Evaluating the impact of regional development policies on future landscape services

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\textbf{A R T I C L E   I N F O}

Abstract
In this paper we analyse the potential impact of an integrated policy package for the Gelderse Vallei region in the Netherlands on seven landscape services (residential use, intensive livestock husbandry, drinking water supply, attractiveness for overnight tourism, habitat provision for rare, endemic and indicator plant species, arable agricultural production, and attractiveness for leisure cycling). The spatially explicit methodology focuses on the changes in landscape properties resulting from the implementation of these policies and its effects on the supply of landscape services and economic values of the landscape services. After the policy implementation the strongest increase in services supply is expected in rural areas while the strongest increase in value is expected to occur in (peri-) urban areas of the study area. In addition, full implementation of the policy package will lead to an increase in multifunctional areas. This study presents one of the first spatially explicit methodologies to quantify and analyse spatial variation in economic value of landscape services in time, and therefore can contribute to well-informed management of landscapes.

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1. Introduction

Besides producing agricultural commodities, rural regions provide a multitude of services that benefit people. Based on the definitions of ‘ecosystem functions’ (De Groot et al., 2002; MA, 2003), we use the term ‘landscape function’ to indicate the capacity of a landscape to provide services to society. These services include, amongst others, benefits such as food and timber production, fresh water supply, and recreational opportunities. The potential to provide such services depends on the spatial configuration and components of the landscape (Wiggering et al., 2006; Syrbe et al., 2007; Egoh et al., 2008). By changing landscape properties, human activities can directly or indirectly affect the supply of landscape services (Bastian et al., 2006; Nelson et al., 2006). Spatial policies are designed to influence the landscape in such a way that the provision of one or more landscape services is improved (Daily and Matson, 2008). For example, creating buffer zones around natural areas may improve wildlife habitats, land consolidation of arable land will enhance agricultural production, and creating access to natural areas can boost recreational activities. However, such changes in the landscape may affect each landscape function in a different manner leading to trade-offs between different functions (Chan et al., 2006; Nelson et al., 2009). Such trade-offs challenge the design and implementation of regional spatial policies.

An ex-ante evaluation of the consequences of spatial planning and policy on the supply of landscape services can support decision making (Bockstael et al., 1995; Verburg et al., 2009). Landscapes are spatially diverse leading to unequal distribution of landscape services over an area. An evaluation of policy effects should therefore be spatially explicit as policies are likely to have a location-specific effect on the provision of landscape services. Additionally, changes in service supply need to be quantified to support decisions regarding possible trade-offs between landscape functions. To be able to compare service provision across different landscape functions, service supply should be standardised to the same units of value. Increasingly, economic valuation techniques are used to quantify landscape functions and their value for society (MA, 2005; Fisher et al., 2008; Schaeffer, 2008; Carpenter et al., 2009). Different approaches have been developed to value landscape services in monetary units (see for an overview e.g. MA, 2003; Turner et al., 2003; Zandersen and Tol, 2009). Monetary valuation can, for example be of use for analysing trade-offs in landscape service supply (Turner et al., 2003; Bateman et al., 2005; Naidoo and Ricketts, 2006). Several studies have included economic values in spatial policy evaluations (Troy and Wilson, 2006; Grêt-Regamey et al., 2008; Vejre et al., In Press). Alternatively, landscape functions can be valued in non-monetary measures representing standardised service supply (Gimona and Van der Horst, 2007; Nelson et al., 2009; Willemen et al., 2010). Using these standardised measures, each landscape function can be evaluated by quantifying the relative change in service provisioning, without explicitly considering the economic
value of a landscape function. To date, studies tend to focus either on a detailed spatial description of service supply or on a valuation of landscape services without explicitly taking into account the spatial variation in service supply. To our knowledge, no earlier study has presented a spatially explicit economic valuation based on the quantified service supply for a broad range of landscape functions.

