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An analytical framework to link governance, agricultural production practices, and the provision of ecosystem services in agricultural landscapes

Claudia Bethwell [a,b,*,1], Claudia Sattler [a,2], Ulrich Stachow [a,3]

[a] Leibniz Centre for Agricultural Landscape Research (ZALF), Eberswalder Straße 84, 15374 Müncheberg, Germany
[b] Geography Department, Humboldt-Universität zu Berlin, Unter den Linden 6, 10099 Berlin, Germany

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ABSTRACT

The provision of ecosystem services (ES) in agricultural landscapes depends, inter alia, on agricultural production, and can therefore be influenced by governance. To capture the impacts of governance on ES via agriculture, we proposed and tested an analytical framework – based on agricultural location theory – to describe possible agricultural impact pathways. These pathways show how different governance approaches (e.g. hierarchical, market-based, collaborative, and their hybrids) influence site and farm conditions, which in turn influence agricultural production practices and thus ES provision. The framework was applied to three European case study regions in the Netherlands, Germany, and Austria. The sub-objectives were: i) to identify regional governance approaches and assess how well they reflect the regional specifics, as a basis for applying the framework; and, by applying the framework, to: ii) investigate how these governance approaches then differ in their agricultural impact pathways and thus effects on agriculture; and iii) evaluate their respective influence on ES provision. The governance approaches were compiled and analysed from several sources, e.g. legal documents and grey literature from regional sources, regional workshops, and consultation with stakeholders. The analyses showed that different governance types indeed differ in how well they accommodate regional specifics in their agricultural impact pathways, and thus in their influence on agriculture and ES provision. Overall, the analytical framework is suited to highlighting the agricultural perspective in the ES concept and to exploring the constraints and opportunities for farmers to adopt agricultural production practices that favour the provision of ES as environmental public goods.

1. Introduction

1.1. Problem definition and research questions

Landscapes shaped by agro-ecosystems[4] dominate much of Europe (EEA, 2019) and other regions of the world (FAO, 2019). While a continued need for agricultural production of food, forage, and fibre (provisioning ecosystem services) is evident, too little attention has been given to ensuring the long-term sustainability of the non-provisioning ecosystem services (ES) that agro-ecosystems can also deliver, such as regulating, habitat and supporting, and cultural services (Tilman et al., 2002). Examples of such services include climate regulation, erosion control, water quantity and quality regulation, pollination, pest control, habitat provision, and aesthetics (e.g. Kremen et al., 2002; Zhang et al., 2007; Gordon et al., 2010; Heathwaite, 2010; Power, 2010; Lal, 2011; Panagos et al., 2015; Powlson et al., 2015). These services often exhibit characteristics of public goods (non-excludability of consumption), and thus provide few incentives to farmers to provide them (e.g. OECD, 2013; Ostrom and Ostrom, 2014; Blackstock et al., 2021). Production of multiple ES is significantly affected by agricultural production practices,

* Corresponding author at: Leibniz Centre for Agricultural Landscape Research (ZALF), Eberswalder Straße 84, 15374 Müncheberg, Germany.
E-mail address: claudia.bethwell@zalf.de (C. Bethwell).
[1] ORCID: 0000-0003-0112-5852.
[2] ORCID: 0000-0002-5588-5075.
[3] ORCID: 0000-0003-0406-0812.

[4] An agro-ecosystem is a representation of agriculture. It represents the ecological perspective, including the governance and provision of ES (Gliessmann, 2007). It is defined as "a site or integrated region of agricultural production … understood as an ecosystem," allowing researchers "to analyse … their complex set of inputs and outputs and the interconnection of their component parts" (Gliessmann, 2007: 23).

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although the interaction between different ES, e.g. between crop yield (a provisioning ES) and other types of ES, is not always straightforward (Power, 2010; Iverson et al., 2014). Agricultural production practices, in turn, result from farmers' decision-making in response to frame conditions. These frame conditions include climate and soil conditions, product prices, factor costs, available technologies, and farm-inherent targets, such as sustaining the economic viability of a farm and using the soil and farm resources in a sustainable way. A crucial scale to analyse the dynamics of agriculture is therefore the farming system[2], i.e. farmers' response to the frame conditions. Many frame conditions can be influenced by governance approaches, which can be broadly differentiated into hierarchical, market-based, and community-based governance (Vatn, 2015). The first includes laws and regulations, or cross-compliance obligations, frequently used to secure public goods provision. The second encompasses financial incentives for public goods provision, e.g. through agri-environment-climate measures (AECM). The third type includes alliances between farmers and other actors to promote more public goods.

To improve the provision of public goods by agro-ecosystems in addition to the provision of private goods such as food and fodder, it is crucial to clarify how particular governance approaches interact with certain frame conditions for farming and thus agricultural production practices, which of course have an effect on ES provision. Approaches that take all these interactions into account are few and far between (Westerink et al., 2020, see also Cochet, 2015; Dwyer et al., 2018; Schlüter et al., 2019). To clarify these interactions, it is important that agriculture is adequately represented at the farm[5] (see above) and regional[6] level, because it is the farmer who makes land use decisions under these frame conditions, which are often regionally distinct. This study therefore aims to provide a comprehensive framework linking governance, its impact on frame conditions for farming, agricultural production practices, and ES provision, and to apply it to three case study regions at the landscape level.

Agricultural location theory is a model that can link governance, agricultural production, and ES provision, and that holds explanatory power for frame conditions for farming (Kuhlmann, 2015). The purpose of agricultural location theory is to explain the existing diversity of farming systems in the light of several frame conditions, for which a very large variety exists across Europe. Some conditions cannot be changed by farmers; these are "site conditions", e.g. soil, climate, and market prices. These conditions typically offer various options for establishing economically viable farming systems, which define farmers' leeway. However, once a system has been chosen, a set of several internal constraints emerges as "farm conditions", which should be obeyed to ensure the long-term viability of the farm, e.g. the efficient use of machinery. This type of constraints is different from site conditions. The theory therefore distinguishes between "site conditions" that cannot be changed and the more flexible "farm conditions" that result from the selection of the farming system. The options that arise for establishing economically viable farming systems, i.e. the leeway for farmers, can be steered through governance, for example, towards environmentally friendly agricultural production practices. While famers' leeway can be defined as "their capacity to adopt technical changes at a particular level without endangering farm system functioning at another level" (Navarette et al., 2006: 77), we apply this concept in relation to governance approaches and their effect on the leeway for adopting environmentally friendly farming practices. This means that the farmers' leeway for environmentally friendly production practices is their capacity to adopt environmentally friendly production practices without compromising the functioning of the farming system. Agricultural location theory then classifies these site and farm conditions according to their respective impacts on agricultural production practices. At the regional and landscape level, agricultural location theory represents agriculture by "typical farms". Consequently, governance can act as one "input", altering frame conditions directly or indirectly, and the agricultural production practices and eventually the ES, which can be interpreted as the "output". While agricultural location theory models the behaviour of farmers, but incorporates a limited number of factors in the analysis, it allows the inference of impacts based on farmers' (economically rational) decision-making (OECD, 2013). Agricultural location theory is a powerful model for explaining what Kuhlmann (2015) termed "land use programmes" (the portfolio of products and production systems, i.e. types of crops and/or livestock, grassland) and "land use intensities" (the input(s) used to grow these crops) resulting in a specific land use pattern for each farm and for agricultural landscapes as shown by implementations of agricultural location theory (e.g. Weber et al., 2001; Sheridan and Waldhardt, 2006; Weinmann et al., 2006). In this way, agricultural location theory allows users to infer a landscape-specific description of agricultural systems.

An extension of agricultural location theory (Kuhlmann, 2015) to include governance and ES provision will allow us to better understand the impact pathways governance takes via the agricultural system to provide ES in agricultural landscapes. This approach to landscape-level assessments of ES incorporates an agricultural, farm-based perspective into the governance analysis of ES, which is desirable, but has not yet been achieved (Tancoigne et al., 2014). Furthermore, the intended extension allows for the systematic inclusion of constraints faced by farmers, i.e. the full range of combinations of frame conditions for farming. As a result, the leverage points and pathways for governance approaches to increase ES provision in agricultural landscapes should become more explicit. The focus on the landscape scale allows to include the relationship between landscape-specific characteristics and governance approaches that address certain key ES. This also implies assessing the level of participation by farmers and other stakeholders, and spatial and temporal dimensions of governance approaches.

The overall objective of this study is to propose a comprehensive analytical framework for describing the impact of governance on the provision of ES via agriculture, with particular emphasis on how it influences the frame conditions and production practices in agriculture, and to test the applicability of the framework using three European case study regions in the Netherlands, Germany, and Austria. The case study regions are used to pursue three sub-objectives. First, to identify regional governance approaches and assess how well they reflect regional specifics in order to provide a basis for the application of the analytical framework. Second, to explore how these governance approaches differ in their agricultural impact pathways and their specific effects on agriculture. Third, to assess the corresponding effects of these governance approaches on ES provision. A qualitative analysis of the governance approaches was conducted to answer the associated research questions (RQ):

- RQ1: Which governance approaches are used in the case study regions to govern agricultural production and to secure particularly significant and important ES, and how do these governance approaches take account of the regional specifics in each region?
- RQ2: Do different types of governance (i.e. hierarchical, market-based, collaborative, and hybrids thereof) differ in terms of the various agricultural impact pathways they each use to affect frame conditions for farming and agricultural production practices and thus ES, and if so, how do they affect farmers' leeway for environmentally friendly production practices?
- RQ3: Do these types of governance approaches affect ES categories (provisioning, regulating, habitat and supporting, cultural ES) and their integration differently, and if so, how can this insight be used to

[5] The farming system is a representation of agriculture at the farm level. It encompasses "principal crops, livestock, and management practices employed on a particular farm" (Connor et al., 2011: 4).

[6] The agricultural system is a representation of agriculture at the regional level. It is defined as the "regional organization of farming systems" (Connor et al., 2011: 5).

guide agricultural production practices towards more favourable ES provision?

To this end, we extend agricultural location theory by incorporating three components (governance, ES, and regionalisation) and by subsequently deriving different pathways from "input" (governance) to "output" (ES) through the agricultural model, which we refer to as "types of agricultural impact pathways" (Section 2). The overall methodological approach for the application of the framework, the case study regions, and the compilation and analysis of the governance approaches are described in Section 3. Subsequently, individual governance approaches and their respective governance types are related to regional specifics, and their impacts on agriculture and thus on ES provision are derived. This illustrates the concept of "agricultural impact pathways". By bringing these results together, we can determine the applicability of the extended agricultural location theory to analyse landscape-specific governance systems in relation to ES (Section 4). Section 5 discusses the results together with the limitations and the implications of the proposed framework in light of similar studies on ES in agricultural landscapes; it also shows possible avenues for further development of the framework. Section 6 offers conclusions related to the overall objective and the three research questions.

