Ecosystem Accounting Limburg Province, the Netherlands

Part II: Monetary supply and use accounts

Abstract

Worldwide, ecosystems and their biodiversity are under severe environmental pressure. Consequently, valuable services provided by these ecosystems, such as the provisioning of timber, water regulation, air filtration or recreation, may be reduced or lost. Ecosystem accounting aims to quantify and monitor the interdependence between ecosystems (and their services) and economic activities, in an internationally consistent manner. The accounting system is based on tracking changes in the supply and economic use of ecosystem services. It also aims to monitor the extent and condition of ecosystems and to identify the underlying causes for change. The methodology was developed in line with the international guidelines provided by UN et al (2014), the System of Environmental Economic Accounts – Experimental Ecosystem Accounting. In two reports we describe the results of a pilot study on ecosystem accounting in Limburg Province, the Netherlands. The current report focusses on the monetary supply and use of ecosystem services. The report is complimentary to Part I on physical supply and ecosystem condition accounts.

1. Introduction

Ecosystems contribute to human welfare and national economies. These contributions are known as ecosystem services. Examples of ecosystem services are the provision of food, nature recreation and air filtration by vegetation. Ecosystem accounting has been developed to consistently monitor and measure ecosystem assets, and the supply and use of ecosystem services, in both physical and monetary terms. In this two part report pilot ecosystem accounts are developed for Limburg province, the Netherlands. In this part of the report, monetary supply and use accounts are developed in order to assess the ecosystem contribution to the regional economy. See Part I of this report, *Physical supply and condition accounts*, for further information on the background of ecosystem accounting and a detailed description of the project objectives.

The System of Environmental Economic Accounts – Experimental Ecosystem Accounting (SEEA-EEA, UN et al., 2014) provides guidelines for monetary valuation of ecosystem services for ecosystem accounting. Further information on valuation is provided in the forthcoming Technical Recommendations for Ecosystem Accounting, draft material of these recommendations has been used in support of this report. Valuation approaches should be aligned with the System of National Accounts (SNA), and are based on exchange values. Such an approach allows for comparing ecosystem accounts with economic statistics measured in national accounts and facilitates the avoidance of double counting (Hein et al., 2015). Alignment with SNA distinguishes valuation methods for ecosystem accounting from other approaches used for ecosystem service valuation, mainly due to the exclusion of methods related to consumer surplus. In this report, monetary valuation of seven ecosystem services is applied and spatially modelled, using the valuation methods described in the SEEA-EEA, to develop supply and use accounts for Limburg. The ecosystem services we value are crop production, fodder production, groundwater supply for drinking water production, hunting, PM_{10} capture by forests, carbon sequestration and nature tourism.

This report first describes the applied valuation methods. Next, the resulting ecosystem service maps, and the monetary supply and use tables are presented. Additionally, we provide a tentative analysis of the implications of ecosystem accounts for the regional economy. Finally, we discuss the implications of the findings and provide recommendations for future work. This report builds on the physical methods applied in Part I of the report.

2. Methods

2.1 Monetary supply of ecosystem services

The SEEA-EEA describes which methods can be applied for monetary valuation methods of ecosystem services in an ecosystem accounting context (see also Obst et al., 2015). Here we briefly present the applied methods for this pilot study. All methods are cost-based methods and are based on Remme et al. (2015). The methods are described there in more detail. We apply the resource rent method, avoided damage costs, and replacement costs described in the SEEA-EEA guidelines (UN et al., 2014). When applied correctly, these methods exclude consumer surplus ('willingness to pay') from monetary valuation and enable comparison with economic data in the national accounts, including indicators such as Gross Domestic Product (GDP).

According to the resource rent method, ecosystem services can be calculated as the residual of the total revenue, after the costs of intermediate inputs, the costs of labour and the user costs of fixed capital have been subtracted. This method can be applied to ecosystem services for which market data is available. In this case, the resource rent method was applied to calculate the monetary value of crop production, fodder production and nature tourism. Hunting was considered primarily as a recreational activity. Its value was analysed on the basis of the price paid to land owners for acquiring hunting rights, i.e. on the basis of the market transaction between land owners and hunters. It is assumed that land owners do not incur any costs for making their land available for hunting. For many regulating services market data does not exist. Therefore, other methods need to be applied, such as the avoided damage cost method. The value of carbon sequestration and PM_{10} capture were assessed using the avoided damage costs approach. PM_{10} capture was based on avoided air pollution-related health costs. Carbon sequestration was valued using the social cost of carbon, which is an estimate for the damage costs of climate change (United States Government, 2013). The replacement cost method is another cost-based method that can be used to value ecosystem services for which there is insufficient market data. The method calculates the value of an ecosystem service as the difference between the costs to acquire the service and the costs of the most viable alternative. This method can be applied in case it can be assumed that the service would indeed be replaced if lost, and on the condition that the least cost alternative is considered (NRC, 2004; UN et al., 2015). The value of groundwater supply for drinking water production was based on the replacement cost method. The costs of drinking water production from groundwater were compared with the use of surface water (in particular from the river Meuse) to provide drinking water, which involves higher treatment costs. In this case the conditions for the use of this method are met; already Meuse river water is used to produce drinking water and if no groundwater would be available the provincial drinking water company would need to increase the use of river water.

