration of landscape-specific characteristics.

1. Introduction

Agricultural landscapes are mosaics of agricultural fields, semi-natural habitats, human infrastructures, and interspersed natural habitats (Marshall, 2004). They provide a range of valued goods and services to people (Power, 2010) including provisioning services (e.g., agricultural products, raw materials), regulating services (e.g., regulation of pests, pollinators, pathogens), and cultural services (e.g., aesthetic functions of these landscapes) (Swinton et al., 2007; van Zanten et al., 2014). Biodiversity has different roles in agroecosystems and thus in agricultural landscapes. It maintains the productivity of cropping systems, enhances the biological regulation of pests, or is appreciated by people for its mere existence (Chopin et al., 2017; Junge et al., 2011). Due to the close relationship between biodiversity and ecosystem services (Schneiders et al., 2012), addressing them jointly in research and policymaking about agricultural landscapes appears crucial.

As agricultural landscapes in many regions in Europe have changed during the last decades–including higher input intensities or land abandonment (van Vliet et al., 2015)–the provision of their services is challenged. Drivers for change are effective at global, national, regional, and local scales and are of biophysical and socio-economic origin (Mottet et al., 2006). Climate change is an example of an important global bio-physical driver. Socio-economic landscape drivers include political and institutional drivers; demographic drivers such as urbanization; economic drivers; technological drivers such as digitalisation and automation; and cultural drivers (Mottet et al., 2006; Zondag and Borsboom, 2009; van Vliet et al., 2015). Both biophysical and socio-economic drivers will likely change fundamentally in the upcoming decades as has been the case in the past. Thus, the future provision of ecosystem services and maintenance of biodiversity may require location-specific adaptive management strategies of current agricultural systems. Knowledge about past changes and current trends in an agricultural landscape can support such a transition.

Ecosystem services from agricultural land use are typically supplied at the field to landscape level, i.e., they may be considered "landscape services" (Hermann et al., 2011; Smith and Sullivan, 2014; Termorshuizen and Opdam, 2009). However, their outreach can be beyond the landscape level. Provisioning services (e.g., biomass production in food and fodder) are traded from the local to the global level. Regulating services can serve global demands (e.g. carbon sequestration) or more regional (e.g. water purification) and local (e.g. maintenance of soil fertility) requirements. Cultural services are more closely related to the local landscape context and the presence of humans. Hence, the governance of multifunctional landscapes needs a transdisciplinary approach that integrates the perspectives of different levels and different stakeholders (Scherr et al., 2012; Selman, 2009; Stosch et al., 2019).

Different stakeholders (e.g., land managers, various user groups of landscape services, decision-makers) may value contrasting services of agricultural landscapes and may therefore prefer different policy options to govern landscape changes (Cord et al., 2017; Hauck et al., 2013; Otto-Banaszak et al., 2011). Numerous studies have explored farmers' perceptions of agricultural ecosystem services (such as Chen et al., 2017; Greenland-Smith et al., 2016; Maas et al., 2021; Smith and Sullivan, 2014) and climate change impact on agricultural systems (Arbuckle et al., 2015; Mitter et al., 2019; Weber, 2010), mostly via quantitative methodologies (e.g. surveys). A few studies have provided a comparative perspective based on stakeholder groups and countries, e.g., perceptions of decision-makers and beneficiaries on grassland ecosystem services in Austria, UK, and France (Lamarque et al., 2011) or perceptions of residents, visitors, and farmers about cultural ecosystem services in Austria and Germany (Bieling et al., 2014). Lautenbach et al. (2019) took a random sample of the ecosystem services literature and revealed that only 37% of the studies involve stakeholders, while only 4% of the studies involved different stakeholder groups (i.e., local beneficiaries, distant beneficiaries, experts, decision-makers, organizations). A small number of studies have explored stakeholder perceptions qualitatively (Lamarque et al., 2011), and have explicitly assessed landscape services (such as Fagerholm et al., 2019) or landscape change drivers from multiple stakeholders' perspectives (Bürgi et al., 2017; Dallimer et al., 2009). Some studies have addressed stakeholder perceptions on drivers for service provision (i.e., links between services, changes, and human well-being) (do Rosário et al., 2019; Iniesta-Arandia et al., 2014). These studies based on stakeholder perceptions mostly focus on single case studies (e.g., Lange et al., 2015) with limited options for generalizations and cross-region comparisons. However, such comparisons are necessary to develop effective policies and governance instruments from regional or national to supranational levels (e.g. EU). Moreover, there are only a few studies evaluating stakeholder perspectives on landscapes from a systems perspective (e.g., van der Sluis et al., 2018). Yet, the inclusion of multiple stakeholders, representing a range of perspectives within a society, can improve the legitimacy of research (Durham et al., 2014) and resulting policies and contributes to the governance principles (principle of equity) suggested by the EU Biodiversity Strategy (European Commission, 2020).

As part of the SALBES project (https://salbes.eu/), we have conducted comparative research in four case studies, situated in four different countries (Austria-AT, Switzerland-CH; Germany-DE, Estonia-EE) and five environmental zones (Continental and Pannonian-AT; Continental-CH; Atlantic-DE; Nemoral-EE) (Metzger et al., 2005) to fill the research gaps mentioned above. We identify perceptions of different stakeholders on relevant biophysical and socio-economic conditions of agricultural landscape services, biodiversity, and drivers that have affected these services in recent decades. This information can support the prioritization of drivers for the design of scenarios in the context of *ex-ante* landscape studies and can result in design principles of regionally adapted policies for the conservation of agricultural landscape services and biodiversity. The following first three research questions provide a synthesized and comparative perspective across the regions; the fourth question compares different stakeholder groups' perceptions.

1. What are stakeholder perceptions on valuable present land uses and biophysical location factors, biodiversity components, and agricultural landscape services of the case studies?
2. How are land use, biodiversity, and agricultural landscape services in the case studies perceived to have changed over the last two decades?
3. Which drivers are perceived to affect land use, biodiversity, and the provision of landscape services?
4. How similar or different are perceptions across stakeholder groups?

The remainder of the article is organised as follows. Section 2 presents our methodology, i.e. the analytical framework, empirical data, and case study selection. Section 3 presents the results and section 4 sets the results into the context of the case countries and earlier studies. Finally, we conclude with recommendations for policies and future research.

2. Methodology and data

2.1. Methodological procedure at a glance

Answering the four research questions requires (i) empirical data at the case study level and (ii) an analytical framework to analyse these data consistently across diverse case studies. Requirements for the latter are the categorization of landscape components, a dynamic perspective to reveal changes over time, and a system definition to analyse drivers and their impacts on different landscape components (Fig. 1).

Here we develop an analytical framework that meets these requirements (Fig. 2 and section 2.2). Bürgi et al. (2004) propose a three-step procedure to analyse landscape change and its driving forces. This procedure serves as the foundation of the analytical framework. Step 1 encompasses a spatial and temporal system definition, including clear specifications of components to be considered in the landscape (section 2.2.1). In step 2, the system has to be analysed concerning the change and persistence of these components over time, the actors and institutions involved with change, and the corresponding driving forces (section 2.2.2). For step 3, a synthesis establishes causal relations between the items of socio-ecological systems, i.e. driving forces, actors, and changes in agricultural landscapes (section 2.2.3). We extend the framework of Bürgi et al. (2004) by step four, i.e. a comparison across regions and two groups of stakeholders (section 2.2.4).

2.2. Analytical framework

2.2.1. Step one: system definition

We define a socio-ecological system. Fig. 2 shows single components of the system and the linkages between them. The main components are (i) drivers that are mainly from outside the agricultural landscape, (ii) the agricultural landscape including location factors, agricultural land use, landscape (dis-)services, and dimension of biodiversity, (iii) stakeholders that act either within or outside this landscape.

Drivers in agricultural landscapes denote any natural or human-induced factors that directly or indirectly cause change (Iniesta-Arandia et al., 2014). Hence, drivers may be of multiple origins (e.g., socio-economic, natural), scale (i.e., local to global), and strength. A typical categorization of drivers includes socio-economic, political, technological, natural, and cultural drivers, such as attitudes, values, and beliefs of a community (Bürgi et al., 2004; Geist and Lambin, 2002; Plieninger et al., 2016), with cultural drivers being the most difficult to conceptualize and measure (Bürgi et al., 2004). We consider the following driver categories: i) climate change; ii) market-based drivers, iii) technologies, iv) policies and v) other drivers. To allow for the categorization of all drivers given by the interviewed stakeholders, we introduce "Other" as a category including cultural drivers as well as those not clearly attributable to any of the other categories.

Biophysical and socio-economic drivers put pressure on the status-quo of agricultural landscapes by impacting the land use decisions of farmers. These decisions again determine landscape services, dis-services, and biodiversity. Climate change as one of the most significant bio-physical drivers also immediately impacts landscape (dis-)services, and biodiversity by-passing land use decision-making. Landscape services not only result from agricultural land use but are determined also by biodiversity and may even become a driver of land use creating a feedback loop. For example, land use determines the diversity and population size of pollinators (biodiversity), which impacts the availability of pollination services (landscape service) and, hence, the productivity of crops (Kirchweger et al., 2020).

In the socio-ecological system, we differentiate drivers from bio-physical location factors. Location factors determine land use. However, they are also framing land use decisions and determine the reaction of land users to drivers, thereby influencing land use change (Levers et al., 2018). For example, soil quality determines crop choices and management intensity. Location factors are stable during the given time scale but can become variable, i.e. they may become drivers, if time scales change. Among the bio-physical location factors, climate is a specific case due to its medium-term dynamics. Hence, it is considered both as part of the location factors and as a driver.

In our socio-ecological system, we consider agricultural land use, including the land cover (e.g., cropland, grassland, permanent crops, landscape elements) and its management (i.e., crop choices, and management intensities). Landscape elements include linear landscape elements (e.g., flower strips, hedgerows, stone-walls), habitat patches (e.g., single trees, groups of trees, small forest patches, bushes), or small water bodies (e.g., ponds) (Bennett et al., 2006; Liira et al., 2008; van der Zanden et al., 2013). Livestock management is not considered a land use category but is related to land cover and management choices, e.g., high livestock densities correlate with high land use intensities.

The concept of landscape services has been proposed as a connecting point between physical landscape features (i.e., landscape components) and human values (Termorshuizen and Opdam, 2009; Vallés-Planells et al., 2014). We define agricultural landscape services as the provision of agricultural commodities and natural benefits of the landscape which contribute to human well-being (Hermann et al., 2011; Smith and Sullivan, 2014). Human well-being is related to the concept of "landscape values". It describes the multiple ways people value landscapes (Bieling et al., 2014). Sources of value in agricultural landscapes may be ecological (e.g., biodiversity), economical (e.g., the monetary and non-monetary benefits resulting from these landscapes), and social (e.g., wider meanings, values, and ideologies attached to landscapes by different stakeholders) (Kizos et al., 2018; Petanidou et al., 2008). The ecological, economic, and social determinants of the agricultural landscape value are linked via the different services from the ecological system and their resulting benefits (Hermann et al., 2011). We do not explicitly address such landscape values but assume they affect the

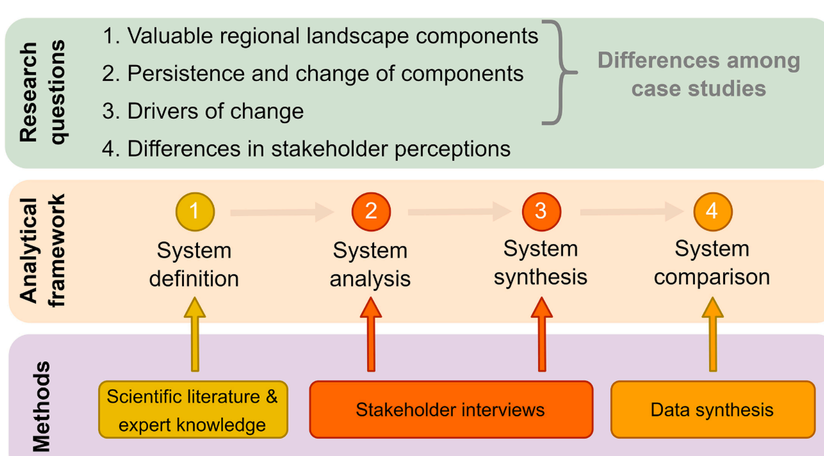


Fig. 1. Research methodology overview.