1.2. Governance of ES in agricultural landscapes

Integrating environmental goals into agricultural production and thus into agricultural landscapes as an objective of the EU's post-2020 Common Agricultural Policy (CAP) is crucial (Runhaar et al., 2016; Jongeneel, 2018; Pe'er et al., 2020) and requires targeted environmental governance (Vatn, 2015). As mentioned above, governance approaches in general can be classified into three ideal types: hierarchical, market-based, and community-based or collaborative, as well as hybrids thereof (Vatn, 2010). It is our basic assumption that these types (or their hybrids) can influence ES supply differently through the way in which priorities are set, which and how actors become involved with different property and use rights, how actors interact with each other at the same or across different governance levels (local, regional, national, or international), and what instruments they apply (Vatn, 2015). The individual ES are differently suited to the governance types (Stallman, 2011). There is greater acceptance of sustainable production practices when these practices benefit farms (e.g. soil fertility) or the local community (e.g. mitigation of nitrate leaching) than when the effect has a more global character (e.g. mitigation of GHG emissions) (Robertson et al., 2014). Other acceptance factors for farmers include perceived manageability, vulnerability to ES loss, and threats to ES (Smith and Sullivan, 2014).

We now describe the ideal and hybrid governance types differentiated for our analysis:

Hierarchical approaches are based on a system of command, where decision-making power rests with the top level, and is then further passed down to subordinate levels (Vatn, 2010, 2015). Such approaches often focus on specific environmental assets that are at risk (Bastian, 2013a). Examples include the European Union's Natura 2000 programme, which aims to maintain natural and semi-natural valuable habitats, and rare or threatened species (ECC, 1992; EC, 2009), and the Water Framework Directive (WFD), which aims to improve the quality and quantity of water bodies (EC, 2000; EC, 2008b,c). Natura 2000 has shown synergies with regulating and cultural ES (Maes et al., 2012; Bastian, 2013b), but can also lead to trade-offs or neutral relationships (Ziv et al., 2018). The WFD does not explicitly mention ES, but can bundle additional ES (e.g. Grunewald et al., 2013; Voulvoulis et al., 2017). Although neither Natura 2000 nor WFD address farmers directly, both pieces of legislation are relevant for agricultural production practices (EC, 2012; EC, 2017a; EC, 2017b), and require governmental efforts; they are implemented differently in the EU Member States, and measures to address Natura 2000 and WFD are also established through other programmes, such as AECM.

Hierarchical approaches with market-based components as a hybrid of two ideal-typical approaches (Vatn, 2010, 2015) include AECM as a key example (EU, 2013a). In broader terms, these approaches can also be understood as payments for ES (PES), where the government pays on behalf of the ES beneficiaries, e.g. the general public (Sattler and Matzdorf, 2013). Greening measures (EU, 2013b; EC, 2017c) including ecological focus areas (EC, 2017d; Nilsson et al., 2019) are another example. Both target a broad range of ES, but their ecological effectiveness has been called into question (Batary et al., 2015; ECA, 2017; Riley et al., 2018). Options to improve AECM include results-based solutions (e.g. Burton and Schwarz, 2013), spatial and ecological targeting (e.g. Reed et al., 2014; Meyer et al., 2015), collaborative implementation at the landscape level (e.g. Pe'er et al., 2020), the use of local intermediaries and agricultural extensions (e.g. Schomers et al., 2015; Schnyder, 2019), and the increased flexibility and involvement of conservationists in designing such measures (Meyer et al., 2015).

Market-based approaches with a collaborative component are also hybrids of two ideal-typical approaches (Vatn, 2010, 2015). Market-based approaches are based on voluntary exchange between two parties (Vatn, 2010, 2015). Two markets are of key importance to farmers: the product market and the factor market, i.e. factors that are used in the production process (e.g. labour, machinery, fertiliser). To strengthen farmers' position in both markets, at least two governance strategies are available in cultural landscapes, both of which need an additional collaborative component. In product markets, it is possible to enhance the value of the landscape as a whole and to capitalise the cultural landscape (i.e. to valorise the cultural landscape) through the sale of high-quality regional products – a strategy driven by product demand and market price pressures (Knickel and Maréchal, 2018). Focusing on cultural landscapes (and thus delivering cultural ES) enables the inclusion of additional ES that are bundled to cultural ES (Raudsepp-Hearne et al., 2010). In factor markets, cost reduction is key to farmers (Firbank et al., 2013b).

Collaborative approaches are based on cooperation among stakeholders, often at the local community level, following a set of self-defined rules (Vatn, 2010, 2015). These approaches are often initiated by local civil society initiatives and are driven by exogenous factors, such as finance gaps (García-Martín et al., 2016). In Europe, they typically aim to tap into additional financial resources for cultural landscape management and to encourage information sharing and cooperation (e.g. Franks and Mc Gloin, 2007; Franks, 2010; van Dijk et al., 2015). Collaborative approaches were promoted in the previous (2014–2020) CAP period (EU, 2013a, Article 35) as "group contract AECM" and were based on the developments of agri-environmental cooperatives (Wiskerke et al., 2003). Group contract AECM can increase economic and social benefits for farmers, such as higher yields, reduced transaction costs, greater capabilities to cope with future challenges, greater social capacity, more sophisticated technical skills, and increased business confidence (Prager, 2015). Moreover, they can use the landscape level as a frame of reference, which then triggers better spatial coordination (Westerink et al., 2017a) and management systems that can cover ecological interactions and principles at this level (Tscharntke et al., 2005; Kleijn et al., 2011; Prager et al., 2016; Nilsson et al., 2019).

2. Development of the analytical framework

2.1. Theoretical background: agricultural location theory

The analytical framework was developed based on agricultural location theory, as outlined by Kuhlmann (2015). The theory itself is rooted in the work of von Thünen (1921), which was later operationalised through programming tools, i.e. mathematical optimisation according to economic objectives to model agricultural land use and patterns (O'Kelly and Bryan, 1996). Agricultural location theory helps to explain the diversity of farming systems across regions (Kuhlmann,

2015) and has at least two implications for recent approaches to agricultural economics research. The first is that bio-economic farm models can apply the operationalisation described (Rossing et al., 2007; Reidsma et al., 2018) and these models are often used for regional spatially explicit modelling approaches (e.g. Weber et al., 2001; Sheridan and Waldhardt, 2006; Weinmann et al., 2006). In this study, however, we use a second, different, aspect of location theory, namely the classification of factors that influence farmers' decisions about what to produce (land use programme) and how to produce it (land use intensity) from an agro-economic perspective.

Kuhlmann (2015) classified the factors that influence farmers' decisions into two types of frame conditions: site conditions and farm conditions. Site conditions cannot be changed by individual farmers; instead, farming must adapt to them (e.g. soil, climate, product prices, and factor costs). In contrast, farm conditions can be changed by individual farmers; they lead to individual production practices within the given frame, and represent the individual's choice to maintain soil fertility, sustain an economically viable existence, reduce risks, and use resources effectively. Both types of frame conditions influence the land use programme, i.e. the portfolio of products on a farm (e.g. cash crops) and the land use intensity,[7] i.e. the amount of inputs to agriculture (e.g. chemicals, machinery, or labour, based on the cropping system(s) applied[8]). The two types of frame conditions drive the farming systems in opposite directions, either towards specialisation and increased intensity or towards diversification and lower intensity. The direction in which the farming system is moving depends to a great extent on the importance and weight of the site and farm conditions. If, for example, the site conditions allow particularly high yields of a specific crop, it is reasonable (and economically rational) to dedicate as much farmland as possible to this crop, causing the farmer to specialise in this crop with high intensity farming. The reasons preventing the farmer from not using 100% of the land to grow this crop are mainly the farm conditions, e.g. risk reduction, maintenance of soil fertility, and use of machinery. The less important these factors are, or can be handled through other means than diversification (e.g. crop rotation), the more the specialisation, and hence intensification, will prevail (Kuhlmann, 2015) – a development that has occurred in recent decades. Since these frame conditions affect all farms and guide trends of regional agricultural activities, performance, and development, they also have an impact on the environment. The frame conditions can be modified through governance, and in this way can influence the environmental impacts of agriculture (e.g. Gottschalk et al., 2007; Schuler and Sattler, 2010; Sattler et al., 2010).

In this study, Kuhlmann's classification (2015) was extended to a comprehensive analytical framework to qualitatively describe the way governance approaches could influence the frame conditions for farming – and thus the land use programme and the intensity as well as the provision of ES. This framework was then applied to three regions as case studies.

2.2. Modules of the analytical framework

The analytical framework consists of seven modules representing governance (Extended Module 1), the original core components of agricultural location theory (Modules 2 to 5), ES (Extended Module 6), and regionalisation (Module 7). Fig. 1 shows how these modules are interlinked.

Module 1, "Governance", can be defined as the establishment, maintenance, and modification of (formal or informal) institutions to promote coordination and cooperation in an effort to resolve conflicts. In the context of environmental governance, conflicts arise over the use of environmental resources and/or the management of ecosystems (Vatn, 2015). Governance relies on three main strategies: hierarchical, market-based, and collaborative approaches (Vatn 2010; see Section 1.2). Governance approaches often combine elements of more than one strategy, which qualifies them as governance hybrids (e.g. Lemos and Agrawal, 2009; van der Heijden, 2011). Since they are differently suited for different ES (Stallman, 2011), governance strategies are likely to influence agricultural frame conditions and production practices in different ways, and they can therefore be used to improve the variety and level of ES provision in agricultural landscapes (Kenward et al., 2011; Ring and Schröter-Schlaack, 2011; Bastian, 2013a; Kristensen, 2016; Westerink et al,. 2020). In our analytical framework, governance is the "input" that influences frame conditions for farming.

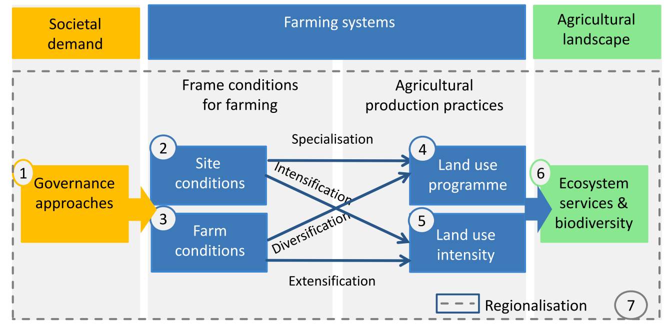

Fig. 1. The analytical framework identifies pathways between governance (Module 1), farming (Modules 2 to 5), and ecosystem services and biodiversity (Module 6). The interactions between frame conditions and agricultural production practices (Modules 2 to 5) are described by agricultural location theory, in which regional farming is characterised by "land use programmes" (the portfolios of the agricultural products) and levels of "land use intensity" (the input used in the production systems) of typical farms. Both aspects affect ecosystem services and biodiversity, and hence governance effects on these issues can become comprehensible. There are two types of frame conditions - site conditions and farm conditions - which have opposite effects on land use programmes and land use intensity, and thus on ecosystem services and biodiversity at the landscape level (7).

Module 2, "Site Conditions", covers external regional factors to which farmers must adapt, such as natural conditions that define the yield level and workability of the land; market conditions represented by factor costs, product prices, and market access; and current technological and structural conditions that have evolved over time (Kuhlmann, 2015). These external factors define the scope for farmers' decisions, i.e. their respective land use programme and land use intensity (Kuhlmann, 2015), and thus for sustainable production practices. The economy, technology, legislation, and natural site conditions are generally seen as the key drivers of farmers' decision-making (Diogo et al., 2015), long-term changes in land use and ES provision (Firbank et al., 2013a; van Vliet et al., 2015; Kristensen et al., 2016), and future developments in the region (Reidsma et al., 2015). These factors can serve as leverage points for governance to better meet society's demands for environmentally friendly agriculture (e.g. Robertson et al., 2014). Decisions on sustainable practices are often related to cost and risk mitigation (Firbank et al., 2013b) or market access and the available labour force (Casagrande et al., 2017).

