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Revisiting production and ecosystem services for evaluating land use alternatives in a rural landscape

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Abstract

Land is a scarce resource and should be used in such a way that the increasing global demand for food and feed can be fulfilled, ensuring sufficient levels of ecosystem services. While the demand on open space to deliver a multitude of services is increasing, drivers like global change and urbanization are undermining these services. Decision makers and other stakeholders are in need of appropriate diagnostic tools to estimate trade-offs and synergies associated with land allocation and land use intensity decisions. This often implies trade-offs between food and biomass production and other non-provisioning ecosystem services. This paper presents an analytical framework to evaluate land use strategies. An integrated approach that combines spatial and economic analyses and that relies on the ecosystem services concept is used to evaluate land use in a rural area under urban pressure. A preliminary application of this framework to a case study area demonstrates the relevance of this approach, and highlights current challenges. The results suggest that the optimal land use scenario in consideration of ecosystem services depends on the biophysical and spatial context as well as on the socio-economic context.

Keywords: bioproductive land, land use strategies, ecosystem services, land sharing vs sparing, wildlife-friendly farming, spatial context

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1 Introduction

Increasing population pressure results in an increasing demand for food and (bio-)energy products and hence also in an increasing demand for agricultural land (Meyfroidt et al., 2013; Tscharntke et al., 2012). It also leads to higher urbanization pressure which is accompanied by an additional demand for land for residential and recreational purposes (Zasada, 2011). This puts more pressure on the remaining land, making it an increasingly scarce resource. For a long time, this has led to a high degree of polarization in land use policies between demands for expanding urbanized fabric and the remaining open space used for agriculture, whilst natural areas are largely pushed back to relatively small and fragmented relics. However, there is a growing awareness that agricultural systems can also provide other services next to food and biomass production (e.g. cultural services such as recreation and landscape amenity, supporting services such as biodiversity, and regulating services such as nutrient cycling) (Zasada, 2011). Many of the services delivered by agricultural systems are non-marketable, so the market economy fails to provide sufficient incentives for delivering these services. A dominant production logic may push provisioning agricultural systems towards a state that is sub-optimal from a societal point of view because several non-provisioning services are not rewarded in the market. On the other hand, predominantly natural or semi-natural lands can also produce food and biomass while they maintain the capacity to deliver non-provisioning services. Hence, there is a need to evaluate land use scenarios with respect to the provisioning (agricultural) services, as well as the non-provisioning (supporting, regulating or cultural) services that they deliver (Bernués et al., 2011; Swinton et al., 2007). While an integrative and spatially explicit approach to land allocation is highly needed, it is largely missing (Bomans et al., 2010b; Termorshuizen and Opdam, 2009).

We use an integrative and transdisciplinary approach to evaluate land use strategies. This approach starts from the consideration that food and biomass production is a provisioning service that is predominantly but not exclusively bound to the agricultural sector. As such, the area taken into consideration is effectively extended from the agricultural area to virtually every potentially productive space, such as forests, nature reserves and domestic gardens. On the other hand, agricultural areas can not only be seen as spaces for the production of food, fuel and fiber. Associated non-productive services should also be recognized (Daniel, 2008; Swinton et al., 2007). Hence, the approach needs to take different food production and farming models into account. The concept of ecosystem services (ES), which was popularized by the Millennium Ecosystem Assessment in the early 2000s (Millennium Ecosystem Assessment, 2005), has proven to be useful in supporting resource management decisions (Wainger et al., 2010). ES are defined as the benefits of ecosystems to human beings and are categorized in provisioning services such as food and biomass production, regulatory services such as carbon sequestration and air and water purification, cultural services such as recreational and aesthetic experiences, and supporting services such as nutrient cycling, pollination and soil formation. However, much work remains to be done in translating the theory into practical applications (Crossman et al., 2013). Meanwhile, the EU called its member states to assess and map the state of ES within their territory in the framework of the Biodiversity Strategy 2020. This development will provide opportunities to incorporate ES into decision making. Nonetheless, application of the ES concept to real-life land management decisions is a major challenge and there is a continuing need to evaluate the available tools against existing cases (Dale and Polasky, 2007).

In this research we use the ES concept to evaluate and maximize the societal benefits delivered by open spaces. We use a regional, instead of a sectoral approach (Kerselaers et al., 2013; Willemen et al., 2010) to evaluate land use strategies. The approach is applied to a case study in Flanders, a peri-urban region with high population pressure. Some challenges and lock-ins for spatial planning can be identified when developing integrative approaches to land allocation in Flanders. First, the use of space in Flanders is intrinsically multifunctional, while spatial planning policies are largely monotypic in nature (Kerselaers et al., 2013), with for agriculture, a clear focus on productive functions (Leinfelder, 2007). Current spatial planning frameworks have difficulties facilitating multifunctional land use strategies. Second, a high spatial fragmentation leads to scale dissociations of spaces from policy, as the role and potential of many small fragments are systematically underrated. Also, there is little knowledge about the privatization (e.g. use of agricultural land in residential gardens) and domestication (e.g. use of agricultural land for hobby activities) of land use types (Dewaelheyns et al., 2014; Gulinck et al., 2013). This results in an additional dissociation of spaces from policy. A fourth dissociation stems from the discrepancy between a relatively static policy framework and a dynamic reality (e.g. climate change, species' adaptation, market change, change of norms and preferences). As such the case of Flanders is representative for many other peri-urban regions experiencing high urbanization pressures and facing similar dissociations of spaces from policy.

