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Revisiting Production and Ecosystem Services on the Farm Scale for Evaluating Land Use Alternatives

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1 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, while 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, from individual farmers to spatial planners, 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 assessment on the farm scale using an integrated approach that combines spatial and economic analyses. It relies on the ecosystem services concept to evaluate land use alternatives. The analysis highlights current challenges to reach a societal optimal land allocation.

2 INTRODUCTION

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). This demand is in competition with the additional demand for land for residential, conservation, forestry, recreational, and other purposes (Zasada, 2011). With land as an increasingly scarce resource, spatial planners seek to balance land use allocation among competing stakeholders. This has led to a 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. Spatial planning has mainly focused on allocation of land to space demanding sectors and minimizing spatial conflicts. This approach falls short in considering present-day demands for multifunctionality, sustainability, ecosystem services, resilience and adaptive governance. 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). Particularly in strongly urbanized regions, the relation between the availability and use of space, and the potential services this space is able to provide to society, needs to be explored further. Increasing service delivery per unit of space can allow a decreasing spatial requirement for delivering this service, and hence, freeing space for other services. Fragmented peri-urban landscapes in particular, where interfaces between different forms of land use and associated actors are plenty, are in need of innovative concepts for land use allocation. Meanwhile, concepts of multifunctionality and ecosystem services already bridge the distinction between classical sectors like agriculture, nature and forestry. In the light of food and biomass production, the principal challenge is to simultaneously assess and maximize production as well as the other ES provided by bioproductive land (Balmford et al., 2012) which inevitably implies trade-offs. A conceptual framework as proposed by (Foley et al., 2005) argues how agro-ecological cropland management might support a larger portfolio of ES. Moving away from a predominantly 'production-oriented' view on the landscape will aid policy makers and other stakeholders to recognize opportunities and innovations within and across landscapes.

In order to gain a better understanding of how this relates to adaptive farm development, we looked into the management rationale for a case farm in the region of Flanders, Belgium. Flanders is a largely 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 this region. 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 shaped by climate change, biodiversity loss, species' adaptation, market change, change of norms and preferences, a.o. As such the case of Flanders is representative for many other peri-urban regions that experience high urbanization pressures and face similar dissociations of spaces from policy.

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, biomass and water production, regulatory services such as carbon sequestration and air and water purification, and cultural services such as recreational and aesthetic experiences (Haines-Young and Potschin, 2010). 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 (Crossman et al., 2013) and there is a continuing need to evaluate the available tools against existing cases (Dale and Polasky, 2007). This is despite the growing awareness that agricultural systems also provide other services besides food and biomass production, for example cultural services such as recreation and landscape amenity, as well as regulating services such as flow regulation and pest control (Haines-Young and Potschin, 2010; Zasada, 2011), which need to be recognized (Daniel, 2008; Swinton et al., 2007). 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, semi-natural lands are also able to contribute to the food and biomass supply, while they simultaneously maintain the capacity to deliver a wider array of essential non-provisioning services (Foley et al., 2005). Hence, there is a need to evaluate land use scenarios with respect to the provisioning services, as well as the non-provisioning services that they deliver (Bernués et al., 2011; Swinton et al., 2007).

We use an integrative and transdisciplinary approach to evaluate potential land use alternatives. We used a thorough indicator-based approach, applied to a case farm. For this case farm, representing a limited stock of land, we benchmark land use alternatives by comparing the services they would deliver. This sets the foundation for a policy supporting approach to evaluate spatial productivity under various land use and land management rationales.