Module 3, "Farm Conditions", addresses the principles that the individual farmer decides on and applies to sustain the farm (Kuhlmann, 2015). They usually address maintenance of soil fertility (e.g. by weed control, maintenance of nutrient status, prevention of soil erosion); the farm's economic viability (e.g. low market and production risks); the continuation of agricultural operations (e.g. ensuring feed for livestock); and the effective use of farm resources (e.g. labour, machinery). As a consequence, farm conditions tend to drive production practices

[7] In this agro-economic perspective, land use intensity is defined as an input intensity (see Section 2.2)

[8] The cropping system is a representation of agriculture at the field level, it is "the temporal sequence of crops and management practices in individual fields" (Connor et al., 2011: 3).

towards diversification and extensification (Kuhlmann, 2015). Moreover, farmers are responsible for how they weigh and achieve the above goals. Both aspects mean that farm conditions can also serve as leverage points to improve the diversity and level of ES supplied – if governance approaches indeed encourage farmers to do so.

Module 4, "Land Use Programme", relates to crops and livestock, i.e. the particular agricultural land use of a farm, landscape, or region. It results from the specific combination of site and farm conditions, marking different "farm types" that reflect the degree of specialisation (Andersen et al., 2007). The contribution of the land use programme to land use intensity (see below) can only be assessed on a crop-specific basis (Herzog et al., 2006). When looking at specific crop types, varieties, and crop rotations, it becomes clear that adaptations of the land use programme can help to reduce intensity in order to support specific ES provision and biodiversity. Together with site and farm conditions, the land use programme provides the frame that determines what range of intensity can be applied to the different crops grown.

Module 5, "Land Use Intensity", in an agro-economic context, can be defined as input intensity (Kuhlmann, 2015). Input intensity refers to all management decisions, e.g. related to tillage, fertilisation, or crop protection. It depends on frame conditions and the land use programme, which defines intensity ranges in a certain region (Kuhlmann, 2015). The range of intensity can be attributed to different farming styles, which can be very heterogeneous within a given region (van der Ploeg and Ventura, 2014). The land use programme applied (see above), path dependencies, and social (Ambrosius et al., 2015) and behavioural factors (Dessart et al., 2019) also determine the land use intensity. However, the three latter factors are not included in the framework described in this paper. It is important to point out that different farming styles also have multiple implications in terms of, e.g. resource efficiency, ES, and biodiversity (Schmitzberger et al., 2005; Swagemakers et al., 2009; van der Ploeg and Ventura, 2014; Hammes et al., 2016; Braito et al., 2020; Jantke et al., 2020). Furthermore, it can be helpful to consider output intensity and the effects of land-based production (Erb et al., 2013). Intensification processes (e.g. Björklund et al., 1999) have stabilised in parts of Europe ((van der Sluis et al., 2016)) in recent years. We consider the effects of these different farming styles, land-based production, and output intensity in the following module.

Module 6, "Ecosystem Services and Biodiversity Conservation", is the "output" of the framework. ES can be defined as "contributions of ecosystem structure and function – in combination with other inputs – to human well-being" (Burkhard et al., 2012: 2). We consider provisioning, regulating, habitat and supporting, and cultural ES (e.g. TEEB (2010)[9]). The diversity and extent of the various ES in agricultural landscapes (Westerink et al., 2020) as well as their synergies and trade-offs (e.g. Power, 2010; TEEB, 2010; Field et al., 2015) significantly depend on agricultural activities, i.e. the land use programme applied and the intensity of use.

Module 7 "Regionalisation" is an inherent part of agricultural location theory, because it helps explain the diversity of farming systems across regions at different scales, and thus also general trends in land use programmes and levels of land use intensity that result from the specific combinations of the frame conditions and farmers' corresponding decisions (Kuhlmann, 2015). Patterns of land use (e.g. Diogo et al., 2015; Rega et al,. 2020) and land use intensity levels (e.g. Temme and Verburg, 2011; Teillard et al., 2012) are an expression of these general trends (Kuhlmann, 2015). Assessments of land use intensity are rare at the regional level, although they are relevant for policy and planning (Ruiz-Martinez et al., 2015; van der Zanden et al., 2016); this is also true for land use patterns (Andersen, 2017; Rega et al., 2020). ES as outputs of the land use programmes applied and land use intensity follow these patterns (Diogo et al., 2015). Regionalisation can help the spatial targeting of agri-environmental measures (Zasada et al., 2017; Rega et al., 2020) and improve the spatial fit of governance approaches (Vatn and Vedeld, 2012).

2.3. Agricultural impact pathways

Agricultural impact pathways represent the chain of effects in how governance influences frame conditions for farming, then subsequently agricultural production practices, and ultimately ES provision and biodiversity conservation. These pathways have different starting points, and utilise different mechanisms. They often differ among individual governance approaches, and thus make the mode of action transparent. Conceptually, they are based on the modules of the analytical framework. These modules can be used to identify pathways taken by a specific governance to affect site and farm conditions. The interface between governance on the one hand and site and farm conditions on the other may represent initial positions where corrective actions in governance can induce changes in agricultural production practices, i.e. changes in the land use programmes and levels of land use intensity, both of which influence ES provision and biodiversity conservation.

We derived seven possible pathways, A to G, see Table 1. While A, B, C, and D straightforwardly connect the modules "Governance", "Site Conditions", "Farm Conditions", "Land Use Programme", "Land Use Intensity", and "ES/Biodiversity" in different ways, Paths E and F are special cases, because feedback loops from farm conditions would also allow them to generate new site conditions, such as market access for regional, high-quality products. By cooperating at the regional scale, farmers are able to change a number of site conditions, which individual farmers cannot. Path G describes approaches that support measures in

Table 1
Description of the types of agricultural impact pathway, i.e. the chain of effects across the modules of the framework, from government approaches via the farming system to ecosystem services and biodiversity.

Type	Pathway	Description
A	GOV – SC – LUP – LUI – ES/BC	Governance (GOV) first affects or is based on the site conditions (SC), which further influence the land use programme (LUP) and the related land use intensity (LUI). The land use programme and land use intensity then affect ES and biodiversity conservation (ES/BC).
B	GOV – SC – LUI – ES/BC	Governance (GOV) first affects or is based on the site conditions, which further influence land use intensity (LUI) only. Land use intensity then affects ES and biodiversity conservation (ES/BC).
C	GOV – FC – LUP – LUI – ES/BC	Governance (GOV) first affects or is based on the farm conditions (FC), which further influence the land use programme (LUP) and the related land use intensity (LUI). Both the land use programme and land use intensity have an impact on ES and biodiversity conservation (ES/BC).
D	GOV – FC – LUI – ES/BC	Governance (GOV) first affects or is based on the farm conditions (FC), which further influence land use intensity (LUI) only. Land use intensity then affects ES and biodiversity conservation (ES/BC).
E	GOV – FC – SC – LUP – LUI – ES/BC	Governance (GOV) first affects or is based on the farm conditions (FC) with a feedback loop to the site conditions (SC), which further influence both the land use programme (LUP) and land use intensity (LUI). The land use programme and land use intensity then affect ES and biodiversity conservation (ES/BC).
F	GOV – FC – SC – LUI – ES/BC	Governance (GOV) first affects or is based on the farm conditions (FC) with a feedback loop to the site conditions (SC), which further influence land use intensity (LUI) only. Land use intensity then affects ES and biodiversity conservation (ES/BC).
G	GOV – ES/BC	Governance (GOV) directly affects ES and biodiversity conservation (ES/BC), not via the farming system.

[9] Other ES classification systems include MEA 2005, Haines-Young and Potschin, 2013, Maes et al., 2013, and Bastian et al. 2013.

agricultural landscapes outside agricultural plots, for example with the aim of maintaining valuable habitats as landscape elements.

3. Methods: application of the analytical framework to the case study regions

3.1. The general approach

We applied the analytical framework to three case study regions that represent different European agricultural landscapes, but that share the features of being at least partially located within a protected area and having a broad range of local stakeholder networks and governance approaches. These characteristics made them ideal for our purposes. Within these case study regions, we identified the relevant governance approaches and assessed in how far they reflect the regional specifics. We then applied the analytical framework to the governance approaches we identified, and analysed their impact on agriculture and their fit to the different agricultural impact pathways (see Table 1), as well as their impact on ES.

3.2. Case study regions

The three case study regions, i.e. the municipality of Berg en Dal in the Netherlands, the Spreewald Biosphere Reserve in Germany, and the municipalities of the Jauerling-Wachau Nature Park in Austria, differ considerably in their natural characteristics, land cover, and agricultural land use (Table 2, Fig. 2).

The Dutch case study, located close to the city of Nijmegen in a riverine landscape between the Waal River and a forested moraine, has a relatively high share of developed areas. It is an intensively used region, dominated by agricultural land use, primarily grassland, arable land, livestock with grazing and housed animals, and horticulture; farms mainly use conventional farming methods. The types of farming focus on different kinds of livestock-based holdings. Other land use includes forests as well as a relatively high share of land used for other purposes, including water courses, water bodies, wetlands, and natural areas (see Table 2, Fig. 2a).

The German case study, 90 km southeast of Berlin, is a cultivated floodplain of the Spree River, characterised by numerous water courses and a sophisticated water regulation system. It is dominated by agriculture, primarily grassland and arable land with grain and forage crops, oilseeds and legumes, as well as livestock farming, and permanent crops and horticulture, established historically to meet Berlin's demand for fresh fruit and vegetables. The livestock density is relatively low (58 livestock units per 100 ha, Amt für Statistik Berlin-Brandenburg, 2017). Mixed farming systems predominate, and there are many organic farms (see Table 2, Fig. 2b).

The Austrian case study of Jauerling-Wachau is a hilly region located 80 km west of Vienna, adjacent to the Danube River. Soil and climate conditions are very heterogeneous, often unfavourable for agriculture (BFW, 2017). Forests predominate, while agricultural land covers 36%; this is mostly grassland with permanent pastures, but arable land with grain and forage crops is also present. Permanent crops are typical, and Christmas tree cultivation in particular generates additional income for small farms, while fruit trees and viticulture dominate the valleys and some south-facing slopes. Due to the heterogeneity of site conditions, the types of farming are diverse, focusing on cash crops, livestock, and various types of mixed farming. The livestock density is 75 livestock units per 100 ha (Statistik Austria, 2015), and organic farming is locally abundant (see Table 2, Fig. 2c).

3.3. Compilation and analysis of regionally relevant governance approaches

Regionally relevant governance approaches were compiled and qualitatively analysed in order to apply the analytical framework and

Table 2
The characteristics of the case study regions. (Data sources for administrative boundaries: CBS 2011[1], BKG 2012[2], Statistik Austria 2016[3]; protected areas: Provincie Gelderland 2017a[1], LfU Brandenburg 2017b, c, e[2], NÖ 2005, 2006, 2017[3]; climate: KNMI 2017[1], DWD 2012[2], ZAMG 2017[3], Hiebl and Frei 2016[3], 2017[3]; soils: Brouwer 2014[1], Wösten 2012[1], De Vries 2003[1], BGR/SDG 2018[2], BFW 2017[3]; land cover: EEA 2016[1], BKG 2009[2], UBA Österreich/EEA 2016[3]; agricultural data: CBS 2020[1], Amt für Statistik Berlin-Brandenburg 2017[2], MIL 2016[2], Statistik Austria 2015[3]).