2 Conceptual framework

To develop an integrative regional approach to evaluate land use strategies for open spaces, the concept of *bioproductive land* is (re)introduced. ‘Bioproductive land’ is defined as the area providing services through primary production processes and includes (semi-) natural as well as agricultural ecosystems. This bioproductive land is key in delivering ES in a landscape. By incorporating non-provisioning ES, we believe to acknowledge both the importance of production, while essential sustainability concepts are not neglected. Hence, the term ‘bioproductive land’ is fundamentally different to the notion of ‘bioproductive capacity’ in ecological footprint calculations. While both terms relate to primary production, the latter term refers to the fraction specifically required for human consumption in the material sense and waste product absorption. The former relates to all fractions that generate benefits to human beings and considers also areas that provide cultural, regulating and maintenance services. As such, bioproductive land is more than the land used for agricultural applications. The concept considers different sectors and land-use categories and allows to take into account ‘hidden’ land uses. A first form of ‘hidden’ land use would be due to underrated transformations, i.e. land use changes that are not or insufficiently picked up by monitoring and feedback systems (Bomans et al., 2010b, 2009; Verhoeve et al., 2015). A typical example is the phenomenon of ‘horsification’ of agricultural land, but the study of Bomans et al. also identifies garden sprawl, farm diversification and recreational use of (semi)natural land as underrated (Bomans et al., 2010b). A second and third form of ‘hidden’ land use is the amount and use of *tare land*, i.e. those parts of the agricultural landscape not directly supporting crops (Bomans et al., 2010a) and hybrid land uses, an example of which is agroforestry (Gulinck et al., 2013). The principal challenge is to simultaneously assess and maximize food and biomass production as well as the ES provided by bioproductive land (Balmford et al., 2012) which inevitably implies trade-offs. Moving away from a predominantly ‘production-oriented’ view on the landscape will aid policy makers and other stakeholders in recognizing opportunities and innovations within and across bioproductive land.

To assess land use scenarios we assess the output for several ES per unit of bioproductive land. This corresponds to agricultural land productivity measures but we take into account the value of non-provisioning ES instead of considering only agricultural output, and we look at all bioproductive land instead of only considering the agricultural land. By assessing agricultural output (which is traded on the market) as well as other valuable services for the society (but which are mostly not traded on the market), we are assessing the optimality of land use scenarios from a societal point of view rather than from a private (or farmer's) point of view.

When assessing the productivity of bioproductive land one should take into account area-bounded thresholds required for delivering certain ES. These thresholds mark the minimum area needed for a service to be present which might result in a jump in the production function (Figure 1). Examples of such thresholds are abundant in ecosystems, where minimum area requirements of qualitative habitat are common for key species to be present in the system (e.g. the potential presence of top predators in an ecosystem depends, amongst others factors, on territorial dimensions). In food systems, many forms of production intensification are area-dependent. Also, land use systems can show complementarities, mutually increasing the level of ES when they are spatially linked (Colding, 2007), resulting in higher ES outputs. An example is the positive pollinator spillover effect of nearby wild bee habitat on flowering fruit crops (Blitzer et al., 2012; Holzschuh et al., 2012).

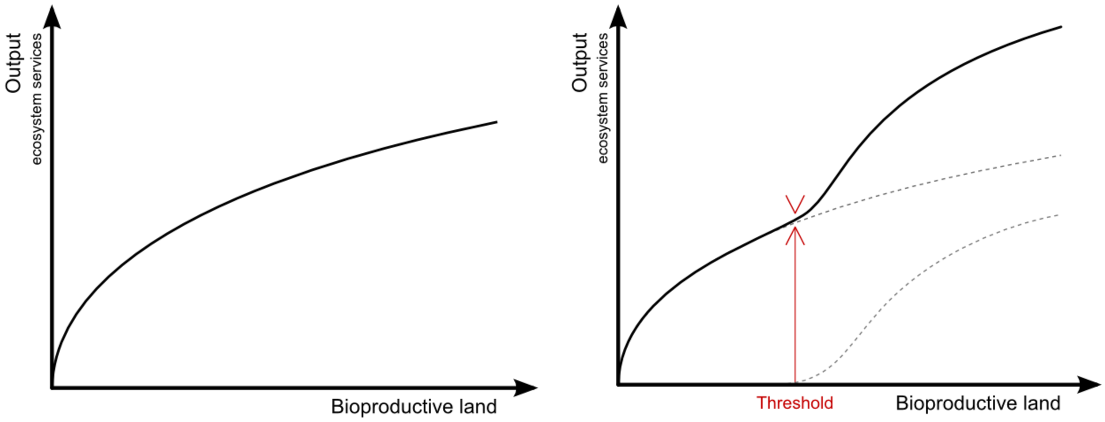

Figure 1. Potential functional forms of production function of ES with and without with the area thresholds for the provisioning of certain ES.

This framework can be used to evaluate strategic land use choices taking ES into account, under different spatial configurations and/or production strategies. Depending on the availability of data and aggregation techniques, this allows for potential positive and negative externalities to be taken into account in evaluating land use alternatives.

3 Case Study Description

The case aims to test this framework by evaluating how an ecological livestock farming output compares to a conventional livestock farming output in a given area, when a selection of ES are taken into account. We selected an area that is currently managed by an ecological farm in the region of Diest, Flanders (Belgium) for the comparison. The ecological farm was established in 2001 on the land of the former conventional dairy farm. The ecological farm manages about 90 hectares in 2011. Most of this area is located within nature reserves called ‘Dassenaarde-Groot Asdonk’ and ‘Webbekoms broek’. The farm is located at 51°00’47”N; 5°02’41”E, within the catchments of two tributaries to the Demer river. The catchments suffers from relatively poor water quality, mainly due to a contamination with a.o. heavy metals and chlorides (VMM, 2014). Aquatic vegetation is largly absent in the main tributaries. Hence, flooding events pose a contamination risk, which needs to be taken into account when evaluating possible land use alternatives for some parcels.