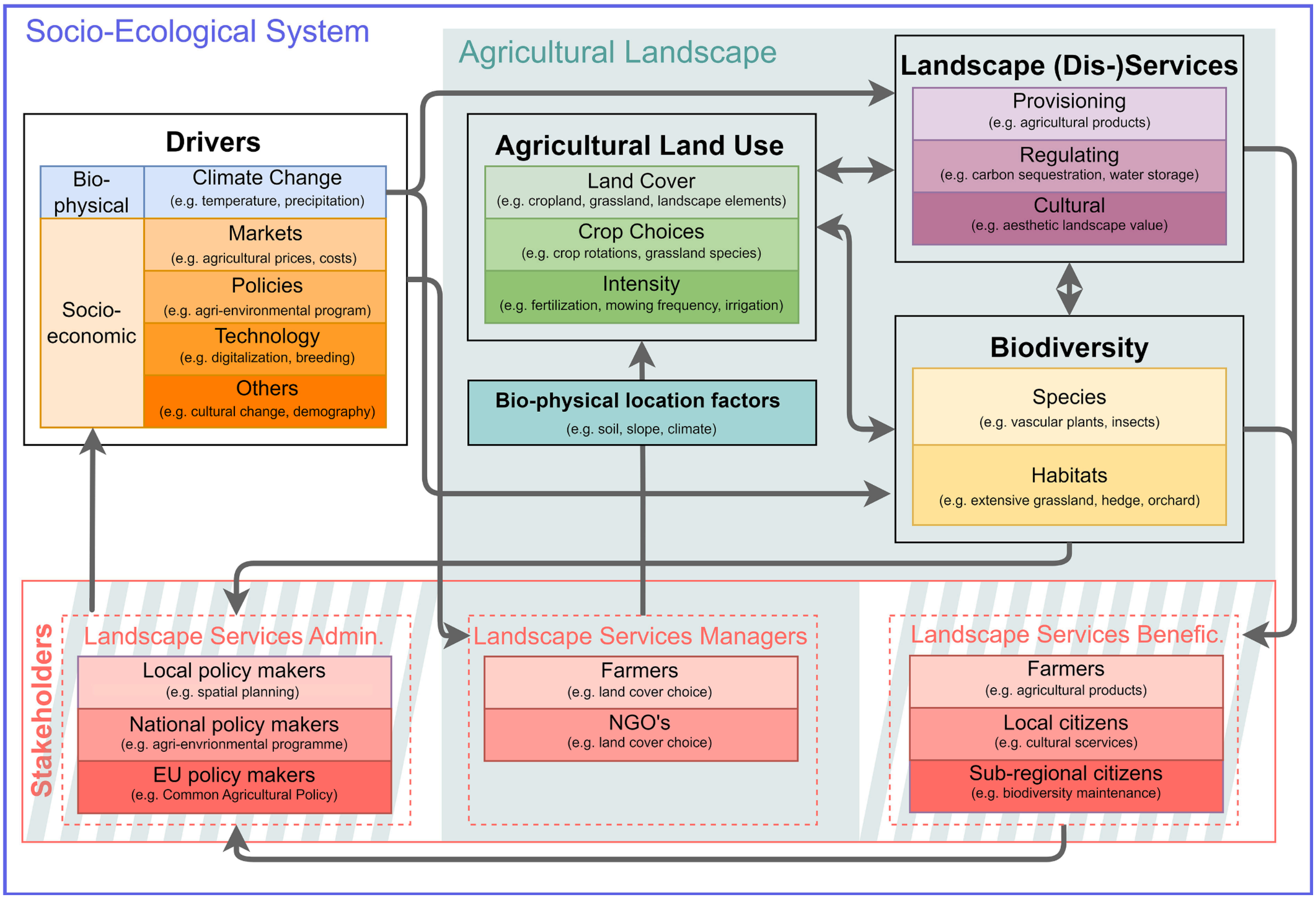


Fig. 2. Socio-ecological system with components and interactions.

perceptions of stakeholders regarding all other components.

As a basic structure, we consider three landscape service categories: provisioning, regulating, and cultural services from the literature on ecosystem services (e.g., Maes et al., 2016), but we allow for further sub-categories to be identified based on the interview data. As disservices have also been discussed in the literature (e.g., Zhang et al., 2007), we introduce them as the fourth service category, by which we mean negative effects of farming activities (e.g., nitrogen leaching) or negative effects from ecosystem functions for farming (e.g., pest damage) (Huang et al., 2015: p. 143). We separately consider three dimensions of biodiversity in addition to landscape services. Dimensions of biodiversity include any aspects of (i) plant and (ii) animal species (e.g. species diversity, population size) as well as (iii) habitats (e.g. extent, quality).

Human society is part of the socio-ecological system. Some societal groups are actors (i.e., landscape service managers and administrators), while others are landscape service beneficiaries with limited impacts on land use decisions. We consider these groups together as stakeholders, i.e., individuals, groups, or organizations that are affected by or can affect system components (Grimble and Wellard, 1997). In the case of the agricultural landscape, we distinguish between those that benefit from landscape services, those that manage landscapes by direct interventions, and those that set the framework conditions for the managers (Fig. 2).

Finally, we determine the spatial and temporal scales including the extent and resolution (Agarwal et al., 2002) of the socio-ecological system under study. This is crucial for understanding and interpreting the dynamics of change and the interactions between the components. For example, drivers, such as market prices, may have different effects in the short term (e.g. determining crop choices) or long term (e.g. determining farm types or structure). Concerning the temporal extent and resolution, the *ex-post* study period covers the recent two decades. We consider the study period as a continuum and did not define sub-units to reduce complexity in the stakeholder interviews. The spatial extent of the case studies is determined by bio-geographic or administrative criteria and, hence, varies considerable across the four case studies (section 2.4). However, we do not explicitly address the spatial resolution to reduce complexity.

2.2.2. *Step two: system analysis*

System analysis links the empirical data from the interviews to the defined system (2.2.1) in two analytical sub-steps in each of the case studies. In the first sub-step, the perceived present status of agricultural landscapes, landscape (dis-)services, and biodiversity is presented and persistence and change during the last two decades are analysed. In the second sub-step, stakeholder perceptions of changes in driving forces along the five driver categories are analysed. The latter results are presented jointly with driver linkages as part of the system synthesis (step three) because stakeholders typically conceived the dynamics of drivers jointly with their impacts.

2.2.3. *Step three: system synthesis*

System synthesis derives causal relationships between the components analysed in step 2 (2.2.2) (Bürgi et al., 2004). It includes both the linkages between two components and the direction of information flows. This analytical step requires flexibility for unexpected relationships in the system. Major linkages can be expected for the drivers, with resulting impacts on land use and for land use impacts on landscape (dis-)services and biodiversity.

2.2.4. Step four: system comparison along four case studies and two stakeholder group aggregates

This step intends to improve the interpretation of perceptions and the understanding of component linkages by comparing the results from the four case studies. Highlighting similarities and differences between the case studies and mapping regional differences in case studies along bio-geographic criteria (Table 2 and Fig. 3) shall result in more robust conclusions. The system comparison is based on synthesised data from each case study (section 2.4). Additionally, a comparison of the two stakeholder group aggregates–the landscape service managers and beneficiaries and the landscape service administrators and scientists–-shall reveal differences and similarities in the perception patterns of these two groups. The two groups as well as the concept of perceptions are explained in the next section.

2.3. Stakeholder perceptions from interview data and standardized analysis

Stakeholder perceptions in our study relate to the observations and interpretations of the components and linkages in the socio-ecological system (Fig. 2). The perceptions of individuals and different stakeholder groups may differ considerably as e.g., the interests of farmers, nature conservationists, and local citizens are often conflicting. Besides economic or professional interests, the value systems, individual mental contexts, personal experiences or stakes, as well as the expertise and knowledge of stakeholders may affect their perceptions (Ekanayake et al., 2020). Consequently, perceptions are subjective by nature and may vary over time. For a broad and balanced assessment, a careful selection of individual stakeholders is pivotal. The data collection and analysis approach has been standardized across all four case studies to make it comparable. It included (i) the identification of stakeholders to be interviewed, (ii) the interviews based on a guideline, and (iii) the data analysis along a shared codebook.

Stakeholder identification began with a systematic stakeholder mapping procedure (Supplementary data 1). Our objective was to include all types of stakeholders who were identified as relevant and invited persons with proven competency to describe processes and changes in landscape dynamics. Such proof either resulted from personal contacts, publicly available output (e.g. publication), or testimonials from other stakeholders. However, a certain degree of subjectivity in this choice remained unavoidable. We aimed to reach different groups of stakeholders: those who are directly involved in agricultural activities in their everyday lives (e.g., farmers) and stakeholders who are affecting and implementing the decisions concerning agricultural landscapes (e.g., professionals of the agricultural and environmental administration).

We aimed for a minimum of 10 structured interviews in each case study which resulted in 49 qualitative interviews with 51 stakeholders. One German and one Estonian interview were group interviews, with two participants in each of them (Table 1). For analysing the 4th research question on differences in stakeholders' perceptions, we have merged stakeholder sub-categories (Table 1) into two stakeholder group aggregates:

- Landscape service managers and beneficiaries (e.g., farmers, NGOs, or agricultural extension service providers) who on the one hand are beneficiaries of landscape services, and on the other hand affect these services when reacting to land use drivers.
- Landscape service administrators and scientists (e.g., ministries and local/regional administration operating in the environmental, land use, protected areas' management domains) frequently determine land use drivers or give advice.

The interviews were supported by a joint interview guideline. It covered eight main topics, to study stakeholders' perceptions of the regionally distinctive land uses (particularly focusing on landscape elements), biodiversity and landscape services, and five driver categories (details in Supplementary data 2). We asked the stakeholders to describe the current situation and perceived changes over the last two decades. Interviews were taken in national languages by each of the four regional research teams from January to May 2020. Interviews were conducted either face-to-face or by phone, lasting between 30 and 120 min. Interviews were audio-recorded and transcribed (mostly), or detailed written notes were kept in case of denied recording.

We analysed the transcribed interview data using structured content analysis and qualitative thematic analysis techniques, where the analysts look for common themes, keywords, and other patterns in the interview texts and report on their frequencies and content (Skovdal and Cornish, 2015). Following (Kuckartz, 2019), we agreed on a spreadsheet codebook with separate code-sheets for all main items of our analytical frame, i.e., agricultural land use, landscape services, biodiversity, and the five drivers. The code-sheet on landscape services was developed based on the division of agricultural landscape services by Huang et al. (2015); Schaller et al. (2018) and Swinton et al. (2007). Further subcategories of landscape services were added if such arose from cases' data. The code-sheets of the other main items were filled in mostly inductively, i.e., codes and categories arising from data. The case study team members extracted relevant passages from the interviews and summarised them according to our framework. Coherence across teams to maintain comparability was checked in regular team meetings. Synthesis within a case study was done semi-quantitatively, i.e., counting the frequencies of mentioned thematic categories, and summarizing main topics qualitatively. This is the prerequisite for the comparison between cases. Supplementary data 5 gives an indication of the main categories in the codebook.

Table 1
Interviewed stakeholder groups and sub-groups in the case studies.

	AT	CH	EE	DE	*TOTAL**
Landscape service beneficiaries/managers	*6*	*4*	*6*	*10*	*26*
Farmers	5	2	4	9	*20*
Agricultural extension service	0	1	1	0	*2*
NGOs	1	1	1	1	*4*
Landscape service administrators and scientists	*5*	*6*	*6*	*8*	*25*
Ministries (e.g., environment, or agriculture)	0	3	1	1	*5*
Nature conservation administration (reg/local)	2	0	1	2	*5*
Agricultural administration (reg/local)	0	1	2	3	*6*
Local governments	2	0	0	0	*2*
Scientists	*1*	*2*	*2*	*2*	*7*
TOTAL	*11*	*10*	*12*	*18*	*51*

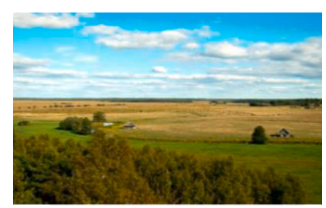
* Total refers to the number of individuals interviewed (51), AT is the acronym for the Austrian case study, CH for the Swiss, EE for the Estonian and DE for the German case study.

2.4. Case studies

This research is part of the European research project SALBES (https://www.salbes.eu), which investigates future scenarios of agricultural landscapes and their relationship to agriculture and biodiversity protection in four case studies (Table 2). A case study refers to a real-life, contemporary bounded system, embedded in a particular context (Baxter and Jack, 2008: p. 548). The case studies in this paper are defined by time horizon (present and past two decades), place (four regions), study phenomenon or object (stakeholder perceptions), and topic (agricultural landscapes and their services). This system is empirically based on the total sets of interviews conducted in each of the four case studies.

The four case studies have been purposefully selected along environmental and political strata, to learn from contrasting case studies and to potentially allow for upscaling of conclusions within other European regions (see background information in Table 2). Gradients include bio-

Table 2
Case studies' characteristics. (If not referenced otherwise, the sources for the data are various national/regional data and our expert judgments).