In addition to the described methods, an experimental approach was tested to value the amenity service of living near green space. Valuation took place based on the hedonic pricing method. Hedonic pricing has been widely applied in the field of environmental economics, and has been applied in the Netherlands to value, for instance, increases in house prices due to a location close to open water or urban green spaces. However, it has not been applied yet in support of ecosystem accounting, which has the specific challenge that the analysis takes place at an aggregated scale requiring a large dataset and making it necessary to consider a wide range of, locally variable, factors that may influence house prices. The aim was to calculate the effect of green areas on housing prices (using WOZ values as a proxy). As the purpose was to test the method and an incomplete dataset was used the results are not presented in accounting tables. The experimental approach is further described in Annex I. A particular challenge in the calculations was not the use of the hedonic pricing method per se (which is fairly straightforward) but that access to all the required datasets was not available in the context of the project. We expect that access to the missing dataset could be secured in case of a follow-up project. This would strongly enhance the accuracy of the result, see Annex I for details.

2.2 Development of accounting tables

All tables were designed according to SEEA-EEA guidelines. Monetary ecosystem service supply was provided for each ecosystem unit from the Ecosystem Units map presented in Part I of this report (columns) and for all ecosystem services (rows) that were included in this study. The monetary values of services supply were based directly on the modelled ecosystem services maps. To determine the monetary supply of ecosystem services per ecosystem unit, for example the monetary supply of the service nature tourism, the monetary supply map for nature tourism was overlaid with the Ecosystem Units map.

The monetary use table was constructed differently. Although a detailed economic users map (based on the ISIC[1] registry) was developed within this project, none of the ecosystem services that were included in this study had spatially explicitly defined economic users, as would have been the case for, for instance, flood protection and noise reduction. Therefore, users were defined depending on the physical and monetary model characteristics, following the ISIC classification.

[1] ISIC = International Standard Industrial Classification of All Economic Activities

3. Results and interpretations

3.1 Ecosystem Service Maps

The ecosystem services with the highest per hectare value are crop production, nature tourism and groundwater supply for drinking water production (Figure 3.1.1). The spatial distributions of the assessed ecosystem services show large variations. Nature tourism values are highest in the south of the province, which is the popular for its hilly landscape. Values for crop production, fodder production and groundwater supply show scattered and variable distributions. High values for carbon sequestration and hunting are found in (large) forest areas. Monetary value for PM_{10} capture is highest in areas with relatively high population densities and relatively large forest areas.