The objective of this paper is thus to analyse the change in landscape service supply and value under influence of policy measures in the rural Gelderse Vallei region of the Netherlands. In this paper we analyse the impact of implementation of policy plans on seven landscape functions: residential use, intensive livestock husbandry, drinking water supply, attractiveness for overnight tourism, habitat provision for rare, endemic and indicator plant species, arable agricultural production, and attractiveness for leisure cycling. We quantitatively and spatially explore the changes in service supply using two measures; (i) a unit-less index related to the level of service provision and (ii) an estimation of the value of these services in monetary terms. We present a methodology that addresses three questions; (i) How will landscape properties change after policy implementation?; (ii) How will changed landscape properties affect the supply of landscape services? and (iii) How will a change in service supply translate into a change in economic value of the study area? We will show that the quantification, valuation and mapping of landscape services can support management and planning activities of multifunctional landscapes.

2. Data and Methods

2.1. Study Area

In this paper the region of the Gelderse Vallei in the Netherlands is used as study area (Fig. 1). Total size of the study area is about 750 km² of which 71% is under agricultural use, 17% of the land is covered by urban areas, the remainder of the area is composed of natural areas, infrastructure and water. The population is expected to increase from six hundred thousand inhabitants in the year 2000 to six hundred twenty thousand people by 2015 (CBS, 2008a). Ecological corridors are being created to connect two national parks located on both sides of the study area. The presence of these national parks has contributed to the development of a large tourism sector in the region (Provinces of Gelderland and Utrecht, 2005). Additionally, the region contains approximately 20% of the intensive livestock production (pork, poultry and eggs) of the Netherlands (CBS, 2008a). As a result of simultaneous claims for space, tension exists between different land uses in the study area. There is a strong demand for residential areas and urban development together with an increasing demand for recreational and nature areas. At the same time, growth of the agricultural sector is restricted by environmental regulations.

In 2002, the Dutch national government introduced a new law to tackle competing land demands in the Dutch rural areas in an integrated manner: the Reconstruction Act. The integrated regional development plans evaluated in this paper are based on the Reconstruction Act of which the implementation for the study area is defined by the provincial administrations. The policy plans envision regional development through improving the conditions for supplying multiple landscape services to fulfill the increasing demands of society (Provinces of Gelderland and Utrecht, 2005). Living conditions and economic development should benefit from the new spatial planning. The first policy measures based on the Reconstruction Act were implemented in 2005, and in 2015 all measures are foreseen to be put in place.

The implementation and regulation of the Reconstruction Act in the study region is strongly based on spatial zones to separate conflicting landscape functions. As especially intensive livestock
husbandry causes conflicts with other functions in the study area, three zones regulating the degree of development in intensive livestock sector have been defined; (i) Agricultural development zones, in which priority is given to growth and establishment of intensive livestock farms; (ii) Extensive agriculture zones, in which priority is given to nature development, residential use and recreation. In this zone the growth of intensive livestock farms is strongly regulated, but large profitable farms are eligible for a full financial compensation from the Dutch government to be reallocated to agricultural development zones; and (iii) Mixed zones, where residential and recreational uses, nature and agriculture should develop side by side. All urban areas are excluded from intensive livestock development zones (Fig. 1).

2.2. Methodological Approaches

To analyse the change in landscape service supply and value under influence of the regional development policies, three methodological steps were taken. The first step describes the effect of changes in land management on landscape properties as a result the implemented policies. Landscape properties include biophysical properties (e.g., soil type or groundwater level) socioeconomic properties (e.g., land use or population pressure), and spatial characteristics (e.g., clustering or proximities measures). Landscape properties determine the presence of landscape functions and the spatial variability of their supply of landscape services (Diaz et al., 2007; Egoh et al., 2008; Willemen et al., 2008; Tallis and Polasky, 2009). In the second step landscape properties are used to quantify and map the level of service provision of the different landscape functions, before and after policy implementation. In the third step, service supply is valued in monetary units, accounting for spatial variation of landscape service supply. Different valuation approaches are used to estimate the economic value of market and non-market landscape functions. As the focus of this paper is on demonstrating an interdisciplinary approach to evaluate spatial policies, simplified methods are used to estimate economic values of landscape services.

To quantify the changes in landscape service supply we compare the situation in 2000 to the expected situation in 2015, when the Reconstruction Act is assumed to be completely implemented. In this study all spatial data sources are converted to a raster format with a spatial resolution of 100 by 100m. To facilitate the visual interpretation of the results, all landscape function maps are aggregated to 186 postal code zones and administrative neighbourhoods of the study area.