The study area comprises five spatially distinct clusters of parcels, which make up the entire farm. In order to take variations between these clusters into account, each of these clusters was evaluated separately, with the exception for the evaluation of cultural benefits. The cultural benefits (recreational and amenity values) were calculated for the case farm as a whole because cultural services depend on the number of households living within a certain radius. If the cultural services delivered by the clusters were evaluated separately, one risks to double count certain households. In addition, for remote sites, site area has a strong positive impact on the valuation of the cultural benefits and for small remote sites, the valuation of the cultural benefits quickly drops to zero. Area thresholds are thus important when valuing cultural benefits. If one neglects the fact that clusters are relatively well connected, then one risks to underestimate the area of the site delivering cultural benefits and hence the value of the delivered cultural services.

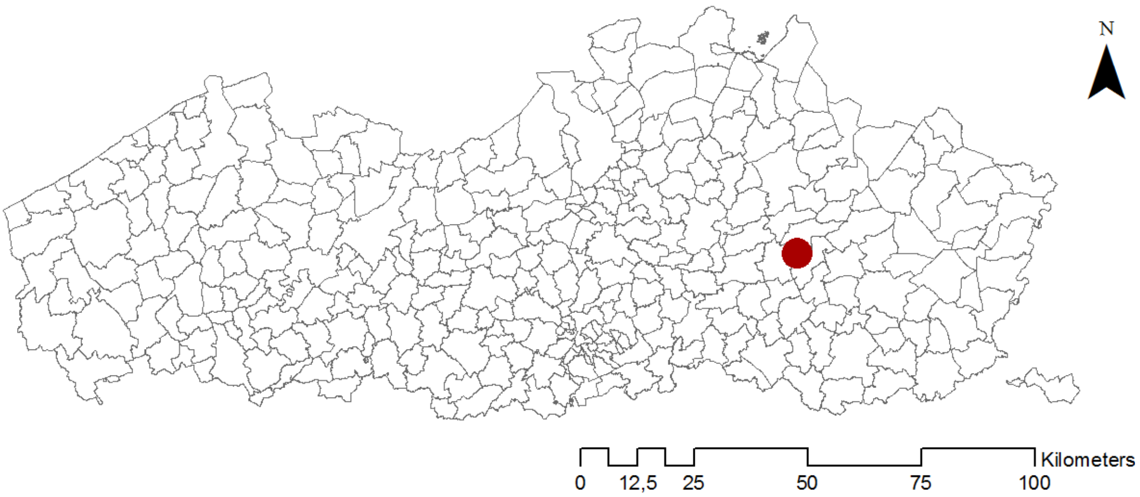

Figure 2. Location of the case area in Flanders.

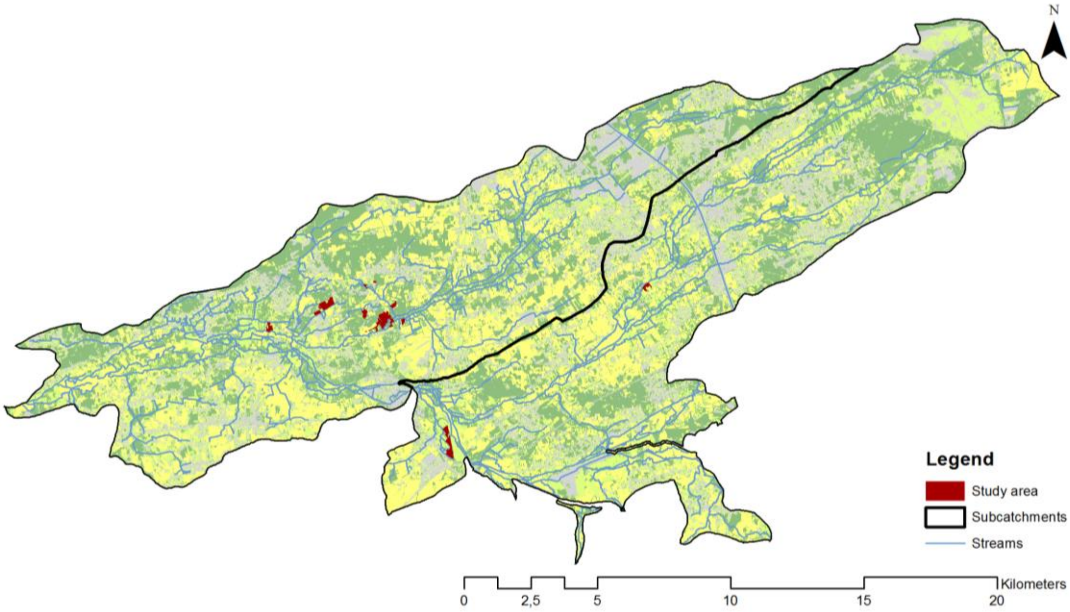

Figure 3. Location of the farmland within the Winterbeek-Ossebeek and Zwarte beek subcatchments

In an ongoing effort to counteract atmospheric nitrogen deposition (Stevens et al., 2011), semi-natural grassland management in Flanders has to make an effort to deplete (excessive) nutrient stocks (Oelmann et al., 2009). Consequently, semi-natural grassland management in Flanders typically produce biomass waste streams from mowing and haymaking. In general, grass from semi-natural grasslands is less suited for conventional livestock breeds, both in terms of digestion and nutritional intake. Therefore, ecological farms typically resort to more sturdy and self-reliant livestock breeds (Bedoin and Kristensen, 2013). The case farm uses the relatively unconventional rustic cattle breed ‘*Kempisch Roodbont*’ and sheep breed ‘*Ardense Voskop*’. Both are able to digest low-quality grass and convert it to high-quality animal protein (i.e. dairy products and meat). Both breeds are threatened by extinction so that preserving their genetic resources can be considered as an additional provisioning service of the farm system.