Case region	Wienerwald (AT)	Schwarzbubenland (CH)	Läänemaa (EE)	Münsterland (DE)
Size	1056 km^2	50 km^2	2383 km^2	6752 km^2
Environmental zone[1]	Continental and Pannonian zone to roughly equal parts	Continental zone	Completely within the Nemoral zone	Atlantic Central zone to a large degree with shares of the Atlantic North zone
Altitude	200–890 m	430–670 m	13–51 m	35–189 m
Slope[2]	0–47.5° (mean: 11.5°)	0–44.2° (mean: 13.4°)	0–14.38° (mean: 0.02°)	0–40.5° (mean: 0.2°)
Average annual temperature, °C[3]	8.8 (1961–2020)	10.1 (1961–2020)	5.9 (1964–2020)	9.9 (1961–2020)
Annual precipitation sums, mm[3]	773 (1961–2020)	965 (1991–2020)	683 (1961–2020)	795 (1961–2020)
Soil type[4]	Dystric planosols in most parts of the Wienerwald accompanied by eutric to calcaric cambisols and rendzic leptosols on the eastern fringe slopes	A mixture of eutricand vertic cambisols and umbrisols	Eutric gleysols, typically of sandy loam to loam textures, and eutric histosols	Haplic (i.e. typical) podzols of loamy sands and a slightly elevated area west of the city of Münster with higher silt contents from eroded loess deposits on which eutric cambisols and haplic luvisols
Landscape	Hilly, diverse landscape with a mix of forests, grassland and arable land	Gently rolling hills with mosaic landscape	Flat landscape, semi-natural habitats with traditional elements, e.g., stone-walls	Flat, agriculturally dominated landscape with characteristic landscape elements
Main land uses	• Forests (70%) • Arable land (7%) • Grasslands (12%) • Urban areas (7%) • Vineyards and orchards (2%)	• Forests (44%) • Arable land (18%) • Grassland (13%) • Urban areas (5%) • Orchards (17%)	• Forests (54%), • Arable land (10%) • Grasslands (20%) • Urban areas (1,4%) • Wetlands (11%)	• Forests (16%) • Arable land (52%) • Grasslands (14%) • Urban areas (13%) • NA
Agricultural production focus	Wine production and grassland-based farming for livestock production (mainly cattle).	Mixed farming, mainly dairy farming; region is well-known for traditional high-stem cherry orchards.	Extensive mixed farms; arable crops (cereals, oil-crops), extensive animal husbandry (beef cattle)	Intensive livestock (pig fattening and breeding, dairy farming, bull fattening); crops for feed, food, and energy.
Average farm size	16 ha (below Austrian average)	23 ha (slightly larger than Swiss average)	78 ha (above the Estonian average)	31–44 ha (mean size; below the German average)
% of organic farming	17%	12.3–15.9%	Ca. 33% (above national average)	0.6–1.6% (below national average)
Biodiversity and nature protection	Wienerwald Biosphere Reserve (BR) has one of the largest complexes of deciduous forests (mostly above-average old, rich in deadwood and other elements important for biodiversity). In the open land areas of the BR, 17 meadow types, over 2000 plant species can be found and ca. 150 bird species are breeding.	Traditional high-stem cherry orchards are classified as semi-natural habitats and recognised as agro-biodiversity hotspots and therefore identified as high nature value farmland. Typical orchard species are rare birds (e.g., the redstart, honey buzzard, cuckoo, wryneck, nightingale) and other species of semi-open landscapes.	23% of the territory of the county is protected, incl. the most famous Matsalu National Park (NP) and semi-natural habitats, including extensive coastal and floodplain meadows, well known as biodiversity hotspots and key stopover locations for migrating birds.	Nature conservation areas cover only between 4-7% of the counties. Some projects aim to promote biodiversity by introducing flower strips. Existing green infrastructure elements are e.g., forest edges, hedgerows, small water bodies, ditches, and small watercourses.
Socio-economic conditions	Rural character, closeness to Vienna creates opportunities for tourism and direct marketing, secondary residences.	Rural character, close to the city of Bale which gives opportunities for regional markets and tourism	Rural character (population density ca. 11 inhabitants/km^2), but well-connected to centres, e.g., Tallinn or Pärnu.	Rural character, but close to highly industrialized and populated areas. The "energy region" has a diverse portfolio of renewable energy (e.g., photovoltaic systems, biogas plants).
Visual representation of a typical landscape	 Photo: T. Wrbka.	 Photo: E. Szerencsits.	 Photo: T. Talvi.	 Photo: U. Stachow.

Notes:
[1](based on Metzger et al., 2005).
[2](calculation based on European Environment Agency, 2019).
[3](Conradt, 2021).
[4]Based on the European soil map as in the four cases (Conradt, 2021).

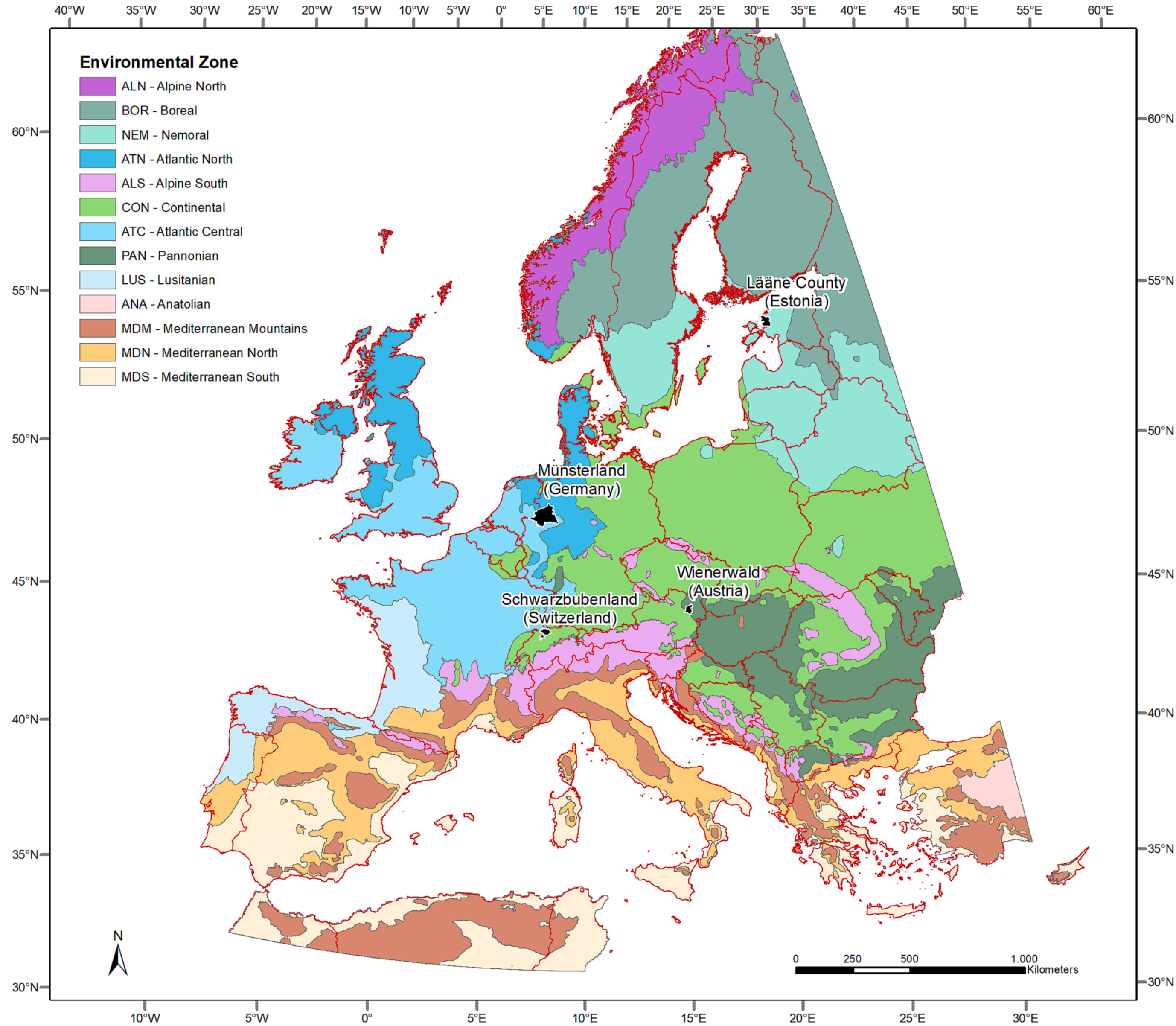


Fig. 3. SALBES case studies' locations after the Environmental Stratification of Europe (Metzger et al., 2005).

physical location factors, farming systems, expected climate change impact, and different socio-economic conditions, which have led to heterogeneous ecological and agricultural infrastructures. Location factors, i.e. climate, altitude, slope, and latitude, also determine the environmental stratification of Europe (Metzger et al., 2005). It shows our case studies to be located in five out of the 13 environmental zones as a proxy for potential landscape services (Fig. 3).

Consequently, the development options and adaptation potentials and capacities are diverse. Besides patterns of supply, the demand for biodiversity and landscape services is expected to be heterogeneous within and between the regions. Each case study is also typical for a landscape setting: intensive crop and livestock production in a rather small scale, flat landscape (Münsterland, Germany), mixed farming and fruit production in gently rolling hills in a mosaic landscape (e.g., small villages, farmland, grasslands, traditional orchards) (Schwarzbubenland, Switzerland), mixed farming and vine production in a hilly, diverse landscape with a mix of forests, grassland and arable land (Wienerwald, Austria), and mixed farming in a predominantly flat landscape, located in the lowlands of west-Estonia (Lääne-County, Estonia).

3. Results

3.1. Comparison of stakeholder perceptions across case studies

We first present the results to research questions 1–3, i.e., comparisons and summaries of the main findings across the four case studies (Fig. 4). Sections 3.1.1 and 3.1.2 analyse the persistence and change of system components including agricultural land use, biodiversity, and landscape (dis-)services (step 2; see section 2.2.2). Section 3.1.3 analyses linkages between the components and the role of drivers (system synthesis, see section 2.2.3). Detailed case study summaries are given in Supplementary data 3. Supplementary data 5 provides an overview of the interviewees' responses by case studies and across the two stakeholder groups.

3.1.1. Perceived valuable present agricultural land uses

Land cover and landscape elements. All interviewees pointed out present agricultural land cover types they consider valuable or typical in their region (Fig. 4), which manifests heterogeneous land uses across the case studies: grasslands (AT); semi-natural grasslands (EE); orchards

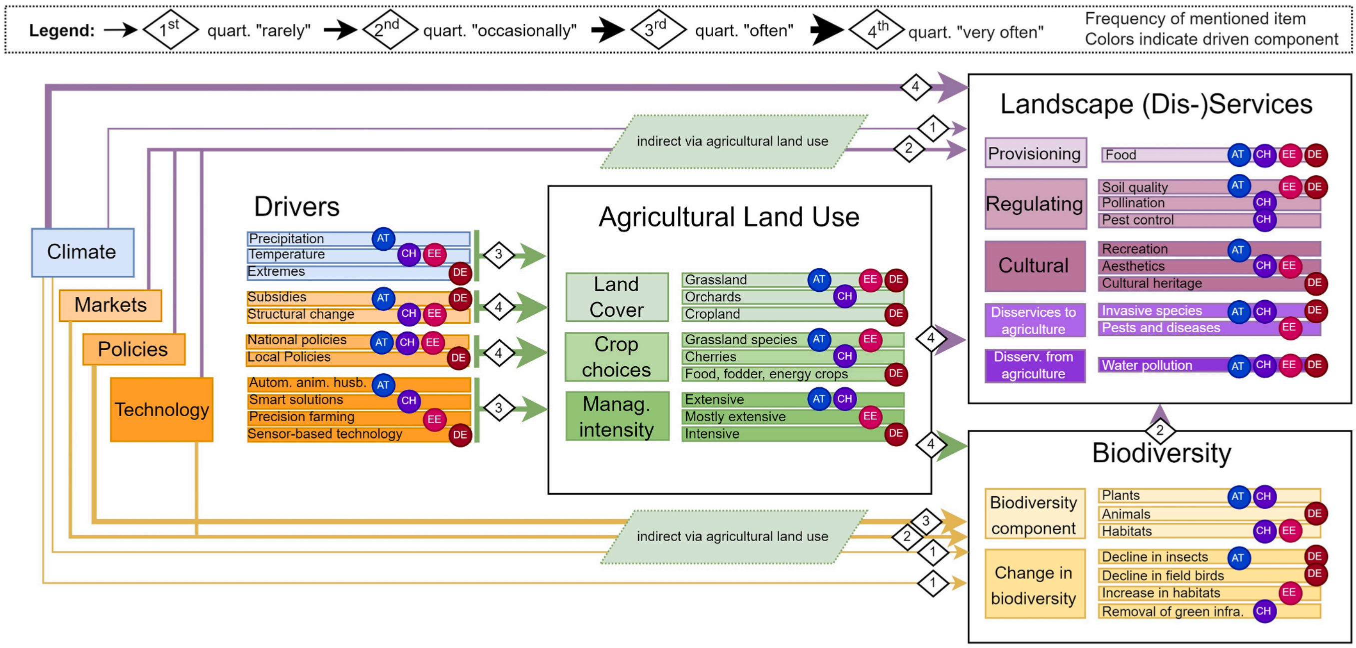


Fig. 4. Summary of the categories mentioned in the interviews and their interlinkages, across all cases. Notes: *Direct driver* links are links where interviewees made an explicit connection between the driver category "climate" to either land use, or landscape services and/or biodiversity (e.g., climate change impacts on soil erosion as direct impacts on landscape services) or other driver categories to landscape services and/or biodiversity. *Indirect driver links* are links where interviewees mentioned drivers affecting landscape services and/or biodiversity via land use, i.e., when they mentioned any of the drivers and landscape services/biodiversity and, at the same time, they also referred to land use. Interpretation example: Change in temperature has been the most important climate change driver in Switzerland and Estonia. Three quarters of all interviewees in the four case studies mentioned it as important for agricultural land use and thereby indirectly impacting landscape (dis-)services. Climate change in general directly impacts landscape (dis-)services according to four quarters of the interviewees. Only one quarter considers it as an impact on biodiversity, either directly or indirectly via land use.

(CH); and crop- and grasslands as part of the "Park landscape of Münsterland" (DE). Examples of main landscape elements in the respective regions include traditional managed elements (e.g., stone-walls or -stacks, EE); woody elements (e.g., single trees and bushes, forest borders, CH; forest patches, AT; hedgerows, DE); and surface water bodies (e.g., ditches and ponds, DE; ditches, EE).