Characteristics	Case study regions		
	Berg en Dal (the Netherlands)	Spreewald Biosphere Reserve (Germany)	Municipalities of Jauerling-Wachau Nature Park (Austria)
Area [km^2]	93	473	197
Municipalities (2010)	1 (3[4])	21[5]	7[6]
Protected area [%]	Natura 2000: 15%	Natura 2000: 90% Biosphere Reserve: 100%	Natura 2000: 68% Nature Park: 58%
Temperature [°C] • Year/ April–July	9.9/14.1	9.5/15.0	9.8/15.7[4] 8.5/14.3[5] 7.5/13.1[6]
Precipitation [mm] • Year/ April–July	804/249	558/209	611/273[4] 671/299[5] 730/323[6]
Soils			
• Soil types	Sandy podzols, polder soils	Organic soils, hydromorphic soils, gleyic soils	Cambisols, gleyic soils, humous soils
Land cover proportion			
• Arable land [%]	16.5	20.8	6.5
• Grassland [%]	21.1	36.2	4.1
• Agricultural land, other [%]	17.1 (16.4[7] + 0.7[8])	0.5[7]	25.2 (23.1[7] + 2.1[8])
• Forest [%]	22.6	29.6	59.0
• Built-up area [%]	10.9	6.1	3.1
• Other [%]	11.8	6.8	2.2
Agricultural land use			
• Types of farming (based on EC 2008a)	Grazing livestock holdings, field crop holdings, processing system holdings, mixed livestock holdings	Grazing livestock holdings, field crop holdings, mixed crops/ livestock holdings, mixed livestock holdings	Permanent crop holdings, grazing livestock holdings, mixed agricultural holdings, forest holdings
• Arable land	Cereals, root crops (sugar beet, potatoes), arable vegetables, industrial crops	Grain crops (breadstuff: rye, wheat; fodder: barley), forage crops (grass, silage maize, grass-clover), oilseeds (winter oilseed rape), legumes (lupin)	Grain crops (fodder: barley, triticale; breadstuff: wheat, rye), forage crops (grass-clover, silage maize, temporary grass)
• Grassland	Grassland (permanent, temporary, natural), green fodder	Moving pastures, meadows	Permanent pastures (2/1-cut meadows, multiple cut meadows, pastures)
• Horticulture[a]/ permanent crops[b]	Open ground (fruit, vegetables, flowers)[a]	Vegetables[a]/ asparagus, short rotational plantations[b]	Plantations of Christmas trees, fruit trees, vineyards[b]
Livestock			
• Categories	Grazing animals (cattle, sheep, horses), housed	Cattle (e.g. dairy cattle), pigs, sheep, chickens	Cattle (e.g. dairy cattle), pigs, sheep, equid, chickens

(continued on next page)

Table 2 (*continued*)

Characteristics	Case study regions		
	Berg en Dal (the Netherlands)	Spreewald Biosphere Reserve (Germany)	Municipalities of Jauerling-Wachau Nature Park (Austria)
	animals (pigs, chickens)		
Organic farming			
• Land share [%]	3	15–31	2–29

[1]Berg en Dal municipality.
[2]Spreewald Biosphere Reserve.
[3]Municipalities of Jauerling-Wachau Nature Park.
[4]Groesbek, Ubbergen, Millingen an de Rijn, former municipalities 2010
[5]Alt Zauche-Wußwerk*, Briesen, Burg (Spreewald)*, Byhleguhre-Byhlen, Dissen-Striesow, Guhrow, Kolkwitz, Krausnick-Groß Wasserburg, Lübben (Spreewald), Lübbenau/Spreewald, Märkisch Buchholz, Märkische Heide, Münchehofe, Neu Zauche, Schlepzig, Schmogrow-Fehrow, Spreewaldheide, Straupitz, Unterspreewald, Vetschau/Spreewald, Werben; *entirely within the Biosphere Reserve.
[6]Mühldorf, Spitz, Raxendorf, Maria Laach am Jauerling, Weiten, Aggsbach, Emmersdorf 4Altitude: <0–350 m, [5]Altitude: from 350 m to 600 m, [6]Altitude: >600 m.
[7]Heterogeneous agricultural land.
[8]Permanent crops.

answer the three research questions. To this end, five subsequent steps were taken (Fig. 3).

- Step 1: We determined the types of agricultural impact pathways using the analytical framework and defined them according to their effects on the frame conditions for farming and on agricultural production practices (see Section 2.3).
- Step 2: During fieldwork, i.e. in regional stakeholder workshops, and in consultations with regional stakeholders, we identified a total of 23 governance approaches in the respective case study regions (A1 to A23), with a multitude of sources (Table 3) that provided more detail on the governance approaches (Meyer et al., 2016).
- Step 3: In consultation with regional stakeholders, the final selection of governance approaches was undertaken. These approaches were then classified into four governance types and hybrids thereof (according to Vatn 2010) (Supplement 1). To identify the groups, we used the following characteristics (Vatn, 2010, 2015): the main type of actors involved, the kind of interaction between actors (e.g. formal vs. informal), and the type of rules applied (hierarchical, market-based, or collaborative). These were then related to the specifics of the three case study regions. A description was then given of how these governance approaches frame the agricultural production, and which ES are regionally required. In addition, we determined which stakeholders were involved (farmers, others), and what their level of participation was (according to Durham et al., 2014) (Supplement 2). The spatial and temporal dimensions of the approaches were also analysed (Supplement 3).
- Step 4: This data was then used to assign and reclassify the regional governance approaches according to the theoretical agricultural impact pathways by assessing the individual impact of each approach on site and farm conditions as well as on the land use programme and intensity based on the data sources (Table 3). To analyse farmers' leeway for environmentally friendly production practices, three categories of farmers' capacity to adopt them were distinguished (basic, extended, and highly extended capacity; Supplement 4). This capacity depends on the influence of governance approaches on the frame conditions for farming (Section 1.1). Governance approaches that change farm conditions to enhance this capacity were categorised as approaches with an extended capacity. Governance approaches that improve site conditions through a feedback loop from farm conditions were categorised as approaches with a highly extended capacity (Supplement 4).
- Step 5: The impact of governance on agriculture-related ES (TEEB, 2010) was analysed by evaluating the sources (Table 3). The analysis looked at the following ES categories: provisioning, regulating, habitat and supporting, and cultural ES, as well as the degree of integration of multiple ES (Supplement 5).

The utility of the framework for analysing the relations between governance, agriculture, and ES was then outlined in order to relate the

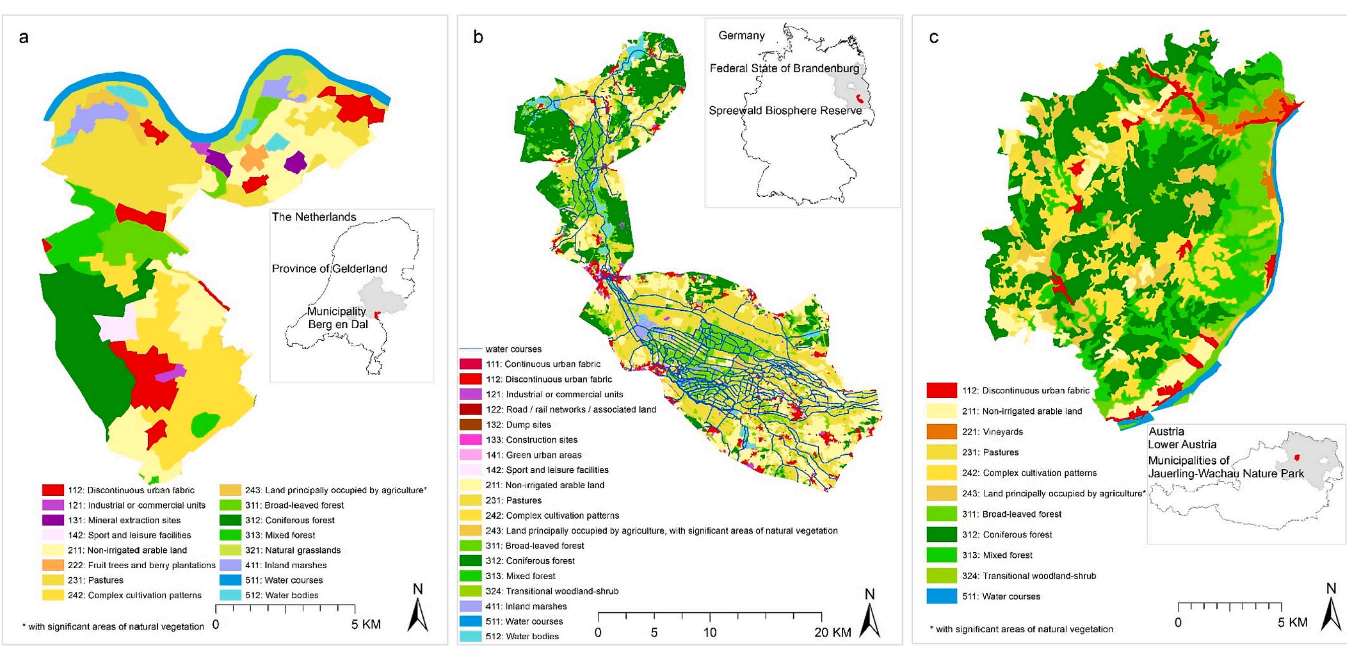

Fig. 2. Land use in the case study regions of a) the municipality of Berg en Dal in the Netherlands, b) the Spreewald Biosphere Reserve in Germany, and c) the municipalities of the Jauerling-Wachau Nature Park in Austria (based on Corine Landcover Data CLC 2012 for the Dutch (EEA 2016) and Austrian (UBA/EEA 2016) case study region and on digital land cover model data for Germany (BKG 2009), depicted according to CLC 2012 categories).

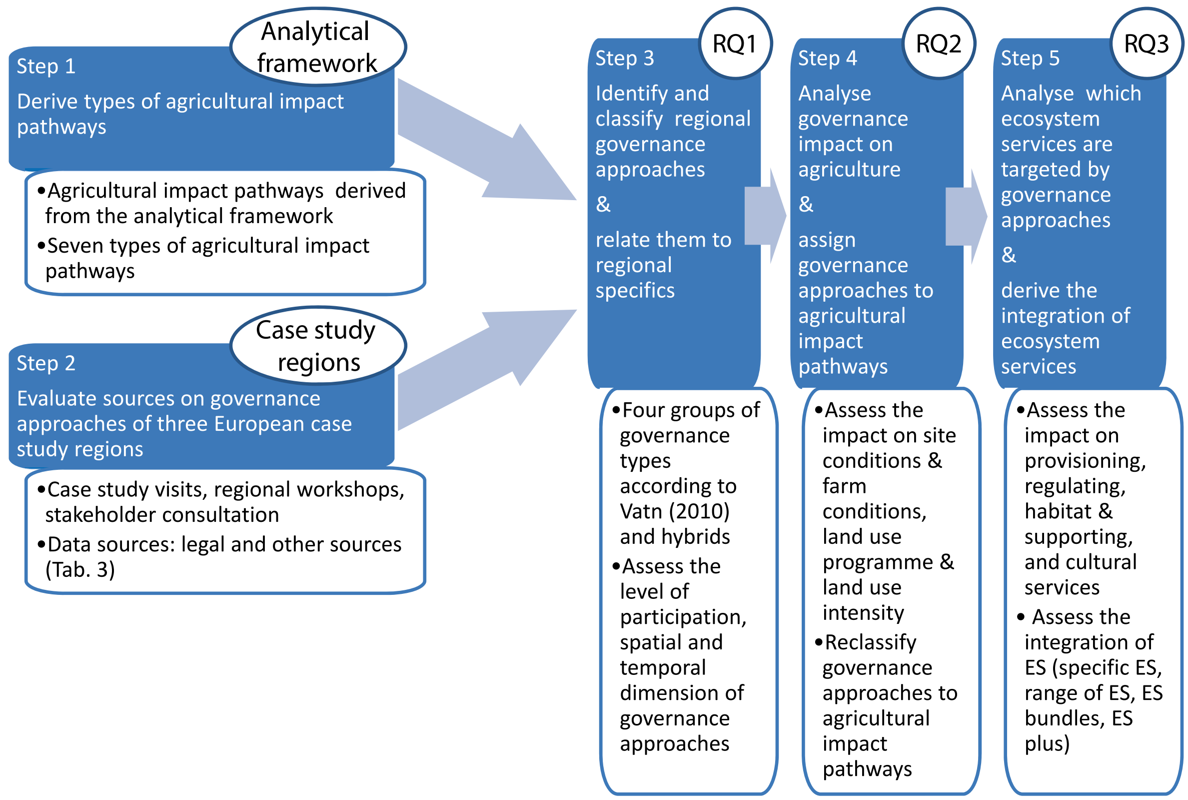

Fig. 3. Methodological approach for a case study application of the analytical framework.

findings of Steps 4 and 5 to the proposed analytical framework.