2.2.1. Assessment of Landscape Properties

The first step in our overall methodology is to assess the changes in landscape properties. In addition to the integrated policy plans a range of development trends are also evaluated for their spatial alterations of the landscape, both in socioeconomic and in biophysical terms. Including development trends is needed to adequately describe the future situation in which policy plans are put into effect. Therefore, we base the assessment of the changes in landscape properties on demographic and economic prognoses and trends, construction licenses, and environmental regulations. Translating spatial policy plans (e.g., construction sites for residential areas) to location-specific landscape properties can be done straightforwardly. On the other hand, (policy induced) development trends often lack detailed information on spatial variability, as these trends are mostly given for administrative units (e.g., population growth per province). Therefore, translating these trends into landscape properties requires that these trends are made spatially explicit. In this section we briefly describe the translation of non-spatially defined trends and spatially explicit regional development policies into future landscape properties for the study area.

2.2.1.1. Development Trends. Demographic trends on population growth are for the study area available at municipality level (CBS, 2008a). We included an increased spatial variation in these trends by distributing the expected population per hectare over all residential areas within the municipality in 2015, using the size of the residential area as relative weight. This results in the estimated population distribution map for 2015. Additionally, agricultural development trends are used to assess the spatial variation of the change in intensive livestock farms. Since a number of decades, there has been a negative trend in number of farms in the Netherlands. The Dutch Farm Accountancy Data Network includes development trends regarding the number and size of farms in the study area (Provinces of Gelderland and Utrecht, 2005). The prognosis for 2015 is an overall decrease in the number of intensive livestock farms of approximately 40% in the study area. However, among farm size classes this percentage differs. Based on the farm size and growth restrictions as defined by the intensive livestock development zones, we estimated the location and size of livestock and arable farms by 2015 (see Appendix A).

2.2.1.2. Spatial Policies. A spatially defined landscape change as described in the regional Reconstruction Act, is the planned conversion of 3800 ha of agricultural land into natural areas to create ecological corridors (VROM, 2006). Additionally, 560 ha of new residential area are envisioned in housing construction plans for the study area (Nirov, 2007). Changes in infrastructure include the construction of a highway in the central part of the study area. In most cases these planned land cover conversions take place at locations that are currently used as agricultural land. Combining the land cover map of 2000 with these foreseen landscape changes, a new land cover map for the year 2015 is constructed for the study area. Additionally, to reduce the chance of water stress for natural vegetation the Reconstruction Act states that the amount of extracted groundwater needs to decrease. Therefore the overall drinking water extraction in 2015 is foreseen to decrease to 94% of the overall amount of water extracted in 2000. Drinking water companies foresee that this reduction goes alongside with a similar expected decrease in water losses due to leakages (VEWIN, 2005).

2.2.2. Quantification of Landscape Service Supply

In the second step of the methodology, landscape service supply and its spatial distribution are assessed based on the spatially explicit landscape properties resulting from the first step (Fig. 2). Willemen et al (2008) quantified the relation between landscape functions and landscape properties. In this section we give a short description of the quantification method of service supply and mapping procedure for the years 2000 and 2015 per landscape function. Based on the situation in the reference year 2000 and the expected landscape properties in the year 2015, landscape function maps are created and subsequently compared. To allow for comparison between different landscape functions and years, all aggregated functions maps are normalised between 0 and 1 based on their minimum and maximum values for 2015.

2.2.2.1. Residential. Service supply of the residential function is quantified by means of the number of people living in a residential area. Based on the population statistics for the year 2000 and the growth prognosis for the year 2015, the population per residential area was estimated for both years. The population per hectare of the study area is mapped for the years 2000 and 2015.  
2.2.2.2. Intensive Livestock Husbandry. The provided services of this function are mapped based on intensive livestock production, measured in the Dutch Standard Unit (DSU). The location and size of each farm in the study area is derived from farm census data for 2000. Combining the assessed livestock farm distribution map for the
year 2015 with the agricultural growth data, results in a map representing the DSU per livestock farm in 2015. On average a livestock farm in the study area possesses 4 ha of land surrounding the farm. Therefore the supplied services of each farm are distributed over the four surrounding hectares.