Crop choices and management intensity. Management practices in the studied regions are mostly extensive, except for the German case. Examples of land management include extensive grazing or mowing 1–2 times per year (AT); traditional fruit orchards' management on steep slopes (CH); or management and restoration of semi-natural grasslands (EE). In the German case study (DE), landscapes are characterized by intensive management, aimed at food, fodder, and energy crop production, e.g., silage maize for livestock and biogas plants; cereals like wheat, rye, or barley; and intensive livestock farming (esp. pig farming).

Bio-physical location factors were mentioned in almost all interviews, with examples of the main location factors summarised in Table 3. In the interviews, most of these factors were perceived to determine present land use (all in the CH, EE, and DE cases; 6 in the AT case) and only in some EE and AT cases also landscape services and/or biodiversity.

3.1.2. *Perceptions about biodiversity, landscape (dis-)services and their changes*

The prevailing biodiversity category differed across the four case studies: habitats (EE, CH), plant species (AT, CH), and animal species (DE) (Fig. 4 and Table 4). However, the differences between the frequencies of mentioned topics, especially in the AT and CH cases were very small (Table 4 and case study figures in Supplementary data 3). Most Swiss and German interviewees perceived changes in these categories, however, only ca. half of the Estonian and Austrian interviews mentioned such changes (Table 6). In the Swiss case study, interviewees mainly perceived changes in animal species and habitats. They mostly

Table 3
Frequencies and examples of bio-physical location factors determining present land use as mentioned in the case studies' interviews. Examples are derived partly inductively from the interview data, and partly they refer to the pre-defined categories as in the categories of location factors defined above (e.g. soil). Note: the table is complete–there were no location factors mentioned "occasionally" (26–50% of each of the four case studies' interviews) or "often" (51–75% of the interviews).

Case study	AT (n_{total} = 11)	CH (n_{total} = 10)	EE (n_{total} = 12)	DE (n_{total} = 18)
Any kind of location factor mentioned in:	10 interviews	9 interviews	12 interviews	13 interviews
Examples of very often mentioned location factors (i.e. mentioned in 76–100% of the interviews)	Soil; steep slopes and hilly landscape	Soil; steep slopes and hilly landscape or topography	Soil; Baltic Sea influence, e.g. rising land as ice age influence; long coastline; flooding risk	Soil; climate
Examples of rarely mentioned location factors (i.e. mentioned in 1–25% of the interviews)	Climate	Bedrock (limestone); continental influence; landscape structure	Flat landscape; climate; bedrock, geomorphology	Landscape structure (small patches)

Table 4
Frequencies of mentioned biodiversity categories and their changes in the case studies' interviews. Legend: ○- not mentioned; ◔- "rarely" (1–25%); ◑- "occasionally" (26–50%); ◕- "often" (51–75%); ●- "very often" (i.e., mentioned in 76–100% of the interviews). ↗ Increase, ↘ decrease, ↕ changing composition, ↔ indifferent, i.e. increase and decline have been mentioned equally often. Columns "a" denote frequencies of each biodiversity category mentioned; columns "b" denote frequencies of mentioned changes of categories in columns "a", columns "c" denote the dominant perceived direction of change (e.g. increase, decrease; diverging perceived directions of change are described in the text). NA: means "Not applicable".

Biodiversity category	AT (n_{total} = 11)			CH (n_{total} = 10)			EE (n_{total} = 12)			DE (n_{total} = 18)		
	a	b	c	a	b	c	a	b	c	a	b	c
Plant species	◕	◔	↔	●	◑	↘	◑	◕	↘	◑	◑	↘
Animal species	◕	●	↘	◕	●	↗	◕	◑	↘	●	●	↘
Habitat	◕	◔	↘	●	●	↘	●	◕	↗	◕	◔	↘
Agrobiodiversity (e.g. crop diversity)	○	NA		◑	●	↗	○	NA		◔	●	↘

mentioned increases in alien or invasive species, and declines in orchard birds, insects, and butterflies in most fields (except where orchards are successfully maintained as mentioned by one interviewee). Habitat losses were described such as the removal of orchards, single trees, or other landscape elements. The interviewees also described a changing composition of habitats due to the abandonment of fields leading to scrub encroachment, which however serves as green infrastructure. Two interviewees perceived such changes as an increase in habitat (vs a changing composition). Two interviewees linked such habitat changes to a changing composition of plant species and two to losses in plants.

Table 5
Frequencies of mentioned landscape service groups and their perceived changes in the case studies' interviews. Legend: ○- not mentioned; ◔- "rarely" (1–25%); ◑- "occasionally" (26–50%); ◕- "often" (51–75%); ●- "very often" (i.e. mentioned in 76–100% interviews of a case). ↗ Increase, ↘ decline, → no change/ constant, ↕ changing composition, ↔indifferent, i.e. increase and decline have been mentioned equally often. Columns "a" denote frequencies of each service category mentioned; columns "b" denote frequencies of mentioned changes in categories in columns "a"; columns "c" denote the dominant perceived direction of change (e.g. increase, decrease; diverging perceived directions of change are described in the text). *denote potential negative effects from farming activities. NA: means "Not applicable.

Main service category	Detailed service category	AT (n_{total} = 11)			CH (n_{total} = 10)			EE (n_{total} = 12)			DE (n_{total} = 18)		
		a	b	c	a	b	c	a	b	c	a	b	c
Provisioning services	Food	●	◔	↘	●	◕	↘	●	◑	↘	●	◑	↘
	Fibre, raw materials	◔	●	↔	◑	◔	→	◑	○		○	NA	
	Biofuels	○	NA		○	NA		◑	◔	↗	◕	◔	↗
	Any provisioning service	●			●			●			●		
Regulating services	Biological pest control	○	NA		◕	◑	↔	◔	○		◔	○	
	Pollination	◔	○		◕	◔	↗	◔	●	↘	◑	◑	↘
	erosion control	◑	◑	↘	◑	◑	↘	◔	◑	↘	◑	◕	↘
	Water provision	◑	○		◔	○		◑	◕	↘	◕	●	↗
	Soil fertility, retention, moisture, stability	◕	○		◔	○	↘	◕	◑	↘	●	◕	↗
	Resistance to disturbances, natural hazards	○	NA		◔	○		◔	○		○	NA	
	Climate regulation	◔	○		◔	○		○	NA		◕	◑	↔
	Nutrient cycling	○	NA		◔	○		◔	○		◑	◕	↗
	Any regulating service	●			●			●			●		
Cultural services	Aesthetics	◑	○		◕	◔	↗	◑	◕	↗	◔	◑	↗
	Recreation	●	◑	↗	◑	◔	↗	◔	○		◔	○	
	Spiritual/religious values	○	NA		○	NA		○	NA		◔	○	
	Cultural heritage	○	NA		◑	○		◔	○		●	●	↘
	Any cultural service	●			◕			◕			●		
Disservices	Competition from surrounding ecosystems	○	NA		○	NA		○	NA		○	NA	
	Invasive species	◕	◕	↗	●	◑	↗	◔	●	↗	◔	◕	↗
	Damages to farmers, e.g. due to wild boars	◑	◔	↗	◔	●	↗	◑	◑	↗	○	NA	
	Pest/disease damage	◔	○		◑	◕	↗	◑	◔	↗	◔	○	
	Water pollution, nutrient runoff	◔	○		◔	○		◑	◕	↗	◕	●	↘
	Sedimentation of waterways	○	NA		○	NA		◔	○		◔	●	↗
	Pesticide drift	◔	○		◔	○		◔	●	↗	◔	○	
	Health risks from pesticides/fertilizers	○	NA		◔	◑	↗	○	NA		○	NA	
	Any disservice	◕			●			●			◕		

However, the interviewees highlighted that in recent years habitat changes could be stopped and remain constant now, in particular regarding cherry trees. In the German case study, interviewees either talked about a decline in field birds or insects (eight interviewees), an increase in predators (e.g., raccoons; two interviewees), or perceived both changes (six interviewees). One interviewee described a decline in plant species due to higher nutrient inputs from agriculture. Habitat changes were mostly described indirectly, e.g. via their impact on animal species. For instance, interviewees perceived an increase in small game or partridges because of newly established flower strips. Habitat losses have been associated with the declining quality and quantity of landscape elements, with perceived negative impacts on field birds. Four Austrian interviewees perceived a decline in animal species (e.g., insects) but no significant changes in plant species were mentioned in the

Table 6
Excerpts from the interviews indicating the perceived severity or magnitude of changes in biodiversity or landscape services.

Biodiversity / Landscape service category	AT	CH	EE	DE
Biodiversity	*What is outstanding is this unbelievable diversity of meadows and pastures with an extremely large number of flowering plants, which is something you often never find. And with it, an enormous diversity of insects, if you compare that with, for example, Bucklige Welt. So, what I know in the area from my childhood is actually all still there.*	*Typical bird species of the Swiss midlands such as Little Owl, Redstart, Red-backed Shrike, Wryneck, but also insects such as grasshoppers or butterflies are found in this area, while they have become very rare in other parts of Switzerland. Also, some rare plants have remained in the area.*	*When you're out in nature in June-July and various farmland birds are chirping and flowers are blooming. You can't find that anywhere else. If we go somewhere else, in Russia for example, only the bear, you don't see it, you don't see what values are still there. The picture has changed: before in childhood, there were goldfinches, swallow-eyes, now there are fewer.*	*So much of its old land use elements such as nutrient-poor heaths, lowlands and raised bogs, wet forests, near-natural river arms, no longer exist. There is no functioning green infrastructure here. That is why we also lose all sorts of birds, skylarks, partridges, curlews, lapwings. They all go back and there are many people in nature conservation who now say "even the lapwing will be extinct here in a few years".*
	From the feeling, fewer insects on the windscreen, so it must be significantly less - although we don't have habitat problems here.	*The collapse [of the orchards/cherry trees] was more than 20 years ago. In the meantime, the number of trees is stabilizing, but "high stem orchards" remain a sensitive issue.* *[High stem cherry trees] The number of trees has been stable for 5 years, but the fruit tree birds have not been able to benefit from this. It seems that not only the preservation of the trees (maintaining the status quo), but an improvement is needed.*	*Now that 15 years have passed since EU accession, the species we used to have become rare.*	*The decline in insects is clearly observed, as well as the game population has decreased. Fewer insects on the windows, greater fear of lack of pollination, this is what characterizes our time right now.* *The small game has declined sharply. Whereas the partridge population has approximately tripled in the last three years. This is certainly due to the subsidised planting of flower strips.*
Provisioning services	*This extensification of agriculture and the reduction of production has been going on for 20-30 years now. That certainly plays a role that less is already being produced today*	*Nowadays, cherries are less important as a marketable product, so cherry trees are no longer replanted and over-aged trees die.*	*The dairy cows disappeared, replaced by beef cattle. But also livestock farming in general, many farmers have given it up, either to cereals or not at all.*	*The maize area has been greatly expanded. Whether this is grain-basket mix, for fattening or whether this is grain maize for chicken farming or whether this is biogas maize.*
Regulating services	*My guess would be that the trends that are going on in Central Europe [for Biodiversity] are also happening in the Wienerwald, but they are happening at a relatively slow pace compared to many other regions. The Wienerwald meadows have changed less than in many other areas of Austria.*	*Soil erosion, humus losses and nitrogen inputs will increase. In addition, water quality and water protection will become more important.* *Soil conditions will stay the same, water availability will decrease* *Little change [with respect to ecosystem services], rather constant*	*The results of soil monitoring are dismal.* *In the context of central Estonia, a very big problem is that the wind carries the soil away because there are big fields.*	*... due to the stronger organic fertilization and the winter furrows left out for 20 to 30 years and the intercrops established as a substitute have had a positive effect on soil fertility or humus content.* *Nitrate levels, pesticide residues and so on, so I think that's actually getting a little bit better. I don't know if it's getting as much better as it should be, but I think it's getting a little bit better.* *So, there are definitely nitrate problems here, and I don't want to deny that now. But I also think that fertilization has become a little more efficient and more thought is being given to it.*
Cultural services	*The Wienerwald is more and more used as a leisure time park. The recreational user slowly no longer allows managing my fields as I would like to because one rather avoids the conflict and says "Ok then I do it differently"* *The recreational aspect is very big - it is not called "the green lung of Vienna" for nothing - the Vienna Woods is used a lot for local recreation. There are always conflicts of interest with the farmers, whether it is that people march across the meadows, dog excrement, and so on. That is definitely a problem.*	*More urban people asked for recreation areas/ beautiful landscapes*	*Changing the view: before and since childhood -- there was just an area where there was scrub, but now it's generally fine.*	*Here I must address the medium- to small-scale, diverse agricultural landscape. Of course, it has lost some of this diversity due to the expanded corn cultivation, but it is still quite varied. This can be summarized under the term "Münsterland park landscape".*
Disservices	*Wild boar damage in grassland is a big issue and is also part of biology. One does not really have these under control.* *Invasive species: "massive problem"*	*High-stem cherries are often not picked and are therefore criticized as a source of diseases and pests (e.g. Drosophila suzukii). In reality, however, they play only a minor role, as woods and hedgerows with native species provide more "breeding ground" for Drosophila suzukii.*	*The changes in the last 5 years have been dramatic. In nitrate-sensitive areas, it is no longer advisable to drink water from springs.*	*Ravens, foxes, raccoons, and cats did not exist in numbers in the past. Thus, useful species decline, and pests and damages increase.*

*Colour code: white: low/medium perceived severity/magnitude of change; grey: medium/high perceived severity/magnitude of change.

interviews. One interviewee also mentioned that wild boars and deer increased in the area. Another interviewee perceived increases in plant and animal species on their fields due to the very extensive grazing with sheep they introduced. The Estonian interviewees noted positive changes in biodiversity (e.g., due to restored habitats), but highlighted also decreases in certain species' abundance (e.g., field birds, insects). Some interviewees perceived on the one hand declines in plant species (3 interviewees), e.g. due to pesticides, fertilizers, and drainage, while others perceived increases in plant species, e.g. due to the restoration of habitats in parts of the region, e.g. by removing shrubs (1 interviewee) or revitalisation of floodplains, also having positive effects on animal species (1 interviewee). Overall, three interviewees perceived increases in restored habitats. However, one interviewee also mentioned that in total the area of habitats is declining despite the restoration efforts. The habitat changes were perceived by two interviewees as a changing composition, while two interviewees only perceived the losses, such as forest loss due to deforestation or loss of grasslands due to afforestation. In the case studies EST, DE, and AT, some interviewees gave the same example – insects on the windscreen of the car when driving – as an indication of a decline in insects. Interviewees were not asked about the perceived severity or magnitude of changes; however, some of their statements allow us to give an approximate indication of the perceived magnitude, summarized in Tables 4, 5, and 6.