4 Methodology

4.1 Data compilation and general analysis

The spatial footprint of the case farm was mapped in ArcGIS 10.1, resulting in a cluster of spatial units or parcels (‘analysis area’). Individual land cover units and associated land use information were added as an attribute based on the farms register, the Biological Valuation Map (AGIV, 2010), and were checked using aerial imagery (Aerodata International Surveys, 2007) combined with verification on the terrain (early 2013). The following data were added to this spatially explicit database: production data (grazing and cutting) from the farm register, soil texture and moisture data (AGIV, 2006), the Habitat map v5.2 expliciting the occurrence of habitats falling under the EU Habitat Directive (INBO, 2010), flooding risk zones (VMM, 2006), and prevalence of woody vegetation based on the ‘Groenkaart’ (ANB, 2013, 2011).

All spatial analysis was done in a GIS environment using ArcGIS 10.1. Statistical analysis was done using R 3.1. Normality was checked using the Shapiro-Wilk test.

4.2 Scenarios for crop and livestock production

To evaluate land use configurations and practices, we considered different scenarios to determine the output of selected ES for the case study area. The existing extensive farm model is used as the baseline scenario (referred to as the *Extensive* scenario in the remainder of the paper). On the same land, we assume two additional normative land use scenarios, which we call *IntensiveMIN* and *IntensiveMAX*.

The *Extensive* scenario describes the case study area as it is currently cultivated by a farm that combines ecological meat production and livestock breeding with nature management and ecotourism. Cultivated grasslands are combined with semi-natural grasslands, but the share of semi-natural grasslands is relatively high and the livestock production is very extensive. This results in a high conservation potential. The other side of the coin is a penalty in terms of animal growth and carcass quality (Bedoin and Kristensen, 2013; Fraser et al., 2009). In addition, the spatial footprint of livestock rearing is relatively high.

The *IntensiveMIN* scenario is designed as a realistic intensive livestock production using the same land as the case farm. It assumes intensive land use, while local biophysical constraints are taken into account. Using a spatial overlay with the flooding risk zone dataset in a GIS environment, frequently inundated parcels and zones showing inundation risks were excluded for intensive livestock production. A similar approach was used to identify and exclude parcels with species communities falling under the EU Habitat Directive, as their presence usually precedes their designation, and not the other way around. For reasons of comparison and in order to minimize dependency on off-farm land, we assumed a largely autonomous production, i.e. the intensive farm meets its own feed requirements from own production within the analysed area. The required ratio of land for grazing to land for feed production could be derived from figures from the agriculture monitoring network of the Flemish Department of Agriculture and Fisheries (Gavilan et al., 2012; Raes et al., 2011). In 2010, an average specialized livestock farm had 81.51 livestock units (LSU) on 30.47

hectares of grassland and an additional 35.48 hectares of feed production. Therefore, the intensive scenarios assume a grassland / feed production spatial ratio of 0.86.

Within the case area several parcels are unsuited for intensive grazing. The cluster ‘Bekkevoortse beemden’ (BVB) mainly consists of wet, semi-natural grasslands and reedbeds. Frequent inundations make most of the parcels unsuited for intensive grazing or feed production. The cluster ‘Bolhuis’ (BH) comprises the farm building, stables and associated infrastructure, as well as all surrounding parcels, mainly semi-natural grasslands with high levels of biodiversity. Part of the parcels in this cluster are extremely wet and inundate frequently. All grasslands that are not frequently flooded can potentially be used for intensive livestock rearing, either as grazing lands or for feed production. The cluster ‘Catselt’ (CT) consists mainly of biologically very valuable land dune ecosystems dominated by very nutrient-poor grass- and heathlands, which are grazed by sheep in the extensive scenario. Based on the previously stated criteria, less than half of this cluster would be converted to intensive grazing lands. The cluster ‘Webbekoms Broek’ (WB) is a protected natural area, mainly wet grasslands and wetlands under extensive grazing. Intensive grazing would be the principal intensive land cover for this cluster. The cluster ‘Zwarte beek’ (ZB) is located upstream in the Winterbeek-Ossebeek subcatchment and consists of species rich grazing lands. Intensive grasslands and feed production are realistic land use alternatives.

In the *IntensiveMAX* scenario, we formulate a corner solution where all land of the case study area is taken into intensive production, irrespective of biophysical constraints that would make some lands unsuitable for intensive livestock production. As such this scenario would be difficult to establish within the spatial footprint of our case farm, but it provides an estimate of the differential output of ES of an unrestrained intensive livestock enterprise within the same catchments. The scenario assumes the removal of all small landscape elements such as hedgerows and isolated trees. Also and in line with the *IntensiveMIN* scenario, maximal autonomy and a grassland / feed production spatial ratio of 0.86 is maintained.

The land use distribution for each of these scenarios is provided in Table 1.