2.2.2.7. Leisure Cycling. The service supply for leisure cycling is defined by the potential number of people visiting the location for cycling recreation. Of the Dutch population approximately 70% participates in cycling recreation, making on average four trips in 2000 and an expected three trips per year in 2015 (CBS, 2008a). An average cycling tour starts at home and covers approximately 15 km in a 5 km radius, following small local roads through areas with little disturbance from highways and industry (Willemen et al., 2008). Based on the suitability of the landscape and the potential leisure population, the leisure cycling function is quantified and mapped for 2000. To map leisure cycling in 2015, estimations of the change in the potential number of people recreating per year and infrastructure changes are included.
2.2.3. Valuation of Landscape Services

The economic valuation of landscape services for the years 2000 and 2015 is based on a selection of economic indicators that are linked to the landscape function maps. All landscape functions are valued in euro (€) per hectare per year. For each landscape service a value is estimated for both evaluation years based on (i) the amount of service supply per hectare and (ii) the price levels. Our valuation approach does not include market models to estimate supply and demand curves. Instead we use an approach based on market prices. For services with a market value our valuation is based on establishing the net value generated for each service, i.e. the gross value (price times quantity) minus the costs of producing the services (including cost of all inputs and depreciation of capital goods). Labour costs are however included in the net value. We are aware that these prices only reflect part of the value of a provided landscape service. Therefore the values assigned to landscape services can only be seen as an illustrative measure. For the year 2000, the prices are derived from different sources, including national statistics and company financial reports. For the year 2015, price levels are not available or price forecasts contain a high uncertainty. Therefore, we decided to base the 2015 price levels on the prices that occurred in the year 2007, i.e. the latest year for which the relevant national statistics are available. Hence, it is assumed that all prices in 2015 equal the prices in 2007. We are aware that this creates a bias, but further estimation of price developments is beyond the scope of this paper. Landscape services of which a significant part of the values are not reflected in market transactions (e.g. recreation and tourism) are additionally valued by simplified monetary measures indicating the consumer surplus based on literature. All prices and consumer values are expressed in 2007 euros. Thus, the prices that were recorded in 2000 are converted to 2007 euros, using a 2.2% annual inflation rate, the average inflation rate in the period 2000 to 2007 (CBS, 2008a).

2.2.3.1. Residential Use. The residential service is valued based on the price of land under residential use. It is assumed that this value can be assessed based on the average house price and the number of houses per hectare of residential area. The house price is estimated based on the average real estate tax values per municipality of 2007, and the growth in house prices between 2000 and 2007 (CBS, 2008a). For the study area the average value per house increased from €211 500 in 2000 (€182 300 in 2000 euros) to €259 000 in 2007. The prices of 2007 are used to assess the house prices of 2015. To translate these house prices into a value per year, the by the Dutch government proposed maximum annual rent of 5.4% of the house value is taken (VROM, 2005). Because this study aims to estimate the value of land for residential purposes, the construction costs of the house are subtracted from the annual value. The construction costs normally are about 70% of the real estate value (Bouwfonds, 2006). For 2000 the land value per house is multiplied by the number of houses per residential area. For 2015 housing development plans are included to determine the residential areas and number of houses (Nirow, 2007). The value of the residential service is mapped per hectare under residential use for both years.

2.2.3.2. Intensive Livestock Husbandry. The service supply of the intensive livestock function is valued based on the net value added (NVA) generated by a livestock farm. The Dutch farm size index DSU is used as starting point in these calculations. The DSU is included in Dutch farm census data and indicates agricultural production units expressed in a monetary term. The monetary term is obtained by taking gross farm revenues minus the costs for variable production inputs such as raw materials, fertilizers and pesticides (one DSU refers to €1390 in 2000 and is, based on 2007 data, estimated to be €1400 in 2015 (LEI, 2008c)). To come to the net value added (NVA) of an intensive livestock farm, all depreciation and interest costs are subtracted from the DSU. Since the NVA of intensive livestock farms strongly fluctuates per year, the average annual NVA between 2001 and 2006 is used (LEI, 2008b). Based on the above, the NVA is estimated at 29% of the gross revenues for 2000 and 2015. For each (predicted) farm size and location the NVA is calculated and mapped for the year 2000 and 2015.