Landscape services. Provisioning services were mentioned in at least three-quarters of the interviews in each case study, represented by food and feed production (all cases), and raw materials, e.g., biofuels (EE, DE) (Table 5). Regulating services were mentioned by almost all (AT, EE, DE) or all interviewees (CH). The most often mentioned subcategories included services associated with soils (e.g., soil fertility, soil retention). Water provision and quality (DE), pollination and biological pest control (CH), but also climate regulation (DE, CH) were also often mentioned. Cultural services were most dominantly spoken about in the Austrian and German cases. Cultural services mostly meant recreation services (AT), aesthetics of landscapes (EE, CH), and cultural heritage (EE, CH, DE). Disservices were mentioned at least in half of the interviews in all case studies. Disservices' content was similar in the Austrian, Swiss, and Estonian case studies: invasive species and increasing pests, diseases, or other damages to crop production, by e.g., wild boars, dog attacks to sheep (AT), wild goose (EE), or cherry flies (CH). The most often mentioned disservice in the German case study was water pollution by nitrate leaching or pesticides.

Changes in landscape services' provision. Approximately half of the Austrian, Swiss, and Estonian interviewees perceived some changes, and three quarters of the German interviewees (Table 5). In the Austrian case study, interviewees mentioned increases in cultural services (recreation) or increases in certain disservices (e.g., poisonous species, like autumn crocus), presumably due to extensive grassland management and climate change. The Swiss interviewees perceived changes in negative terms (e.g., reduced fruit yields and pollination because of fewer orchards, and problematic pest control). Positive perceived changes related to e.g. pollination services, which interviewees perceived to benefit from nature conservation. In the Estonian case study, most changes were perceived in regulating services: in negative terms (e.g., less diversity in landscapes) but also in positive terms (e.g., more maintained coastal meadows with perceived positive effects on e.g. aesthetics). In the German case study, changes were mostly perceived in the regulating services, with mixed connotations (e.g., better water quality, water scarcity but also problems due to flooding of fields) and cultural services (e.g., threatened cultural heritage). For instance, several interviewees perceived the decline in grassland as negative for cultural heritage, as well as biodiversity, whereas the maintenance of landscape elements was perceived positively for both. Views diverged for instance for soil-related landscape services. Five interviewees mentioned increases in soil fertility and/or soil humus because of high organic fertilization, while three interviewees highlighted declining soil moisture or soil structure. Interviewees perceived disservices from agriculture to ecosystems because of nutrient pollution, however, some also mentioned improvements in the last years, particularly for water quality, because of e.g. better liquid manure management.

3.1.3. *Perceived links between the system components and their drivers*

3.1.3.1. Driver content and links. Across all cases, the perceived links from climate change, policies, and market-based drivers to land use, landscape services, and biodiversity seem most pronounced (Fig. 4). We next explain these links and driver contents in detail, by comparing the cases and giving examples. Detailed empirical system depictions of cases are given in Supplementary data 3.

Climate change. Climate change has been discussed differently across our case studies, e.g., temperature changes (EE, CH), precipitation changes (AT), or more frequent weather extremes (DE) (Fig. 4). About ¾ of the interviewees in all cases mentioned a direct link between climate change and landscape services, mostly regarding agricultural yields. Direct climate change impacts on crop yield reductions or loss of crop quality were mentioned at least by some interviewees in all cases. In Austria, mentioned links included grassland yields which are expected to decline due to less precipitation, thus leading to reduced grazing intensity. German and Estonian interviewees highlighted a need to change farming work schedules: e.g., sowing date for catch crops earlier (DE), or timing of summer crop ploughing (EE). Prolonged vegetation periods were mentioned in the Estonian interviews as positive impacts. Chances to develop and use new crops and cultivars have been mentioned in all cases. A direct impact of climate change on biodiversity was mentioned by ca. half of the Austrian and Swiss interviewees, but less by the Estonian and not at all by German interviewees. An indirect link to either landscape services or biodiversity was only rarely mentioned in all cases. Examples include changes in phenology (AT, EE), plant-pollinator relationships in the changing climate (CH), or the impact of storms, droughts, and bark beetle events on forests (DE).

Technology. In all cases, interviewees could name new technologies affecting agricultural production, either adopted in the region or elsewhere in the country. These included precision livestock farming (e.g., automatic feeding systems), adapted soil management (incl. reduced tillage, direct sowing), and renewable energy solutions (e.g., solar panels for herding). Some of the Austrian and Estonian interviewees mentioned potential technologies not yet adopted (e.g., smart drainage, EE) or not yet permitted by law (e.g., virtual fencing, AT). Explicit links to land use, landscape services, and biodiversity were discussed in approx. three quarters of the German interviews and ca. half of the Austrian, Swiss and Estonian interviews. Examples of links include the impact of precision farming on the amounts of fertilizers and pesticides applied and respective positive impacts on water quality and biodiversity (AT, DE, EE), weather forecasts for pest control, and mechanical fruit protection, leading to lower pesticide use and positive effects on biodiversity (CH), and machines for steep or wet areas which allow their continued management and thus provide habitats for endangered species (CH, AT). However, the trend towards bigger machinery was also mentioned, leading to the abandonment of management on steep slopes (AT).

Market-based drivers. In most or all interviews in all four case studies, direct links between market-based drivers and land use were mentioned. Indirect links between market-based drivers and landscape services or biodiversity were mentioned in more than half of the Swiss interviews, approx. half of the Austrian and Estonian interviews, and approx. one-third of the German interviews. Such links included, for instance, the impact of market pressure on the intensification of agriculture and removal of landscape elements, leading to negative consequences for biodiversity (AT, CH, DE), or the maintenance of extensively managed grasslands due to subsidies, which would otherwise have been abandoned or intensified (AT, CH, EE). Other examples include the restoration of landscape elements due to subsidies (e.g., single trees; stone walls, CH/EE) as having had positive effects on biodiversity. Global or EU market conditions were highlighted foremost in the German case: the growing demand for meat in China implies that the higher exporting price of pork has become a high incentive for pig farmers to expand their production. Interviewees mentioned further topics, which closely relate to the wider economic and policy setting, such as structural change (e.g., raised farm size, urbanization (CH, DE)).

Policies. National policies were most often mentioned in three cases (AT, CH, EE). These meant policies from agricultural and environmental domains (e.g., agri-environmental schemes), but also other policy sectors (e.g., real estate, EE; landscape planning, CH, DE). International policies (foremost EU) came up in about half of the Austrian, Estonian and German cases. These included the CAP (all three cases), but also EU's Green Deal, the new biodiversity strategy, and LEADER (EE). Local policies were mentioned mostly in the German case, and in about half of the AT, CH, and EE interviews. Examples include local nature conservation actions by NGOs (AT, CH, EE), food marketing cooperatives (EE), cantonal subsidies (CH), and projects of the cultural landscape foundation (DE). Explicit links between policies and land use were made in most interviews in all cases (Fig. 4). However, policy links to landscape services or biodiversity were made in most Swiss and German interviews, about half of the Austrian interviews but only in a few Estonian interviews. Mentioned links include, for instance, that the CAP protects the maintenance or enables the establishment of landscape elements and set-aside land, thus positively affecting soil quality and biodiversity (AT, DE, EE), or water policies regulating fertilization and affecting water quality (AT, DE, CH). Yet, some interviewees also mentioned that the CAP contributed to the loss of landscape elements (DE). Other links include regional or national programmes targeting biodiversity-friendly agricultural management like flower strips (AT), supporting fruit orchards (CH), contractual nature conservation (DE), or extensive grassland management (AT, EE), and different incentives (e.g., renewable energy use incentives, DE).

As important other drivers, interviewees mentioned land ownership issues and historical influences of the past political regimes (EE), drivers related to information and education (AT, EE), and social changes (e.g., farming styles and traditions, AT, CH).

3.1.3.2. Links between land use management, biodiversity, and landscape services. Links between land use and biodiversity were mentioned in most interviews in all four case studies (Fig. 4). Links between land use and landscape services were made in all case studies, except for the Estonian interviews, where such a link was made by half of the interviewees. In Austria, extensive grassland management was related to the high regional biodiversity and aesthetics, leading to a high recreation value. In the Swiss case, links were related to the intensification of agricultural production or removal of orchards and landscape elements, identified as a major cause for a decline in habitats. This affects especially the provision of food (cherries), biological pest control, and pollination according to the interviewees – which are the links that have been most frequently established between biodiversity and landscape services. In Estonia, restoration and management of semi-natural grasslands were associated with increased biodiversity in the region. In Germany, intensive land use was mentioned to contribute to nutrient surplus and thus deteriorating water quality. Several German interviewees also mentioned the positive effect of landscape elements on pollination, pest control, soil fertility, and water provision.

3.2. Comparison of the perceptions of two stakeholder groups aggregates

Below, we present the summary of results about dominant patterns in two stakeholder group aggregates we compared: landscape service managers and beneficiaries (hereafter: "managers", 26 interviews) and landscape service administrators and scientists (hereafter: "administrators", 25 interviews) (details in Supplementary data 4).

3.2.1. Biodiversity, landscape services, and their changes

Overall, managers considered different biodiversity categories more often than administrators (Supplementary data 4), while administrators more frequently highlighted the sub-categories "plant species" and "habitats" and changes thereof. Managers mentioned provisioning and regulating services more often, while administrators highlighted cultural services, especially aesthetics and recreation. More administrators mentioned disservices from agriculture and changes thereof (mostly increases).

3.2.2. Links between driver categories and land use, landscape services, and biodiversity

Climate drivers (esp. temperature change, precipitation), certain market-based drivers, and technologies were mentioned more often by the managers (Supplementary data 4). Qualitative content analysis confirms this finding–the managers described the drivers in more detail: e.g., mentioning specific seasons when talking about climate change, detailing specifics on output prices, or consumption patterns related to market-based drivers. Policies were more frequently mentioned by the administrators, except for regional/local policies, which were more often discussed and elaborated by managers.

Explicit links of land use to biodiversity were approx. equally often perceived by both groups, while links from biodiversity to landscape services were more often drawn in the interviews with the administrators. The impact of climate change (esp. temperature change, precipitation), market-based drivers, and policies on land use were mentioned almost equally in both groups. The link of technology drivers to land use has been mentioned more often by managers. Links of all drivers to landscape services and biodiversity have been made more often by administrators, especially for direct climate change effects on biodiversity and the indirect impacts of market-based drivers on landscape services and biodiversity. Indirect links to landscape services and biodiversity have been made more-or-less equally often by both groups in the case of technology and policy drivers.

4. Discussion

This study analyses stakeholder perceptions from four regional case studies located in different countries (AT, CH, EE, DE) and five environmental zones in Europe. We elicited stakeholders' perceptions about regionally important land uses, landscape services, biodiversity, and drivers affecting their evolution in these regions. We took a systems perspective, trying to empirically map what stakeholders think of their current landscapes and factors affecting landscape change during the last two decades.

4.1. How do the stakeholders' perceptions differ across the four case studies?

The four case studies are located in five environmental zones (Metzger et al., 2005) which differ in their climate and associated biophysical factors, e.g., geomorphology or soil types. This gives a basis for different biodiversity and the provision of landscape services. The regions also differ in their socio-economic conditions, e.g., rural–urban character, historical legacies, how agricultural policies are implemented, etc. How are these biophysical and socio-economic differences and their trends reflected in stakeholders' perceptions? We first summarize and discuss the similarities and then differences between the case studies.

4.1.1. Similarities in perceptions across the case studies

Across all cases, provisioning and especially regulating services were mentioned in almost all interviews, whereas cultural services were less represented. The high proportion of regulating services is in contrast with many studies, except a few (Chen et al., 2017; Iniesta-Arandia et al., 2014), which highlight that more tangible landscape services (e.g., food provision, aesthetics) tend to be represented more often in stakeholder perceptions than more abstract ones (e.g., water purification, soil quality maintenance). One reason for this might be our stakeholder composition, which included many regional experts (either by profession or local knowledge-holders), who might have more complex mental models about the system than e.g., laypeople. However, across all cases, only about one-quarter of all interviewees have perceived at least some changes in the four landscape service groups.