4. Results: application of the analytical framework to the case study regions

The following section briefly describes the three case study regions according to the main characteristics of the landscape and land use, in order to relate to them the main targets of the governance approaches focusing on agriculture and ES. The individual governance approaches are then analysed using the extended agricultural location theory to identify differences between them and chains of effects in terms of the frame conditions for farming, the affected land use programmes, land use intensity, and targeted ES.

4.1. Regional specifics and governance approaches (RQ1)

To answer RQ1, we identified the governance approaches applied in the case study regions that shape agricultural production and secure particularly significant important ES (Table 4), and describe how both are related to regional specifics. This was underpinned with assessments of participation and the temporal and spatial dimensions inherent in each governance approach (Table 5). The level of participation was indicated for farmers and other stakeholders for both local level as well as their non-local representatives and the administration. The spatial dimension was given for each approach's implementation level and measure level. The temporal dimension was assessed for the duration of each governance approach and its frequency of adaptation. Details of the categories are provided in Supplements 2 and 3. We based our assessments on the sources of the governance approaches (Table 3). The four groups of governance approaches are described in detail in Supplement 1. We found that important hierarchical approaches apply to all regions. Hierarchical approaches with a market-based component were also found in all regions. Other approaches were found to be more specific to the regions, and in most cases were more collaborative in nature.

The Berg en Dal region is an intensively used agricultural landscape, located in a floodplain between the Waal River and a forested, undulating moraine, and in the vicinity of the densely populated area of the city of Nijmegen (see Section 3.3). These characteristics are crucial for an accurate assessment of governance approaches that focus on the delivery of landscape-specific ES. Taken together, most of the eight governance approaches identified (Table 4) have three goals: i) linking agricultural use with environmental aims; ii) strengthening ecological linkages between habitats to support biodiversity; and iii) improving the attractiveness of the landscape for recreation and building environmental awareness. Hierarchical governance systems are present, such as Natura 2000 (A1), which focuses on the conservation of valuable habitats and rare species (A1: S11-23), WFD (A2), which focuses on the quality and quantity of water (A2: S41-47), and, with a market-based component, Greening (A3), which focuses on grassland, crop diversity, and ecological focus areas (A3: S61, S64-67), see Tables 3 and 4. However, the majority of regional governance arrangements are collaborative approaches, focusing on regional goals (A16-A20, Tables 3 and 4), as mentioned above. In particular, efforts to support biodiversity are combined with efforts to support cultural ES in various ways, especially by enhancing the recreational value of the area. Examples include "agri-environmental cooperatives" dedicated to biodiversity, landscape elements, and water management (A16-A17: S114-133), activities to develop and maintain species-rich landscape elements (A18-A19: S134-135), idea exchange and joint activities for landscape improvements by landscape planning (A20: S136-140), and resource mobilisation for landscape (A17: S124-133), see Tables 3 and 4. The more hierarchical governance arrangements (A1-A2) and the hierarchical arrangement with a market-based component (A3) mostly apply to large spatial and temporal scales (Table 5). They allow the participation of farmers and other stakeholders in varying degrees, although only non-local representatives of non-farmers have high levels of participation (Table 5). On the other hand, many collaborative approaches exist in the area (A16-A20), all with high levels of participation for farmers and other

Table 3
The legal basis and other sources of the selected governance approaches. The superscript numbers ([1, 2, 3]) refer to the study regions; 1: the municipality of Berg en Dal; 2: the Spreewald Biosphere Reserve; 3: the municipalities of the Jauerling-Wachau Nature Park. All information is taken either from a "legal basis" or "other sources", which are cited in the text as "S1", "S2", etc., and marked accordingly in this table.

No.	Governance approach	Sources
	Group 1: Hierarchical approaches	
A1	Natura 2000[1, 2, 3]	Legal basis: ECC (1992) (S1), EC (2009) (S2), Wet natuurbescherming (2020)[1] (S3), BNatSchG (2009)[2] (S4), BbgNatSchAG (2013)[2] (S5), Bbg. 9. ErhZV (2017)[2] (S6), MLUL (2015a)[2] (S7), NÖ NSchG (2000)[3] (S8), Verordnung über die Europaschutzgebiete (2020)[3] (S9), BMNT (2018a)[3] (S10)Other sources: EC (2017a, b) (S11-12), LNV (2006, 2017)[1] (S13-14), Provincie Gelderland (2016, 2017a, b, 2018a, b, 2019)[1] (S15-20), Provincie Limburg (2019)[1] (S21), Bouwma (2008, 2018)[1] (S22-23), LfU Brandenburg (2017a, b, c, d)[2] (S24-27), NÖ (2005, 2006, 2008a, b, 2009a, b)[3] (S28-33), Ellmauer 2005[3] (S34)
A2	Water Framework Directive[1, 2, 3]	Legal basis: EC (2000) (S35), Waterwet (2020)[1] (S36), WHG 2018[2] (S37), compensation by: MLUL (2017b)[2] (S38), WRG 2018[3] (S39), compensation by: BMNT (2018a)[3] (S40)Other sources: EC (2008b, c) (S41-42), EC (2012) (S43), MIM (2012, 2015, 2016)[1] (S44-46), Rijkswaterstaat (2019)[1] (S47), MLUV (2005) (S48), MUGV (2011) (S49), MLUL (2016)[2] (S50), BfG (2018)[2] (S51), LfU Brandenburg (2018)[2] (S52), BMLFUW (2010, 2017a)[3] (S53-54), WISA Austria (2020) (S55)
	Group 2: Hierarchical approaches with a market-based component	
A3	Greening[1, 2, 3]	Legal basis: EU (2013b) (S56), Staatssecretaris EZ (2014)[1] (S57), DirektZahlDurchfG (2014)[2] (S58), DirektZahlDurchfV (2014)[2] (S59), BMLFUW (2015)[3] (S60)Other sources: EC (2016a, b, c) (S61-63), EC (2017c, d) (S64-65), ECA (2017) (S66), RVO (2020)[1] (S67), BMEL (2015)[2] (S68), DBV (2019)[2] (S69), AMA (2020)[3] (S70)
A4	Compensatory allowances for less favoured areas[2, 3]	Legal basis: EU (2013a) (S71), MLUL (2017a)[2] (S72), MLUL (Spreewald meadows 2015b, 2020)[2] (S73-74), BMLFUW (2017b)[3] (S75),Other sources: EC (2017e, 2018a, b, c) (S76-79), ENRD (2015a, b, 2016a) (S80-82), MLUL (2018)[2] (S83), BMNT (2018b)[3] (S84)
A5	AECM (single contract)[2, 3]	Legal basis: EU (2013a) (S85), MLUL (2017b)[2] (S86), BMNT (2018a)[3] (S87), Other sources: EC (2017f) (S88), MLUL (2018)[2] (S89), BMNT (2018b)[3] (S90)
A6	LEADER project (hay combustion)[2]	EU (2013a) (S91), Busse et al. (2019b)[2] (S92)
	Group 3: Market-based approaches with a collaborative component	
A7	Spreewald association[2]	MLUL (2017c)[2] (S93), MLUL (2018)[2] (S94), LAG SV (2014, 2018)[2] (S95-96)
A8	Producer-consumer initiative[3]	EVI (2018)[3] (S97)
A9	Nature Park producers[3]	Verein der Naturparke NÖ (2021)[3] (S98), VNÖ (2018a, b)[3] (S99-100)
	Geographical indications and association:	
A10	• PGI[a, 2]	EU (2012) (S101), MLUL (2017c)[2] (S102), MLUL (2018)[2] (S103), LAG SV (2014, 2018, 2019)[2] (S104-106)
A11	• PDO[b, 3]	EU (2012) (S107), VWM (2018)[3] (S108)
A12	• Regional association of winemakers[c, 3]	VWND (2018)[3] (S109)
A13	Sustainable Christmas tree production[3]	Statistik Austria (2015)[3] (S110), Verein Naturpark Jauerling-Wachau (2021)[3] (S111)
A14	Machinery ring[2]	MR Brandenburg (2019)[2] (S112)
A15	Employer grouping[2]	SK Brandenburg (2019)[2] (S113)
	Group 4: Collaborative approaches	
	Agri-environmental cooperatives	
A16	• AECM (group contract)[1]	Legal basis: EU (2013a) (S114), Staatssecretaris EZ (2015)[1] (S115)Other sources: ENRD (2016b) (S116), Deelen and Mulders (2016) (S117), EZ (2016)[1] (S118), EZ (2017)[1] (S119), RVO (2018)[1] (S120), BIJ12 (2018)[1] (S121), Boerennatuur (2018)[1] (S122), CR (2018)[1] (S123)
A17	• Pilot for green and blue services[1]	LNV/VROM (2008)[1] (S124), Bekers et al. (2011)[1] (S125), Niemeijer et al. (2012, 2014)[1] (S126-127), Nijssen et al. (2016)[1] (S128), Overbeek et al. (2009, 2010, 2011a, b)[1] (S129-132), Wigmann and Willers (2018)[1] (S133)
A18	Landscape Oijpolder-Groesbek Foundation[1]	SLOG (2018)[1] (S134)
A19	Association of farmers and citizens[1]	De Ploegdriver (2018)[1] (S135)
A20	Landscape community & development plan[1]	De Ploegdriver (2012)[1] (S136), LC (2018)[1] (S137), Gemeente Groesbeek (2015a, b, c)[1] (S138-140)
A21	Water management board[2]	Traditional commitment[2], Kubatzki (2018)[2] (S141)
A22	Citizen Foundation Cultural Landscape Spreewald[2]	Spreewaldstiftung (2019a, b)[2] (S142-143), Hirt (2017)[2] (S144), Busse et al. (2019a)[2] (S145), Petschick (2018)[2] (S146)
A23	Association of the municipalities of Jauerling-Wachau Nature Park[3]	Legal basis: NÖ NSchG (2000)[3] (S147) Other sources: Verein Naturpark Jauerling-Wachau (2021)[3] (S148)

[a]PGI = Protected Geographical Indication, [b]PDO = Protected Designation of Origin, [c]Regional association of winemakers with legally defined growing area

stakeholders. They target ES more on a local to regional scale, and have short-term to long-term perspectives (Table 5).

