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Ecological Indicators 117 (2020) 106510

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Community-based governance: Implications for ecosystem service supply in Berg en Dal, the Netherlands

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ARTICLE INFO

Keywords:
Multi-level governance
Co-management
Collaborative management
Land-use maps
Agricultural landscape
Temporal dynamics

ABSTRACT

Governance is an essential element in land-use decision-making and ecosystem management choices and thus for ecosystem service provisioning. Although a community-based approach, i.e. governance involving actors from all spheres of society (the state, market and civil society), is considered most appropriate for natural resource management, there is a lack of knowledge about its actual effects on environmental outcomes and ecosystem service supply in particular. To obtain insight in the effect of governance on ecosystem service provision in our study region (Berg en Dal, the Netherlands), we constructed ecosystem service maps for the period 1995 to 2012 using land-use maps. Also an inventory of the implemented governance models was created, based on interviews with stakeholders, supplemented with literature research. Our results show that 1) governance in Berg en Dal changed from top-down to more community-based models during the studied period; and 2) that the potential and actual supply of the majority of the investigated regulating, cultural and habitat ecosystem services increased during the studied period, at the expense of agricultural production. The interviewed local stakeholders also indicated that they have the perception that the landscape has improved during the last two decades. Although there is a clear connection between governance and improved ecosystem service supply, more research is needed to further develop causal relationships explaining the indirect effects and non-linear behavior within ecosystem service governance systems.

1. Introduction

Many trade-offs exist between food and feed production on the one hand and the provision and conservation of other ecosystem services and biodiversity on the other hand (Millennium Ecosystem Assessment, 2005; Power, 2010; Tilman et al., 2002; Zhang et al., 2007). An answer to the challenge of producing food and other ecosystem services simultaneously is the implementation of multifunctional rural landscapes (de Groot et al., 2010; Holt et al., 2016). The type, amount and relative mix of ecosystem services provided by these multifunctional rural landscapes are influenced by their heterogeneity (Holt et al., 2016). This heterogeneity is determined by the applied land-use and land cover types (i.e. composition) and the connectivity between them (i.e. configuration) (Verhagen et al., 2016), both influenced by management choices (Rodriguez et al., 2006). To understand and improve the effects of land-use policies and decision-making on ecosystem service provisioning it is important to analyze the capacity of multifunctional rural landscapes to provide several ecosystem services, using quantitative indicators.

Governance is an essential element in land-use and ecosystem management decision-making and thus for ecosystem service provisioning (Spangenberg et al., 2015). The term governance is used for all processes of governing, it is about creating institutional structures (Vatn, 2010). Following Vatn (2010), governance is about '*how we establish goals, how we define rules for reaching the defined goals, and finally how we control outcomes following from the use of these rules*.' Identification of effective governance practices is essential to sustain ecosystem service supply (Primmer et al., 2015). Without this knowledge we are likely to overlook opportunities to promote synergies and reduce trade-offs between food supply and other ecosystem services, including habitat protection.

Recently, governance changed to more market- and community-based approaches as a response to the ineffectiveness to overcome environmental problems by top-down command and control-based governance approaches (Koontz and Thomas, 2006; Loft et al., 2015; Mattijssen et al., 2015; Sattler et al., 2018). Especially community-based governance is considered an appropriate approach for the achievement of more effective management of natural resources

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https://doi.org/10.1016/j.ecolind.2020.106510
Received 24 September 2019; Received in revised form 16 April 2020; Accepted 10 May 2020
Available online 09 June 2020
1470-160X/

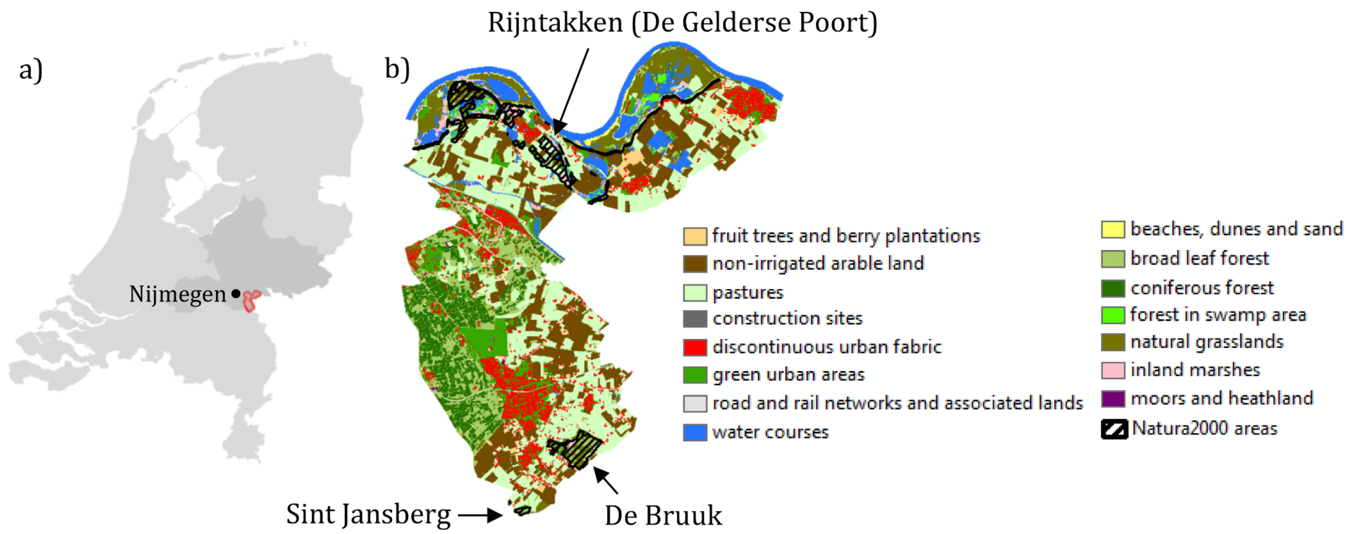

Fig. 1. a) Location of Berg en Dal in the Netherlands (indicated with red); b) Land cover of Berg en Dal in 2012 (based on the Land Use Database of the Netherlands (LGN database), available for download from: www.lgn.nl, with LGN classes converted to CORINE land-cover classes, see Appendix B Table B.1), including the names of the Natura2000 areas.

(Bodin, 2017; Koontz and Thomas, 2006; Wallington and Lawrence, 2008). Within community-based governance (also called multi-level governance, collaborative governance or co-management, but many more terms are being used, see Sattler et al. (2018)) a broad range of partnerships can be identified. Ideally multiple actors from all spheres of society, including the state, market and civil society collaborate together (Sattler et al., 2018). Community-based governance is based on the idea that the ones whose living environment or livelihood is influenced by management choices should have a stake in these choices (Berkes, 2009). The considered effectiveness of community-based governance follows from the assumption that regional or local communities are able to respond more effectively to local environmental problems because they are more responsive to context and local priorities. Moreover, local stakeholders have the ability to recruit people from local communities to implement measures, possibly resulting in more efficient governance (Lane and Corbett, 2005). And finally, the proper management of complex socio-ecological systems, like multifunctional landscapes, requires knowledge from actors from all spheres of society (Berkes, 2009).

Although the community-based governance approach is considered effective and is increasingly applied, there is a lack of knowledge about the actual effects of this governance approach on environmental outcomes (Bodin, 2017; Koontz and Thomas, 2006) and ecosystem service supply in particular (Sattler et al., 2018). Several reasons can be identified for this lack of knowledge. Previous research about ecosystem service governance mainly looked at only one point in time (Sattler et al., 2018), neglecting that it takes time before implemented management decisions affect ecosystem service supply. Koontz and Thomas (2006) argued that to investigate the effect of community-based governance, data collection on indicators of environmental conditions should start before the implementation of the community-based governance and extend for years (if not decades) afterwards. Finally, it is a challenge to demonstrate that the implemented community-based governance approach changed the supply of ecosystem services rather than other factors due to the complexity of socio-ecological systems and the fact that they cannot be analyzed in isolation (Koontz and Thomas, 2006).

Our study aims to test the hypothesis that community-based governance approaches have a positive effect on the potential and actual supply of ecosystem services by the landscape of Berg en Dal, the Netherlands. We selected the landscape of Berg en Dal because: community-based governance plays an increasingly important role in its governance system, it is an area in which agriculture, nature and cultural history are all considered important, and land-use data for multiple years is available. An important community-based governance model within our study area is the project ‘Pilot green-blue services’. This pilot project aimed to obtain a coherent and connecting network of small-scale landscape elements within the rural landscape to preserve the cultural landscape and increase its quality. In addition, the pilot aimed to establish a network of freely accessible recreational pathways through the agricultural lands to make it accessible and attractive for recreationalists. While research on community-based governance approaches often applies mostly qualitative methods (Primmer et al., 2015; Sattler et al., 2018), we employ a combination of qualitative and quantitative research. We combined literature research, semi-structured interviews with local stakeholders to identify changes in governance approaches, and objective spatial analysis techniques to derive quantitative indicators to reconstruct how the provision of ecosystem services has changed over time. To explain trends we calculated several landscape metrics, following previous studies who found that landscape metrics can be used as indicators for the provision of ecosystem services by landscapes (also referred to by some other studies as landscape services) (e.g. Frank et al., 2013; Nowak and Grunewald, 2018; Zhang and Gao, 2015). We also evaluate the added value of the network of small-scale landscapes elements resulting from the ‘Pilot green-blue services’ for ecosystem service supply by analyzing indicators for landscape connectivity and landscape aesthetics more in depth.

2. Material and methods

To test our hypothesis we needed to get insights in developments in governance approaches and ecosystem service provisioning in the study area during the period 1995–2012. To get insights in developments in governance we employed interviews with relevant stakeholders and did literature research. In addition, we carried out a semi-quantitative method to evaluate ecosystem service provisioning in the study area during the same period. Finally, we compared the developments in governance and ecosystem service provisioning to test our hypothesis.

2.1. Study area

Berg en Dal is located east from Nijmegen in the Netherlands (Fig. 1). This municipality is part of the National Landscape Gelderse Poort. National Landscapes are areas of large agricultural, natural and historic value and aim for socio-economic development while the special natural and cultural characteristics of the area are maintained or even strengthened.

Berg en Dal covers a land area of 93 km^2. The area includes a variety of landscapes, among others floodplains, forests and mixed agricultural lands. The region wants to change from intensive agriculture towards a landscape in which agriculture, nature conservation and recreation are combined.