3 APPROACH OF THE STUDY

To develop an integrative regional approach to evaluate land use strategies for open spaces, the concept of bioproductive land is introduced. 'Bioproductive land' is defined as the area providing services through primary production processes. It includes semi-natural as well as agricultural ecosystems. This bioproductive land is key in delivering ES in a landscape. By incorporating also non-provisioning ES, we acknowledge both the importance of production, while other essential sustainability concepts are not neglected. Hence, we emphasize that 'bioproductive land' encompasses more than 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. In contrast, bioproductive land provides a multitude of provisioning, cultural, regulating and maintenance services. As such we are able to consider different sectors and land-use categories, which in turn allows us 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). Our case is an example of farm diversification and recreational use of semi-natural land, which can be seen as underrated transformations. The selected case farm is also 'hidden' in the sense that much of the area used for production is not situated within the statutory demarcated agricultural space. A second 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). We also take tare land into account since they provide ES. We use an indicator based assessment to take ES into account. This allows for identifying differences in societal benefits between land use alternatives. These benefits can either be marketable or, alternatively, be regarded as externalities. Adaptive management of bioproductive land aims amongst other at internalizing positive externalities. Adaptive governance can both aim to facilitate internalizing such externalities, as well as compensating for those externalities that are difficult to internalize, e.g. through subsidies, payments for ES (PES), tax reductions, or other means.

To assess land use alternatives we assess the output of 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. Depending on the availability of data and aggregation techniques, this allows to take potential externalities into account in evaluating land use alternatives.

4 CASE FARM DESCRIPTION

The case farm is an organic farm that was established in 2001 on the land of a former conventional dairy farm. It covers about 112 hectares in 2013. 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, in two subcatchments of the Demer river. The catchments suffer from relatively poor water quality, mainly due to a contamination with a.o. heavy metals and chlorides (VMM, 2014). Aquatic vegetation is largely 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.

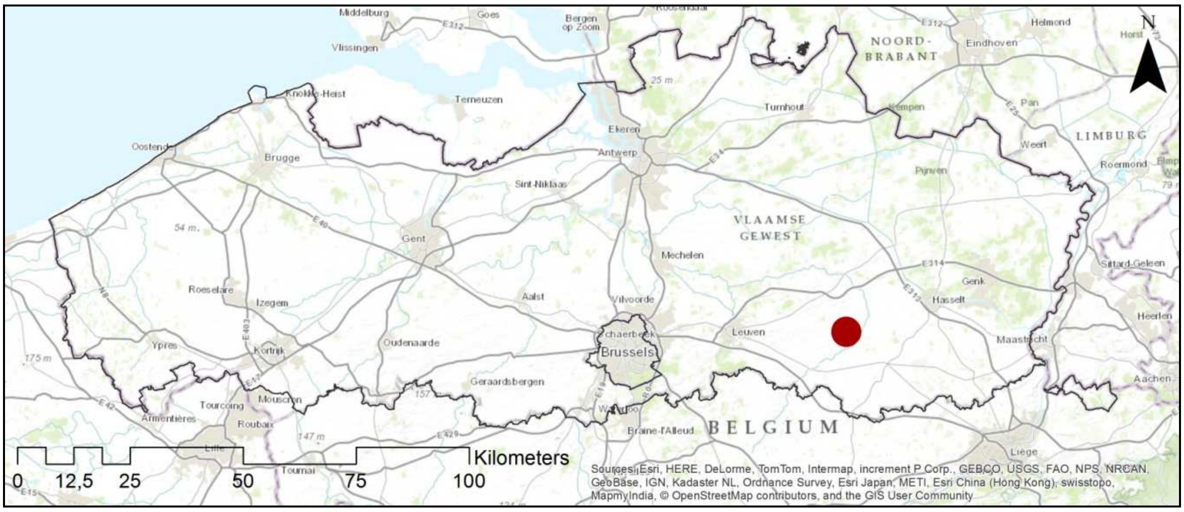

Fig. 1: Location of the case farm in Flanders.

In an ongoing effort to counteract atmospheric nitrogen deposition (Stevens et al., 2011), semi-natural grassland management in Flanders has to deplete nutrient stocks (Oelmann et al., 2009). Consequently, semi-natural grassland management typically produces 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 rustic cattle breed ‘Kempisch Roodbont’ and the rustic sheep breed ‘Ardense Voskop’. Both are able to digest low-quality feeds 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 delivered by the farm system, internalized by means of live sales.

5 METHODOLOGY

5.1 Data compilation and general analysis

The case farm parcels were mapped in ArcGIS 10.1. Land use was based on the farms register, the Biological Valuation Map (AGIV, 2010), and verified using aerial imagery (Aerodata International Surveys, 2007) combined with verification in 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), flood risk zones (VMM, 2006), and presence of woody vegetation such as hedgerows, isolated trees and orchards based on a map of green components in the landscape, i.e. the 'Groenkaart' (ANB, 2013, 2010). Livestock and feed production figures were attributed to the respective parcels by a parcel-by-parcel breakdown of the livestock movement and mowing registers. Statistical analysis was done using R 3.1.