Perceptions about biodiversity components share some similar patterns about change in the case of AT, CH, and DE, where the stakeholders more often highlighted negative trends. This result resembles Steentjes et al. (2017) in which they found that most interviewees in European countries thought that the effect of climate change would be more negative. Such trends could be understood by the argument by Rosling et al. (2018) that negative events tend to draw our attention more than positive events do due to the belief that "things are getting worse". An ex-ante scenario-based quantification involving stakeholders would be necessary to validate stakeholders' perceptions.

In all case studies, not a single but several drivers appear decisive for land use changes. Among those, climate change seems to be the most often perceived driver affecting landscape services, followed by policies, markets, and technology, which affect landscape services indirectly via land use. So far, the climate has been seen as an underlying driver, which is part of the natural site conditions and varies regionally (Plieninger et al., 2016; van Vliet et al., 2015). However, climate change has brought this driver more to the fore (Rounsevell et al., 2005). Stakeholders, especially land managers, have already noticed changes in temperature or precipitation in recent years and are aware of further changes, as our study shows. The relative importance of climate change can also be attributed to the recent high attention to climate issues by media and political discussions.

Markets can be seen as the manifestation of economic drivers, which are one of the main land use change drivers (van Vliet et al., 2015). Policies also play a strong role as a driver of land use changes and landscape services' provision and are often intertwined with market drivers. This somewhat resembles earlier studies, e.g., van der Sluis et al. (2018), who found policy and legislation as well as the global economy to be among the most important drivers. Our stakeholders discussed market-based drivers often together with policy drivers, e.g., subsidies were often mentioned as general economic drivers (i.e., as the immediate driver influencing land use and financial statuses), although the underlying drivers here are policies. Results from all case studies underline the influence of policies, partly as a direct link through policies regulating land use (i.e., cross-compliance regulations in the first pillar of the CAP), and partly through setting the legal ground for financial support for specific land use practices (i.e., payments from the second pillar of the CAP).

Technology was mentioned as the least important driver among our considered drivers. Two reasons may explain the results. First of all, digital technologies are less often implemented in the lower part of the farm size distribution (Groher et al., 2020a, 2020b). Out of the four case studies, three regions consist of very small farms (AT, CH) or are below the national average (DE). Therefore, it is likely that new technologies are not perceived as an important driver for change. Second, the uptake of precision agriculture technologies is still low in Europe (Barnes et al., 2019). In Switzerland, adoption trends are in line with results from the EU, demonstrating that driver assistance systems, such as cruise control, automatic steering, or row guidance, are more frequently used on farms than Electronic Measuring systems such as site-specific fertilization, automatic hoeing or weed detection (Groher et al., 2020b). The authors found an indication that technologies are rather used to reduce physical workload than for management decisions. This means that the impact of the new technologies has not yet been felt by the stakeholders to achieve the support of the landscape services and that some doubts about the effectiveness of such measures are likely influencing their judgment.

4.1.2. Differences in perceptions across the case studies

Perceived distinctive land uses and landscape elements are not necessarily the most dominant ones as detectable from statistical data or land use maps (e.g., as compared to the background info on our case studies in Table 2). The general land use and landscape elements that were most often talked about reflect the biophysical differences of the regions, but also the iconic landscape features that may have an identity value for the stakeholders (Bieling et al., 2014; Termorshuizen and Opdam, 2009). Stakeholders may more likely have iconic (e.g., traditional stone-walls) or typical features (e.g., hedges) as well as those creating clear-cut landscape services (e.g. field strips) in mind than those of the largest spatial extent. For instance, this meant small structured "Park-like landscape of Münsterland" (DE) and semi-natural grasslands and traditional landscape elements (e.g., stone walls) (EE).

While soil was very often perceived as an important location factor in all case studies, climate was rarely mentioned in AT and EE but very often in CH and DE. Climate as a location factor describes the currently dominant climate. Interviewees in AT or EE might not have perceived the current climate as an important location factor providing biophysical constraints, however, they attributed high importance to climate change as a driver of the socio-ecological system. Thus, the dynamics of our current climate system- caused through anthropogenic climate change- is perceived to affect land use, landscape services, and biodiversity in all case studies.

Various landscape services were mentioned in all cases, but in the Swiss case study interviews, compared to the other regions, the different subgroups of landscape services were perhaps the most often mentioned, i.e. in all interviews, and the most diverse. Another distinguishing feature between the regions is the disservices' content discussed by the stakeholders which reflects the diverse nature of the services in the regions, e.g. intensive management affecting water resources (DE), invasive species posing a challenge to agriculture, general recreation pressure in the region (AT) and invasive cherry flies as a threat to orchards (CH). The frequency of perceptions of changes in biodiversity and landscape services was higher in the German and Swiss cases, which also may reflect the management characteristics, e.g., intensive management (DE), and niche products (CH), of the regions. Whereas the driver "climate change" was important in all case studies, the content of this driver was most different in the EE case: here, interviewees perceived more often also positive changes, than the DE, CH, or AT interviewees, which partly could be due to the regions' bio-geographical situation, i.e. the northern position in Europe and proximity to the sea, where climate change has had less adverse impacts on agriculture than in the south.

Our case studies reflect different agricultural structures with different importance and levels of subsidies and related agri-environmental policy measures. The farmers in the Swiss, case, who receive half of their farm income from agricultural subsidies (OECD, 2022), profit from the relatively high level of support for extensive, family-run farming types, which slows down the trend towards larger farms and machines. Agri-environmental payments in the Austrian case study support less intensive grassland-based production practices. The Austrian and Swiss case studies also share some similarities in biophysical location factors (e.g., hilly, not suitable for large-scale arable production), which provides fewer options for intensification and hence are more dependent on subsidies. This is somewhat similar in the EE case study as well: subsidies have supported the maintenance and restoration of semi-natural grasslands which were associated with high biodiversity in the region. However, the link between subsidies to the system components in the EE case study was not as evident as in the other cases. This could partly be because AES subsidy rates are 4–5 times smaller than EU (European Parliament, 2021) which may have affected the perception that policies are not so often mentioned as in the remaining three case studies. The Estonian case study also reflects path-dependencies from post-soviet farm structures (e.g., large farm types). As the agricultural sector in Münsterland is among the most intensive livestock farming regions in Germany and since this sector highly depends on market conditions, the perception of the interviewees leans toward market-based drivers. Local policies were mentioned mostly in the German case study due to a highly active and well-known organization that negotiates regional conservation programmes, and in about half of the AT, CH, and EE interviews.

Technology was mentioned as a driver more often in the high-intensity case study (DE) than in the less intensive EE and AT regions. The high-intensity case study relates especially to livestock farming. The higher degree of Precision Livestock Systems is related to higher-intensive production systems (Groher et al., 2020a). According to the interviewees, intensive livestock farming in the region generates high nitrogen and greenhouse gas emissions, and farmers are interested in, and in many cases already using, technical solutions to reduce these emissions. In the German case study, interviewees state that highly efficient modern technologies such as low-emission slurry application or slurry drying have been adopted. On the other hand, there are only a few new technologies available for extensive grassland production systems and also for sheep and goats compared to dairy cows and (Groher et al., 2020a), which is relevant for the less intensive EE and AT regions. This could lead to a higher number of mentions in the interviews. Van Vliet et al. (2015) also stated that technology is frequently associated with the intensification of agricultural land than extensification. Adopting new technologies is a complex process that depends on farmers and the characteristics of the technology (Aubert et al., 2012; Long et al., 2016; Paustian and Theuvsen, 2017). Interestingly, technology was also mentioned quite frequently in the Swiss case study, which might show the status quo of Swiss agriculture as small-scale, diversified but highly mechanised (Groher et al., 2020b).

4.2. Do the perceptions differ between managers and administrators?

In our study, managers' (i.e., farmers, agricultural extension, NGOs) perceptions of landscape services, biodiversity, and their driving forces seem to slightly differ from those of the administrators (i.e., decision-makers, scientists). This resembles the outcomes from certain previous studies (Iniesta-Arandia et al., 2014; Lamarque et al., 2011; Maas et al., 2021). Part of the reason for this may be their differing roles, e.g., a land user or owner, a researcher or policymaker. For example, Iniesta-Arandia et al. (2014) showed that local experts more often put forward direct land use drivers (e.g., land use intensification, water management) while the environmental professionals focus more on indirect drivers (e.g., economic development, policies). This mismatch in perception results from different knowledge (sources) and different backgrounds (Lamarque et al., 2011). E.g., farmers refer to government and agricultural-sector information ("practice information") while science and administration focus on scientific information (Maas et al., 2021). This mismatch points to the need for enhanced communication platforms and cooperation between different stakeholder groups.

4.3. Methodological reflection and challenges

We developed a generic methodological framework based on the "standard procedure to study the driving forces of landscape change" by Bürgi et al. (2004) p. 865. We applied it empirically in four case studies in Europe. At the core of our framework is a definition of the socio-ecological system linking drivers, location factors, agricultural land use, and its effects on landscape (dis-)services and biodiversity. Our objective was to develop a meaningful socio-ecological system description that is simple enough to be of use in the coding process of case study data. Simplicity may come at the cost of clarity in certain cases. For example, some overlaps are apparent in our system definition: "Land use" includes components such as arable land, grassland, and landscape elements. Some of them may also be considered semi-natural habitats and are part of the item "Biodiversity".

In our methodological framework, we considered biodiversity and landscape services as separate components of the socio-ecological system. Some authors (e.g., Huang et al., 2015; Maes et al., 2016) argue that some aspects of biodiversity (e.g. genetic diversity of wild species) can be considered as final landscape services; however, biodiversity can also act as a regulator of ecosystem services (e.g., the presence of pollinators can enhance the pollination service or microorganisms can contribute to nutrient cycling). To avoid confusion and better illustrate the manifold role of biodiversity in agricultural landscapes, we consider on the one hand biodiversity as a separate component in our description of the socio-ecological system and illustrate links to land use and landscape services. On the other hand, we still count mentioned landscape services which are related to biodiversity such as pollination or pest control to adequately capture its role as a regulator. Yet, we avoid the general categorization of biodiversity or habitats as landscape service to avoid such overlaps and double-counting with regulating services.

A noteworthy extension of the study compared to Bürgi et al. (2004) is the analysis of the effects of land use change on other landscape components, i.e. the changing supply of landscape services and alternative biodiversity outcomes. On the other hand, we partly deviated from step two "system analysis". According to Bürgi et al. (2004), the roles of actors and institutions should be analysed. We analysed potential actors in a stakeholder mapping procedure but did not determine their role in impacting drivers or regional landscape change explicitly in our interview guidelines. We argue that additional research dimensions would have risked to overload the interviews, which have already been demanding for many interview partners. Nevertheless, stakeholders were free to address arguments regarding actor involvement in the socio-ecological system.

Stakeholder perceptions are of value to supplement and interpret observed data, to explain component relationships and functioning in the socio-ecological system, or to reveal preferences and expectations towards the future (Schaller et al., 2018; Shackleton et al., 2019; van der Sluis et al., 2018). While data on land use characteristics are available in good quality in many European countries (e.g., from remote sensing), the perceptions of stakeholders and their interpretation of local land use, its drivers and effects are difficult to access and synthesize. However, it is helpful to develop and prioritize specific objectives for different landscapes that could lead to better-targeted policies.

The protocol-based data generation (e.g., stakeholder selection, interview guideline) and data analyses (e.g., coding) ensure a high level of comparability. Data synthesis and semi-quantitative routines finally enabled the comparison between case studies. However, it turned out that highly aggregated and synthesized information on the case studies (e.g. approximated importance of certain components or links based on the frequency of references by stakeholders) is insufficient to draw conclusions but requires revisiting the original statements in the interview data and is an iterative analysis process. The resulting comparison helps to reveal regional characteristics of land use. It can prove whether stakeholder perceptions are likely related to regional characteristics (including landscape composition, institutions, governance systems, etc.) or stakeholder characteristics (e.g., "managers" vs. "administrators"). Such information appears crucial to contextualize (at the EU level) and design policy drivers at national and regional levels and to better anticipate future land use decisions. One of the strong points of our research might have been that we covered a range of different stakeholders, contrary to several earlier studies (Chen et al., 2017; Greenland-Smith et al., 2016; Smith and Sullivan, 2014). This enables us to grasp the diversity of perceptions instead of studying only certain groups (e.g., farmers).

Typical to qualitative studies, our sample of respondents was small, which challenges the quantitative interpretation and comparison across case studies. We were able to identify some trends of perceived changes of drivers, land use, and effects, which provides a basis for more extensive larger-scale quantitative surveys. However, we may not have succeeded in determining all linkages of the socio-ecological system

(Figs. 2 and 4), nor have we been able to fully utilize the potential of qualitative interviews to gain a deeper understanding of stakeholders' perceptions, value systems, or mental models. The interviews tried to cover the breadth of the socio-ecological system at the cost of its depth. For example, we did not ask explicitly for relationships between its components (i.e., linkages). Therefore, we may have missed some perceptions but, on the other hand, may have revealed an unbiased awareness of the stakeholders. Due to the focus on stakeholder perceptions, we did not systematically and in-depth analyse further datasets than the interview data (e.g., maps, policy documents, or statistical socio-economic data). However, such data did inform the case studies' descriptions (Table 2) and may have impacted the informed case study researchers when interpreting the interview data.

5. Conclusions

This study found similarities and differences in how stakeholders perceive agricultural landscapes as socio-ecological systems. The underlying methodological framework turned out to be appropriate for the research questions at hand. We next summarize three key observations and give recommendations for future research and practices, structured along the four initially posed research questions.