2.2. Qualitative data collection

We made an inventory of the governance models in place in Berg en Dal including their approach (top-down, market-based and community-based approach) during the period 1995–2012 by interviewing stakeholders and literature research. The period 1995–2012 has been selected because we assumed that people could still remember the situation in 1995 and the most recent land-use map of the Netherlands was of 2012.

2.2.1. Interviews

Five stakeholders were interviewed in May and June 2017. These five stakeholders represent the key organizations involved in the management of the landscape of Berg en Dal. These organizations have the common goal, although their focus may be slightly different, to change the landscape from intensive agriculture to a landscape in which agriculture, nature and recreation can co-exist. The interviewees included: 1) an employee of the municipality of Berg en Dal, 2) an employee of the Dutch Water Authority Rivierenland, the public organization responsible for water management in the area, including the management of water levels and water quality, 3) a farmer located in Berg en Dal who is active in nature conservation on his agricultural fields, 4) an employee from an association that promotes and executes landscape and agricultural nature management (http://www.ploegdriever.nl/) and 5) an employee from the association that is responsible for the Landscape Development Plan of the municipality Berg en Dal (http://vianatura.nl/). Four out of the five of the interviewees have been involved in the governance of our study area for a long time. Most interviewees were well acquainted with the ecosystem service concept.

The format of the interviews was semi-structured. The exact questions and topics addressed in the interviews (see Appendix A) differed slightly among stakeholders, based on their specific expertise. We discussed with them the current governance models implemented in Berg en Dal and governance changes in the area between 1995 and 2012. They selected the most important ecosystem services from their own perspective and described the trends in the actual supply of ecosystem services in the area during two periods (1995–2005 and 2006–2012). We split the period because we assumed that the change in the supply of ecosystem services could differ in these two periods. Especially because of the launch of the first Landscape Development Plan, which envisioned how the region should develop after 2005 and it introduced a collaborative land governance approach for the region. We also asked the interviewees to evaluate the spatial patterns of the ecosystem service maps that were created based on the most recent land-use map to better understand the legitimacy and credibility of these maps for local stakeholders.

2.2.2. Literature research

Information from the interviews was supplemented with online documents such as government documents, legal regulations, reports and presentations about recent developments in Berg en Dal to get the most complete overview of the governance system in Berg en Dal. Literature was mainly found on the website of the municipality (www.bergendal.nl), of the Dutch Water Authority Rivierenland (www.waterschaprivierenland.nl/) and of civil organizations actively involved in the area (www.vianatura.nl and www.ploegdriever.nl). The most important reports are the two Landscape Development Plans for the time periods 2005 to 2014 and 2015 to 2025, which have been developed by the municipality Berg en Dal (and its predecessors, the former municipalities Groesbeek, Millingen aan de Rijn and Ubbergen).

2.3. Semi-quantitative method to evaluate ecosystem service provisioning

2.3.1. Method to map ecosystem services

To get insight in the potential ecosystem service provision in Berg en Dal during the period 1995–2012 we applied the "matrix method" as proposed by Burkhard et al. (2009) and refined by Burkhard et al. (2014, 2012). This method uses a relatively simple matrix with the ecosystem services as columns and geospatial units such as ecosystem, land-use or cover type, as rows. On each intersection a number from 0 to 5 is given, reflecting that ecosystem type, land-use or land-cover type can serve as an indicator for the provision of a certain ecosystem service, with 0 indicating no relevant supply and 5 very high supply (see Appendix B, Tables B.2-4). We assumed that the landscape in Berg en Dal can be considered a "normal" European landscape and we used the information from Fig. 4 from Burkhard et al. (2014) to arrive at the potential of each geospatial unit to supply a certain ecosystem service. Following Burkhard et al. (2012) we defined ecosystem service potential supply as: *'the hypothetical maximum yield of a selected ecosystem service'*.

Based on the occurring land-use and land-cover types and the policy reports about Berg en Dal, the following ecosystem services were selected for detailed study: water flow regulation, pollination and pest and disease control (regulating services), crop and livestock production (provisioning services), recreation and tourism (cultural service) and natural heritage and natural diversity (habitat service), following the classification system developed by TEEB (2010).

2.3.2. Input data to map ecosystem services

Potential supply of ecosystem services over time was assessed using five land-use maps from the Land Use Database of the Netherlands (in Dutch: Landelijk Grondgebruiksbestand Nederland, LGN database). LGN maps were available with a resolution of 25 × 25 m for the reference years 1997, 2000, 2003, 2007 and 2012 (see for more details Hazeu, 2014a). Input data for the LGN database consist of among others satellite imagery, the Dutch topographical map, aerial photographs, natural area databases and land-use information from Statistics Netherlands (Hazeu, 2014b). Because of increased data availability and changing user requirements the versions of the LGN maps from different years are based on slightly different methodologies. Burkhard et al. (2014) used CORINE land-cover types, we therefore translated LGN classes to corresponding CORINE land-cover types following Table 18.6 of Hazeu (2014b) (see Appendix B Table B1).

The potential supply of each ecosystem service of the total area of Berg en Dal ($PsupplyES_{k_{\mathrm{BergenDal}}}$) was calculated for each reference year applying the following equation developed for this study:

$$PsupplyES_{k_{\mathrm{BergenDal}}} = \frac{\sum_{i=1}^{n} PsupplyvalueES_{k_{CLC_i}} \times area_{CLC_i}}{totalarea_{\mathrm{BergenDal}}} \quad (1)$$

with $PsupplyvalueES_{k_{CLC_i}}$ the potential supply value of CORINE land-cover type i (Appendix B Table B.1) for ecosystem service k (value 0–5, see Appendix B, Tables B2-3), $area_{CLC_i}$ the area of CORINE land-cover type i, n the total of CORINE land-cover types providing ecosystem service k and $totalarea_{\mathrm{BergenDal}}$ the total area of Berg en Dal.

2.3.3. Evaluation of ecosystem service maps by stakeholders

We asked the interviewed stakeholders for a visual assessment of the maps to get a better understanding about the validity of the produced ecosystem service maps. They were asked to assess the spatial pattern of the supply of the services for the reference year 2012, i.e. if they recognized the locations with high values of supply of an ecosystem service and the locations with low values.

2.3.4. Calculation of landscape metrics

2.3.4.1. Landscape metrics to explain trends in ecosystem service provisioning. The mix of ecosystem services supplied by a landscape is influenced by its composition and the connectivity between land-use and cover types (Syrbe and Walz, 2012; Verhagen et al., 2016). To better explain the influence of landscape composition and connectivity on the changes in ecosystem service supply during the period 1995–2012 we calculated several landscape metrics using the LGN maps as input in the spatial pattern analysis software program FRAGSTATS v4.2 (McGarigal et al., 2012). Numerous studies have been carried out to link ecosystem service provision to landscape metrics without clear overall conclusions. We applied the findings of the recent study of Nowak and Grunewald (2018) in this study, because they also studied rural landscapes. Before calculating the landscape metrics we clustered several land-cover types into broader categories based on their potential supply values for ecosystem services (see Appendix B Table B1). As indicators for the composition of the landscape we calculated proportion (%) of cropland and orchards, pastures, (semi-)natural ecosystems and artificial surfaces. As indicators for configuration we calculated the Shannon's Diversity Index (SHDI, –) at landscape level indicating the richness of land-cover types in the landscape and the Contagion Index (CI, %) measuring both land-cover type interspersion and dispersion indicating the clumpiness of land-cover types within the landscape. A higher SHDI value indicates that the landscape contains more land-cover types and/or that the the proportional distribution of area among land-cover types is more equal. CI ranges from 0 (when the land-cover types are maximally disaggregated and interspersed) to 100 (when all land-cover types are maximally aggregated). Finally, we calculated the Euclidean Nearest-Neighbor Distance (ENN_N, m) at class level for the (semi-)natural ecosystems to determine landscape connectivity. The (semi-)natural ecosystems class was selected because these land-cover types are assumed to provide habitats and to contribute to the provision of most ecosystem services (see Appendix B Table B2-4). See for detailed explanations of the landscape metrics McGarigal and Marks (1995) and McGarigal (2015).

2.3.4.2. Landscape metrics to evaluate the project 'Pilot green-blue services'. The project 'Pilot green-blue services' aimed to create a coherent and connecting network of small-scale landscape elements through the rural landscape to increase its quality and to make it accessible and attractive for recreation. To evaluate the change in landscape aesthetics due to the added small-scale landscape elements we calculated several landscape metrics at landscape level as proposed by Frank et al. (2013) for the situation before and after the implementation of the pilot: the Shannon's Diversity Index (SHDI, –), Patch Density (PD, per km^2), the mean Shape Index (SHAPE, –). A higher SHAPE value indicates a higher complexity of the shapes of the patches in the landscape and a higher value PD indicates a higher landscape diversity. Frank et al. (2013) selected these landscape metrics to evaluate the naturalness and landscape diversity, which are assumed to determine the scenic beauty of a landscape.

A clustering of the CORINE land-cover types was required for the calculation of the landscape metrics. The land-cover types were clustered using the concept of "hemeroby", describing the extent of human impact on ecosystems as a measure of naturalness and in 17 diversity groups to evaluate landscape diversity (see Appendix B Table B5). We used Patch Analyst v5.1.0.7 software (Rempel et al., 2012). SHAPE was calculated with the degree of hemeroby as input and SHDI and PD with diversity group as input.

Another important aim of the pilot project was to improve natural diversity by increasing connectivity between (semi) natural habitats. Several metrics exist that estimate patch connectivity in landscapes with patches which differ in habitat quality (Visconti and Elkin, 2009). The metric probability of connectivity (PC) is a metric that incorporates both habitat quality and dispersal distances of species to calculate connectivity. We used the parameterization of the ecosystem service natural heritage and natural diversity from the matrix method as a measure for habitat quality (see Appendix B Table B4). For distance between patches we used edge-to-edge distance. The probability of connectivity index (PC) is defined as the probability that two animals randomly placed in the landscape occupy habitat patches that are reachable from each other given a set of n habitat patches and the connections p_{ij} between them (Saura and Pascual-Hortal, 2007). The original index is given by the following equation:

$$PC = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} a_i a_j p_{ij}}{A^2} \tag{2}$$

where a_i and a_j represent a relevant characteristic of the habitat patch like area, habitat quality or carrying capacity, and A represents the sum of the relevant characteristic over all patches in the landscape. Our goal is to compare the PC index for two different situations: the landscape connectivity before and after the realization of the green and blue line elements. To make the index comparable between these two situations, we adapted it to:

$$PC = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} a_i a_j p_{ij}}{A_{max}} \tag{3}$$

now, A_{max} is the sum $\sum_{i=1}^{n}\sum_{j=1}^{n} a_i a_j$ with the relevant characteristic of all n patches equal to the highest value possible, a_{max} (this can easily be calculated by $(a_{max})^2 n(n+1)/2$). In this case, the index PC is a value between 0 (when all the patches are too far apart to be connected) and 1 (when all the patches are of high quality and perfectly connected, i.e. $p_{ij} = 1$).