5.2 Aggregation of ES delivered by bioproductive land

In order to evaluate the relative performance of land use scenarios in 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 different land use alternatives were estimated using the "Ecosystem Service Valuation Tool" developed by VITO (Broekx et al., 2013; Liekens et al., 2013). The land use alternatives include a reference scenario based on the actual land use, and some more conventional land use scenarios. They are described in detail in Section 4.3. Some corrections in the calculations were applied based on additional data, e.g. for the added value of crop and livestock under the Reference scenario (see further). In order to take local variations into account, the farm was divided in five spatially distinct clusters, and each of these clusters was evaluated separately. The evaluation of cultural services was done for the case farm as a whole. The valuation tool provides a lower and upper estimate for the value of the considered ES, and the comparison is based on the minimal estimates to avoid potential overestimation of the positive externalities.

The crops and livestock values as well as wood production value under the Reference scenario were quantitatively estimated based on accountancy data of the farm case and interviews with the case farm manager. For the other land use scenarios, these estimations are based on average Flemish farm income registrations 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 in kg/year 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 PM10, 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) (Hoyos, 2010). 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. This is the radius for which the value function is larger than zero. This number is multiplied with a mean WTP based on the type of ecosystem, species richness, accessibility, surrounding land use, size and distance to the household (Broekx et al., 2013). A similar approach was used by Costanza et al. (1997) to estimate the value of world ES.

5.3 Land use alternatives 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 *Reference* scenario in the remainder of the paper. On the same land, we assume three additional normative land use scenarios, which we call *IntensiveMIN*, *IntensiveMAX* and *IntensiveSRC*.

The Reference 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 nature 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 conventional livestock production, and local biophysical constraints are taken into account. Using a spatial overlay with the flood 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 subject to the EU Habitat Directive. For reasons of comparison and in order to minimize dependency on off-farm land, we assumed a largely autonomous production, i.e. the *IntensiveMIN* farm meets its own feed requirements from own production within the analyzed 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 *IntensiveMIN* alternative assume a spatial ratio between grassland and feed production of 0.86.

Within the case area several parcels are unsuited for intensive grazing. The ‘Bekkevoortse beemden’ (BVB) mainly consist 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. 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 Reference 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 over feed production spatial ratio of 0.86 is maintained.

Finally, the *IntensiveSRC* scenario explores the application of short rotation coppice (SRC) (willow and poplar) for biomass production in the most humid parcels. The cultivation of SRC can be seen as a relevant alternative strategy to increase the provisioning services delivered by the most humid parcels in this farming system. To select parcels for SRC production, a spatial overlay with the flooding risk zones was used and a total of 12.7 ha was selected. Willow (Salix spp.) was assumed for the parcels that effectively inundate, otherwise, poplar (Populus spp.) was assumed. All small landscape elements (single trees, hedgerows) and forest cover on land dunes remain in place. On the other parcels, livestock production remains as in the *Reference* scenario.