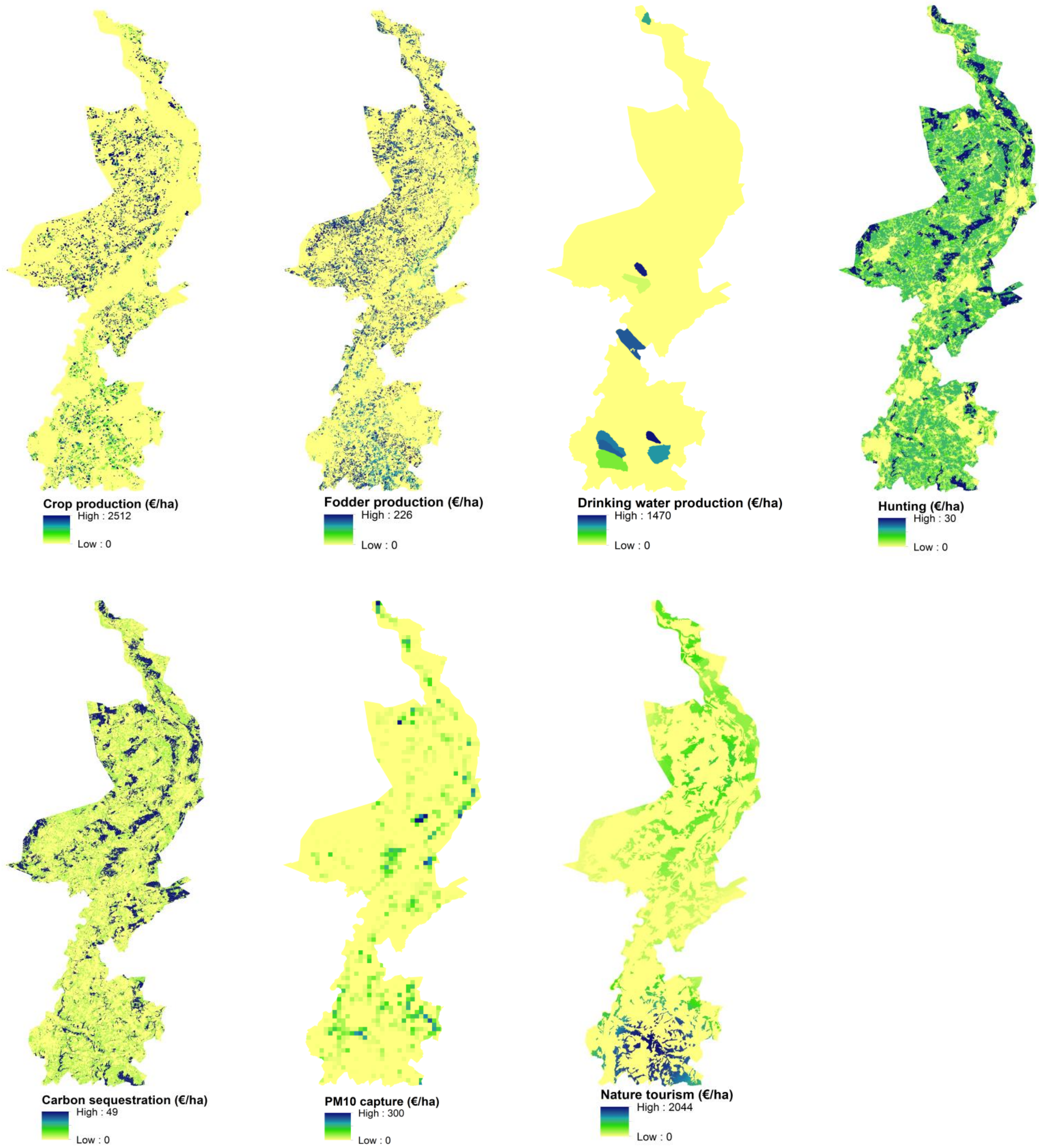

Figure 3.1.1 Monetary ecosystem service maps (€/ha).

Figure 3.1.2 shows the total monetary value map for the analysed ecosystem services. The nature areas in the southern part of the province have the highest values, especially due to the combination of nature tourism and groundwater supply.

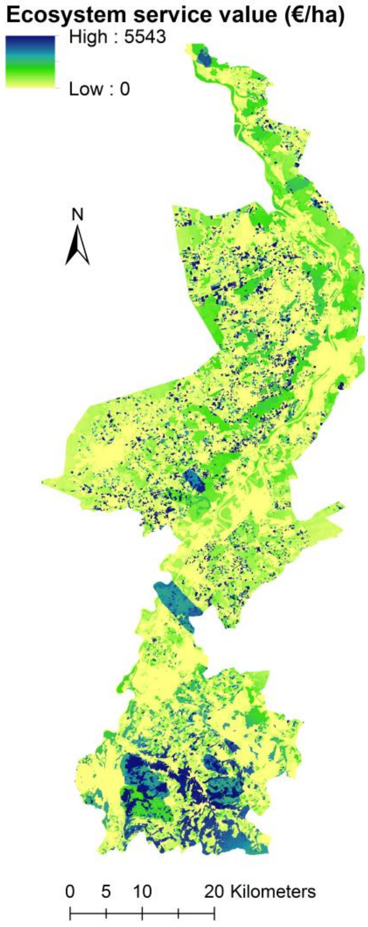

Figure 3.1.2 Total monetary value of assessed ecosystem services (€/ha).

3.2 Monetary Supply Tables

The Ecosystem Unit non-perennial plants) provides the largest value in terms of ecosystem service supply (Table 3.1). About 75% of this value is determined by the ecosystem service crop production (i.e. annual crops such as potatoes, corn, vegetables). Non-perennial plants was also the Ecosystem Unit with the largest extent, followed by paved areas and meadows. Meadows, deciduous forests and mixed forests also have high total monetary supply values. For meadows this can be attributed for a large part to its importance for fodder production, but even more to its value for nature tourism. For all natural ecosystem units nature tourism contributes substantially to their monetary value. In all cases nature tourism contributed more than 80% of their total value. Hedgerows also contribute to the monetary value of nature tourism as they provide an attractive landscape feature. Paved areas contribute to the monetary value of groundwater due to the method used to model groundwater supply. The entire groundwater protection zones were included, which can include paved areas. However, we recognize that paved areas do not contribute to infiltration, and we would discuss in a follow-up project if the method for physical and monetary analysis of this service should be updated.