Table 1. Land use (in ha) for each cluster under different scenarios (see text for acronyms)

	Land Clusters					
	BH	CT	BVB	ZB	WB	**Total**
Extensive						
Urban land	0.5	0.1	0.0	0.0	0.0	0.6
Agriculture and pastures	2.1	0.7	0.0	0.2	0.4	3.4
Rivers and ponds	0.1	<0.1	<0.1	0.0	0.1	0.1
Wetlands	<0.1	0.0	0.9	0.0	1.3	2.2
Heath and land dunes	1.4	0.1	0.0	0.0	0.0	1.5
Forests and shrubs	3.0	3.8	0.0	<0.1	4.8	11.6
Semi-natural grasslands	31.6	13.1	4.9	4.5	12.1	66.2
IntensiveMIN						
Urban land	0.5	0.1	0.0	0.0	0.0	0.6
Agriculture and pastures	14.1	9.6	0.0	4.7	0.4	28.8
Rivers and ponds	0.0	0.0	<0.1	0.0	<0.1	<0.1
Wetlands	0.0	0.0	0.9	0.0	1.3	2.2
Heath and land dunes	1.4	0.0	0.0	0.0	0.0	1.4
Forests and shrubs	0.2	3.8	0.0	0.0	4.8	8.8
Semi-natural grasslands	22.6	4.3	4.9	0.0	12.1	43.9
IntensiveMAX						
Urban land	0.5	0.1	0.0	0.0	0.0	0.6
Agriculture and pastures	36.7	17.7	5.8	4.7	17.2	82.1
Rivers and ponds	0.0	0.0	0.0	0.0	0.0	0.0
Wetlands	0.0	0.0	0.0	0.0	1.3	1.3
Heath and land dunes	1.4	0.0	0.0	0.0	0.0	1.4
Forests and shrubs	0.2	0.0	0.0	0.0	0.0	0.2
Semi-natural grasslands	0.0	0.0	0.0	0.0	0.0	0.0

4.3 Aggregation of ES delivered by bioproductive land

In order to evaluate the relative performance of land use scenarios on providing ES, a selection of ES is aggregated. For this study, we used monetary valuation as an aggregation tool. Differences in provision of ES among the different scenarios were estimated using the "Ecosystem Service Valuation Tool" developed by VITO (Broekx et al., 2013; Liekens et al., 2013). Some corrections were applied based on additional data, e.g. for the added value of crop and livestock under the *Extensive* scenario.

The crops and livestock values as well as wood production value under the *Extensive* scenario were quantitatively estimated based on accountancy data of the farm case and interviews with the case farm manager. For the other scenarios, these estimations are based on Flemish farm income registrations (n=750) over various sectors, combined with crop registration and soil suitability data.

Calculation of feed production values cannot be done based on market prices since most feed is cultivated and used on the farm itself. Instead, gross livestock revenues are distributed over the area used for feed production (Liekens et al., 2013). Quantitative assessment and valuation of wood production is done by multiplying the area under forest cover with matched productivity figures (Jansen et al., 1996), related to the type of forest and the typology of the physical system. The results are multiplied with a harvest factor (%),the percentage wood actually harvested in relation to the maximal potential harvest, to estimate the effective wood production. Valuation is done by multiplying this estimate by the market price for standing timber.

For the regulating services, fine particle filtration ('air quality'), carbon sequestration in soil and biomass, and N and P sequestration in soil were evaluated. Subsidies are not taken into account in the aggregation. The air quality estimations are based on figures by Oosterbaan et al. 2006. Valuation is done by multiplying these estimates by a generic avoided medical cost of 54 €/kg PM_{10}, derived from De Nocker et al. 2010. For soil carbon storage the regression model by Meersmans et al. 2008 is applied, estimating maximal potential carbon stocks taking soil texture class, water tables and land use into account. Valuation is again based on De Nocker et al. 2010.

The valuation function used to calculate cultural services was obtained using a stated preference method (willingness to pay, WTP) for transformations between agricultural and natural land use. This value function combines the values for recreation, amenity and education, and takes the number of households and the distance to the case site into account. The methodology calculates the number of households within a 50km radius for which the value function is larger than zero. This number is multiplied with a mean willingness to pay based on the type of ecosystem, species richness, accessibility, surrounding land use, size and distance to the household (Broekx et al., 2013).

5 Results

Table 2 provides an overview of the output of ES under the principal scenarios of interest, i.e. the *IntensiveMIN* and *Extensive* scenarios. The valuation tool provides a lower and upper estimate for the value of the considered ES. Therefore, the difference in the value of ES is calculated for the lower and upper estimate. In addition, we calculate the mean difference between the two scenarios.

Table 2. Per annum ES under the Extensive and IntensiveMIN scenarios

		IntensiveMIN		Extensive		Difference (in €) between Extensive and IntensiveMIN scenario		
ES		low	high	low	high	low	**mean**	high
Crop & livestock	€	36 520	53 688	27 000	27 000	-9 519	**-18 104**	-26 688
Wood	m^3	39.9	39.9	41.7	41.7	60	**60**	60
Air quality (PM$_{10}$)	kg	1 746	3 504	1 833	3 663	4 692	**6 650**	8 608
C storage soil	Ton	283	423	287	426	797	**667**	537
C storage biomass	Ton	4.8	4.8	10.2	10.2	1 179	**1 179**	1 179
N storage soil	kg	18 532	42 310	18 051	39 502	3 817	**30 150**	56 484
P storage soil	kg	1 236	2 821	1 203	2 634	4 071	**22 390**	40 709
Cultural services	#HH	9 749	36 312	16 876	44 237	9 250	**25 014**	40 777