Stakeholder perceptions on present land uses, location factors, biodiversity, and landscape services (RQ1). In each region, there are valuable land uses typical or iconic for the region. Within the stakeholder interviews, iconic land uses were often mentioned, such as the semi-natural grasslands in the Estonian case, or the cultural landscape ("*Kulturlandschaft*") in the German case. Compared to earlier studies, we found more frequent mentions of provisioning and regulating landscape services, when comparing the different service categories. The stakeholders have a common perception that drivers impact land use, and land use determines landscape services and biodiversity. However, the perception of the valuable iconic land uses of the region was not always linked to specific landscape services. For example, the promotion of cultural landscape elements does not necessarily address regulating services (e.g., mitigation of nitrate leaching). Bio-physical location factors, reflected in the bio-geographical regional characterization, clearly determine the regional landscapes. This justifies the choice of contrasting case studies across Europe. Since the results appear driven by local specificities to a high degree and since those are the result of bio-physical and socio-economic drivers in the past, generalizations for other regions appear difficult. Further research such as cluster analysis to determine similar regions and further case studies would be required. They could verify similarities and differences regarding the socio-ecological system components and behaviour to learn more about out-scaling options.

Perceived changes in land use, biodiversity, and landscape services (RQ2) and their drivers (RQ3). Stakeholders perceived changes in biodiversity and landscape services over time in all studied regions. The direction of changes was mixed: mostly it was perceived towards intensification of management and the resultant more homogeneous landscapes, as well as increases in disservices (e.g., AT, CH, DE). For some stakeholders, however, more extensive management and restoration of grassland landscapes led to more diverse landscapes (some examples in the EE case) and preserved landscape elements (DE). Different components of biodiversity were discussed in the different case studies but the direction of change was partly perceived differently (e.g., EE, CH). In all regions, provisioning and regulating services were mostly perceived to have declined but cultural services and disservices increased. On the one hand, the interviewees perceived changes for different landscape service or biodiversity categories; on the other hand, the interviewees perceived the impact of the same underlying land use changes on landscape services or biodiversity differently (e.g., land abandonment as habitat and plant species loss vs. new habitats and species due to scrub encroachment in the CH case study). The results indicate the role of personal observations and interpretations of changes in the socio-ecological system. While this was the purpose of the study, it reveals a weakness regarding the robustness of the data for certain purposes. For example, biodiversity indicators may not be robust enough if derived from such data. We, therefore, highlight the need for complementary long-term monitoring of landscape services and biodiversity to support policy design.

The stakeholders confirmed previous studies that show that typical land use change can be attributed to multiple drivers of various strengths. A major driver in the socio-ecological system has been climate change, which directly impacted both land use and landscape services and biodiversity. While climate change was mostly negatively associated by the Swiss, German and Austrian case interviewees, the Estonian case interviewees saw also the opportunities for their case study. Results on past changes show a clear need for intervention if landscapes and their services should be maintained. This is particularly true for the impact of climate change. However, the heterogeneity in land uses and the location-specific linkages between bio-physical and socio-economic conditions, resulting land uses, and environmental outcomes demand adapted policy and/or market responses in each region or country. The regional differences in stakeholder perceptions about the drivers and their respective impact on agricultural landscapes show a need for future agricultural policies to be regionally targeted and landscape-specific characteristics to be considered.

Similarities and differences in perceptions held by landscape service managers and administrators (RQ4). Differences in the perceptions of the administrators (e.g., ministries, and public officials) and the managers (e.g., farmers and other land users) dealt mostly with how the links between system components were perceived. Landscape services managers described more often the drivers in more detail than the landscape service administrators. Also, not all stakeholders (e.g., farmers) are fully aware of their important role in the maintenance of landscape services and the conservation of biodiversity. Thus, policy-making should be based on the best knowledge of different stakeholder groups and therefore support an exchange of the managers and the administration and consider its outcome in decision making.

As regional differences were identified, policies need to be adapted to regional circumstances. Our results on the importance of the regional circumstances for landscape services provision and biodiversity are along the lines of the current idea of regionally targeted European policies e.g., eco-schemes resulting from the CAP national strategic plans, although those are hardly landscape-specific due to high transaction costs. The complementary knowledge of different stakeholder groups can be a valuable information source to design effective policies. A clear limitation of our study is the focus on agricultural land use. Other land uses such as forests, water bodies, wetlands, or urban areas do play a role at a varying degree in the case studies. While this gap may not impact the main conclusions for agricultural policy design, further research should encompass full land use coverage. This requires an extended pool of stakeholders.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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Appendix A. Supplementary data

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References

Agarwal, C., Green, G.M., Grove, J.M., Evans, T.P., Schweik, C.M., 2002. A review and assessment of land-use change models: dynamics of space, time, and human choice. U.S. Department of Agriculture, Forest Service, Northeastern Research Station, Newtown Square, PA. doi:10.2737/NE-GTR-297.

Arbuckle, J.G., Morton, L.W., Hobbs, J., 2015. Understanding farmer perspectives on climate change adaptation and mitigation: the roles of trust in sources of climate information, climate change beliefs, and perceived risk. Environ. Behav. 47 (2), 205–234.

Aubert, B.A., Schroeder, A., Grimaudo, J., 2012. IT as enabler of sustainable farming: An empirical analysis of farmers' adoption decision of precision agriculture technology. Decis. Support Syst. 54, 510–520. https://doi.org/10.1016/j.dss.2012.07.002.

Barnes, A.P., Soto, I., Eory, V., Beck, B., Balafoutis, A., Sánchez, B., Vangeyte, J., Fountas, S., van der Wal, T., Gómez-Barbero, M., 2019. Exploring the adoption of precision agricultural technologies: A cross regional study of EU farmers. Land Use Policy 80, 163–174. https://doi.org/10.1016/j.landusepol.2018.10.004.

Baxter, P., Jack, S., 2008. Qualitative case study methodology: study design and implementation for novice researchers. Qual. Rep. 13, 544–559.

Bennett, A.F., Radford, J.Q., Haslem, A., 2006. Properties of land mosaics: Implications for nature conservation in agricultural environments. Biol. Conserv. 133, 250–264. https://doi.org/10.1016/j.biocon.2006.06.008.

Bieling, C., Plieninger, T., Pirker, H., Vogl, C.R., 2014. Linkages between landscapes and human well-being: An empirical exploration with short interviews. Ecol. Econ. 105, 19–30. https://doi.org/10.1016/j.ecolecon.2014.05.013.

Bürgi, M., Hersperger, A.M., Schneeberger, N., 2004. Driving forces of landscape change – current and new directions. Landsc. Ecol. 19, 857–868. https://doi.org/10.1007/s10980-004-0245-8.

Bürgi, M., Bieling, C., von Hackwitz, K., Kizos, T., Lieskovský, J., Martín, M.G., McCarthy, S., Müller, M., Palang, H., Plieninger, T., Printsmann, A., 2017. Processes and driving forces in changing cultural landscapes across Europe. Landsc. Ecol. 32, 2097–2112. https://doi.org/10.1007/s10980-017-0513-z.

Chen, Y., Zhang, Q., Liu, W., Yu, Z., 2017. Analyzing Farmers' Perceptions of Ecosystem Services and PES Schemes within Agricultural Landscapes in Mengyin County, China: Transforming Trade-Offs into Synergies. Sustainability 9, 1459. https://doi.org/10.3390/su9081459.

Chopin, P., Blazy, J.-M., Guindé, L., Tournebize, R., Doré, T., 2017. A novel approach for assessing the contribution of agricultural systems to the sustainable development of regions with multi-scale indicators: Application to Guadeloupe. Land Use Policy 62, 132–142. https://doi.org/10.1016/j.landusepol.2016.12.021.

European Commission, 2020. EU Biodiversity Strategy for 2030. Communication from the Commission to the European Parliament, The Council, The European Economic and Social Committee and the Committee of The Regions. Brussels, 20.5.2020, COM (2020) 380 final. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52020DC0380&from=EN.

Conradt, T., 2021. Climate scenario report for the case study regions including a first assessment of climate analogue regions, SALBES Deliverable Report, Deliverable 3.1. V.2.0. https://salbes.eu.

Cord, A.F., Bartkowski, B., Beckmann, M., Dittrich, A., Hermans-Neumann, K., Kaim, A., Lienhoop, N., Locher-Krause, K., Priess, J., Schröter-Schlaack, C., Schwarz, N., Seppelt, R., Strauch, M., Václavík, T., Volk, M., 2017. Towards systematic analyses of ecosystem service trade-offs and synergies: Main concepts, methods and the road ahead. Ecosyst. Serv. 28, 264–272. https://doi.org/10.1016/j.ecoser.2017.07.012.

Dallimer, M., Tinch, D., Acs, S., Hanley, N., Southall, H.R., Gaston, K.J., Armsworth, P.R., 2009. 100 years of change: examining agricultural trends, habitat change and stakeholder perceptions through the 20th century. J. Appl. Ecol. 46, 334–343. https://doi.org/10.1111/j.1365-2664.2009.01619.x.

Do Rosário, I.T., Rebelo, R., Caser, U., Vasconcelos, L., Santos-Reis, M., 2019. Valuation of ecosystem services by stakeholders operating at different levels: insights from the Portuguese cultural montado landscape. Reg. Environ. Chang. 19, 2173–2185. https://doi.org/10.1007/s10113-019-01527-2.

Durham, E., Baker, H., Smith, M., Moore, E., Morgan, V., 2014. The BiodivERsA Stakeholder Engagement Handbook. BiodivERsA. https://www.biodiversa.eu/wp-content/uploads/2022/12/stakeholder-engagement-handbook.pdf.

Ekanayake, E.M.B.P., Xie, Y., Ibrahim, A.S., Karunaratne, N.T.P., Ahmad, S., 2020. Effective governance for management of invasive alien plants: evidence from the perspective of forest and wildlife officers in Sri Lanka. PeerJ 8, e8343. https://doi.org/10.7717/peerj.8343.

European Environment Agency, 2019. COPERNICUS Digital Elevation Model (DEM) [WWW Document]. DATA Copernicus Land Monitoring Service - EU-DEM. https://www.eea.europa.eu/data-and-maps/data/copernicus-land-monitoring-service-eu-dem.

European Parliament, 2021. EU agriculture statistics: Subsidies, jobs, production [WWW Document]. URL https://www.eureporter.co/economy/agriculture/2021/11/25/eu-agriculture-statistics-subsidies-jobs-production/.

Fagerholm, N., Torralba, M., Moreno, G., Girardello, M., Herzog, F., Aviron, S., Burgess, P., Crous-Duran, J., Ferreiro-Domínguez, N., Graves, A., Hartel, T., Măcicăsan, V., Kay, S., Pantera, A., Varga, A., Plieninger, T., 2019. Cross-site analysis of perceived ecosystem service benefits in multifunctional landscapes. Glob. Environ. Change 56, 134–147. https://doi.org/10.1016/j.gloenvcha.2019.04.002.

Geist, H.J., Lambin, E.F., 2002. Proximate causes and underlying driving forces of tropical deforestation. Bioscience 52, 143. https://doi.org/10.1641/0006-3568(2002)052[0143:PCAUDF]2.0.CO;2.

Greenland-Smith, S., Brazner, J., Sherren, K., 2016. Farmer perceptions of wetlands and waterbodies: Using social metrics as an alternative to ecosystem service valuation. Ecol. Econ. 126, 58–69. https://doi.org/10.1016/j.ecolecon.2016.04.002.

Grimble, R., Wellard, K., 1997. Stakeholder methodologies in natural resource management: a review of principles, contexts, experiences and opportunities. Agr. Syst. 55, 173–193. https://doi.org/10.1016/S0308-521X(97)00006-1.

Groher, T., Heitkämper, K., Umstätter, C., 2020a. Digital technology adoption in livestock production with a special focus on ruminant farming. Animal 14, 2404–2413. https://doi.org/10.1017/S1751731120001391.

Groher, T., Heitkämper, K., Walter, A., Liebisch, F., Umstätter, C., 2020b. Status quo of adoption of precision agriculture enabling technologies in Swiss plant production. Precis. Agric. 21, 1327–1350. https://doi.org/10.1007/s11119-020-09723-5.

Hauck, J., Görg, C., Varjopuro, R., Ratamäki, O., Jax, K., 2013. Benefits and limitations of the ecosystem services concept in environmental policy and decision making: Some stakeholder perspectives. Environ. Sci. Policy 25, 13–21. https://doi.org/10.1016/j.envsci.2012.08.001.

Hermann, A., Schleifer, S., Wrbka, T., 2011. The concept of ecosystem services regarding landscape research: A review. Living reviews. Landsc. Res. 5. https://uscholar.univie.ac.at/detail/o:245398.pdf.

Huang, J., Tichit, M., Poulot, M., Darly, S., Li, S., Petit, C., Aubry, C., 2015. Comparative review of multifunctionality and ecosystem services in sustainable agriculture. J. Environ. Manage. 149, 138–147. https://doi.org/10.1016/j.jenvman.2014.10.020.

Iniesta-Arandia, I., García-Llorente, M., Aguilera, P.A., Montes, C., Martín-López, B., 2014. Socio-cultural valuation of ecosystem services: uncovering the links between values, drivers of change, and human well-being. Ecol. Econ. 108, 36–48. https://doi.org/10.1016/j.ecolecon.2014.09.028.

Junge, X., Lindemann-Matthies, P., Hunziker, M., Schüpbach, B., 2011. Aesthetic preferences of non-farmers and farmers for different land-use types and proportions of ecological compensation areas in the Swiss lowlands. Biol. Conserv. 144, 1430–1440. https://doi.org/10.1016/j.biocon.2011.01.012.