Table 3.2.1 Monetary supply table with total values per ecosystem unit for Limburg

LIMBURG				1 Non-perennial plants	2 Perennial plants	4 Meadows (for grazing)	5 Hedgerows	6 Farmyards and barns
extent			ha	**53.629**	**8.133**	**27.066**	**2.940**	**2.142**
Provisioning	Crops		€	35.303.100	2.605.287	-	-	-
	Fodder		€	1.960.900	66.000	4.587.100	-	-
	Meat (from game)		€	817.700	112.900	223.400	-	9.600
	Ground water		€	3.861.200	607.200	1.802.300	193.900	61.800
Regulating	capture of PM10		€	301.200	54.300	173.700	30.400	11.700
	Carbon sequestration		€	300	80.200	165.700	18.000	100
Cultural	Nature tourism		€	4.410.000	1.042.600	6.349.100	2.357.700	-
	Recreation (cycling)		€	NA				
Totals			€	**46.654.400**	**4.568.500**	**13.301.400**	**2.600.000**	**83.200**
	value per ha (excl. Amenity service)		€/ha	**870**	**562**	**491**	**884**	**39**
	value per ha (incl. Amenity service)*		€/ha	**870**	**562**	**491**	**884**	**39**

Table 3.2.1 Monetary supply table with values per ecosystem unit and service, per ha

LIMBURG			1 Non-perennial plants	2 Perennial plants	4 Meadows (for grazing)	5 Hedgerows	6 Farmyards and barns
Provisioning	Crops	€/ha	658	320	-	-	-
	Fodder	€/ha	37	8	169	-	-
	Meat (from game)	€/ha	15	14	8	-	4
	Ground water	€/ha	72	75	67	66	29
Regulating	capture of PM10	€/ha	6	7	6	10	5
	Carbon sequestration	€/ha	0	10	6	6	0
Cultural	Nature tourism	€/ha	82	128	235	802	-

21 Deciduous forest	22 Coniferous forest	23 Mixed forest	24 Heath land	25 Inland dunes	26 Fresh water wetlands	27 Natural grassland	28 Public green space	29 Other unpaved terrain	31 River flood basin	41-48 Paved areas	52 Lakes and ponds	53 Rivers and streams	Totals
11.414	**7.091**	**10.437**	**2.149**	**114**	**936**	**3.121**	**4.761**	**22.591**	**14.126**	**42.349**	**3.122**	**3.807**	**220.922**
-	-	-	-	-	-	-	-	-	-	-	-	-	**37.908.400**
-	-	-	-	-	-	-	-	-	942.300	-	-	-	**7.556.200**
186.800	192.700	261.100	35.600	2.000	12.700	32.900	14.700	211.200	136.000	-	-	-	**2.249.400**
824.200	63.500	218.700	57.300	300	11.200	295.700	192.600	1.041.100	545.700	1.620.500	200.800	4.800	**11.602.800**
200.200	185.700	200.700	27.200	2.200	2.400	46.700	78.100	258.200	85.900	574.500	27.300	15.400	**2.275.900**
562.500	350.300	515.000	13.200	-	6.400	19.300	40.500	139.000	95.600	-	-	-	**2.006.100**
6.930.100	3.162.500	5.443.100	917.000	41.600	392.800	2.488.900	625.900	2.870.600	3.162.100	-	719.600	902.400	**41.816.200**
													NA
8.703.800	**3.954.700**	**6.638.800**	**1.050.400**	**46.100**	**425.400**	**2.883.500**	**951.700**	**4.520.200**	**4.967.500**	**2.195.000**	**947.700**	**922.600**	**105.415.000**
763	**558**	**636**	**489**	**403**	**454**	**924**	**200**	**200**	**352**	**52**	**304**	**242**	**477**
1.193	**988**	**1.066**	**489**	**403**	**454**	**924**	**688**	**220**	**352**	**52**	**768**	**242**	**553**

21 Deciduous forest	22 Coniferous forest	23 Mixed forest	24 Heath land	25 Inland dunes	26 Fresh water wetlands	27 Natural grassland	28 Public green space	29 Other unpaved terrain	31 River flood basin	41-48 Paved areas	52 Lakes and ponds	53 Rivers and streams
-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	67	-	-	-
16	27	25	17	17	14	11	3	9	10	-	-	-
72	9	21	27	3	12	95	40	46	39	38	64	1
18	26	19	13	19	3	15	16	11	6	14	9	4
49	49	49	6	-	7	6	9	6	7	-	-	-
607	446	522	427	363	420	797	131	127	224	-	230	237