2.2.3.3. Drinking Water. The value of the service supply of the drinking water function is estimated using the NVA of the drinking water companies and expressed per cubic meter water. Hence, the water extraction volumes for 2000 and 2015 are linked to the consumer prices of drinking water per cubic meter. These prices were €1.40 in 2000 and are estimated at €1.35 in 2015, based on 2007 prices (Hydron, 2004; Vitens, 2008). This decrease in real value of water relates to a lower price increase as compared to the inflation rate. The NVA as a percentage of the gross revenues is 20% for 2000 and is expected to be 23% in 2015 (Hydron, 2004; Vitens, 2008). Per drinking water extraction zone, the (expected) NVA generated by water extraction per hectare is mapped for the year 2000 and 2015.

2.2.3.4. Tourism. The total value of the service supply of the tourism function is estimated by accounting for both the NVA generated by the tourism sector (producers) and the net benefits accrued to tourists (consumers). To estimate the value of the tourism service related to the tourism industry, the NVA of the economic turnover of the tourism sector is calculated for 2000 and estimated for 2015 based on 2007 values. In 2000 a total 4.5 million overnight stays in tourist accommodations (camping, holiday homes, group accommodations) were registered for our study area. On average, a tourist spent €23 per day during a stay (CBS, 2008a; NBTC, 2008). In 2015 a slight increase (to 4.6 million) in overnight stays and a small decrease in expenses (to €22.50) is expected (CBS, 2008a; NBTC, 2008). The NVA of a tourism accommodation equals on average 32% of the total turnover in 2000 and is expected to be 34% in 2015 (CBS, 2008b). To estimate the value for consumers of the tourism service, we consider a range of studies to assess the consumers’ surplus accruing to visitors of natural areas in The Netherlands. In particular, we considered the results of a travel cost method for wetlands (Hein et al., 2006) and a national park (Van der Heide, 2005) and a contingent value method for a lake area (Van der Veeren, 2002). Based on the results of these studies we assume that visitors accrue a surplus of €2 per tourist per day in both evaluation years. For both evaluation years the sum of the two values is distributed over the area suitable for tourism (i.e. the area falling within a 5 km circle from a tourism accommodation) and weighed by the number of overnight stays per accommodation site.

2.2.3.5. Plant Habitat. The service supply of the plant habitat function has no direct market value and could not be valued with a price-based valuation method. There is at present insufficient data on the value of this service to come with a value estimate. Therefore the changes in plant habitat are only measured in service supply quantities.

2.2.3.6. Arable Production. The service supply of the arable production function is valued by linking the NVA of the crop market prices to the yield (ton per hectare) estimations of the function maps of 2000 and 2015. For the year 2000 the average market price for one ton of fodder maize was €24.35 with a NVA of 28.8%. In 2015 the prices are estimated to be €27.60 with a NVA of 30.5%. In 2015 the prices are estimated to be €27.60 with a NVA of 30.5%. In 2015 the prices are estimated to be €27.60 with a NVA of 30.5%. In 2015 the prices are estimated to be €27.60 with a NVA of 30.5%. In 2015 the prices are estimated to be €27.60 with a NVA of 30.5%. In 2015 the prices are estimated to be €27.60 with a NVA of 30.5%. In 2015 the prices are estimated to be €27.60 with a NVA of 30.5%. In 2015 the prices are estimated to be €27.60 with a NVA of 30.5%.
average €6.18 is expected to be spent, based on 2007 statistics (CBS, 2008a). The NVA of total turnover of cafes and restaurants in the Netherlands in 2000 was 34% and estimated 36% in 2015 (CBS, 2008a). The total value for the recreation sector (indicating the producer surplus) is therefore assumed to be the number of people times the expenditure per person times the NVA (as percentage). The surplus accrued to visitors by leisure cycling is assumed to be €2 per person per day based on earlier recreation studies in a Dutch context (Van der Veen, 2002; Van der Heide, 2005; Hein et al., 2006). The sum of the NVA and WTP of the leisure cycling function is distributed over the area suitable for leisure cycling and weighed by the potential number of people recreating at that location.

3. Results

3.1. Assessment of Landscape Properties

Based on policy plans and development trends we mapped the expected changes in land cover, drinking water extraction, intensive livestock and arable farms, and population for the year 2015. From these maps we subsequently derived the landscape properties to map and quantify landscape functions and their service supply.