The dispersal probability between patches p_{ij}, is calculated by a negative exponential equation:

$$p_{ij} = e^{-\alpha d_{ij}} \tag{4}$$

where α is the inverse of the species dispersal distance and d_{ij} is the edge-to-edge shortest interpatch distance. We took values for α based on a meta-analysis for butterfly dispersal and one more value with a longer dispersal distance where all landscape elements can be reached (Stevens et al., 2010).

The metric PC assesses the effect of the small landscape elements on the connectivity of the whole landscape. A relative ranking of landscape elements by their contribution to overall landscape connectivity can be used to assess whether placement of the small landscape elements in Berg en Dal improved the connectivity of the semi-natural ecosystems that were already present in the area. This relative ranking (Saura and Pascual-Hortal, 2007; Visconti and Elkin, 2009) can be calculated by:

$$\Delta PC(\%) = 100 \times \frac{PC - PC'}{PC} \tag{5}$$

where PC' is the PC index after the removal of the patch of interest. We assessed the effect of the 'Pilot green-blue services' on connectivity by comparing the relative ranking of landscape elements by their contribution to overall landscape connectivity in Berg en Dal in the situation before and after the implementation. As the absolute value of the relative contribution can change when more landscape elements are taken into account, we compared the ranking relative to the maximum value of ΔPC in each situation.

2.3.5. Input data to evaluate the project 'Pilot green-blue services'

From the organization Via Natura, which coordinated the implementation of the project 'Pilot green-blue services', we obtained a map with the locations of all the landscape elements. This map was processed in ArcMap 10.3.1., making an overlay with the LGN7 map, i.e. replacing the LGN7 CORINE land-cover types with the landscape elements. The width of some of the landscape elements, e.g. hedgerows, is not more than 1 m. We therefore decreased the resolution of the LGN7 map used to evaluate the pilot project, as well as the LGN7 map with landscape elements, to 0.5 × 0.5 m. Based on our own expert knowledge and Burkhard et al. (2014) we allocated potential supply values for natural heritage and natural diversity to the landscape elements (see Appendix B Table B4). If two or more landscape elements overlap, the maximum value of the overlapping elements was allocated, because we assumed that this additional landscape complexity benefits the potential for natural heritage and natural diversity.

3. Results

3.1. Governance models in Berg en Dal

This section shows which governance models were in place in Berg en Dal during the period 1995–2012. Before discussing governance of the landscape of Berg en Dal, we first give a brief history of European and Dutch governance of agricultural landscapes, as these governance models have influenced the former.

3.1.1. Brief history of European and Dutch governance of agricultural landscapes

Since World War II, the focus of agriculture in the EU had been on securing food supply and ensuring income for the agricultural sector (Buizer et al., 2016). In 1958, the Common Agricultural Policy (CAP) was implemented within the EU with the purpose of maximizing food production. After the initial production goals of CAP had been achieved and degradation of the landscape was noticed, governance shifted to a more decentralized form in which the management of the agricultural landscapes relied less on central government (Schouten et al., 2013). As part of this shift, agri-environmental schemes (AESs) were integrated in the CAP, through which farmers could voluntarily commit themselves to maintain nature on their land in return for compensation payments for costs incurred by implementing nature measures and income losses (Schouten et al., 2013).

Since the 1980s, but especially during the 1990s, Dutch farmers have organized themselves into agri-environmental cooperatives. They did this in response to the top-down governance, but also to get more responsibilities and freedom to conserve nature on their land. In addition to this development, other governance approaches were established: NGOs cooperated with farmers and agri-food supply chain companies developed initiatives to improve the sustainability of Dutch agriculture (Runhaar et al., 2016).

3.1.2. Inventory of governance of the agricultural landscape of Berg en Dal

We made an inventory of applied governance models that focus on the (agricultural) landscape of Berg en Dal and that we considered to be critical for the provision of ecosystem services. Per governance approach we determined its (ecological) aim, its governance approach following Vatn (2010) and the year it was implemented (Fig. 2). See Appendix C for detailed descriptions of all identified governance models. Note that the distinction in different governance approaches is an analytical one and that in reality the main types of governance coexist, or even fundamentally depend on each other to form governance systems (Vatn, 2010).

Two developments relevant for the governance of the (agricultural) landscape of Berg en Dal were the establishments of two private initiatives: De Ploegdriever and Via Natura. De Ploegdriever is a local agri-environmental organization focusing on landscape management and founded by nature conservationists and farmers in 1999 with the aim of conserving the beauty of the rural cultural landscape. De Ploegdriever manages many natural areas and small-scale landscape elements throughout Berg en Dal on behalf of several public authorities, organizations and private clients, including: municipalities, the Dutch Water Authority Rivierenland, State Forestry Service, Natuurmonumenten, Via Natura and private land-owners. From 2016 onwards, De Ploegdriever also facilitates the Agricultural Nature and Landscape Management subsidy program. In 2005, Via Natura was established through a bottom-up process. Via Natura and the three municipalities initiated the first Landscape Development Plan (LOP). Via Natura coordinated the implementation of this LOP and the project 'Pilot green–blue services' (see Appendix C for more details about this governance model). This pilot project resulted in 20 ha green–blue veining of the landscape (approx. 5% of the total area) and 10.5 km new recreation routes connecting 560 ha in the region (Personal communication employee Via Natura, 2017).

3.2. Ecosystem service selection by stakeholders

To verify our selection of ecosystem services for detailed study we asked the stakeholders to select the most important ecosystem services in Berg en Dal, using Fig. 4. from Burkhard et al. (2014). Stakeholders were asked to select 4–5 ecosystem services or more if preferred; they all selected more than five. All stakeholders selected the cultural ecosystem services and the habitat services as being important for the region. Also the provisioning role of agriculture in the landscape of Berg en Dal was indicated as being important by the majority of the stakeholders (four out of five of the stakeholders) (see Appendix D for more detailed results). The selection made by the stakeholders compares well to our pre-selection. From the seven most selected ecosystem services (selected 3–5 times), five were also in the pre-selection. The two others that were often selected by stakeholders (landscape aesthetics, amenity and inspiration (five times) and erosion regulation (three times)) are however indirectly studied: the service landscape aesthetics and inspiration is related to recreation and tourism, and erosion regulation is related to water flow regulation.

3.3. Maps of ecosystem services in Berg en Dal for 2012

The potential supply of crops and livestock shows a patchy distribution (Fig. 3) because of the patchwork of agricultural parcels in Berg en Dal (Fig. 1). The natural grasslands, which are mainly situated in the floodplains and in the natural area De Bruuk (see Fig. 1 for the location of this natural area), have a medium potential supply of agricultural products. The regulating services and the cultural services have more complex spatial distributions because more land-cover types are assumed to provide these ecosystem services. The maps (Fig. 3) show that the forested areas have a relatively high potential supply for regulating, cultural and habitat services. The floodplain area has a great variety of land-cover types, consisting of among others natural grasslands, inland marshes, water bodies, and forest located in swamps. This variety in land-cover types results in the potential supply of a large variety of mainly regulating, but also cultural and habitat services. The cultural service and the habitat service (Fig. 5a) show similar spatial distributions, with relatively high values in natural grasslands and forested areas and lower values in the agricultural areas.

3.4. Ecosystem service supply in Berg en Dal over time

3.4.1. Actual ecosystem service supply over time

The interviewees were asked to indicate whether the supply of the selected ecosystem services has changed during two periods (1995–2005 and 2006–2012) (see Appendix D for detailed results). According to them, there was an increasing trend in the actual supply of all ecosystem services during the two periods, especially during the second period. The supply of the cultural ecosystem service (recreation and tourism) increased the most.

3.4.2. Potential ecosystem service supply over time

Fig. 4 shows the temporal developments of potential supply of the studied ecosystem services for the total area of Berg en Dal (see Eq. (1)) over the period 1997 to 2012 based on the matrix method. We found

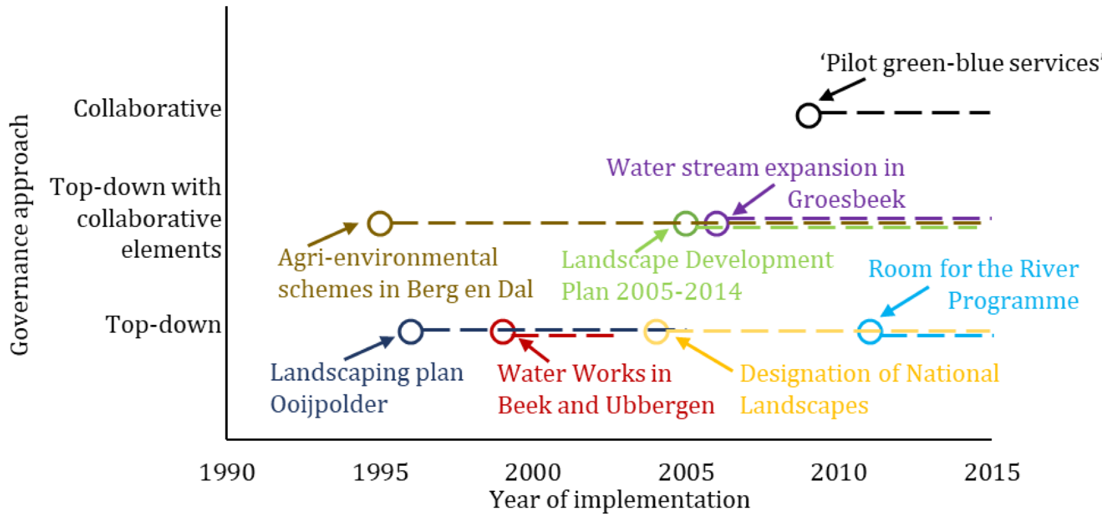

Fig. 2. An overview of applied governance models in Berg en Dal, with on the x-axis the year of implementation and on the y-axis the governance approach of the model. The circle indicates the year of implementation of the project. The dashed line indicates the length of the project.

that the potential supply of regulating services (water flow regulation, pollination and pest and disease control) increased between 1997 and 2007 followed by a slight decrease between 2007 and 2012. The potential supply of crops first increased from 1997 to 2003 followed by a decrease until 2012. These changes predominantly resulted from a decrease in non-irrigated arable land. The potential supply of livestock decreased from 1997 to 2007, with the largest decrease between 1997 and 2000. From 2007 to 2012 the potential supply of livestock slightly increased, resulting from an increase in natural grassland area. The cultural service recreation and tourism and the habitat service natural heritage and natural diversity show an increase over the whole studied period. Over the first three assessment years the potential supply values are rather constant, whereas from 2003 to 2012 there are relatively large increases in the potential supply of both services. These increases can mainly be attributed to the increased natural grassland area.