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

	Land Clusters					
	BH	CT	BVB	ZB	WB	**Total**
Reference						
Urban land	0.5	0.1	0.0	0.0	0.0	**0.6**
Agriculture and pastures	9.2	0.1	0.0	0.2	0.4	**9.9**
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	6.0	0.0	0.0	0.0	**7.4**
Forests and shrubs	3.0	6.1	0.0	<0.1	6.7	**15.8**
Semi-natural grasslands	35.6	9.3	4.9	4.5	22.0	**76.3**
IntensiveMIN						
Urban land	0.5	0.1	0.0	0.0	0.0	**0.6**
Agriculture and pastures	21.4	5.4	0.0	4.7	0.4	**31.9**
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	6.0	0.0	0.0	0.0	**7.4**
Forests and shrubs	2.8	6.1	0.0	0.0	6.7	**15.6**
Semi-natural grasslands	23.7	4.0	4.9	0.0	22.0	**54.6**
IntensiveMAX						
Urban land	0.5	0.1	0.0	0.0	0.0	**0.6**
Agriculture and pastures	44.0	9.4	5.8	4.7	9.6	**73.5**
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	6.0	0.0	0.0	0.0	**7.4**
Forests and shrubs	2.8	6.1	0.0	0.0	6.7	**15.6**
Semi-natural grasslands	1.1	0.0	0.0	0.0	12.8	**13.9**
IntensiveSRC						
Urban land	0.5	0.1	0.0	0.0	0.0	**0.6**
Agriculture and pastures	9.2	0.1	0.0	0.2	0.4	**9.9**
Rivers and ponds	0.1	0.0	0.0	0.0	0.0	**0.1**
Wetlands	0.0	0.0	0.9	0.0	1.3	**2.2**
Heath and land dunes	1.4	6.0	0.0	0.0	0.0	**7.4**
Forests and shrubs	13.3	6.1	2.4	0.0	6.7	**28.5**
Semi-natural grasslands	25.3	9.3	2.5	4.5	22.0	**63.6**

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

6 RESULTS

For livestock production, the valuation tool estimates a mean yearly added value of € 6 971 (min: € 5 480, max: € 8 460) under the reference scenario. However, semi-natural grasslands are considered unsuitable for livestock production in the valuation tool's methodology. As such, this tool only takes into account parcels with intensive grasslands. Since sturdy and self-reliant livestock breeds enables the case farm to use most semi-natural grasslands for production, we derived the estimates for the *Reference* scenario from accountancy data. As such, a value for livestock production of 27 000 euro is used for the *Reference* scenario. About 55% or 15 000 euro of this output stems from meat production, while the remaining 45% or 12 000 euro results from rustic breed sales. Concerning livestock productivity on semi-natural grasslands, research by Pelve et al. (2012) indicates that live weight gain of about 400 to 500 g/day is feasible using adapted breeds. While weight gain figures reported in literature surpass 1 000 g/day for meat production breeds like Limousin, they only range between 260 g/day and 650 g/day for Galloway (Bedoin and Kristensen, 2013; Fraser et al., 2013), a breed typically used in nature management practices in Flanders. With an estimated live weight gain of about 800 g/day, the Kempisch Roodbont perform relatively well. Kempisch Roodbont has the added advantage of being suited for both milk and meat production, contrary to Limousin.

In terms of crop and livestock output, the *IntensiveMIN* and *IntensiveMAX* scenarios perform better than the *Reference* scenario, while the added production value of the *IntensiveSRC* scenario is lower. The differences are much less obvious for the value of wood production, for which *IntensiveSRC* performs slightly better.

For most regulating services taken into account, the *Reference* scenario is preferred over *IntensiveMIN* and *IntensiveMAX*, and is on par with *IntensiveSRC*. The exception here is the service air quality, for which *IntensiveSRC* is the best performer. Differences are negligible for carbon storage services in biomass. The differences in terms of fine particle filtration (air quality) can be attributed to the presence of small landscape elements in the *Reference* scenario, and of coppice in the *IntensiveSRC* scenario.

The value of the cultural services is highly dependent on the aesthetic value of the local landscape and is much higher under the *Reference* scenario than under the *IntensiveMIN* and *IntensiveMAX* scenarios. The WTP for cultural services is depending amongst others 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 very fast. As such, for remote sites the site area has a strong positive impact on the valuation of the cultural benefits in the methodology used.

Table 2 and Figure 2 compare the relative monetary value of ES delivered under the *Reference* scenario with these delivered by the other scenarios. The vertical line in the graph marks the *Reference* land use. Positive values in this table are situated to the right of this line and indicate that the alternative land use performs better that the *Reference* land use for that particular ES. The largest differences between the land use alternatives are in crop & livestock production, air quality, and cultural services. Table 2 and Figure 2 illustrate that the potential societal benefits (in terms of selected ES) provided by bioproductive land of the case study is considerably higher in the *Reference* scenario than in the *IntensiveMIN*, but the difference between both is less obvious for the *IntensiveMAX* scenario. Of course one should take into consideration that *IntensiveMAX* is a corner solution that neglects biophysical constraints.