3.2. Quantification of Landscape Service Supply

For the years 2000 and 2015 the provided services of the seven main landscape functions of our study region were mapped for each postal code area. In Fig. 3 we present the landscape function maps for the year 2000 and the change in service supply between the years 2000 and 2015. Only postal code areas with a change in service supply of more than 5% of the average postal code service supply in 2000 are mapped as change. Smaller differences in change in service supply are indicated as ‘no change’.

Several observations from the change maps as presented in Fig. 3 can be made. First, all landscape functions, except for the drinking water extraction and arable production function, show an overall increase in service supply by 2015, with the largest gains for the plant habitat and tourism functions. Nevertheless, within the study area different patterns of change can be observed. Second, the foreseen effect of policy has a wide spread impact on some functions (plant habitat, tourism, arable production), while other functions are more locally affected (residential, cycling leisure). The planned policies to stimulate nature development (i.e., implementation of ecological corridors), clearly increases in spatial extent and quantity of the plant habitat function by the year 2015. Some postal code areas are foreseen to lose small patches of nature, which leads to a decrease in plant habitat. The tourism function is for a large part defined by the presence of natural areas and is therefore also expected to increase strongly in most areas. Third, around the residential centres, the leisure cycling function is foreseen to increase in service supply. This increase is not a result of an improved spatial configuration but is caused by an increase of population in nearby residential areas i.e., more people that can reach the location for cycling leisure. Fourth, the largest reduction in service supply is seen in the arable production function, as agricultural land is being converted to other land uses. This land use conversion however did enhance the service supply of other functions (plant habitat, tourism, residential use). Other trade-offs can be observed near cities, where urban expansion is at the cost of the cycling leisure function. However these trade-offs are also spatially variable, as can be observed from Fig. 3. For example, an increase of residential use leads not at all locations to a decrease in cycling leisure.

The seven normalised function maps are summed to visualise the total service supply in 2000 and the change by 2015 (Fig. 3). As all landscape function maps are normalised to a 0 to 1 scale, the maximal achievable index would be 7. However the service provision in the study area varies between 0 to 2.5. In 2000 the strongest providing multifunctional areas are located the east of the study area. In this part no changes in service supply are foreseen by 2015, while the overall picture of the study area shows an increase in overall service provision. A few postal code zones show a reduction in service supply. These areas are mainly the locations where agricultural production (arable and livestock) is foreseen to decrease.

3.3. Valuation of Landscape Services

The results of the valuation of the landscape functions, minus the plant habitat function, are presented in Fig. 4. Per function we show the value of the landscape service per hectare per year and its change between 2000 and 2015. Here again, we only classify the difference in service supply between the two evaluation years as ‘change’ when the service provision increased or decreased with more than five% of the average service supply per postal code in 2000. In Table 2 we present the average value per hectare of a landscape function before aggregation to postal code level, and the total value per landscape function for the study area as a whole.

For the year 2000 monetary valuation maps show similar patterns as seen in service supply maps, because the valuation of services is directly linked to service supply. The economic value of all landscape functions is foreseen to increase by 2015, except for the arable production function (Table 2). However, at some locations an increase instead of a decrease in monetary value of arable production is found. This increase is a result of an increase in net value added per hectare, resulting from increased production efficiency and market prices, which outweighs the decrease due to loss in agricultural land. Next, the impact of the spatial zones regulating intensive livestock development is visible in the map indicating change in economic value of the intensive livestock function (Fig. 4). This function shows a decrease in monetary value in the postal code zones located in the ‘extensive agriculture zones’, in which the growth of intensive livestock farms is strictly regulated. In other zones, the overall economic value of the intensive livestock sector is foreseen to grow despite a decrease in intensive livestock farms, so the remaining farms become more intensive. Another observation from Fig. 4 is that the tourism function shows a decrease in economic value by 2015 in many areas which had the highest economic value in 2000. This is a result of the expansion of the tourism function towards the central part of the study area, leading to lower average value per hectare, even though the overall value of tourism of the study area is expected to increase.

We summed all valued landscape function maps (i.e. plant habitat function excluded) in order to visualise the spatial distribution of the total value. Looking at the spatial distribution of the aggregated total value of the year 2000 we clearly recognise the high value of urban areas (Fig. 4). Therefore, mainly in areas with urban expansion a strong increase in the total value of landscape services is expected in 2015. For most other areas no large changes in the economic value are observed. This means that at most locations the decreases in economic value are compensated by increases of other landscape functions. In Table 2 the total value per landscape function in euro per year for the study area and the average value per hectare is given for the year 2000 and 2015. In both years the capital intensive functions; residential use, tourism and intensive livestock contribute most to the total value of the region.