Another interesting comparison is shown in the bottom rows of Table 3.2. Here the total value of the included ecosystem services was divided by the total extent of each ecosystem unit, providing a provisional ‘value per ha’. This comparison shows that natural grasslands, non-perennial crops, hedgerows and forests are valued most highly. These units provide high values for a wide range of services. Non-perennial plants provide a high value per ha almost entirely due to the provisioning of crops. An interesting comparison that can be made here is between the high total value per ha of natural grasslands compared to meadows (for grazing). The natural grasslands are likely located in or near natural parks, resulting in a relatively high number of nature tourist visits per hectare and a corresponding high monetary value.

Although these tables provide interesting data, it is important to keep in mind that the ecosystem services included in this pilot project only represent a small part of all ecosystem services provided in Limburg. Other important ecosystem services (e.g. timber supply, water recreation, recreation) were not included in the current study. As a consequence, for example the monetary value per hectare (Table 3.2) of floodplains is very low. If protection against river floods would have been included as an ecosystem service in this study, this would have resulted in a much higher total value of floodplains. In addition, it is important to keep in mind that the monetary results in this study are strongly influenced by the choice of valuation methods aligned with the SNA. Because consumer surplus is not included in the valuation methods of the SNA, values of some services may appear to be small (for instance in the case of air filtration, where a welfare based valuation approach would lead to a value that is around a factor four higher, see Remme et al. (2015)). Consumer surplus is not included because this would not be consistent with the national accounts.

3.3 Monetary Use Table

Table 3.3 shows the monetary use table. Following standard SNA accounting rules, total supply must equal total use, hence total sums are the same. The tables shows who benefits from the different ecosystem services that are provided in Limburg.

The ecosystem contribution to the production of crops and fodder is used by the agricultural section (A). The users of the service provisioning of meat (from hunting game) are defined as households; hunting in the Netherlands is primarily a recreational activity and the monetary value of this service was calculated as such (based on hunting rights paid). The use of PM_{10} capture was also tentatively assigned to households. Although for example governments, companies and health insurers also benefit indirectly from this service, for the moment households were assigned as the primary user since they incur lower health negative effects from air pollution. The provisioning of ground water for drinking water purposes was assigned entirely to water companies (section E). The reason for this is that in the model, only water extraction for drinking water was included, whereas groundwater extraction for other uses, such as irrigation, was disregarded in the current model. For the moment, carbon sequestration was attributed to Global Goods, because in essence carbon sequestration (like carbon emissions) has a global impact rather than a national or regional one. This attribution may change depending on the further development of the guidelines for ecosystem accounting. Finally, the benefits of the ecosystem contribution to nature tourism were attributed to those economic activities that provide tourist accommodation; hotels, holiday houses and campgrounds (ISIC sections I and R).

Table 3.3.1 Use per ISIC section; monetary values (euro), year: 2013

Ecosystem services	Economic Users (ISIC Sections) / Ecosystem Units	A	B-D	E	F-H	I,R	Rest	Export	Household cons	Government cons.	Investments	Inventories	Env (global goods)
Crops	€	37.908.400											
Fodder	€	7.556.200											
Meat (from game)	€								2.249.400				
Ground water (drinking water only)	€			11.602.800									
Capture of PM10	€								2.275.900				
Carbon sequestration	€												2.006.100
Recreation (cycling)	€								na				
Nature tourism	€					41.816.200							

3.4 Relation to the economy of Limburg province

Table 3.4.1 shows the summary statistics for the population and economy of Limburg Province. More detail is provided in Table 3.4.2 for ISIC section A in total (Agriculture, Forestry and Fishery) and for the individual economic activities within agriculture for the three main regions (Corop areas) within Limburg. Due to secrecy rules, the water company data are only available at the provincial level.

Table 3.4.1 Economic and population summary statistics for Limburgfor 2013

	Population	Value Added	Employment
		million euro	fte
North	280.418	8.326	112.900
Central	235.573	6.347	86.700
South	605.900	17.350	225.700
Limburg totals	1.121.891	32.023	425.300

Table 3.4.2 Employment and value added per sector, Limburg province, 2013

	Total employment (fte) ISIC section A (agriculture, forestry, fishery)	**Employment for employees*** fte			**Value Added** million euros		
		arable farming, hortic.	livestock farming	water companies	arable farming, hortic.	livestock farming	water companies
North	7300	3660	400	x	480	110	x
Central	2800	570	280	x	100	80	x
South	1700	250	60	x	50	20	x
Limburg totals	11800	4470	740	780	630	210	160

* At the regional level and for the subdivisions of the different agricultural activities, employment data are only available for employees, thus excluding self-employment. In the case of agriculture, this likely results in a substantial underestimation of total employment, given the generally high rate of self-employment among farmers.