Ecosystem service	IntensiveMIN - Reference	IntensiveMAX - Reference	IntensiveSRC - Reference
Crop & livestock	20 200	65 900	-8 900
Wood	300	500	3 300
Air quality	-7 300	-17 450	17 800
C storage in soil	-100	-5 300	500
C storage in biomass	-200	-850	0
N storage in soil	-4 000	-8 850	0
P storage in soil	-4 250	-9 450	0
Cultural services	-9 250	-23 750	2 600
Total (€)	**-4 600**	**750**	**15 300**

Table 2: Aggregated differences in ES delivery between the Reference and respective intensive scenarios, based on conservative estimates. A negative value indicates the respective land use alternative performs worse than the Reference scenario, a positive value indicates it performs better.

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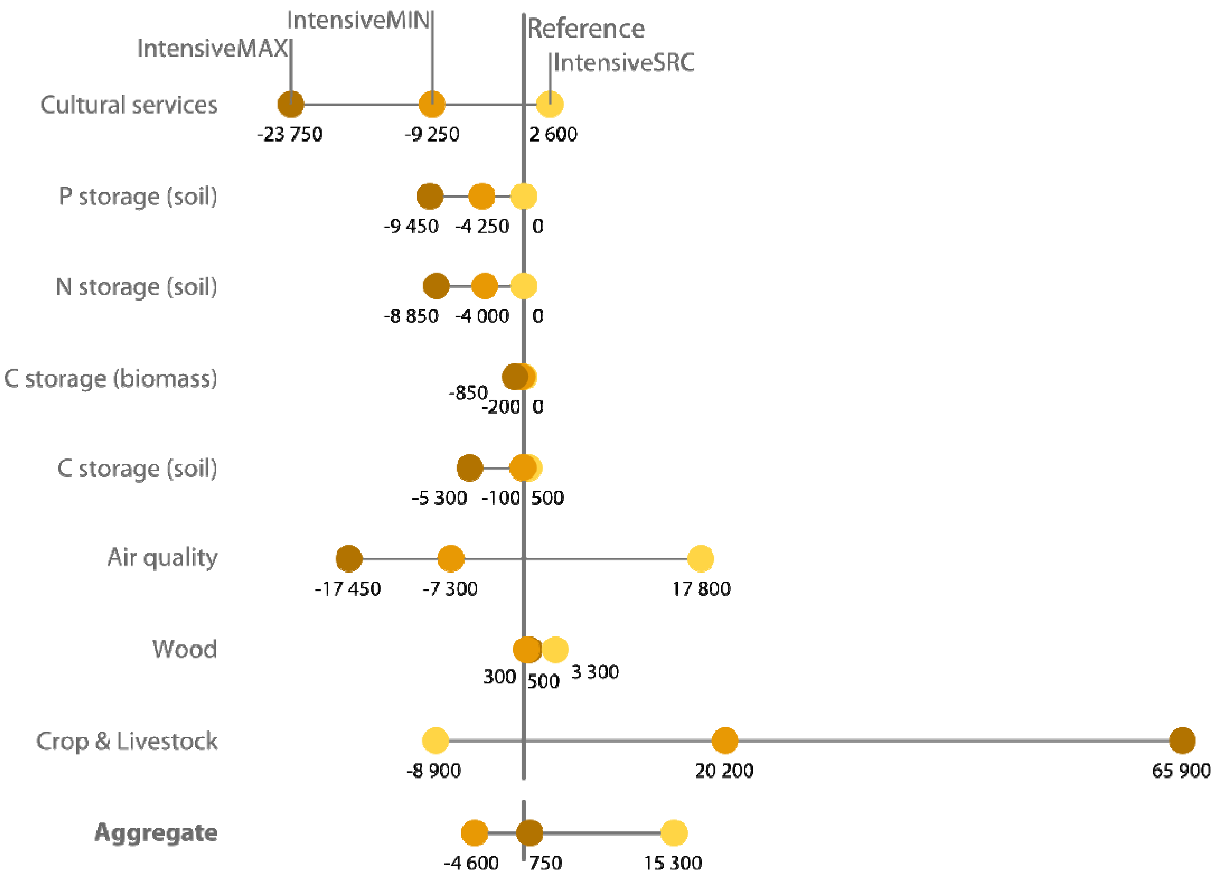

Fig. 2: Relative differences in valued ecosystem service provision between the Reference scenario and the intensive scenarios. The central axis represents the Reference scenario. Alternatives performing better for a given ecosystem service are positioned to the right of this line, and alternatives performing worse are positioned to the left.