4. Discussion

4.1. Policy Impact

The regional development policy package that is addressed in this study aims to enhance regional development through an improved spatial structure for agriculture, nature, forests, landscape, recreation,
In this section, we discuss the major policy impacts on the spatial pattern of service supply and value for our study area. From our results we can observe that by 2015 the strongest increase in services supply is found in rural areas while the strongest increase in value is foreseen to take place in and around urban centres. Also, we observe a general trend that the value of all studied landscape functions increases by 2015, except for the arable production function. So for our selection of landscape functions, the policy package will likely be successful in achieving its objectives. In Fig. 5 the foreseen changes between 2000 and 2015 in normalised service provision and economic value (with 2015 values based on the price levels of 2007) are presented per landscape function. The percentage of change between the landscape functions in the study area clearly differs between the two methods for landscape service quantification. So the choice of quantification method likely influences the interpretation of the policy impact. For example, when looking at the cycling leisure function the change in service supply only increases a few percentages but the economic value is foreseen to increase by almost 50%. This strong increase in value is a result of the increasing demand and therefore economic value (prices) of the cycling leisure function. A similar effect of price development on the service value is seen for the residential function and to a smaller extent for drinking water supply and arable production functions. For the interpretation of our results it is important to realise that differences between the change in normalised service provision and the change in economic values are caused by a price effect, as a consequence of economic development. Hence, changes in economic value are not solely an effect of the evaluated policy package; the strong increases in the economic value of some services (residential, cycling leisure) would also have occurred without policy intervention.
4.2. Quantifying Change in Service Supply and Value

This study presents one of the first attempts to make the economic value of landscape functions spatially explicit by linking economic values to supplied landscape services on a detailed spatial resolution. This step is perceived crucial in land management and for planning purposes (Daily et al., 2009; De Groot et al., 2010). Even though quantified services give a direct view on the relation between the landscape and the supplied benefits, for decision making purposes it is important to translate these benefits into a unit that allows for trade-off analyses and cost–benefit comparisons. An additional advantage of evaluating changes in landscape functions based on changes in economic value is that an economic valuation takes societal preferences, which are reflected in the price (and value) of the supplied services, into account. One should, however, be aware that an economic valuation based on service supply measures leads to an increased uncertainty in the outcomes, as a result of the strong data requirements and assumptions to make calculations possible. Additionally, carrying out an economic valuation based on price-levels is challenging for landscape services without a use value or market value, i.e. plant habitat. It might therefore be more meaningful to express these functions in service supply instead of their assessed economic value (Schaeffer, 2008; Daily et al., 2009). The economic valuation carried out in this study could be improved by more detailed valuation data and analyses (e.g. like in Bateman et al., 2005; Maler et al., 2008). By describing the economic value as a function of service supply and demand, for example, more accurate trade-offs calculations between the total benefits for society and the losses in other landscape functions can be made (Fishner et al., 2008).

To evaluate changes in service supply it is needed to account for factors on different spatial scales (Hein et al., 2006; Carpenter et al., 2009). In this study we included national and provincial policies,

![Fig. 4. Economic value in euro per hectare in 2000 and the changes in value between 2000 and 2015 for each landscape function and the total economic value in the study area. Only areas with a difference >5% of the average economic value per postal code in 2000 are mapped as 'change'.](image-url)
regional characteristics and location properties to describe the future location and quantity of landscape services. To reduce the complexity of our analysis we did not explicitly include global processes and individual choices, even though processes on these scales are known to play an important role (O’Rourke, 2005; Nelson et al., 2006; Yadav et al., 2008). Different spatial scales also play a role in linking economic values to landscape services (Bateman et al., 2005). By using market prices to quantify the economic value of a landscape service, often point observations need to be linked to the complete spatial extent of a landscape function. For example, in our study the tourism service is partly valued based on tourist accommodation revenues. We showed that not only the location of the camp site generates the service value, the surrounding landscape also contributes to this value. To adequately distribute the economic value to the total function area, the spatial extent of each landscape function needs to be known (i.e. the area of the landscape that contributes to the tourism function). The spatial extent of landscape functions is also reflected in the value per hectare. The value per hectare will decrease with the total needed land per function in the study area. Depending on the evaluation level, a hectare or the complete study area, a different ranking in values can appear. In our study the value of 1 ha with intensive livestock is much higher than one hectare land having a tourism function, while the total value of the tourism service for the study area overtakes the value of livestock. However, one should be aware that the actual spatial extent of some functions goes beyond the limits of the study area; the intensive livestock function uses land for fodder production outside the study area. Additionally, the negative externalities of livestock production are not accounted for in this study.