ISIC section A represents agriculture, forestry and fishery activities. This sector (in Limburg strongly dominated by agriculture), provides 11800 fte's of employment, with most employment in the north of Limburg (7300 fte). The majority of employees within the agricultural sector are active in arable farming and horticulture (4471 fte for employees, self-employed fte's not known) and hence depend upon the ecosystem service crop provisioning. Similarly, employees active within livestock farming (740, Limburg total) depend on the ecosystem service fodder provisioning. Due to the expected high rate of self-employment within agriculture and livestock farming, these numbers are most likely an underestimation of employment related to the ecosystem services crop and fodder provisioning. In Limburg, 780 employees work for water companies, which use the ecosystem service ground water provisioning to produce drinking water. The value added of these sectors and activities is shown to the right; € 633 million for arable farming and horticulture, €210 million for livestock farming, and € 160 million for water companies. The data presented in these tables are readily available. Regional data on e.g. tourism and related employment may be derived from detailed analyses, which may be part of a future project.

4. Discussion and conclusions

This pilot project shows the possibility of developing monetary supply and use accounts at provincial level. The valuation methods are aligned with the SNA and based upon, among others NRC (2004), UN et al. (2014), Remme et al. (2015), Obst et al. (2015), and the forthcoming UN Technical Recommendations for Ecosystem Accounting. Note that two principal approaches were followed to valuation. One approach involved spatial allocation of values retrieved from the SNA, as in the case of the market ecosystem services (where the accounts show the contribution of the ecosystem to such services, these are not explicit in the national accounts). In this case the aggregate value estimates can be attributed a fairly high degree of confidence, but there is some uncertainty in terms of the spatial allocation and the resulting maps representing values. In other cases, in particular with regulating services such as carbon sequestration and air filtration, the uncertainties relate both to the spatial model and the aggregate value of the service. In the case of carbon sequestration, the marginal value of an unit of emitted carbon is uncertain, given the uncertainties related to the pace of climate change (also as a function of mitigation policies) and the costs of the associated effects, in particular at medium or long term. We have therefore used a conservative marginal damage cost value for a unit of sequestered carbon. In the case of air filtration, the main uncertainty pertains to at what scale the effects of vegetation on air quality is still measurable (there is also still some uncertainty regarding the actual air pollutant deposition capacity of vegetation). A sensitivity analysis on the scale of the effects conducted in the context of Remme et al. (2015) showed that increasing the range from 1 km to 2 km increased the value by about 30%. The dose-response curve for human health effects of air pollution is by now well established (e.g. IIASA, 2014) and the SNA-conform benefits of air filtration are related to the costs of hospital treatments, which are also well documented. Further work would be needed to value additional services when the accounts are scaled up to the Netherlands, for instance in order to value recreation (using the UK NEA (2011) as input, where this service has been valued), and in order to value flood control (potentially using a replacement cost method, e.g. considering that dunes would have to be replaced by dykes if not present). Importantly, the selected methods allow scaling up to the national level. They also allow integration with data form the national accounts, for instance permitting analysis of employment generated through the use of ecosystems.

Crucial in accounting is that valuation approaches are used that are aligned with the SNA, which sometimes leads to different valuation approaches compared to a welfare based valuation approach (see e.g. NRC, 2004). Note however that the monetary information in the ecosystem accounts presents an important part of the data that is also required for welfare based valuation (in particular: the producer surplus part of the welfare value can be derived from the accounts, as well as the physical information on the use of ecosystem services that is needed to establish a consumer surplus). Hence, the accounts, one established and regularly updated, will also provide a very important resource for welfare based valuation studies, for instance social cost benefit analysis (e.g. of major infrastructure projects, as required by Dutch law).

An additional added value of the ecosystem accounts, as now developed in pilot format, is that it follows and international framework, and that accounts produced in different countries with the same framework will be comparable. This facilitates comparison of natural resource management strategies in different countries as well as aggregation to produce continental or, eventually, global estimates of natural capital. The Limburg pilot has played a crucial role in supporting the further development of international guidelines, intermediate results from the study have been presented to and discussed with among others the UN and the World Bank, and have been considered in the forthcoming Technical Recommendations for Ecosystem Accounting.