Source: Nature Value Explorer; own calculations

For the *Extensive* scenario, the value of crop and livestock output is based on the actual on-site production rather than on the valuation tool. The tool would underestimate the actual crop and livestock production under the *Extensive* scenario because semi-natural grasslands are not considered as suitable for livestock production in the valuation tool methodology. Therefore, the valuation tool only takes into account those parcels with intensive grasslands, estimating a mean yearly added value of € 6 971 (min: € 5 480, max: € 8 460). However, by using sturdy and self-reliant livestock breeds such as the *Kempisch Roodbont*, the case farm manages to use most of these semi-natural grasslands for production. Research of Pelve et al. (2012) indicates that live weight gains of about 400 to 500 g/day should be feasible using adapted breeds on semi-natural grasslands. With an estimated live weight gain of about 800 g/day, the *Kempisch Roodbont* calves are performing relatively well. For comparison, weight gain figures reported in literature surpass 1 000 g/day for *Limousin* and range between 260 g/day and 650 g/day for *Galloway* (Bedoin and Kristensen, 2013; Fraser et al., 2013). *Kempisch Roodbont* has the additional advantage of being suited for both milk and meat production. According to the case farm accountancy data, the value of crop and livestock output augments to 27 000 euro under the *Extensive* scenario. About 55% (or 15 000 euro) of this output stems from meat production while the remaining 45% (or 12 000 euro) stems from the sale of the rustic breeds.

The value of crop and livestock output is clearly higher under the *IntensiveMIN* scenario than under the *Extensive* scenario, while the difference between the two scenarios is only marginal for wood production value. On the other hand, the values of the regulating services provided under the *Extensive* scenario are higher than under the *IntensiveMIN* scenario, but the difference is small for carbon storage services in soil and biomass. This is not the case for Nitrogen and Phosphorous soil storage for which the *Extensive* scenario performs considerably better. Also in terms of particle filtration and thus air purification, the *Extensive* scenario performs better than the *IntensiveMIN* scenario due to the presence of small landscape elements.

The value of the cultural services is highly dependent on the aesthetic value of the local landscape and is much higher under the *Extensive* scenario than under the *IntensiveMIN* scenario. The WTP for cultural services depends on the number of households living within a certain radius and on the site area. Although relative WTP/ha is higher for smaller sites, the WTP per ha quickly decreases when households are living farther away from the site. This is in particular the case for smaller parcels that are remotely located so that the WTP drops to zero. For remote sites, site area has a strong positive impact on the valuation of the cultural benefits. This effect is illustrated in table 2. The valuation of the cultural benefits of the entire case farm land as a whole is much larger than the sum of the cultural benefits of the individual clusters. This illustrates the presence of area thresholds for delivering cultural services.

While Table 2 only provides information on the *Extensive* and *IntensiveMIN* scenario, Table 3 and Figure 4 compare the ES delivered under the *Extensive* scenario with these delivered by the two intensive scenarios. Positive values in this table indicate that the *Extensive* scenario performs better. A conservative approach was used for the aggregation of the ES, i.e. the lower estimates were used for every ES.

Table 3 and Figure 4 illustrate that the potential societal benefits (in terms of selected ES) provided by bioproductive land of the case study is considerably higher in the *Extensive* scenario than in the *IntensiveMIN*, but the difference between both is less obvious for the *IntensiveMAX* scenario.

Table 3. Aggregated differences in ES delivery (excl. non-use value) based on lower conservative estimates.

Ecosystem service	Extensive vs. IntensiveMIN	Extensive vs. IntensiveMAX
Crop & livestock	-9 520	-75 615
Wood	60	1 655
Air quality	4 692	15 772
C storage in soil	797	2 095
C storage in biomass	1 179	9 877
N storage in soil	3 817	11 546
P storage in soil	4 071	12 315
Cultural benefits	9 250	23 743
Total (€)	**14 346**	**1 388**

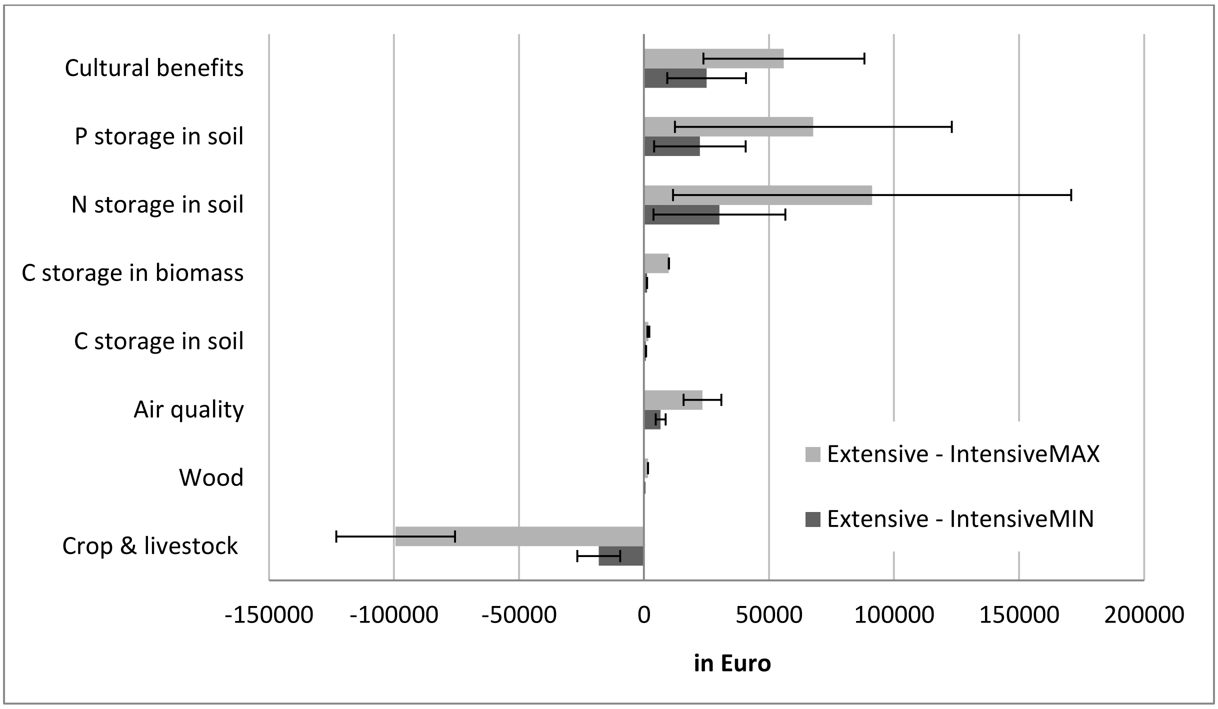

Figure 4. Difference in valued ecosystem service provision between the Extensive scenario and the intensive scenarios.