The Spreewald is a cultural landscape with unique natural habitats in the lowlands around the Spree River. Water management has dominated the historical landscape development, and is still crucial for the current situation, especially in light of recent efforts to integrate various types of land use, including agriculture, forestry, and fisheries, with the significant attractiveness of the area as a tourist destination. We identified various major characteristics unique to the region that the twelve governance approaches address: i) the maintenance of protected, valuable habitats and species, as well as improvements in water quality and the structure of watercourses; ii) further development of the Spreewald's image as a marketing strategy for agricultural products and a recreation destination; iii) preservation of the main characteristics of the cultural landscape, including agricultural and forested areas, natural and semi-natural habitats (such as valuable and typical meadows), and places of interest for tourism. Purely hierarchical approaches are in place to conserve valuable habitats and rare species (A1: S11-12, S24-27), as well as secure the quantity and quality of water (A2: S41-43, S48-52), see Tables 3 and 4. Several hierarchical approaches with a market-based component support sustainable agricultural practices (e.g. A3, A5: S62, S64-66, S68-69, S88-89) and work to maintain the management of poor grassland (A4, A5, A6: S73-74, S88-89, S91-92), see Tables 3 and 4. Market-based approaches with a collaborative component are used to enhance the value of the cultural landscape (e.g. A7: S93-96), to

Table 4
Objectives of the analysed governance approaches in the case study regions. The superscript numbers ([1, 2, 3]) refer to the study regions; 1: the municipality of Berg en Dal; 2: the Spreewald Biosphere Reserve; 3: the municipalities of the Jauerling-Wachau Nature Park.

No.	Governance approach	Objective
	Group 1: Hierarchical approaches	
A1	Natura 2000[1, 2, 3]	Valuable habitats, rare and threatened species
A2	Water Framework Directive[1, 2, 3]	Quantity and quality of water
	Group 2: Hierarchical approaches with a market-based component	
A3	Greening[1, 2, 3]	Permanent grassland, crop diversity, EFA[d]
A4	Compensatory allowances for less favoured areas[2, 3]	Agricultural land use on less favoured areas
A5	AECM (single contract)[2, 3]	A wide variety of aspects of sustainable agriculture
A6	LEADER project (hay combustion)[2]	Energy production with otherwise unusable biomass, traditional meadows
	Group 3: Market-based approaches with a collaborative component	
A7	Spreewald association[2]	Valorisation of a cultural landscape (e. g. market access)
A8	Producer-consumer initiative[3]	Sustainable production, direct marketing
A9	Nature Park producers[3]	Cultural landscape, traditional and organic production
	Geographical indications and association:	
A10	• PGI[a, 2]	Vegetable production (traditional products)
A11	• PDO[b, 3]	Fruit production (traditional products)
A12	• Regional association of winemakers[c, 3]	Protection of quality and origin of wine by designating territory of origin
A13	Sustainable Christmas tree production[3]	Sustainable cash crop production on unfavourable agricultural land involving cooperation between producers and the Nature park association
A14	Machinery ring[2]	Machinery sharing
A15	Employer grouping[2]	Employee sharing
	Group 4: Collaborative approaches	
	Agri-environmental cooperatives	
A16	• AECM (group contract)[1]	Specific objectives of biodiversity, landscape elements, water management
A17	• Pilot for green and blue services[1]	Exploitation of private resources for landscape, green infrastructure, biodiversity, local recreation
A18	Landscape Oijpolder-Groesbek Foundation[1]	Landscape elements of the cultural landscape (administer development/ maintenance of landscape elements)
A19	Association of farmers and citizens[1]	Landscape elements of the cultural landscape (practical realisation)
A20	Landscape community & development plan[1]	Strengthening of contact and joint activities between initiatives, provision of the planning basis for all landscape activities
A21	Water management board[2]	Water management for land users, fostering of collaboration
A22	Citizen Foundation Cultural Landscape Spreewald[2]	Exploitation of civil/public/private resources for cultural landscapes
A23	Association of the municipalities of Jauerling-Wachau Nature Park[3]	Pooling of municipal resources, grassland preservation, tourism

[a]PGI = Protected Geographical Indication, [b]PDO = Protected Designation of Origin, [c]Regional association of winemakers with legally defined growing area, [d]EFA = Ecological Focus Areas.

establish the name of the area as a sign for high-quality vegetable products (A10: 101–106), and to support agriculture in the more efficient use of machinery and labour (A14-A15: S112-113), see Tables 3 and 4. Purely collaborative approaches include water management arrangements for the benefit of all land users (A21: S141) and an initiative to exploit various resources for the development of the cultural landscape (A22: S142-146), see Tables 3 and 4. All four groups of governance approaches were detected in the region (Table 4). The general hierarchical approaches, some with a market-based component (A1-A6), mostly cover larger temporal and spatial scales, with A6 being a regionally specific exception (addressing hay combustion), with a high level of stakeholder participation (Table 5). Market-based approaches with a collaborative component and collaborative approaches achieve medium to high stakeholder participation; the collaborative approaches especially involve local farmers on high participation levels (Table 5).

Table 5
The level of participation (by farmers and other stakeholders) and the spatial/ temporal dimension of the governance approaches identified in the case study areas. The superscript numbers ([1, 2, 3]) refer to the study regions; 1: the municipality of Berg en Dal; 2: the Spreewald Biosphere Reserve; 3: the municipalities of the Jauerling-Wachau Nature Park. (L-local, R-representatives & administration; with participation level A: very low*, B: low, C: medium, D: high; see Supplement 2); the spatial dimension of the implementation/measure level (n: national; s: state/province; r: regional; l: local; p: plot; for combinations; see Supplement 3); the temporal dimension for duration/frequency of adaptation (s: short; m: medium; l: long term; see Supplement 3).

No.	Governance approach	Participation				Dimension	
		Farmers		Others		Spatial	Temporal
		L	R	L	R		
	Group 1: Hierarchical approaches						
A1	Natura 2000[1,2,3]	C	B	B	D	s,r/p	l/m
A2	Water Framework Directive[1,2,3]	C	B	B	D	r/r,p	l/m
	Group 2: Hierarchical approaches with a market-based component						
A3	Greening[1,2,3]	C	B	B	D	n,s/-	m/m
A4	Compensatory allowances for less favoured areas[2,3]	C	B	B	D	n,s/r	m/m
A5	AECM (single contract)[2,3]	C	B	B	D	n,s/r	m/m
A6	LEADER-project (hay combustion)[2]	C, D			D	l/p	l/s
	Group 3: Market-based approaches with a collaborative component						
A7	Spreewald association[2]	C	D	C	D	r/l	l/s
A8	Producer-consumer initiative[3]	D		D		r/l	l/s
A9	Nature Park producers[3]	C		D	D	r/l	l/s
	Geographical indications and association:						
A10	• PGI[a, 2]	C	D		D	r/l	l/l
A11	• PDO[b, 3]	C				r/l	l/l
A12	• Regional association of winemakers[c, 3]	D				r/l	l/l
A13	Sustainable Christmas tree production[3]	D			C	l/p	l/l
A14	Machinery ring[2]	C			D	s/-	l/s
A15	Employer grouping[2]	C		C	D	r/-	l/s
	Group 4: Collaborative approaches						
	Agri-environmental cooperatives:						
A16	• AECM (group contract)[1]	C, D	D	C, D	D	r/p	m/s
A17	• Pilot for green and blue services[1]	C, D	D	C, D	D	r/p	l/s
A18	Landscape Oijpolder-Groesbek Foundation[1]	C, D		C, D		r/p	l/s
A19	Association of farmers & citizens[1]	C, D		C, D		r/p	l/s
A20	Landscape community & development plan[1]	C, D	D	C, D	D	r/p	l/s
A21	Water management board[2]	D	D	D	D	r/r,p	l/s
A22	Citizen Foundation Cultural Landscape Spreewald [2]	C, D		C, D	D	r/p	l/s
A23	Association of the municipalities of Jauerling-Wachau NP[3]			D		r/r	l/s

[a]PGI - Protected Geographical Indication, [b]PDO - Protected Designation of Origin, [c]Regional association of winemakers with legally defined growing area
*Level A: very low was not identified in the governance approaches analysed.

The Jauerling-Wachau region is a predominantly mountainous area, bounded by the Danube in the southeast (see Section 3.2). The site conditions vary dramatically in terms of both suitability for agricultural production and attractiveness for tourism. South-facing slopes and plains allow the cultivation of high-quality grapes and apricots, especially near the river. Many of these areas are also significant for tourism, with picturesque villages on the river banks, which also serve as markets for regional agricultural products. At the other extreme are locations in the higher altitudes of the nature park, which are isolated from the river and have a poor infrastructure. Here, sustainable agricultural production faces several challenges, including the maintenance of the agricultural landscape structure as such, in combination with cultural ES and biodiversity protection. Relevant governance approaches for agriculture and ES address either i) sustainable agricultural production, including the maintenance of landscape characteristics and biological diversity; ii) specific regional agricultural products and their marketing; or iii) the nature park as a whole. While the hierarchical approaches of Natura 2000 (A1: S11-12, S28-34) and WFD (A2: S41-43, S53-55) focus on specific targets, or those hierarchical approaches with a market-based component on ES ranges (A3, A5: S63-66, S70, S88, S90) or ES bundles (A4: S79, S81, S84), most approaches are market-based approaches with a collaborative component, see Tables 3 and 4. Examples include the direct marketing of sustainable agricultural production (A8-A9, A11-A13), sometimes with a focus on organic production (A9: S98-100) or with an emphasis on the local origin of the goods (A11-A12: S107-109). One aspect specific to the more remote areas is the support of Christmas tree cultivation (A13: S110-111), which has become an important source of income in otherwise uneconomical agricultural systems. The only collaborative approach detected aims to support and coordinate grassland preservation and tourism (A23: S148). Altogether, eleven governance approaches were identified, representing all types (Table 4). One special characteristic of the area is the focus on regional products, e.g. wine and Christmas trees. This is facilitated by market-based approaches with a collaborative component, characterised by intense participation by farmers as well as other stakeholders (Table 5). The collaborative approach (A23) addresses the nature park as a whole, bringing together the municipalities as local stakeholders (Table 5).

4.2. The impact of governance approaches on agriculture (RQ2)

To answer RQ2, each governance approach was analysed (Tables 3 and 4) with regard to agricultural location theory, first concerning whether they are based on or have an effect on site conditions, or whether they affect farm conditions. We then assessed whether the approach deals with the land use programme and consequently, but indirectly, the land use intensity, or whether instead it deals directly with land use intensity. Finally, we examined whether the approaches directly affected ES. According to these findings, we assigned each governance approach to different "agricultural impact pathways" (from Paths A to G, see Table 6). The paths can be traced using the description in Table 1; they are shown in Fig. 1. Detailed assessments of the governance approaches can be found in Supplement 6.