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Annex I – Amenity service: the value of living in a 'green' environment

1. Introduction

A hedonic pricing study was also carried out within this project. Aim of this experiment was to test whether it was possible to detect the influence of 'green' areas on house prices (WOZ values were used as a proxy) and to gain insight into the hedonic pricing methodology in the context of accounting. Hedonic pricing, or assessing the influence of a variable on the value of a given commodity, is a method to assess the relative importance of environmental variables on the price of a target commodity. In this case, we used hedonic pricing to assess the effect of a 'green' environment on housing prices in Limburg. The basic assumption underlying the method is that spatial variability of a known variable can be explained by a number of other, independent variables plus a degree of noise. Thus, we test whether housing prices are positively influenced by the (nearby) presence of publicly accessible 'green' areas: forests, parks, water bodies suitable for recreation, open natural terrain (e.g. heathlands, moors) and public allotments. Hedonic pricing can be carried out using linear regression methods. Although multiple linear regression is a straightforward approach, the reliability of the final linear model depends on data quality as well as careful selection of included variables.

2. Methods

For hedonic pricing to provide reliable results, detailed analysis of variable characteristics and in particular, of multi-collinearity, is required. Multi-collinearity, or interdependence between two or more explanatory variables in a statistical analysis, is very common in real life spatial gradients. For example, generally when moving outwards from a city centre to the suburbs, the average distance to a range of facilities (central station, café's, restaurants, shops etc.) will increase. At the same time house plot sizes and the average year of construction increase (oldest houses in the city centre). Clearly, there is no causal relation between plot size and distance to a restaurant, and the direct correlations between such variables is not necessarily high. However, together, these variables clearly show multi-collinear dependencies. Multi-collinearity of environmental variables leads to an overly strong influence of co-varying variables on linear regression models at the cost of other, unrelated variables. Therefore, the first step in spatial gradient analyses is assessment and reduction of such relations.

Data selection prior to analyses

- Method: hedonic pricing – multiple linear regression model
- Target variable: WOZ housing value (€)
- Objects in original dataset: 550.000 housing units
- Explanatory variables;
    - For each dwelling: total living area (m^2), type of dwelling (terraced house, end of terrace house, semi-detached or villa), year of construction
    - Average values for neighbourhoods (CBS nabijheidsstatistieken voor buurten en wijken): distance to facilities (shops, supermarkets, primary and secondary schools, daycare, cinema, library, restaurants, cafés and hotels, sports grounds, and public 'green' spaces (forests, parks, water bodies suitable for recreation, open natural terrain and public allotments).
    - We excluded variables, which do not (usually) influence housing prices, such as distance to an amusement park, hotel or cemetery.

The average neighbourhood statistics on distance to facilities and green areas of a specific neighbourhood were linked to each house within that neighbourhood.

Criteria for selection

To enhance continuity in the dataset a number of selections were made:

- Only residential houses were included; farms, practices-at-home etc. were removed
- All apartments were removed. Only low rise buildings were retained.
- WOZ house value > €50.000
- Total living area < 700 m^2
- Ratio WOZ house value : total living area < 5000
- Obvious errors were removed from the dataset (e.g. houses for which the housing price was equal to the construction year).

After selection a total number of 350.000 objects was retained for analysis.

Statistical analyses

Prior to analyses, variables were transformed to reduce the influence of variable quantity and to obtain a (near) normal distribution. Due to the transformation all variables obtained values within a similar range (approximately 0-15). All analyses were carried out in R, using packages VEGAN and PackFor. Multi-collinearity was analysed using correlation coefficients, Principal Component Analysis (PCA) and by assessing the Variance Inflation Factors (VIF). Because all variables displayed a short response gradient (Detrended Correspondence Analysis, axis 1 < 2), PCA was suitable to identify dependencies between variables.

Strongly correlated or overlapping variables were reduced (e.g. 'distance to VMBO high school', 'distance to HAVO-VWO high school ', 'distance to all high schools'). Because high schools of different educational levels are often situated on the same high school campus, these distances were strongly correlated ($R > 0.9$, $p < 0.05$) . Subsequent PCA analysis showed that a number of variables (e.g. distance to cinema, music halls, train station, public library, hotels, restaurants and bars) controlled the first PCA axis. These variables together were interpreted as showing 'distance to the city centre'. To tackle this problem of multi-collinearity we used two approaches: 1) variables indicating distance to the city centre were reduced, only 'distance to train station' was retained and considered representative for this gradient, and 2) the original dataset was split into two, representing urban areas (urbanisation codes 1-2 in the CBS nabijheidsstatistieken) and rural areas (codes 3-5). After this reduction, VIFs were < 20 for all remaining variables, indicating that these did not show a high tendency to multi-collinearity.