The success of the *Extensive* scenario relies on the successful adaptation of the farm to biophysical constraints, while the natural environment also benefits from the chosen strategy. The ecological farm adapts to its environmental constraints by using specific livestock breeds. While cattle grazing preferably takes place on grasslands that are less subjected to inundation, the rustic cattle breed does allow for limited grazing management on parcels that are effectively sensitive to flooding. However, parcels with tree cover (and small landscape elements) are less suited for cattle breeding. This is not the case for the sheep breeds used (Figure 5). Sheep provide grazing management on those parcels that inundate significantly less frequent (Wilcoxon W=130, $p<0.05$), but contain significantly more trees (Wilcoxon W=43, $p<0.05$).

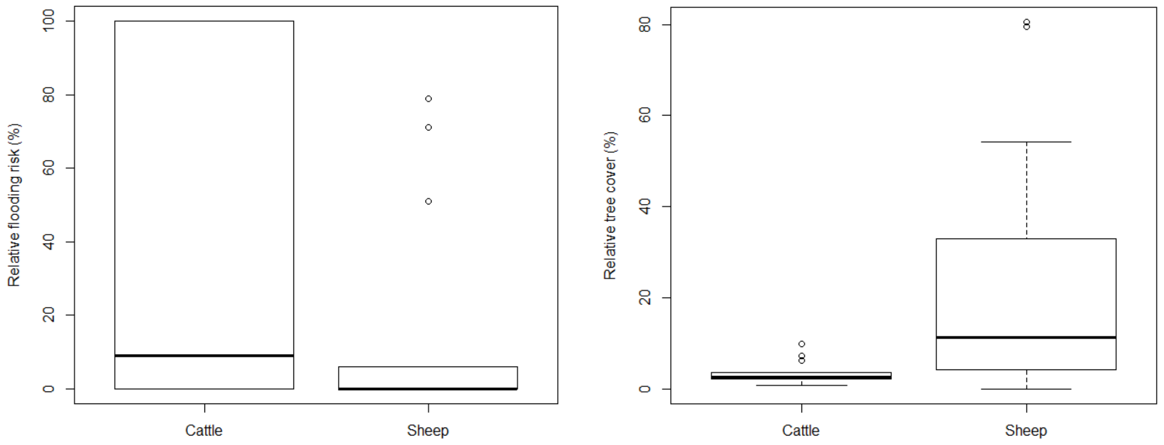

Figure 5. The use of cattle and sheep in an adaptive farming strategy: in relation to the flooding risk (left), and in relation to tree cover (right).

As such, the farm also acts as a buffer zone for water retention, reducing flooding risks in the downstream city of Diest. In addition, using rustic breeds on semi-natural grasslands and heathlands reduces the biomass waste streams from these lands.

Table 4. Comparison of the mean cultural service estimation based on separate and aggregated clusters.

Cultural benefits	Individual clusters	Whole case farm
Extensive vs. intensiveMAX	6 911	55 925
Extensive vs. intensiveMIN	3 318	25 014

6 Discussion

In this study we assess a farming model that combines livestock production and nature management on ‘marginal’ land and compare it with other models that use land more intensively. We compare the value of ecosystem services under different land use scenarios to benchmark an ecological farming model against more conventional models. The results illustrate how optimal land use (from a societal perspective) depends on biophysical constraints as well as on the spatial and socio-economic context. In the case study area, ‘extensive’ crop and livestock production provides the highest societal benefits (i.e. the highest value of ES). However, if the same area would be located in another region with no biophysical constraints (a situation corresponding to the *IntensiveMAX* scenario), the differences in delivering societal benefits decrease and more intensive approaches might outperform extensive approaches. In addition, the spatial and socio-economic context plays an important role. The valuation of regulating and cultural ES is highly dependent on regional population densities and the societal demand for, and hence valuation of, recreational services, landscape aesthetics and biodiversity. For the case study area, the calculated differences are exacerbated by the relative high population density, low number of alternative semi natural areas in this highly urbanized peri-urban region. The valuation of cultural benefits is also area dependent: small sites are only valued by those living close by, while the cultural benefits of larger sites (or rather well connected sites) are valued by people living close by as well as further away. As such, in a different spatial and socio-economic context (e.g. smaller sites that are not connected or lower population densities), the optimal land use strategy could be very different.

Furthermore, the results should be interpreted with care because a comparison is made between real-life and hypothetical scenarios. Obviously, some assumptions needed to be made in drafting the intensive scenarios. We stress that the objective of the research is not to provide an absolute valuation of the ES delivered, but rather a relative positioning of the alternative farming models that might emerge in the considered subcatchments. This farming model co-evolves in response to very common nature management strategies in developed regions such as Flanders, where ecosystems are dealing with excess nutrient loads, to the benefit of generalist species. Through combined grazing and cutting management, nutrients are removed from the system and floristic diversity is able to increase. Such management should at minimum compensate for the nutrient outflux through dry and wet deposition, but from a floristic perspective, it is desirable for the system to progressively become more nutrient poor.