While purely hierarchical (A1-A2) approaches and hierarchical approaches with a market-based component (A3-A5) were predominantly assigned to Paths A and/or B, as well as to Path G (A1-A2) and once to Path C (A6), the market-based approaches with a collaborative component and the purely collaborative approaches were mainly assigned to Paths E and/or F (A7-A12, A16-A20) and to a lesser extent to Paths C or D (A13-A15) and Path A (A21-22); some approaches follow Path G (A16-A23), see Table 6.

Governance approaches differ significantly in the first step of the pathway, i.e. how they address the frame conditions for farming (Table 6, Supplement 6). The hierarchical approaches are mainly based on natural site conditions, i.e. they are related to specific target areas, such as Natura 2000 sites (A1: e.g. S13-14, S24, S32-33) or river basins (A2: e.g. S46, S50, S54) (see Tables 3 and 6, Supplement 6). The hierarchical approaches with a market-based component mainly impact site conditions related to markets; AECM (A5: S89, S90), for example, they

Table 6
The main characteristics of the governance approaches detected in the case study areas, divided into four groups; their respective chain of effects on the farming systems (types of agricultural impact pathways: A-G, see Section 2.3); the farmers' leeway for environmentally friendly farming (leeway with B - basic capacity, E - extended capacity, HE - highly extended capacity to adopt production practices); the mainly targeted ecosystem services: P (provisioning: 1-food, 2-fodder, 3-special crops, 4-energy crops, 5-animal products), R (regulating: 1-climate, 2-soil, 3-water, 4-biological control, 5-pollination); H (habitat & supporting: 1-habitats, 2-species, 3-landscape elements); C (cultural: 1-cultural landscape, 2-recreation, tourism, 3-education); integration of ES (s: specific ES, r: range of ES, b: ES bundle, b+: ES plus, additional affected ES, not explicitly targeted).

No.	Governance approach	Agricultural impact pathways							Leeway	Mainly targeted ES: Provisioning (P)					Regulating (R)					Habitat (H)			Cultural (C)			Integration of ES
		A	B	C	D	E	F	G		1	2	3	4	5	1	2	3	4	5	1	2	3	1	2	3	
	Group 1: Hierarchical approaches																									
A1	Natura 2000[1, 2, 3]	X	X					X	B											X	X	X				s, b+
A2	Water Framework Directive[1, 2, 3]	X	X					X	B								X									s, b+
	Group 2: Hierarchical approaches with a market-based component																									
A3	Greening[1, 2, 3]	X	X						B	X	X	X	X		X	X	X		X	X	X	X	X			r
A4	Compensatory allowances for less favoured areas[2, 3]	X							B	X	X	X	X	X		X				X	X	X	X	X	X	b
A5	AECM (single contract)[2, 3]	X	X						B	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	r
A6	LEADER project (Hay combustion)[2]			X					E			X			X					X	X	X	X	X		b
	Group 3: Market-based approaches with a collaborative component																									
A7	Spreewald association[2]					X	X		HE	X	X	X	X	X	X		X					X	X	X	X	r
A8	Producer-consumer initiative[3]						X		HE	X	X		X	X	X								X			b
A9	Nature Park producers[3]					X	X		HE	X	X		X	X						X	X	X	X			b
	Geographical indications:																									
A10	• PGI[a, 2]					X	X		HE				X										X			b
A11	• PDO[b, 3]					X	X		HE				X										X			b
A12	• Regional association of winemakers[c, 3]					X	X		HE				X							X	X	X	X			b
A13	Sustainable Christmas tree production[3]			X					E				X										X			b
A14	Machinery ring[2]				X				-*	X	X	X	X	X												s
A15	Employer grouping[2]				X				E	X	X	X	X	X											X	b
	Group 4: Collaborative approaches																									
	Agri-environmental cooperatives:																									
A16	• AECM (group contract)[1]					X	X	X	HE	X	X		X	X			X	X	X	X	X	X	X			b
A17	• Pilot for green and blue services[1]					X	X	X	HE		X			X			X	X	X	X	X	X	X	X	X	b
A18	Landscape Oijpolder-Groesbek Foundation[1]							X	-**								X	X	X	X	X	X	X	X	X	b
A19	Association of farmers & citizens[1]					X	X	X	HE	X	X		X	X			X	X	X	X	X	X	X	X	X	b
A20	Landscape community & development plan[1]					X	X	X	HE								X	X	X	X	X	X	X	X	X	b
A21	Water management board[2]	X						X	B	X	X	X	X	X			X			X	X	X	X	X		b
A22	Citizen Foundation Cultural Landscape Spreewald[2]	X						X	B				X	X	X	X	X		X	X	X	X	X	X	X	b
A23	Association of the municipalities of Jauerling-Wachau NP[3]							X	-**											X	X	X	X	X	X	b

[a]PGI - Protected Geographical Indication, [b]PDO - Protected Designation of Origin, [c]Regional association of winemakers with legally defined growing area, *environmentally friendly production practices are not explicitly mentioned, **not via agriculture.

can have an impact on market-related site conditions: depending on farmers' opportunity costs, the payments they receive from the programme either offset foregone earnings or even supplement farmers' incomes. The "Hay Combustion" LEADER project (A6: S92) is an exception to the focus on market-related site conditions, since it instead addresses farm conditions by preventing land abandonment. It helps to empower the farm estate, and facilitate the effective use of farm resources by using biomass from small-scale wet meadows (see Tables 3, 4, and 6, Supplement 6).

The market-based approaches with a collaborative component revealed systems that created feedback loops between farm and site conditions (Path E and/or F); i.e. by collaboratively defining the specific qualities of production and products, these approaches enabled all participating farmers to change site conditions (A8-12) (see Tables 3 and 6). For example, geographical indications (A10-A12: S106, S108, S109) generate market access for high-quality regional products ("branding"). In doing so, they enhance the value of the cultural landscape and create new site conditions for farmers. Some approaches only affect farm conditions (A13-15), either by allowing the continuation of farming under unfavourable site conditions (A13: S110-111) or by helping farmers to use their farm resources more effectively (A14-15: S112-113) (see Tables 3 and 6, Supplement 6). The collaborative approaches were assigned to different agricultural impact pathways because they affect the frame conditions differently: governance approaches in the Berg en Dal region mainly follow Paths E and F (Table 6). For example, in AECM group contracts, an agri-environmental cooperative coordinates environmentally friendly measures for farms at the landscape level in a designated area and aligns them with the regional objectives (A16: S120-123) (see Tables 3 and 6, Supplement 6). This has an impact on the chain of effects, encouraging farmers from this area to join the cooperative. Farmers who apply management packages based on the cooperative's management strategy change their farming conditions, and thus agricultural practices, in line with the cooperative's objectives. As a consequence, farmers may receive payment claims from the cooperative, and the cooperative can mobilise resources for sustainable landscape management, i.e. farmers collectively change site conditions as part of the cooperative. In the Spreewald region, the governance approaches are based on landscape-specific site conditions, and thus follow Path A (Table 6). For instance, water management is steered collaboratively to balance the interests of all land users, including farmers, to ensure, for example, the productivity of fields, water retention in dry years, and water drainage in wet years (A21: S141). Maintaining valuable elements (wet meadows, meadow orchards, meadows with a flood regime) and avoiding land abandonment are also addressed by collaborative approaches, and require maintenance measures that are applied by farmers (A22: S142-146) (see Tables 3 and 6, Supplement 6).

The consequences for the land use programme or land use intensity differ only slightly among the governance approaches (see Tables 3 and 6, Supplement 6). The extent to which the land use programme or land use intensity is addressed depends on the objectives of the governance approaches. Most governance approaches (A1-A3, A5, A7, A9-A12, A16-A17, A19-A20) address the land use programme and land use intensity, and have a broad portfolio of measures for agriculture to achieve their objectives (see Table 4). A few governance approaches have a smaller portfolio of measures, i.e. they address either the land use programme and consequently land use intensity (A4, A6, A13, A21-A22) or land use intensity only (A8, A14-A15) to achieve their objectives (see Table 4). Some governance approaches also address ES through pathways outside agriculture (A1-A2 and A16-A23, Table 6).

The farmers' leeway for environmentally friendly farming, i.e. the capacity to adopt environmentally friendly production practices (see Section 1.1, Table 6) differs between the governance approaches. The capacity was enhanced in one hierarchical governance approach with a market-based component (A6) and in two market-based approaches with a collaborative component (A13, A15). Moreover, the capacity was highly enhanced in most of the market-based approaches with a collaborative component (A7-A12) and the collaborative approaches (A16-A17, A19-A20). The purely hierarchical governance approaches (A1-A2) and half of the hierarchical approaches with a market-based component (A3-A5) were categorised as approaches with a basic capacity to adopt environmentally friendly production practices.

4.3. The impact of governance approaches on ES (RQ3)

To address RQ3, we explored the extent to which the different types of governance approaches influence the ES categories. To this end, we analysed which ES are targeted in particular, and examined the extent to which ES from different categories are combined.

All governance approaches under review address ES, but vary in their exact targets and the number and combination of targets. We classified them as either specific ES (targeted ES belonging to the same category of ES), a range of ES (targeted ES belonging to at least two ES categories), an ES bundle (targeted ES belonging to at least two categories of ES and which are synergistic), or ES plus (additional affected ES, not explicitly targeted) (see Supplement 5). Table 6 summarises the governance approaches and the ES addressed (see Supplement 6 for more details).

Purely hierarchical approaches (A1, A2) attempt to foster specific ES that are both valuable to society and particularly vulnerable, especially biological diversity (A1: S13-14, S24, S32-33) and water quality and quantity (A2: S46, S50, S54), see Tables 3 and 6. These approaches can also address additional ES (Table 6). Hierarchical approaches with a market-based component clearly differ from this. They address either a broad range of ES, such as "Greening" (A3: S66) and AECM (A5: S89-90) or ES bundles, such as "Compensatory allowances for less favoured areas" (A4: S72, S75) and the "Hay Combustion" LEADER project (A6: S92), see Tables 3 and 6. Market-based approaches with a collaborative component generally address the marketing of regional products and increase the value of the cultural landscape, e.g. through the support of adequate production systems. Accordingly, provisioning and cultural ES are the main targets (A7-A13), which can be regarded as ES bundles, such as the targeted ES by the "Spreewald Association" (A7: 95–96), see Tables 3 and 6. Some approaches attempt to deliver additional ES, e.g. for specific habitat types (A7, A9, A12) or specific regulating ES (A7, A8), such as Spreewald Meadows as a landscape-shaping element (A7: 95–96), see Tables 3 and 6. The "machinery ring" addresses only provisioning ES (A14: S112), see Tables 3 and 6. All the collaborative approaches are designed to deliver ES bundles, combining habitat and cultural services (A16-A23) with regulating ES (A16-A22) and/or provisioning ES (A16-A17, A19, A21-22) (see Table 6). These include, for example, the "Pilot for Green and Blue Services" (A17: S124-133) and the "Citizen Foundation Cultural Landscape Spreewald" (A22: S142-146), see Tables 3 and 6.