5. Conclusions

This study presents one of the first attempts to make the economic value of landscape functions spatially explicit by linking economic values to supplied landscape services on a detailed spatial resolution. In this paper we assessed the changes in landscape service supply as a result of the implementation of an integrated policy package and regional development trends. We used a methodology to translate policy implementation into changes in landscape properties and subsequently assessed how these changes affect the location and supply of landscape services and their value in the study area. The resulting maps visualise trade-offs between different landscape functions and we were able to show side-benefits as a result of policy implementation. Additionally, by taking into account the spatial scale of landscape functions we were able to show how non-overlapping functions can influence each other. These complex interactions often prove land management difficult. Also, as an addition to most policy evaluation studies so far, we included both the intensity and the extent of policy impact on the landscape to quantify the provisioning of landscape services.

The uncertainties in extrapolation methods, model and value assumptions, render our study as a methodological scientific contribution rather than a complete ex-ante evaluation or feasibility study to be used by policy makers. Therefore the current outcomes need to be considered indicative, and a stepping stone for future research. By linking service supply to economic values an important step is taken in institutionalising landscape services and guiding decision making (Cowling et al., 2008; Fisher et al., 2008; Daily et al., 2009). As landscape services link to both natural and agricultural systems in which many interactions take place, an evaluation of policy based on landscape services can make an important contribution to regional integrated assessments.

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Appendix A. Future Changes in Farm Size and Farm Distribution

Farm size is in the Netherlands commonly expressed in Dutch Standard Units (DSU) representing, amongst others, the size of a farm in number of livestock units (e.g. in 2000 one DSU relates to three adult pigs or 385 chickens). In 2015, the number of livestock farms smaller than 50 DSU is expected to decrease by 55%, farms of size 50 to 70 DSU are forecasted to decrease by 45%, the class of farms between 70 and 100 DSU are expected to decrease by 19% while the number of farms larger than 100 DSU is expected to increase by 2% (Provinces of Gelderland and Utrecht, 2005). The intensive livestock development zones as described in the Reconstruction Act are used to explore the future situation of the intensive livestock sector in the study area. To create a map with possible locations of intensive livestock farms in 2015, current farms within the ‘agricultural development zone’, ‘mixed zone’ and outside the zones, are selected in an automated procedure. In this procedure farms are randomly selected based on their probability to continue farming given their current size and location. Subsequently, according to plans of the Reconstruction Act, all farms larger than 70 DSU within the ‘extensive agriculture zone’ are relocated to abandoned farms in the ‘agriculture development zone’. The final map of intensive farm locations in 2015 is based on 100 replications of this procedure. The growth in terms of DSU of intensive livestock farms is expected to follow a different trend. Almost all intensive livestock farms are envisioned to grow between 2000 and 2015. The prognosis on the amount of growth depends on the location of the farm within the different spatial zones (RPB, 2007). In the ‘agricultural development zone’ a farm is expected to grow with 51%, in the ‘mixed zones’ growth in DSU of 33% is expected, within the ‘extensive agriculture zone’ farms are not foreseen to grow, and outside the spatial zoning areas a decrease of 3.3% in DSU is expected. Combining the estimated locations and growth of intensive livestock farms, a map of the intensive livestock sector of the study area is made for 2015. Based on similar calculations the change in arable production farms between 2000 and 2015 is estimated and mapped. Here again, the repeated random selection procedure based on an overall farm abandonment chance (of 43%) and growth prognoses derived from the Dutch Farm Accountancy Data Network of arable farms are used to assess the situation in 2015.

References

Indicators for multifunctional land use—linking socio-economic requirements with landscape potentials. Ecol. Indic. 6, 238–249.