3.5. Landscape metrics

3.5.1. Changes in landscape composition and configuration in Berg en Dal over time

We evaluated the changes in land-cover composition in Berg en Dal in the period 1997–2012 to explain changes in potential ecosystem service provision (Table 1). Especially the surface for the production of agricultural products (cropland, orchards and pastures) decreased, while the surface of (semi-)natural ecosystems increased over the studied period. The landscape metric SHDI decreased slightly, indicating that the proportional distribution of area among land-cover types became less equal over time, which can be explained by the larger share of (semi-)natural ecosystems. The value of the other indicator for diversity (CI) also decreased between 1997 and 2000 and subsequently stabilized, indicating that the landscape became more disaggregated thus more diverse. Finally Table 1 shows that the mean distance between (semi-)natural ecosystems (ENN_N) decreased over time, indicating that connectivity between (semi-)natural ecosystems increased during the studied period.

3.5.2. Landscape connectivity due to the project 'Pilot green-blue services'

The small landscape elements that were implemented in Berg en Dal within the 'Pilot green-blue services' improved the connectivity of the landscape elements in Berg en Dal. This can both be seen in the increase in the probability of connectivity index PC (Table 2) and in the change of relative importance of landscape elements to the overall landscape connectivity in Berg en Dal (Fig. 5). The increase in PC is strongest for species with large dispersal distances. Dispersal distance affects the number of landscape elements that increase in relative importance. For short scale dispersal only the landscape elements close to a newly implemented landscape element show an increase in the relative importance, while for medium dispersal distances almost the whole landscape is positively affected.

3.5.3. Landscape aesthetics due to the project 'Pilot green-blue services'

To evaluate if the landscape elements implemented in the context of the project 'Pilot green-blue services' increased the aesthetics of the landscape of Berg en Dal we calculated several landscape metrics (Table 3). The results show that the scenic beauty of the landscape indeed increased due to the implementation: the landscape became more complex (higher mean SHAPE) and more diverse (higher PD and slightly higher SHDI). Note that for the evaluation of the landscape elements with SHDI the land-cover types and landscape elements were clustered into diversity groups, in contrast with the SHDI values presented in Section 3.5.1., which are calculated using clustering based on land-cover type.

4. Discussion

We compared the trends in implemented governance models, structure of the landscape of Berg en Dal, and ecosystem service supply to analyze the implications of community-based governance for ecosystem service supply in Berg en Dal. Between 1995 and 2012 numerous community-based approaches were initiated and have become more important for the governance of the landscape of Berg en Dal (Fig. 2). We found that simultaneously the landscape became more diverse and connected (Table 1), which resulted in an increase in potential and actual supply of the majority of the regulating, cultural and habitat ecosystem services at the expense of agricultural production. Also, the interviewed local stakeholders indicated that they have the perception that the landscape has improved during the last two decades. Our analysis cannot definitively show causality between increased community-based governance and increases in landscape diversity, landscape connectivity and ecosystem services provision. However, combining all our findings from the matrix method (Fig. 4) and the stakeholder consultation it seems very likely that the increased community-based governance in which local stakeholders play a major role has indeed positively influence the landscape of Berg en Dal.

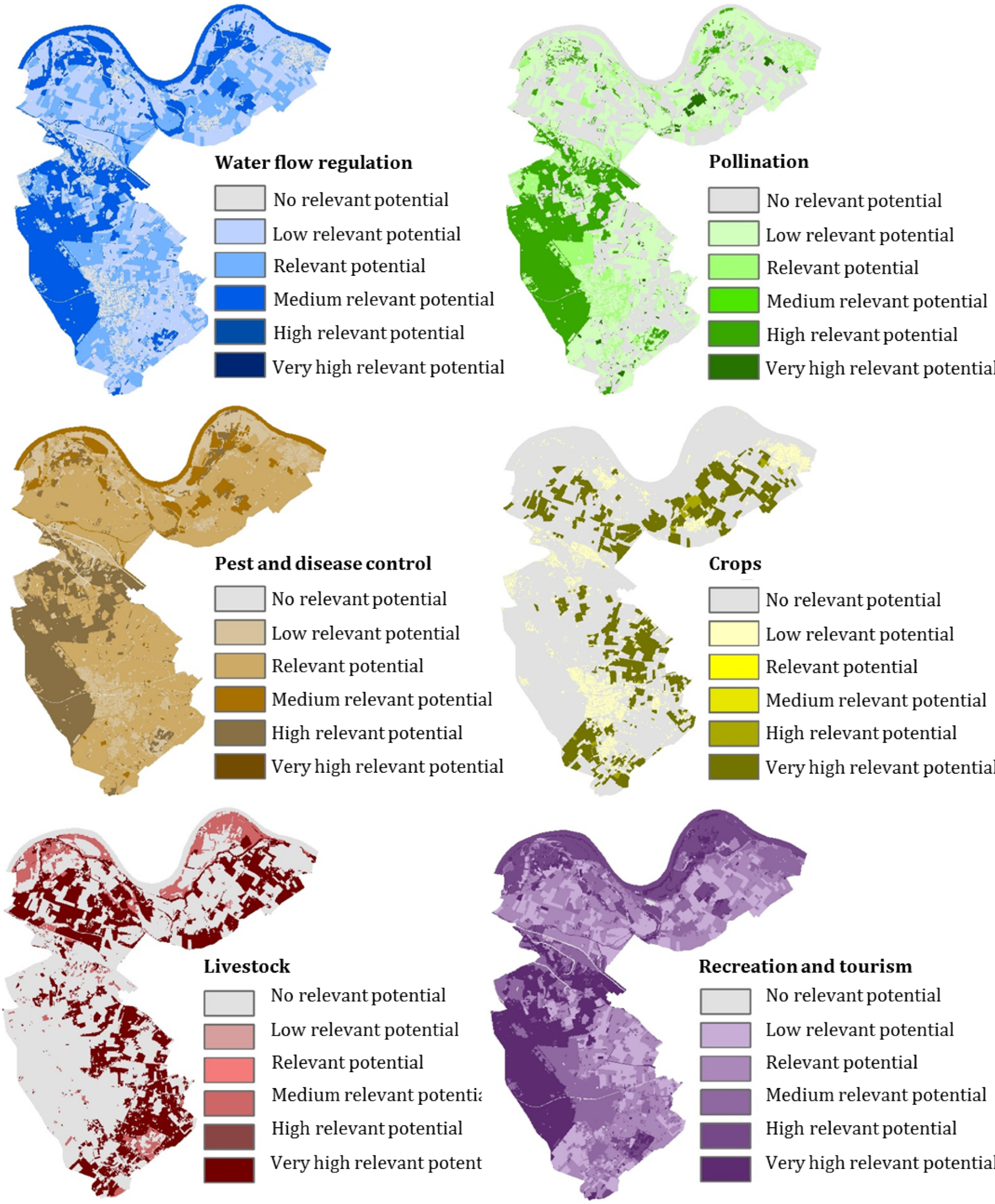

Fig. 3. The potential supply of the ecosystem services water flow regulation, pollination, pest and disease control, crops, livestock, recreation and tourism in Berg en Dal based on the LGN7 map with reference year 2012. The potential supply of natural heritage and natural diversity can be found in Fig. 5a.

4.1. Community-based governance in Berg en Dal: Strengths and weaknesses for ecosystem service supply

The general trend of governance approaches changing from top-down to bottom-up community-based approaches (Koontz and Thomas, 2006; Mattijssen et al., 2015) is also visible in Berg en Dal. The participation and cooperation of stakeholders in Berg en Dal has increased in recent years (Municipality Groesbeek, 2015a,b). During the interviews with local stakeholders it was mentioned that De Ploegdriever played an important role in increasing the involvement of inhabitants with the landscape and its management. The interviewed stakeholders were positive about their cooperation. They meet regularly, they know how to find each other and they can count on each other. Stakeholders seemed to be more positive about cooperation among local stakeholders than about cooperation with stakeholders on higher governance levels with larger administrative areas. Local stakeholders sense that they