At first glance, this seems to result in a ‘paradox of provision’. Biodiversity targets conflict with food and biomass production targets because the former benefits from harvesting nutrients (either as vegetative biomass, meat or live cattle), the latter does not. Various measures like on-farm diversification aiming to validate biodiversity (e.g. engaging in agrotourism), and payments for ES (e.g. payments for the provision of positive externalities in the form of subsidies) help relieve this paradox. While the extensive scenario outperforms the intensive scenario from a societal point of view, the economic viability of farming in the case study area remains limited. The case farm depends heavily on additional financial inputs (e.g. government subsidies) and this adds to its vulnerability. However, our results illustrate that these subsidies are justified from a societal point of view.

When assessing the ecosystems delivered under the *Extensive* scenario, some important benefits are neglected which would make the case of extensive land use in this region with both ‘inferior’ and high quality land only stronger. First, the case farm manages to valorize the biodiversity in its surrounding through ecotourism. Revenues from ecotourism are not included in the valuation of the land use scenarios. Second, as agricultural research faces a lock-in that favors innovations in the field of genetic engineering and locks out agro-ecological innovations (Vanloqueren and Baret, 2009, 2008), this case illustrates the potential of using selected rare breeds and generates positive externalities through the conservation of genetic resources. Third, several parcels managed by the case farm inundate regularly, contributing to the flooding risk reduction for a nearby provincial town. In addition, nutrient flows from local intensive farming systems in the stream valley are buffered by the case farm. These regulating and maintenance services provided under the extensive scenario were not considered when assessing the land use scenarios.

For the calculation of the ecosystem services, the study applies the “Ecosystem Service Valuation Tool” developed by VITO, with the exception for the crop and livestock output under the *extensive* scenario. This valuation tool makes use of benefit transfer functions to estimate the value of the ES delivered by the considered bioproductive space. Benefit functions are based on several other studies and easy to use but typically fail to consider the specific characteristics of study area of interest. This became clear when we calculated the value of crop and livestock production under the *Extensive* scenario with the valuation tool and compared that estimate with the on-site production data. The value calculated by the tool was considerably lower than the actual production value because high-diversity semi-natural grasslands are not considered as sites suitable for livestock production in the valuation tool. However, the case farm does manage to use these grasslands. Meat from rustic breed is often not suited for conventional meat markets and requires ‘alternative’ markets with different quality criteria (e.g. sustainable, good taste, local, …) (Bedoin and Kristensen, 2013). Nevertheless, the case farm does manage to sell its meat to local customers by organizing periodical sales in collaboration with other producers of regional products. In that way, the value of their crop and livestock output is considerably higher than what the tool predicts. For other ES, the valuation tool might also not take all local conditions properly into account. Therefore, the tool provides a lower and upper boundary for the value of the delivered ES. While the tool allows for the evaluation of relatively conventional farming models, some agro-ecological innovations, in this case the use of adapted breeds, are not taken into account. Similarly, the added value of agro-ecological innovations that rely on land use complementarities, such as buffer strips or agroforestry, are not yet included in the methodology.

7 Conclusion

This paper illustrates how the concept of ES can make a contribution to spatial planning by integrating various ES in a spatially explicit manner. High population levels and urbanization have historically led to a high degree of polarization between expanding urbanized tissue and the remaining open space used for agriculture, with natural areas largely pushed back to relatively small and fragmented relics. As pressure on remaining open spaces increases, more actors adopt a conservational attitude of safeguarding a spatial niche from claims of other sectors. However, there is growing awareness that one spatial niche can provide services that are beneficial to several sectors. Not surprisingly, efforts to reconcile food production with ecosystem rehabilitation in Flanders have therefore mainly been focusing on land sharing strategies. While nature organizations are increasingly willing to cooperate with livestock farmers, many farmers show little interest in nutrient-poor or wet grasslands. In addition, land sharing strategies, in particular agri-environmental schemes, are not always achieving the expected results (Balmford et al., 2012; Kleijn et al., 2011, 2001). This makes it difficult for land planners to assess whether a land sharing or sparing policy is preferable. An assessment and valuation of all ES provided by bioproductive land can be used as a framework assess land use strategies. ES can help to make the services provided by different land uses more easy to understand and more comprehensive. Our study develops such an integrative and transdisciplinary framework and applies it to a case study.

Our results demonstrate how extensive land use strategies may provide higher societal benefits (i.e. output of ES) than intensive land use strategies in regions with both ‘inferior’ and high quality land and with high population densities. Furthermore, the spatial configuration will also determine whether extensive land scenarios are preferable over intensive scenarios. The cultural ES (recreational and amenity services) provided by extensively managed land increase exponentially with the area. Hence, extensive land use scenarios are more likely to outperform intensive scenarios if the extensively managed area is sufficiently large and if the plots are relatively well connected. Some forms of agro-ecology can thus generate higher societal benefits than intensive land use scenarios under certain biophysical, spatial and socio-economic conditions by creating added value in a broad range of ES. However, if there are no biophysical constraints, if the potential area for extensive land management is small and/or not connected, or if the population density is low (i.e. if the value of the cultural and some regulating services is low), the intensive land use strategies might still outperform extensive land use strategies. The local demand for ES can thus be addressed by a multitude of different farming models (Firbank et al., 2012). The analysis illustrates that the optimal land use strategy (land sharing versus sparing; extensive versus intensive) is likely to be context and scale-dependent and that the concept of ES can be very useful in designing optimal land policies.

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