Kirchweger, S., Clough, Y., Kapfer, M., Steffan-Dewenter, I., Kantelhardt, J., 2020. Do improved pollination services outweigh farm-economic disadvantages of working in small-structured agricultural landscapes? - Development and application of a bio-economic model. Ecol. Econ. 169, 106535 https://doi.org/10.1016/j.ecolecon.2019.106535.

Kizos, T., Plieninger, T., Iosifides, T., García-Martín, M., Girod, G., Karro, K., Palang, H., Printsmann, A., Shaw, B., Nagy, J., Budniok, M.-A., 2018. Responding to landscape change: stakeholder participation and social capital in five European landscapes. Land 7, 14. https://doi.org/10.3390/land7010014.

Kuckartz, U., 2019. Qualitative text analysis: A systematic approach, in: Kaiser, G., Presmeg, N. (Eds.), Compendium for early career researchers in mathematics education, ICME-13 Monographs. Springer International Publishing, Cham, pp. 181–197. doi:10.1007/978-3-030-15636-7_8.

Lamarque, P., Tappeiner, U., Turner, C., Steinbacher, M., Bardgett, R.D., Szukics, U., Schermer, M., Lavorel, S., 2011. Stakeholder perceptions of grassland ecosystem services in relation to knowledge on soil fertility and biodiversity. Reg. Environ. Chang. 11, 791–804. https://doi.org/10.1007/s10113-011-0214-0.

Lange, A., Siebert, R., Barkmann, T., 2015. Sustainability in land management: an analysis of stakeholder perceptions in rural northern Germany. Sustainability 7, 683–704. https://doi.org/10.3390/su7010683.

Lautenbach, S., Mupepele, A.-C., Dormann, C.F., Lee, H., Schmidt, S., Scholte, S.S.K., Seppelt, R., van Teeffelen, A.J.A., Verhagen, W., Volk, M., 2019. Blind spots in ecosystem services research and challenges for implementation. Reg. Environ. Chang. 19, 2151–2172. https://doi.org/10.1007/s10113-018-1457-9.

Levers, C., Müller, D., Erb, K., Haberl, H., Jepsen, M.R., Metzger, M.J., Meyfroidt, P., Plieninger, T., Plutzar, C., Stürck, J., Verburg, P.H., Verkerk, P.J., Kuemmerle, T., 2018. Archetypical patterns and trajectories of land systems in Europe. Reg. Environ. Chang. 18, 715–732. https://doi.org/10.1007/s10113-015-0907-x.

Liira, J., Schmidt, T., Aavik, T., Arens, P., Augenstein, I., Bailey, D., Billeter, R., Bukáček, R., Burel, F., Blust, G., Cock, R., Dirksen, J., Edwards, P.J., Hamerský, R., Herzog, F., Klotz, S., Kühn, I., Le Coeur, D., Miklová, P., Roubalova, M., Schweiger, O., Smulders, M.J.M., Wingerden, W.K.R.E., Bugter, R., Zobel, M., 2008. Plant functional group composition and large-scale species richness in European agricultural landscapes. J. Veg. Sci. 19, 3–14. https://doi.org/10.3170/2007-8-18308.

Long, T.B., Blok, V., Coninx, I., 2016. Barriers to the adoption and diffusion of technological innovations for climate-smart agriculture in Europe: evidence from the

Netherlands, France, Switzerland and Italy. J. Clean. Prod. 112, 9–21. https://doi.org/10.1016/j.jclepro.2015.06.044.
Maas, B., Fabian, Y., Kross, S.M., Richter, A., 2021. Divergent farmer and scientist perceptions of agricultural biodiversity, ecosystem services and decision-making. Biol. Conserv. 256, 109065 https://doi.org/10.1016/j.biocon.2021.109065.
Maes, J., Liquete, C., Teller, A., Erhard, M., Paracchini, M.L., Barredo, J.I., Grizzetti, B., Cardoso, A., Somma, F., Petersen, J.-E., Meiner, A., Gelabert, E.R., Zal, N., Kristensen, P., Bastrup-Birk, A., Biala, K., Piroddi, C., Egoh, B., Degeorges, P., Fiorina, C., Santos-Martín, F., Naruševičius, V., Verboven, J., Pereira, H.M., Bengtsson, J., Gocheva, K., Marta-Pedroso, C., Snäll, T., Estreguil, C., San-Miguel-Ayanz, J., Pérez-Soba, M., Grêt-Regamey, A., Lillebø, A.I., Malak, D.A., Condé, S., Moen, J., Czúcz, B., Drakou, E.G., Zulian, G., Lavalle, C., 2016. An indicator framework for assessing ecosystem services in support of the EU Biodiversity Strategy to 2020. Ecosyst. Serv. 17, 14–23. https://doi.org/10.1016/j.ecoser.2015.10.023.
Marshall, E.J.P., 2004. Agricultural landscapes: field margin habitats and their interaction with crop production. Agricultural landscapes. J. Crop Improv. 12 (1-2), 365–404.
Metzger, M.J., Bunce, R.G.H., Jongman, R.H.G., Mücher, C.A., Watkins, J.W., 2005. A climatic stratification of the environment of Europe. Glob. Ecol. Biogeogr. 14, 549–563. https://doi.org/10.1111/j.1466-822X.2005.00190.x.
Mitter, H., Larcher, M., Schönhart, M., Stöttinger, M., Schmid, E., 2019. Exploring farmers' climate change perceptions and adaptation intentions: empirical evidence from Austria. Environ. Manag. 63, 804–821. https://doi.org/10.1007/s00267-019-01158-7.
Mottet, A., Ladet, S., Coqué, N., Gibon, A., 2006. Agricultural land-use change and its drivers in mountain landscapes: A case study in the Pyrenees. Agr. Ecosyst. Environ. 114, 296–310. https://doi.org/10.1016/j.agee.2005.11.017.
OECD, 2022. OECD Support for Agriculture | Compare Your Country. http://www.compareyourcountry.org/support-for-agriculture/en/1/CHE.
Otto-Banaszak, I., Matczak, P., Wesseler, J., Wechsung, F., 2011. Different perceptions of adaptation to climate change: a mental model approach applied to the evidence from expert interviews. Reg. Environ. Chang. 11, 217–228. https://doi.org/10.1007/s10113-010-0144-2.
Paustian, M., Theuvsen, L., 2017. Adoption of precision agriculture technologies by German crop farmers. Precis. Agric. 18, 701–716. https://doi.org/10.1007/s11119-016-9482-5.
Petanidou, T., Kizos, T., Soulakellis, N., 2008. Socioeconomic dimensions of changes in the agricultural landscape of the Mediterranean basin: a case study of the abandonment of cultivation terraces on Nisyros Island. Greece. Environ. Manage. 41, 250–266. https://doi.org/10.1007/s00267-007-9054-6.
Plieninger, T., Draux, H., Fagerholm, N., Bieling, C., Bürgi, M., Kizos, T., Kuemmerle, T., Primdahl, J., Verburg, P.H., 2016. The driving forces of landscape change in Europe: A systematic review of the evidence. Land Use Policy 57, 204–214. https://doi.org/10.1016/j.landusepol.2016.04.040.
Power, A.G., 2010. Ecosystem services and agriculture: tradeoffs and synergies. Philos. Trans. R. Soc. Lond. B Biol. Sci. 365, 2959–2971. https://doi.org/10.1098/rstb.2010.0143.
Rosling, H., Rönnlund, A.R., Rosling, O., 2018. Factfulness: ten reasons we're wrong about the world–and why things are better than you think, 1st ed. Flatiron Books, New York.
Rounsevell, M.D.A., Ewert, F., Reginster, I., Leemans, R., Carter, T.R., 2005. Future scenarios of European agricultural land use. Agr. Ecosyst. Environ. 107, 117–135. https://doi.org/10.1016/j.agee.2004.12.002.
Schaller, L., Targetti, S., Villanueva, A.J., Zasada, I., Kantelhardt, J., Arriaza, M., Bal, T., Fedrigotti, V.B., Giray, F.H., Häfner, K., Majewski, E., Malak-Rawlikowska, A., Nikolov, D., Paoli, J.-C., Piorr, A., Rodríguez-Entrena, M., Ungaro, F., Verburg, P.H., van Zanten, B., Viaggi, D., 2018. Agricultural landscapes, ecosystem services and regional competitiveness—Assessing drivers and mechanisms in nine European case study areas. Land Use Policy 76, 735–745. https://doi.org/10.1016/j.landusepol.2018.03.001.
Scherr, S.J., Shames, S., Friedman, R., 2012. From climate-smart agriculture to climate-smart landscapes. Agric. Food Secur. 1, 12. https://doi.org/10.1186/2048-7010-1-12.
Schneiders, A., Van Daele, T., Van Landuyt, W., Van Reeth, W., 2012. Biodiversity and ecosystem services: Complementary approaches for ecosystem management? Ecol. Ind. 21, 123–133. https://doi.org/10.1016/j.ecolind.2011.06.021.
Selman, P., 2009. Planning for landscape multifunctionality. Sustainability: Science Practice and Policy 5, 45–52. https://doi.org/10.1080/15487733.2009.11908035.
Shackleton, R.T., Richardson, D.M., Shackleton, C.M., Bennett, B., Crowley, S.L., Dehnen-Schmutz, K., Estévez, R.A., Fischer, A., Kueffer, C., Kull, C.A., Marchante, E., Novoa, A., Potgieter, L.J., Vaas, J., Vaz, A.S., Larson, B.M.H., 2019. Explaining people's perceptions of invasive alien species: A conceptual framework. J. Environ. Manage. 229, 10–26. https://doi.org/10.1016/j.jenvman.2018.04.045.
Skovdal, M., Cornish, F., 2015. Qualitative research for development: a guide for practitioners. Practical Action Publishing Ltd. https://doi.org/10.3362/9781780448534.
Smith, H.F., Sullivan, C.A., 2014. Ecosystem services within agricultural landscapes—Farmers' perceptions. Ecol. Econ. 98, 72–80. https://doi.org/10.1016/j.ecolecon.2013.12.008.
Steentjes, K., Pidgeon, N., Poortinga, W., Corner, A., Arnold, A., Böhm, G., Mays, C., Poumadère, M., Ruddat, M., Scheer, D., Sonnberger, M., Tvinnereim, E., 2017. European Perceptions of Climate Change: Topline findings of a survey conducted in four European countries in 2016. Cardiff University, Cardiff.
Stosch, K.C., Quilliam, R.S., Bunnefeld, N., Oliver, D.M., 2019. Quantifying stakeholder understanding of an ecosystem service trade-off. Sci. Total Environ. 651, 2524–2534. https://doi.org/10.1016/j.scitotenv.2018.10.090.
Swinton, S.M., Lupi, F., Robertson, G.P., Hamilton, S.K., 2007. Ecosystem services and agriculture: cultivating agricultural ecosystems for diverse benefits. Ecol. Econ. 64, 245–252. https://doi.org/10.1016/j.ecolecon.2007.09.020.
Termorshuizen, J.W., Opdam, P., 2009. Landscape services as a bridge between landscape ecology and sustainable development. Landsc. Ecol. 24, 1037–1052. https://doi.org/10.1007/s10980-008-9314-8.
Vallés-Planells, M., Galiana, F., Van Eetvelde, V., 2014. A classification of landscape services to support local landscape planning. E&S 19. https://doi.org/10.5751/ES-06251-190144.
van der Sluis, T., Arts, B., Kok, K., Bogers, M., Busck, A.G., Sepp, K., Loupa-Ramos, I., Pavlis, V., Geamana, N., Crouzat, E., 2018. Drivers of European landscape change: stakeholders' perspectives through Fuzzy Cognitive Mapping. Landsc. Res. 44, 1–19. https://doi.org/10.1080/01426397.2018.1446074.
van der Zanden, E.H., Verburg, P.H., Mücher, C.A., 2013. Modelling the spatial distribution of linear landscape elements in Europe. Ecol. Ind. 27, 125–136. https://doi.org/10.1016/j.ecolind.2012.12.002.
van Vliet, J., de Groot, H.L.F., Rietveld, P., Verburg, P.H., 2015. Manifestations and underlying drivers of agricultural land use change in Europe. Landsc. Urban Plan. 133, 24–36. https://doi.org/10.1016/j.landurbplan.2014.09.001.
van Zanten, B.T., Verburg, P.H., Espinosa, M., Gomez-y-Paloma, S., Galimberti, G., Kantelhardt, J., Kapfer, M., Lefebvre, M., Manrique, R., Piorr, A., Raggi, M., Schaller, L., Targetti, S., Zasada, I., Viaggi, D., 2014. European agricultural landscapes, common agricultural policy and ecosystem services: a review. Agron. Sust. Developm. 34, 309–325. https://doi.org/10.1007/s13593-013-0183-4.
Weber, E.U., 2010. What shapes perceptions of climate change? WIREs Clim. Change 1, 332–342. https://doi.org/10.1002/wcc.41.
Zhang, W., Ricketts, T.H., Kremen, C., Carney, K., Swinton, S.M., 2007. Ecosystem services and dis-services to agriculture. Ecol. Econ. 64, 253–260. https://doi.org/10.1016/j.ecolecon.2007.02.024.
Zondag, B., Borsboom, J., 2009. Driving forces of land-use change. Presented at the Paper prepared for the 49th ERSA conference, August 2009, Lodz, Poland.