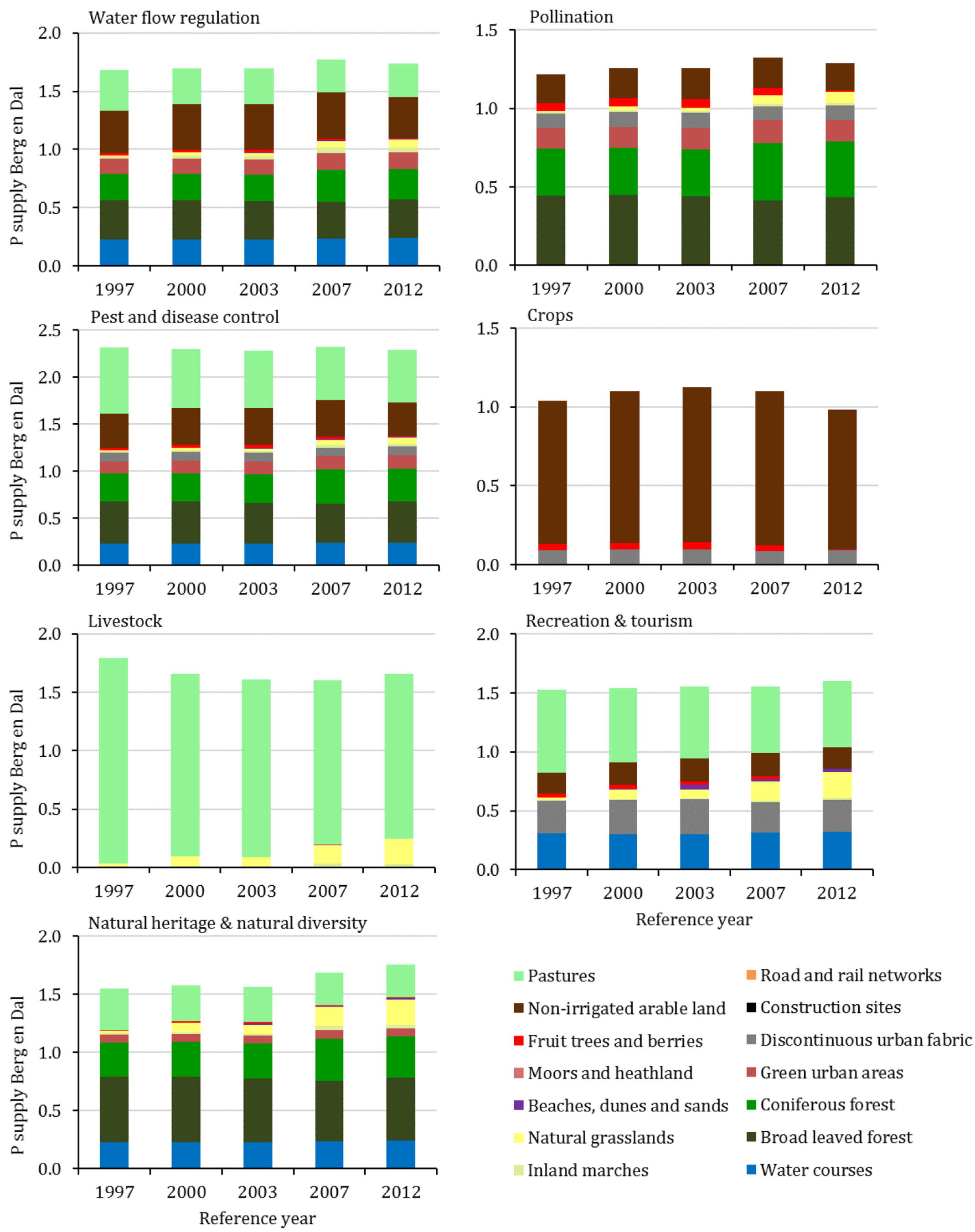

Fig. 4. The potential supply of the total area of Berg en Dal for the ecosystem services water flow regulation, pollination, pest and disease control, crops, livestock, recreation and tourism, and natural heritage and natural diversity. On the x-axis the different reference years of the LGN database are displayed. On the y-axis the potential supply of each ecosystem service for the whole of Berg en Dal is displayed (calculated with help of Eq. (1)). The different colours represent the contribution of different land-cover types to this potential supply.

have common goals and work together towards achieving those goals, whereas with parties that are more distant it is harder to communicate and cooperation more often takes place in the form of formal top-down regulations. One stakeholder was positive about the fact that he could approach De Ploegdriever and related organizations if he had issues with other organizations on higher governance levels. De Ploegdriever could often mediate to make the process easier. The Dutch Water Authority Rivierenland employee that was interviewed was also positive about the cooperation in the area, although the Dutch Water Authority Rivierenland itself is more distant because of its larger working area.

These findings are in line with a recent study of Fischer et al. (2017). They also argued that the diverse set of ecosystem services provided by multifunctional landscapes, like Berg en Dal, is usually experienced more by local people and that local people are often in charge of the landscape management. Runhaar et al. (2016) also studied the governance of the landscape of Berg en Dal. They indicated, in line with our findings, that the community-based approach 'Pilot green-blue services' is effective, but that collaboration requires time, energy and local knowledge by the involved actors. These prerequisites also became clear from the interviews we conducted. A study by Sattler et al. (2015) showed that factors such as bottom-up initiation, commitment and leadership and additional funding contribute to the success of community-based governance. These factors were also present in our study area: the 'Pilot area green-blue services' was initiated by the

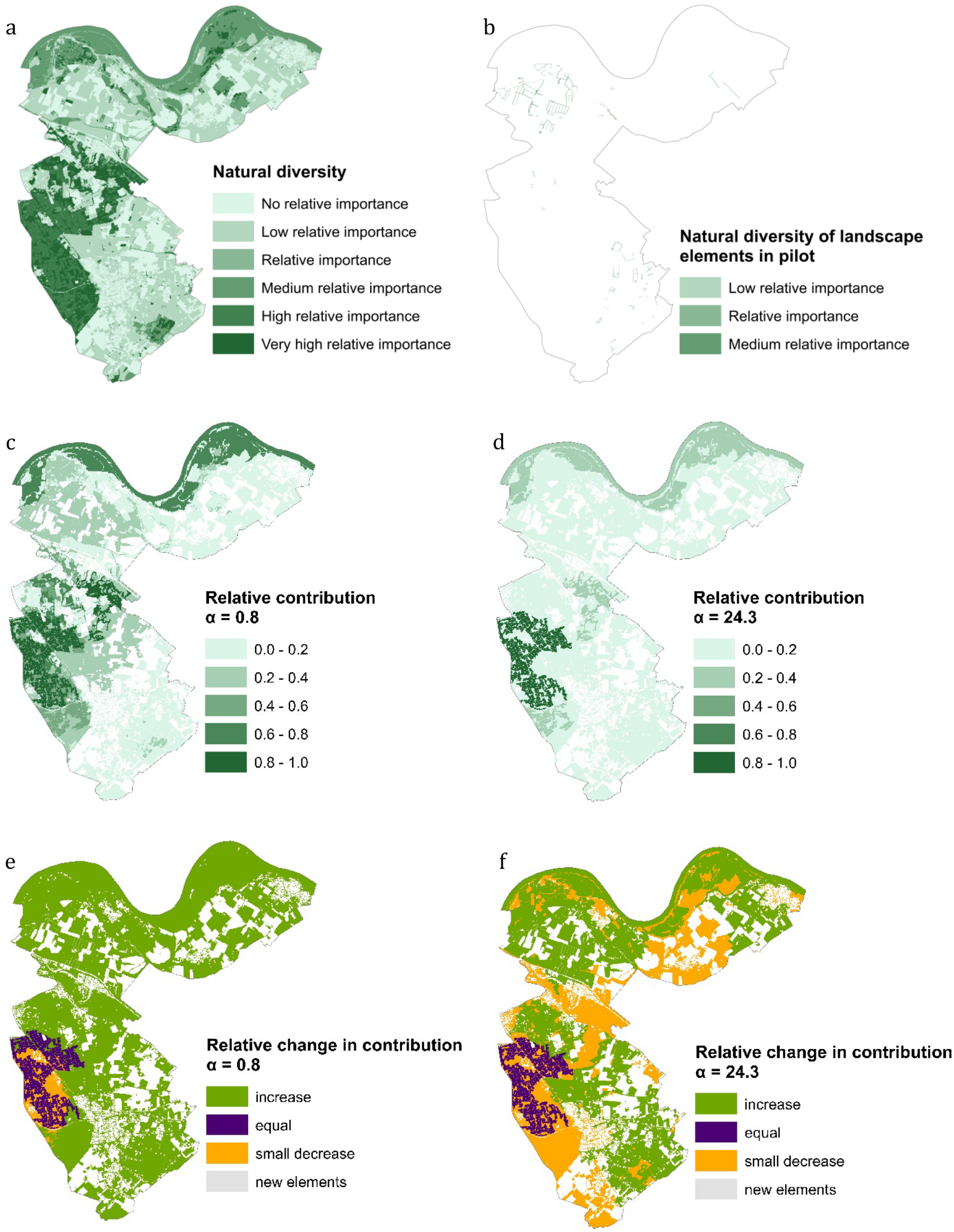

Fig. 5. a) The potential supply of the natural diversity in Berg en Dal based on the LGN7 map with reference year 2012; b) Position and quality of the small landscape elements of the 'Pilot green–blue services'; c, d) Relative contribution of landscape elements to overall landscape connectivity in their Berg en Dal after the implementation of the pilot, and e, f) the change in relative contribution of landscape elements due to the implementation of the pilot, depicted for species with a medium range dispersal distance of about 1 km ($\alpha = 0.8$), and short range dispersal distance of about 40 m ($\alpha = 24.3$).

Table 1
Calculated landscape metrics based on the LGN maps with clustering of CORINE land-cover types to broader land-cover types.

		Reference year				
		1997	2000	2003	2007	2012
Composition	Proportion of cropland and orchards (%)	19	20	21	21	18
	Pastures (%)	35	31	30	28	28
	(semi-) natural ecosystems (%)	34	37	37	42	44
	artificial surfaces (%)	11	12	12	9	10
Configuration	SHDI(-)	1.31	1.31	1.31	1.26	1.26
	CI(%)	46	37	37	37	37
	ENN_N(m)	85	79	78	70	70

organization Via Natura together with a local government official, public funding was supplemented with several other sources and De Ploegdriever had a mediating role and could increase, together with other actors, the involvement of inhabitants with the landscape management.

4.2. Limitations and directions for further research

Some limitations of our study are briefly discussed here. First of all, although the matrix approach is one of the most popular ecosystem service assessments techniques today (Jacobs et al., 2015), it has also received a lot of critique, especially regarding its subjectivisms to arrive at the potential values. It has also been argued that more process-based models should be applied to increase biophysical realism in ecosystem service maps (Lavorel et al., 2017). The evaluation of the potential supply capacities of ecosystem services over time demands data for multiple years. It is however unlikely that the high data requirements of process-based models can be fulfilled for multiple years. We think that for the focus of studies like ours it is more important to have outcomes for multiple years instead of having ‘perfect’ maps of ecosystem services. In addition, Roche and Campagne (2019) recently demonstrated that results from the matrix approach are very close to results from biophysical models. We therefore considered the “matrix method” as the most appropriate methodology for this study. The temporal changes in ecosystem service potential and the changes in landscape metrics underlined the general usefulness of the matrix approach, as the results reflected changes aimed for by the Berg en Dal community-based governance initiatives. More research is however needed to further develop causal relationships that capture the non-linear behavior and system dynamics that characterize the complex relationships between governance and ecosystem service supply (Sattler et al., 2018). Ideally, our results should be compared with temporal changes in ecosystem service potential and the changes in similar regions in which no community-based governance approaches are in place.