4.4. Using the framework to analyse relations between governance, agriculture, and ecosystem services

The three case study regions are cultural landscapes dominated by agricultural land use, and thus have a number of characteristics in common. In addition, they all have a unique status as a nature conservation area and other specifics that must be protected and thus individually governed. Typically for these landscapes, the demand for ES is manifold, and the provision of ES is often closely related to the prevailing agricultural systems. Hence it is particularly important to know what is produced and how this is done. Some ES are of interest for the public in general and for all locations. Examples include clean water, or valuable habitats and species (A1-A2, Tables 3, 4, and 6). Other ES are defined at the local level, such as the provision of specific regional agricultural products, which is important for local producers and consumers (e.g. A8-A9), cultural services that are related to the use and value of the cultural landscape (e.g. A7), or collaboratively managed ES bundles (e.g. A16, A22), see Tables 3, 4, and 6. Our analyses of the governance approaches revealed typical pathways in which they affect agriculture through the effects on certain frame conditions for farming, to which farms must or can adapt in predictable ways by modifying the land use programme, the land use intensity, or both (Section 4.2). "Predictable ways" include farmers' leeway for environmentally friendly farming, which may differ significantly among the governance approaches (Section 4.2). Furthermore, different types of governance approaches address different types of ES and achieve different levels of ES integration (Section 4.3). Taken together, the mechanisms through which the components of farming systems are influenced by the specific governance approaches in the case study regions became transparent through the use of the analytical framework for RQ 2 and 3, see the previous two sections.

5. Discussion

5.1. Benefits of the proposed framework

In order to analyse the impact of governance approaches on ES in agricultural landscapes, we used agricultural location theory as a simple farm model and extended it to include governance and its impact on the frame conditions for farming as well as the ES affected by farming systems. The integrative nature of the framework, which is crucial for an ES assessment at the landscape level (Müller et al., 2010), was covered by interlinked modules. The core modules represent specifics of agriculture (i.e. frame conditions for farming, production practices). The modules define a limited number of impact chains, which we call "agricultural impact pathways", describing how different governance approaches can influence the frame conditions for farming, and how this in turn can influence ES provision through farming at the farm level and through agricultural land use patterns also at the regional level (see Section 2.2). All governance approaches identified in the contrasting case study regions could be assigned to such an impact pathway (see Section 4.2). This made the impact of these approaches on land use programmes and levels of land use intensity – and consequently on ES provision (see Section 4.3) – more transparent. Furthermore, it demonstrated the applicability of the framework.

5.2. Addressing regional specifics by governance approaches (RQ1)

The specific characteristics of the case study regions in terms of natural conditions, land use, historical land use development, and ES needs were clearly reflected in the governance approaches. In the intensively used agricultural landscape of Berg en Dal, there was an obvious demand for habitat and cultural ES; collaborative approaches predominated, and focused on the mobilisation of resources to increase the amount and quality of these ES. The cultural landscape of the Spreewald is characterised by diverse types of land use, with a broad governance mix: market-based approaches with a collaborative component and collaborative approaches complement the hierarchical ones to enhance the value of the cultural landscape and balance the diverse interests of land users. In the extensively used region of Jauerling-Wachau, market-based approaches support the economic development of the cultural landscape by bringing quality products to market; these approaches complement more hierarchical ones. The results for the three case study regions show that market-based approaches with a collaborative component and collaborative approaches fulfil regional demands that seem unachievable with more hierarchical approaches, and they achieve high levels of participation, which are crucial for regional development and the integration of sustainable practices (Prager and Freese, 2009; Menconi et al., 2017). This is in line with studies which indicate that a regionally adapted governance mix is often the most powerful option to improve ES provision (Kenward et al., 2011; Ring and Schröter-Schlaack, 2011; Bastian, 2013a). Instruments other than agricultural policy are often established at the local level to improve ES provision (Dwyer et al., 2020). In each case study region, the region-specific components of the governance mix identified fit to regional demand for cultural, biodiversity, and provisioning ES, and are designed by regional stakeholders.

5.3. Governance types and differences in agricultural impact pathways (RQ2)

The different types of governance approach differ clearly in their agricultural impact pathways. These differences emerged in the corresponding frame conditions, rather than in the production practices themselves. While hierarchical approaches mainly dealt with natural site conditions, and hierarchical approaches with a market-based component affected market site conditions, the market-based approaches with a collaborative component created entirely new site conditions for farmers by generating market access for regional, premium-quality products. They thus increase the economic value of the cultural landscape (Knickel and Maréchal, 2018). Another strategy was to reduce costs by sharing resources. This is important, because when farmers focus on external factors other than product prices and sales, such as cost and risk reduction (e.g. Firbank et al., 2013a; Firbank et al., 2013b), their efforts also affect production practices and environmental outcomes (e.g. Albert et al., 2017, Diogo et al., 2015, Ruijs and Van Egmond, 2017). However, these cost-reduction efforts occurred less frequently in the case study regions. The findings among 11 European case studies (Brouwer et al., 2018) confirm that the valorisation process is often based on labelling and certification, and on value chain integration, with a prominent positioning of producers. Less frequently, emerging strategies aim at cost reduction. Collaborative approaches can change farm conditions and, in a feedback loop, also site conditions. For example, the results in the Berg en Dal region show that actions to improve ES provision at the level of individual farms and plots as targeted and regionally concerted actions generate additional financial resources from private funding for the whole landscape, as shown also by Maréchal et al. (2018), and with benefits for farmers, as also shown by Prager et al. (2015). Collaborative approaches can thus be used in a targeted way to obtain financial resources for maintaining the cultural landscape and to promote information exchange and cooperation (e.g. Franks and Mc Gloin, 2007; Franks 2010; van Dijk et al., 2015). Such collaborative approaches should be supported by agricultural policy, e.g. by strengthening their position in the future CAP in the European Union (Maréchal et al., 2018). In the case study regions considered in this study, exogenous factors driving such approaches (García-Martín et al., 2016) were the lack of long-term, flexible financial resources for maintaining cultural landscapes, as well as the need to cooperate due to environmental or legal requirements. Collaborative approaches can be beneficial to farmers in many ways (Prager, 2015, see Section 1.2). Besides these benefits, we found that the collaborative approaches and the market-based approaches with a collaborative component can improve frame conditions at the local level, as well as farmers' leeway for environmentally friendly farming, which might in turn help them to implement sustainable production practices.

5.4. Governance types and their effects on various ES (RQ3)

We found that the types of governance approach affect ES differently in terms of targeted ES categories and the integration of ES. While hierarchical approaches address specific ES that have widespread societal interest and are highly vulnerable, hierarchical approaches with a market-based component address a broader range of ES, or work to bundle ES from multiple ES categories. The market-based approaches with a collaborative component also address ES bundles, but mainly provisioning and cultural ES, using various means to increase the value of the cultural landscape. This also holds for collaborative approaches, which combine all ES categories. These findings confirm that the various individual governance approaches have different purposes that complement each other, leading to regionally specific governance mixes (see

Section 5.2). Stallman (2011) asserted, for the example of collaborative approaches, that different types of governance approaches are more effective in producing different ES. They found that collaborative governance was only moderately suited for cultural and habitat ES. Our results are different, however. These types of ES were often governed collaboratively in the case study regions. Hence, regional processes might make all the difference (de Krom, 2017; Westerink et al., 2017b). The findings confirm the results of a European study (Knickel and Maréchal, 2018; Dwyer et al., 2018: PEGASUS research project) that also demonstrated the added value of market-based (Brouwer et al., 2018) and collaborative (Maréchal et al., 2018) governance approaches in complementing hierarchical approaches to ES provision and public benefit generation (Dwyer et al., 2020).

5.5. Possible avenues for further development of the framework

One important difficulty emerged over the course of the research for assessing potential effects of governance approaches on ES via farming. It was particularly difficult to assess the options available to farmers, i.e. the leeway for environmentally friendly farming, to adapt to changes in frame conditions. Many governance approaches are put into effect to secure or improve specific ES. However, it often remains unclear whether farmers use the available leeway to change their land use programmes and land use intensity towards more sustainable farming. The framework discussed in this paper allows a more detailed analysis of these uncertainties, and may offer strategies to steer farmers in a more sustainable direction, especially it allows researchers to relate and compare the effects of different governance types to each other. This touches on another area of research, namely farmer behaviour (Howley et al., 2015; van Dijk et al., 2016; Bartkowsky and Bartke, 2018; Dessart et al., 2019), which cannot be explained by wholly economic considerations, and which has not yet been considered in the suggested framework.

Focusing the framework on farming systems and the corresponding effects on ES can also help address the effects of driving forces of land use that shape the landscape in terms of ES and biodiversity. This may also be useful to describe the impact of other drivers on ES and biodiversity beyond farming systems (Maes et al., 2015) that have not been covered by the analytical framework. We developed and tested the extended framework using governance approaches that were analysed as aggregates, and did not take into account the individual measures of these approaches. It would therefore make sense to improve the analytical depth of the framework by including more detailed "input" related to governance.

Furthermore, our applications were of a qualitative nature, seeking to address frame conditions for farming, the intended land use programmes, levels of land use intensity, and ES. This enabled us to determine whether governance approaches respected farmers' opportunities and constraints in a balanced way. Quantitative analyses would also be possible using the analytical framework, and would significantly expand the repertoire for further applications.

6. Conclusions

To achieve the overall objective of this study, a comprehensive analytical framework was developed and applied that allows to identify the impact of governance approaches in agricultural landscapes on ES through agriculture, i.e. farming systems, to evaluate the overall performance of governance approaches. Agricultural location theory as the core of this framework, extended to include governance and ES, is suitable to provide a detailed insight into regional agriculture and its frame conditions. This insight is necessary to identify the specific impacts of governance on agriculture, and thus on ES. Obviously, each agricultural landscape has specific characteristics at various levels, including traits such as natural site conditions, the typical types of farm, and demand for ES. In order to bundle and streamline governance approaches to efficiently address regional specifics, a specifically designed mix of governance approaches seems appropriate. This kind of framework enables such a holistic assessment.

The application of the framework to the case study regions also shows that a mix of governance approaches is appropriate to address a wide range of ES by different agricultural impact pathways at the regional level. The analyses show that the governance types differ in: their adaptation to regional specifics (RQ1); their agricultural impact pathways and thus the effects on agriculture addressed (RQ2); and ES provision (RQ3). Hierarchical approaches and hierarchical approaches with a market-based component mainly deal with natural site conditions and affect market site conditions. They usually target specific sets of ES of high societal interest and vulnerability or a broader range of unrelated ES. Market-based approaches with a collaborative component and purely collaborative approaches complement the above approaches. In contrast to these, they tend to create new site conditions, e.g. market access, valuing cultural landscapes through premium-quality products, for instance, and mobilising resources for the maintenance of cultural landscapes. They can improve farmers' leeway for environmentally friendly farming. They usually address ES of high regional demand, often as ES bundles combining provisioning and cultural ES or cultural and habitat ES.

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.

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Appendix

Regulatory frameworks

Bbg. 9. ErhZV, 2017. Neunte Verordnung zur Festsetzung von Erhaltungszielen und Gebietsabgrenzungen für Gebiete von gemeinschaftlicher Bedeutung (Neunte Erhaltungszielverordnung - 9. ErhZV) *) vom 29. Juni 2017 (GVBl.II/17, [Nr. 35]).

BbgNatSchAG, 2013. Brandenburgisches Ausführungsgesetz zum Bundesnaturschutzgesetz (Brandenburgisches Naturschutzausführu ngsgesetz) vom 21. Januar 2013 (GVBl.I/13, [Nr. 3]).

BMLFUW [Bundesministers für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft], 2015. Direktzahlungsverordnung 2015. Verordnung des Bundesministers für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft über Direktzahlungen im Rahmen der gemeinsamen Agrarpolitik (Direktzahlungs-Verordnung 2015) StF: BGBl. II Nr. 368/2014.

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Appendix A. Supplementary data

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