We compare land use scenarios by aggregating ES at 3 levels (Figure 3): (1) aggregation of only provisioning services; (2) aggregation of provisioning and regulating services, and (3) aggregation of all selected ecosystem services.

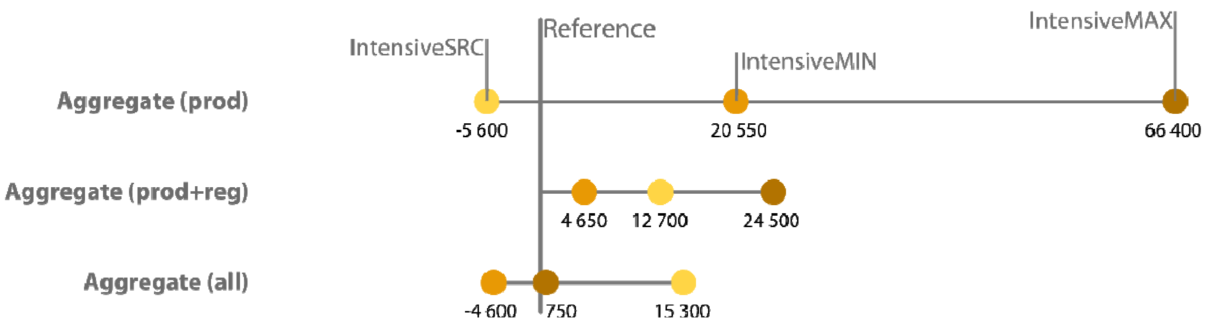

Fig. 3: Comparison of aggregation based on (1) only provisioning services, (2) provisioning and regulating services, and (3) all selected ecosystem services.

The success of the *Reference* scenario relies in 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 traditional 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 4). 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, $p<0.05$).

As such, the farm also acts as a buffer zone for water retention and reduces 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 natural grasslands.

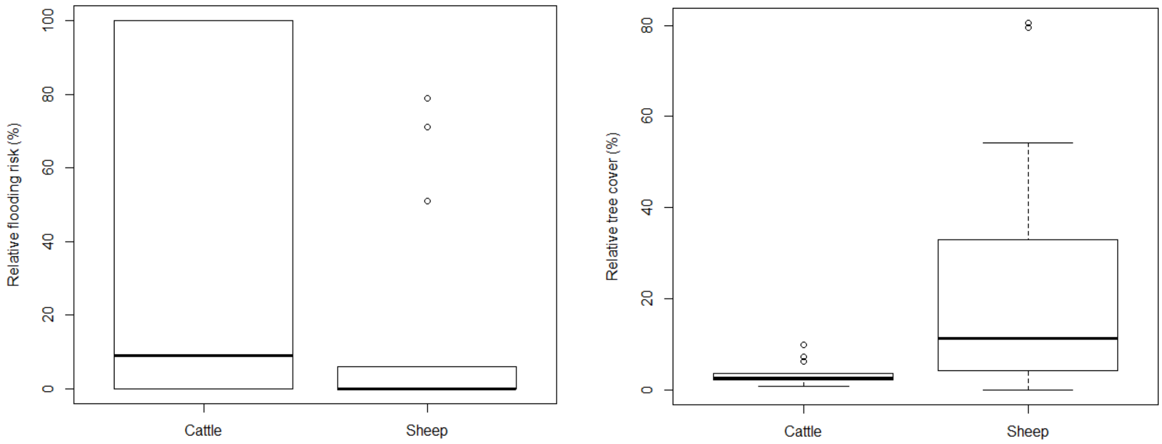

Fig. 3: The use of cattle and sheep in an adaptive farming strategy: in relation to the flooding risk (left), and in relation to tree cover (right).