The interviewed stakeholders found the ecosystem service maps in general too ‘coarse’. They commented that small-scale landscape elements are not visible on the maps, whereas these are important for the supply of several ecosystem services, a statement that is confirmed by a recent review (van Zanten et al., 2014). The same negative comments were given by interviewed stakeholders in a study by Dick et al. (2016), who applied methods similar to ours. This coarseness results however from the resolution of the used input maps. In addition, the interviewed stakeholders in our study remarked that the provision of many ecosystem services is influenced by quality differences within the landscape or within a land-cover type, which is not acknowledged by the matrix method. Stakeholders recommended to examine (potential) supply on a smaller spatial scale, in particular to include more information about the real quality of the area and supplement the LGN maps with the present small-scale landscape elements, which was subsequently done in our landscape diversity and connectivity analysis. The analysis confirmed the stakeholder views that the landscape elements were of importance for several ecosystem services. Nevertheless the stakeholders recognized the spatial patterns on the maps of the potential supply crop and livestock provision. Exceptions to this were the areas De Bruuk and Natura2000 area De Ooische Graaf, in which the maps overestimated agricultural production according to the stakeholders. Generally, the stakeholders did not agree with the recreation and tourism map. The map shows relatively low values for the agricultural land area, but it was argued that variation within the landscape due to the presence of small-scale landscape elements should have resulted in a higher potential supply. Stakeholders indicated that the floodplain area is as important as the forests in Groesbeek for recreation and tourism and that not all forests have the same potential supply. The other maps were more difficult to interpret and therefore stakeholders were more hesitant to comment. Multiple stakeholders mentioned that the water flow regulation map is not specific enough: some important elements, like small water courses are not visible. In addition, there were comments about the scores given to the different land-cover types, e.g. retention basins and the push moraine should have higher supply values. Multiple stakeholders mentioned that the term ‘natural pest and disease control’ is difficult to interpret. Several stakeholders indicated that the low supply of pastures and arable land is in agreement with reality. In contrast, the natural grasslands in floodplain areas should have a higher relevant potential than what is mapped. Stakeholders also doubted whether the floodplain area has a lower supply than forests, among others because the forest is believed to be too far from the arable land to be of importance for pest and disease control. The same remark was made for the pollination map. In line with the maps, natural grasslands are thought to have a higher supply than pastures, although some stakeholders stated that the supply of natural grasslands should even be higher than the currently used values. Stakeholders agreed with the spatial pattern of the map ‘natural heritage and natural diversity’. They did stress that the species composition differs between land-cover

Table 3
Calculated landscape metrics for landscape aesthetics based on the LGN7 map before and after the implementation of the project ‘Pilot green-blue services’ with clustering of CORINE land-cover types to hemeroby and diversity groups.

	LGN7 without elements	LGN7 with elements
Mean SHAPE (-)	1.33	1.58
PD (per km^2)	82	89
SHDI (-)	2.06	2.07

Table 2
Probability of connectivity index before and after the implementation of the pilot ‘green–blue services’ for a range of dispersal distances, ranging from very local dispersal to dispersal distances where all the landscape elements are connected. The index is calculated based on the LGN7 map with reference year 2012, with and without the additional small-scale landscape elements. The indices are both calculated with same A_{max} (see Eq. (3)) based on the number of patches after the implementation.

	$\alpha = 0.05$	$\alpha = 0.8$	$\alpha = 2.6$	$\alpha = 12.2$	$\alpha = 24.3$
Dispersal distance	20 km	1.25 km	~385 m	~80 m	~40 m
PC before pilot	1.20×10^{-1}	1.32×10^{-2}	2.44×10^{-3}	4.14×10^{-4}	2.75×10^{-4}
PC after pilot	1.38×10^{-1}	1.49×10^{-2}	2.67×10^{-3}	4.44×10^{-4}	2.95×10^{-4}

types.

A recent review (van Zanten et al., 2014) confirms the finding of the stakeholders that the supply of certain regulating, cultural and habitat ecosystem services not only depends on the present land-cover types, but also on the presence of small-scale landscape elements, such as hedges and tree lines. Particularly biodiversity benefits from a mosaic of different fields connected by non-cropped habitat (Benton et al., 2003). The added value of the 'Green-blue service pilot' for biodiversity was scientifically monitored by comparing biodiversity in the area before and after the pilot was implemented (Niemeijer, 2016). Niemeijer (2016) concluded that the small-scale landscape elements contained more biodiversity than the surrounding agricultural fields, which is in line with our findings for habitat services based on our additional analysis with the small landscape elements.

During the interviews it became clear that not all farmers in Berg en Dal participate in the governance models that aim to improve the agricultural landscape. Further research should therefore focus not only on the differences between actor groups within community-based governance approaches but also on differences between (groups of) farmers in their motivation to participate or not to participate in the type of governance models discussed in this study. The existing or planned governance models should be analyzed with respect to the preconditions for farmers to participate in nature conservation models, i.e. motivation ability, demand and legitimation, following the approach of Runhaar et al. (2016). Finally, more effort is needed to explore the added value of the small-scale landscape elements, resulting from the community-based governance approaches, for the supply of ecosystem services of the landscape of Berg en Dal besides the ones we have studied. Ideally, these results should be compared with ecosystem service provision in another similar region in which no community-based governance approaches are in place.

5. Conclusions

Community-based governance is seen as the preferred way of solving environmental problems. However, efforts are needed that determine whether community-based governance models are indeed better performing than other governance models. The aim of this study was to test the hypothesis that community-based governance approaches have a positive effect on the supply of ecosystem services by the landscape of Berg en Dal, the Netherlands. Following the suggestion by Koontz and Thomas (2006) and Sattler et al. (2018), we combined indirect and subjective measures of stakeholders with direct and objectives measures of environmental conditions via land-use maps. Using objective measures of environmental conditions prevents the possible exaggeration of the positive outcomes of community-based governance on the environment by the involved stakeholders (Koontz and Thomas, 2006). Our results confirm our hypothesis: changes in governance from top-down to more community-based models in Berg en Dal coincide with an increase in multifunctional land-use and consequently an enhancement of potential and actual ecosystem services provision. We also found that the small-scale landscape elements added to the landscape in the context of the community-based project 'Pilot green-blue services' enhanced the quality of the landscape. To conclude, our novel approach combining literature research, semi-structured interviews with local stakeholders and objective spatial analysis techniques provides new insights in the benefits of collaboration between the state, market and civil society to enhance the governance of our natural environment.

CRediT authorship contribution statement

Lenny G.J. Van Bussel: Conceptualization, Methodology, Formal analysis, Writing - original draft. **Nina De Haan:** Methodology, Formal analysis, Investigation, Writing - original draft. **Roy P. Remme:** Conceptualization, Writing - review & editing. **Marjolein E. Lof:** Methodology, Software, Writing - review & editing. **Rudolf De Groot:** Conceptualization, Writing - review & editing.

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.

Acknowledgements

We are very grateful to the interviewees for the time they have spent and for the useful insights they have given us. We also thank two anonymous reviewers for their valuable comments. This study is part of the cp^3 project (Civil-public-private-partnerships, http://cp3-project.eu/). The research of cp^3 is funded through BiodivERsA/FACCE-JPI, with three national funders: BMBF Germany, FWF Austria and NWO the Netherlands.

Appendix A. Topics and questions addressed in the interviews

The abbreviations indicate which stakeholder was addressed, ALL = all stakeholders; FA = farmer; MU = employee municipality; VN = employee Via Natura; PD = employee Ploegdriever; WB = employee Water board.

<u>Start of the interview</u>

- General questions about profession, motivation to participate in research, attitude toward landscape of Berg en Dal and knowledge about changes in landscape since 1995 (ALL)
- Questions about farm management and activities related to nature and landscape, how farmers take into account nature and the landscape, functions of the agricultural landscape (FA)

<u>Ecosystem services</u>

- Knowledge about ecosystem services, selection of most important (4–5) ecosystem services and if this has changed since 1995 (ALL)
- Questions per ecosystem service:
  - Crop and livestock: (development of) market of local products (FA)
  - Water-flow regulation: frequency, intensity, regulation (Ruimte voor de Rivier, natural elements) and effects of flooding of river Waal; problems with drainage (FA, WB, MU)
  - Pollination: if pollination is required, use of honey bees or wild pollinators, trends of wild pollinators and their importance for production (FA)
  - Pest and disease control: if natural pest and disease control is happening on agricultural lands and the trends (FA)
  - Natural heritage and natural diversity: habitats on farm/land (FA)
  - Recreation and tourism: which part of the landscape or ecosystem services are popular among tourists, (expected) trends of number and origin of tourists, conflicts between recreation, and nature and agriculture, which investments have been done between 1995 and 2015, are

additional investments required (FA, MU)
Knowledge systems: educational activities for local inhabitants or tourists, focused on children or adults (PD)
Cultural heritage and cultural diversity: environment important for culture-historical experience and (trends in) appreciation of cultural-historical heritage (FA)

Validation of ecosystem service maps
Per ecosystem service: representative for Berg en Dal, spatial pattern of 0–5 values (ALL)
Land use and land cover: land use a correct indicator for potential ecosystem service supply, how did land use change after 2012 and the effects on ecosystem service supply (ALL)
Trends in ecosystem service supply in periods 1995–2005 and 2006–2015 (ALL)

Governance and land use
The (changing) role of EU, the Dutch state and provinces (MU, WB, VN)
Local actors, decentralization and regionalization: more responsibility, the role of the municipality, which actors and which factors are important and did this change since 1995, conflicts, influence on improvement of landscape (MU, WB, VN)
Execution of management: by whom (MU, WB, VN)
Municipality Berg en Dal and Landscape Development Plan:
Vision of municipality Berg en Dal: did the vision change between 1995 and 2015, effect of merging of three municipalities, do local people share the vision and their involvement (MU, VN)
Execution of LOP (Landscape Development Plan): actors satisfied concerning the execution and results, reflection and evaluation (MU, VN)
Participation: municipality satisfied with participation actors, participation of inhabitants, factors important for participation, effect of LOP 2004 and LOP 2015 on management (MU, VN)
Subsidy scheme for Nature and Landscape (SNL)/De Ploegdriever:
Role of De Ploegdriever concerning the landscape and the execution of the SNL, how does the SNL work, conflicts with other programs (PD)
Pilot green-blue services: role of Via Natura, how does the pilot works, conflicts with other programs, landscape elements part of EHS/NNN (VN, PD, FA)
Funds: aim of Via Natura as landscape fund, limitations, how was the funding of the Postcodeloterij organized, other funding (VN, PD, FA)
Water Board Rivierland:
Role of the Water Board, cooperation, executed projects between 1995 and 2015, cooperation (WB)
Involvement with landscape management: role of water management, role of Water Board with execution of LOP 2004, communication with stakeholders (WB)
Governance of water and landscape: role of Dutch State, province and municipality, decentralization or regionalization, role of European Kaderrichtlijn Water (KRW) and Bestuursakkoord Water (WB)
Landscape development Ooijpolder, Millingerwaard & Erlecom: which development, which aims, which actors, which governance approaches (WB, MU)
Land consolidation and farm size: land consolidation in Berg en Dal, effects, average size of agricultural fields, effects on management small-scale landscape elements

Appendix B

Input for semi-quantitative method to evaluate ecosystem services provisioning

Table B1
LGN classes occurring in Berg en Dal, corresponding CORINE land-cover types based on Hazeu (2014b) and corresponding aggregated classes as used to calculate the landscape metrics (see paragraph 2.3.4).

LGN class	Corresponding CORINE land-cover types	Class for landscape metrics
Drifting sands/river sandbanks	Beaches, sand, dunes	(Semi-)natural ecosystem
Deciduous forest and Forest in swamp areas	Broad-leaved forest	(Semi-)natural ecosystem
Coniferous forest	Coniferous forest	(Semi-)natural ecosystem
Bare soil in built-up areas	Construction sites	Artificial surface
Grass in built-up areas	Construction sites, Green urban areas and Sport and leisure facilities	Artificial surface
Built-up areas outside urban areas	Discontinuous urban fabric	Artificial surface
Urban built-up areas	Discontinuous urban fabric and Industrial and commercial units	Artificial surface
Semi urban built-up areas	Discontinuous urban fabric, Sport and leisure facilities, Industrial and commercial units	Artificial surface
Grass in semi built-up areas	Dump sites, Construction sites, Green urban areas and Sport and leisure facilities	Artificial surface
Orchards and Fruit cultivation	Fruit trees and berry plantation	Cropland and orchards
Forest in built-up areas	Green urban areas	(Semi-)natural ecosystem
Forest in semi built-up areas	Green urban areas and Sport and leisure facilities	(Semi-)natural ecosystem
Reeds and Other swamp vegetation	Inland marshes	(Semi-)natural ecosystem
Heathland, Grassy heathland, and Very grassy heathland	Moors and heath lands	(Semi-)natural ecosystem
Natural grasslands	Natural grasslands	(Semi-)natural ecosystem
Maize, Potatoes, Sugar beet, Cereals, Greenhouses, Flower bulbs, Tree nurseries and Other agricultural crops	Non-irrigated arable land	Cropland and orchards
Pasture	Pastures	Pastures
Main roads & railways	Road and rail networks and associated land	Artificial surface
Fresh water	Water courses	(Semi-)natural ecosystem

Table B2
Matrix with potential supply values for LGN3 +, LGN4 and LGN5, based on Fig. 4 from Burkhard et al. (2014). On each intersection a number from 0 to 5 is given, indicating the potential of the CORINE land-cover type to provide a certain ecosystem service, with 0 implying no relevant supply and 5 very high supply.

CORINE land-cover type	CORINE land-cover type number	Potential supply values						
		Water flow regulation	Pollination	Pest and disease control	Crops	Livestock	Recreation and tourism	Natural heritage and natural diversity
Discontinuous urban fabric	112	0	1	1	1	0	3	0
Road and rail networks	122	0	0	0	0	0	0	0
Construction sites	133	0	0	0	0	0	0	0
Green urban areas	141	2	2	2	0	0	3	1
Non-irrigated arable land	211	2	1	2	5	0	1	0
Fruit trees and berry plantations	222	2	5	3	4	0	3	1
Pastures	231	1	0	2	0	5	2	1
Broad leaved forest	311	3	4	4	0	0	5	5
Coniferous forest	312	3	4	4	0	0	5	4
Natural grasslands	321	1	1	1	0	3	3	3
Beaches, dunes and sands	331	1	0	1	0	0	5	2
Inland marshes	411	3	1	2	0	2	1	2
Water courses	511	3	0	3	0	0	4	3

Table B3
Matrix with potential supply values for LGN6 and LGN7, based on Fig. 4 from Burkhard et al. (2014). On each intersection a number from 0 to 5 is given, indicating the potential of the CORINE land-cover type to provide a certain ecosystem service, with 0 implying no relevant supply and 5 very high supply.

CORINE land-cover type	CORINE land-cover type number	Potential supply values						
		Water flow regulation	Pollination	Pest and disease control	Crops	Livestock	Recreation and tourism	Natural heritage and natural diversity
Discontinuous urban fabric	112	0	1	1	1	0	3	0
Road and rail networks and associated land	122	0	0	0	0	0	0	0
Construction sites	133	0	0	0	0	0	0	0
Green urban areas	141	2	2	2	0	0	3	1
Non-irrigated arable land	211	2	1	2	5	0	1	0
Fruit trees and berry plantations	222	2	5	3	4	0	3	1
Pastures	231	1	0	2	0	5	2	1
Broad leaved forest	311	3	4	4	0	0	5	5
Coniferous forest	312	3	4	4	0	0	5	4
Natural grasslands	321	1	1	1	0	3	3	3
Moors and heathland	322	2	2	2	0	1	4	4
Beaches, dunes and sands	331	1	0	1	0	0	5	2
Inland marshes	411	3	1	2	0	2	1	2
Water courses	511	3	0	3	0	0	4	3

Table B4
Matrix with potential supply values for the small-scale landscape elements from the project Pilot green–blue services', based on Fig. 4 from Burkhard et al. (2014) and own expert knowledge. On each intersection a number from 0 to 5 is given, indicating the potential of the landscape element for natural heritage and natural diversity, with 0 implying no relevant potential and 5 very high potential.

Dutch name pilot element	English translation	CORINE land-cover type	Potential supply values natural heritage and natural diversity
Houtsingel	Line of trees	Transitional woodland shrub	2
Graskruidenstrook	Grass margins	Agriculture & natural vegetation	3
Struweelhaag/struweel	Hedgerow	Transitional woodland shrub	2
Natuurvriendelijke oever/moerasoever	Ecologically sound water bank	Agriculture & natural vegetation	3
Knip- of scheerheg/heg	Hedgerow	Transitional woodland shrub	2
Struweelrand/ruige greppel	Strip of herbaceous vegetation	Transitional woodland shrub	2
Knotboom < 20 cm	Pollarded tree < 20 cm	Transitional woodland shrub	2
Knotboom > 60 cm	Pollarded tree > 20 cm	Transitional woodland shrub	2
Knotboom 20–60 cm	Pollarded tree 20–60 cm	Transitional woodland shrub	2
Faunastrook A	Grass margins	Agriculture & natural vegetation	3
Houtwal	Line of trees	Transitional woodland shrub	2
Bomenrij, bomen < 20 cm	Line of trees, trees < 20 cm	Transitional woodland shrub	2
Solitaire boom > 60 cm	Solitary tree > 60 cm	Transitional woodland shrub	2
Solitaire boom < 20 cm	Solitary tree < 20 cm	Transitional woodland shrub	2
Solitaire boom 20–60 cm	Solitary tree 20–60 cm	Transitional woodland shrub	2
Hoogstamboomgaard/fruitbomen	Standard Orchard/fruit trees	Fruit trees and berry plantations	1
Poel < 175 m2	Pond < 175 m2	Water body < 175 m2	3
Poel > 175 m2	Pond > 175 m2	Water body > 175 m2	3

Table B5
Clustering of the CORINE land-cover types to hemeroby groups and diversity groups.

CLC-class	Degree of hemeroby	Diversity group
Construction sites	Metahemerobe	1
Discontinuous urban fabric	Polyhemerobe	1
Road and rail networks and associated lands	Polyhemerobe	1
Green urban area	Euhemerobe	2
Non-irrigated arable land	Euhemerobe	3
Fruit trees and berry plantations	Euhemerobe	4
Standard Orchard/fruit trees	Euhemerobe	4
Pastures	Euhemerobe	5
Broad leaved forest	Mesohemerobe	6
Forest in swamp area	Mesohemerobe	6
Coniferous forest	Mesohemerobe	7
Natural grasslands	Oligohemerobe	8
Moors and heathland	Oligohemerobe	9
Water courses	Euhemerobe	10
Inland marshes	Oligohemerobe	11
Beaches, dunes and sands	Oligohemerobe	12
Overlapping elements	Mesohemerobe	13
Pollarded tree < 20 cm trunk diameter	Mesohemerobe	14
Pollarded tree 20–60 cm trunk diameter	Mesohemerobe	14
Pollarded tree > 60 cm trunk diameter	Mesohemerobe	14
Solitary tree < 20 cm trunk diameter	Mesohemerobe	14
Solitary tree 20–60 cm trunk diameter	Mesohemerobe	14
Solitary tree > 60 cm trunk diameter	Mesohemerobe	14
Hedgerow	Mesohemerobe	15
Line of trees	Mesohemerobe	15
Line of trees, trees < 20 cm trunk diameter	Mesohemerobe	15
Strip of herbaceous vegetation	Mesohemerobe	15
Ecologically sound water bank	Mesohemerobe	16
Pond < 175 m^2	Mesohemerobe	16
Pond > 175 m^2	Mesohemerobe	16
Grass margins	Mesohemerobe	17

Appendix C

Governance models in Berg en Dal 1995–2012

Table C1
Overview of governance arrangement focused on the (agricultural) landscape of Berg en Dal.