7 DISCUSSION

In this study we assess a farming model that combines livestock production and nature management on relatively marginal lands and compare it with more production-oriented land use alternatives. We compare the monetary value of ES under different land use scenarios to benchmark the land use alternatives. The results illustrate how the optimal land use from a societal perspective depends on biophysical constraints, and points out the importance of internalizing positive externalities. It provides insights in the rationale of on-farm diversification. In the case study area, organic livestock production is able to provide comparable societal benefits compared to more conventional approaches, while serving the local biodiversity targets. However, if biophysical constraints are less restricting, a situation corresponding to the *IntensiveMAX* scenario, the differences in delivering non-provisioning societal benefits decrease and more intensive approaches might outperform extensive approaches.

According to the valuation method used, the value of cultural services depends on both local population densities and area. Small sites are only valued by those living close by, while the cultural benefits of large and well connected sites are also valued by people living 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 outcome of the evaluation of optimal land use strategies could be very different.

Aggregating only provisioning services would result in a distinct choice for *IntensiveMAX* and *IntensiveMIN* over the *Reference*, which in turn would be preferred over *IntensiveSRC*. This corresponds to an exclusively production-oriented rationale. Taking regulating and cultural services into account shifts the preference towards more unconventional land use alternatives. Taking all selected ES into account, the aggregated differences between the *Reference* and the *IntensiveMIN* land use become very small, highlighting the potential of the *Reference* land use in delivering a broad range of societal benefits. The *IntensiveSRC* scenario performs relatively well, also in comparison with the *Reference* land use. Possible limiting factors for this development path can be economical, logistic, cultural, or related to legislation, e.g. conflicts with nature development targets. Future research is needed to reveal which, if any, factors are the most limiting.

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. The extensive 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. Through combined grazing and cutting management, nutrients are removed from the system and floristic diversity is able to increase. This should at minimum compensate for the nutrient influx through dry and wet deposition, but from a floristic diversity perspective, it is desirable for the system to progressively become more nutrient poor.

On-farm diversification is aiming to validate this biodiversity, e.g. by engaging in ecotourism, but also subsidies and payments for ES partially enable to internalize positive externalities. While the *Reference* scenario is able to outperform the *IntensiveMIN* farming strategy, and is almost on par with the *IntensiveMAX* corner solution when taking a wider range of ES into account, the increasingly limited income for farmers remains a cause of concern. The case farm is partially dependent on additional government subsidies and this adds to its vulnerability.

Some functions and services provided under the *Reference* scenario are underestimated. 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 risks locking 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. This flood protection service delivered by the case farm is also not yet taken into account.

For the calculation of the ecosystem services, the study applies the "Ecosystem Service Valuation Tool" developed by VITO. This tool applies benefit transfer functions to estimate the value of the ES delivered by the considered bioproductive land. Benefit functions are based on several other studies and easy to use. As such, benefit transfer has some advantages and is widely used (Costanza et al., 1997). However, it typically fails 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 Reference 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 properly considered as sites suitable for livestock production. However, the case farm does manage to use these grasslands and to sell its meat to local customers by organizing periodical sales in collaboration with other producers of regional products . As such, decision making based on such tool can be biased towards conventional land use systems. This stresses the need to highlight the potential of agro-ecological innovations and take them into account in spatial planning processes. One of the key innovations in our case is the use of adapted rustic breeds. Further, 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, while it is an important lever for spatial planning to work with.

8 CONCLUSION

Like many urbanized regions, Flanders is characterized by 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 managing nutrient-poor or wet grasslands. In addition, land sharing strategies, in particular agri-environmental schemes, are not achieving the expected results (Balmford et al., 2012; Kleijn et al., 2011, 2001; Pe'er et al., 2014). 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 to 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 applies an integrative and transdisciplinary approach to evaluate land use of a case farm.

The results demonstrate how the agro-ecological land use strategy of this farm may or may not be preferred over more conventional land use strategies, depending on which services are taken into account. The results demonstrate the potential of the agro-ecological land use to provide higher levels of societal benefits (i.e. output of ES) in regions with both 'inferior' and high quality land and with high population densities. 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, the intensive land use strategies might outperform agro-ecological land use strategies. A 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 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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