Governance approach/development	Description	(Ecological) aim	Governance approach	Time period it has been implemented
Designation of National Landscapes	Part of Berg en Dal is a protected landscape (i.e. a National Landscape) and parts are protected natural area	Preserving cultural heritage and nature conservation	Top-down	2004
Landscaping plan Ooijpolder (Dutch: Landinrichting Ooijpolder)	In 1996 the Landscaping plan for the area of the Ooijpolder and an area southern of Groesbeek was established, based on the Land Arrangement Law of 1985. The land arrangement was requested by farmers who wanted more productive parcels. Because of the optimization of parcels many natural corners and ditches disappeared and the natural and agricultural areas became more separated (Personal communication employee municipality Berg en Dal, 2017).	Nature conservation and increasing agricultural production	Top-down	1996–2006
Water Works in Beek and Ubbergen (Dutch: Water Werkt in Beek en Ubbergen)	Several government bodies and organizations were involved in this project, including the municipality of Ubbergen, the Dutch Water Authority Rivierenland, the province and the Ministry of Agriculture, Nature and Fisheries. The project plan was developed in collaboration with interested parties, including inhabitants (http://www.txt.nl/waterwerkt/index.html).	Improving water flow regulation and water quality	Mainly top-down	1999–2003
Landscape Development Plan 2005–2014 (in Dutch: Landschapsontwikkelings-plan 2005–2014) (LOP 2005–2014)	The LOP 2005–2014 presented a vision for the development of the landscape of the municipalities Groesbeek, Millingen a/d Rijn and Ubbergen. This vision was created in collaboration with different stakeholders. LOP 2005–2014 included 77 projects proposals to be taken up by stakeholders, but it also encouraged stakeholders to start other projects in line with the vision of LOP. LOP also presented an overview of subsidy programs and regulations that are relevant concerning the funding of landscape development projects (Municipalities Groesbeek Millingen a/d Rijn en Ubbergen, 2004).	Strengthening the identity of the region; conserving sustainable extensive agriculture; increasing the value of nature; increasing recreation possibilities; to realizing sustainable forms of rural living.	Mainly top-down, but also community-based because the initiative came from the local public	2005–2014
'Pilot area green-blue services' (in Dutch: Groenblauwe Diensten programma)	One of the main projects in the LOP 2005–2014 was the 'Pilot area green–blue services'. The organization Via Natura applied together with a local government official from the city of Nijmegen for public funding. This funding was supplemented with several other sources: 1) private funding, secured via the national 'Zip code lottery' (attracted by The national Association for the Preservation of Dutch Cultural Landscapes), 2) landscape auction (targeting citizens and businesses), 3) a Regional fund and 4) funds for compensation of spatial developments. The agri-environmental cooperative De Ploegdriever facilitated the communication towards the farmers and land-owners, the local government played a minor role. The organizations De Ploegdriever and The national Association for the Preservation of Dutch Cultural Landscapes helped the farmers and land-owners to create suitable landscape management plans, which were checked by Via Natura. Participants signed a 30-year contract in which compensation for income losses and payment for the implementation and maintenance of the landscape elements was secured (Municipalities Groesbeek Millingen a/d Rijn en Ubbergen, 2004; Personal communication Personal communication employee Via Natura, 2017).	The 'Pilot green-blue services' program aims: 1) to obtain a coherent network of small-scale landscape elements through the rural landscape, to preserve the cultural landscape and increase its quality.; and 2) to establish a network of open recreational pathways through the agricultural lands to make it accessible for recreationalists.	Community-based	2009–2015

(continued on next page)

Table C1 (*continued*)

Governance approach/development	Description	(Ecological) aim	Governance approach	Time period it has been implemented
Agri-environmental schemes (AESs) in Berg en Dal	Multiple AESs were in place in Berg en Dal from 1995 to 2015, including: the 'Pilot green-blue services' through Via Natura; the Agricultural Nature and Landscape Management subsidy program; Stimuleringsregeling Akkeranden Rivierengebied 2011; and Stimuleringsregeling Natuurvriendelijke Oevers 2014. These subsidy programs are managed by different government bodies: the municipality, the province and the Dutch Water Authority Rivierenland.	Increasing water quality, water storage capacity and biodiversity	Mainly top-down, but also community-based	1995–2015
Water stream expansion in Groesbeek	In the former municipality of Groesbeek multiple water streams are reconstructed (Waterplan Groesbeek, 2015).	Increasing biodiversity and recreation opportunities along the water streams and increasing the water storage capacity	Top-down, but also community-based because of input from the local public	2006–2015
Room for the River Programme (in Dutch: Ruimte voor de Rivier): reconstruction of floodplains of Millingerwaard	The floodplain area of the Millingerwaard is being reconstructed between 2011 and 2020 as part of this program which is initiated by Rijkswaterstaat. The State Foresty Service is responsible for the execution (https://www.staatsbosbeheer.nl/over-staatsbosbeheer/projecten/gelderse-poort-herinrichting-millingerwaard)	Increasing water storage capacity through the creation of additional water channels next to the main water course	Top-down	2011–2020

Appendix D

Detailed results from interviews

Evaluation of maps of ecosystem services in Berg en Dal for 2012 by stakeholders

Generally, the maps of crops and livestock product provision were easiest to interpret for the stakeholders. Also the service recreation and tourism was relatively easy to interpret, which resulted in many comments about this map by the stakeholders. The maps of other services such as pollination and pest and disease control were more difficult to interpret and therefore stakeholders were more hesitant in commenting.

Water flow regulation

Multiple stakeholders mention that the map is not specific enough: some elements that are important are not visible on the map, like small water courses that should have a high relevant potential supply. In addition, there were comments about the scores given to the different land use types, e.g. retention basins should also have a higher potential supply, as well as the area of the moraine. One stakeholder mentioned that in reality there is more differentiation in classes than the four classes that are visible on the map.

Pest and disease control

Multiple stakeholders mentioned that the term 'natural pest and disease control' is difficult to interpret. Several stakeholders agreed that pastures and arable land have a minimally relevant potential supply, because of the intensive use and the use of chemical pesticides. In contrast, the natural grasslands in floodplain areas have a higher relevant potential supply than arable land, according to the stakeholders, which is not visible on the map. Stakeholders also doubted whether the floodplain area has a lower potential supply than forests. The floodplain area is thought to harbor many predatory insects and to be more diverse than the forest. In addition, the forest is believed to be too far from the arable land to be of importance for pest and disease control in agriculture. According to the stakeholders water does not contribute to pest and disease control. In contrast, flower strips along agricultural parcels are thought to be important for pest and disease control, but these are not visible on the map.

Pollination

The stakeholders agreed that fruit trees and berry plantations have the highest relevant supply of pollination. Natural grasslands are thought to have a higher potential supply than pastures because they harbor more flowering grasses and herbs, which is in line with the maps, although some

Table D1
Selected ecosystem services per stakeholder.

Ecosystem service	Employee De Ploegdriever	Employee Via Natura	Employee muni-cipality Berg en Dal	Employee of the Dutch Water Authority	Farmer	Total
Provisioning services						
Crops	×		×	×	×	××××
Livestock (domestic)	×	×	×		×	××××
Aquaculture				×		×
Wild foods, semi-domestic livestock and ornamental resources		×		×		××
Freshwater			×			×
Regulating services						
Local climate regulation				×		×
Water flow regulation	×		×	×		×××
Erosion regulation		×		×	×	×××
Pollination	×	×				××
Pest and disease control	×					×
Regulation of waste					×	×
Cultural services						
Recreation and tourism	×	×	×	×	×	×××××
Landscape aesthetics, amenity and inspiration	×	×	×	×	×	×××××
Habitat service						
Natural heritage and natural diversity	×	×	×	×	×	×××××

Table D2
Changes in ecosystem service potential supply in the periods 1995 to 2005 and 2006 to 2015 as indicated by interviewees, in - means declined, -+ means both declined and increased, 0 means constant, + means increased, + + means strongly increased. In some cases + + + is used to indicate changes in the rate of increase between the two periods. In some cases the field was left blank because the interviewee did not have enough information.

Ecosystem service	Time period	Employee De Ploegdriever	Employee Via Natura	Employee municipality Berg en Dal	Employee of the Dutch Water Authority	Farmer	Average
Water flow regulation	1995–2005	+	+	+ +		+	+
	2006–2015	+	+ +	0	+ +	+	+
Pollination	1995–2005	+	+	–			0
	2006–2015	+	+ +	+	+ +	+	+
Pest and disease control	1995–2005	+	0	–			0
	2006–2015	+	+	+	+		+
Crops	1995–2005	+ +	+	+		+	+
	2006–2015	+ +	+ +	0	0	+	+
Livestock (domestic)	1995–2005	+ +	+	+		+	+
	2006–2015	+ +	+ +	0	0	0	+
Recreation and tourism	1995–2005	+	+ +	+		+	+
	2006–2015	+	+ + +	+ +	+ +	+	+ +
Natural heritage and natural diversity	1995–2005	-+	+	0		+	+
	2006–2015	-+	+ + +	+	+ +	+	+

stakeholders stated that the potential supply of natural grasslands should be higher than the currently used values. One stakeholder mentioned that urban area could be important for pollination, because the vegetation in gardens is quite varied. The three larger green urban areas are thought to have a lower potential supply value than what is shown on the map. One stakeholder doubted the importance of forests for pollination of crops because of the distance between the forest and the crop land.

Agricultural products (crops and domestic livestock)

The maps for crops and domestic livestock products provision were easiest to interpret. Stakeholders commented that these maps represent facts, because the areas that are marked as relevant are areas which are actually used for the purpose of cultivating crops or producing animal products. Stakeholders confirmed that in the urban built-up areas there is a (low) relevant potential supply of crops, because people in Berg en Dal have vegetable gardens. The natural area De Bruuk is not used for livestock and the production of maize and other grains. Therefore, this area should be indicated as no relevant potential supply on the map. There is no livestock in the Natura2000 area Ooische Graaf either.

Recreation and tourism

Generally, the stakeholders did not agree with this map. The stakeholders stressed that perception of the landscape is an important factor in recreation and tourism and that this cannot be seen in the maps. The variation in the landscape of Berg en Dal with respect to nature and geology is very important for recreation and tourism. The stakeholders stressed that there are many options for recreation and tourism in Berg en Dal and that different areas allow for different ways of recreating and attracting different people. The map shows relatively low values for the agricultural land area but most stakeholders argued that variation within the landscape due to the presence of small-scale landscape elements should result in a higher potential supply. The stakeholders thought that the floodplain area is as important as the forests in Groesbeek. One stakeholder also mentioned that not all forests have the same potential supply: De Bruuk has a higher potential supply than other forests.

Natural heritage and natural diversity

Stakeholders agreed with the spatial pattern of this map: high values for the forests and the floodplain area and lower values for pastures and arable land. They stressed that the biodiversity is very different in each of these land-cover types, but to quantify biodiversity is difficult. One stakeholder mentioned that the dikes next to the Waal have a higher potential supply value than is visible in the map.

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