For three datasets (1: the full dataset, 2: only rural areas, 3: only urban areas) linear models were developed with the WOZ as the target. The explained proportion of variance in the linear model for WOZ housing values was given by Analysis of Variance (ANOVA).

3. Results and interpretation

Model coefficients and explained proportions of variance (sum of squares) by each variable are shown for each dataset in Table 1. All three models explained ca. 70% of the observed variance in the WOZ housing values, which is a substantial proportion of the total variance. Table 1 shows that in all datasets, the total living area and the type of dwelling (villa, semi-detached, terraced house, end-of-terrace house) explain a very large proportion of WOZ housing values. The third significant variable in all three datasets is the year of construction. About 30% of the composition of the housing prices remains unexplained. Part of this 'noise' is likely due to the absence of plot-size data. In the

Netherlands, in particular in urban areas, housing prices are influenced by plot size, but unfortunately no consistent data for total plot size per dwelling were available for this analysis.

Table 1: Statistics for the three different hedonic pricing models.

	Urban areas		Rural areas		All areas	
# of houses in selection	155.390		197.902		353.292	
average WOZ house value (€)	184.827		230.780		210.568	
	% explained	coeff.	% explained	coeff.	% explained	coeff.
Total living area	33,33	1,14	28,74	0,93	28,85	1,01
Type of dwelling	29,24	*	38,52	*	37,59	*
Year of construction	1,76	0,39	1,32	0,37	1,53	0,40
Forest - distance to	1,31	0,18	0,00	0,01	0,18	0,06
Train station -distance to	0,62	-0,05	0,08	-0,02	0,04	-0,02
Shops -distance to	0,40	0,36	0,13	0,04	0,14	0,06
Primary school -distance to	0,26	0,23	0,20	0,09	0,14	0,12
Total explained variance (%)	68		70		69	
Total possible 'green' influence on WOZ in %:	**1,6**		**0,3**		**0,5**	

Interestingly, in the urban dataset, distance to forests is the 4th most important variable influencing WOZ housing prices. Although the influence is relatively small at 1.3%, it is significant at the 0.01 confidence level, and moreover, it is far greater than any of the other environmental variables. Thus, in urban areas, the distance to forests is a significant factor determining housing prices. According to our preliminary analysis, the total influence of all natural areas combined adds up to 1.6% of WOZ housing prices. In urban areas, the amenity service provided by 'green spaces' thus nearly equals the relative importance of the year of construction and is the single most important environmental variable influencing WOZ housing prices. However, we believe that this is a (strong) underestimate of the actual contribution to house prices. The reason is that we have analysed the distance of the neighbourhood to forest rather than the distance of each individual house. The latter would have resulted in a much clearer correlation between distance and price. However, unfortunately, the dataset that contained this information (distance individual house to green) was encrypted in such a way that we could not get access within the period of this project. We therefore plan to use the same basic methodology as developed in the pilot phase in a follow up phase, but with a new dataset that specifies the location of each house. This would be possible because the previously available dataset can be recovered, if more time is available.

In rural areas, the influence of a green living environment is very low according to our preliminary analysis. However, this is not unexpected given the input of variables that were available and especially given that also in this case the average distance from the neighbourhood to green spaces was used as predictor for house value. Since the analysed rural areas are much larger than the urban areas (and since green areas are more widespread within the neighbourhood) this leads to a dilution of the effect of distance on house price. In addition, being surrounded by a comparably green living environment, it may be that other environmental variables, in particular the distance to facilities, have a higher weight in relative terms.

Hence, the urban result of 1.6 % of WOZ housing prices attributable to a green living environment seems low. Other studies often show a much stronger influence of green areas and water, ranging from 5-15 % (Bervaes and Vreke, 2004; Luttik, 2000). However, these studies refer to the influence of a (direct) view on parks, forests and waterways. In our study, because we could only use average distances per neighbourhood, having a direct view on or being situated immediately next to such areas was not accounted for. Despite these shortcomings of the available data, for urban areas a significant influence of a green living environment was detected. The influence of all green areas combined were shown to be equally determining for WOZ housing value as the year of construction was. These results thus clearly illustrate the importance of a green living environment, in particular in urban areas. However, to more accurately estimate the exact contribution we need to have price and location data per plot rather than per neighbourhood. Hence our percentage contribution to WOZ housing value must be seen as an underestimate that requires further analysis, using basically the same methodology but more detailed data. Our analysis shows that the factor is significant and should be considered as an economically significant ecosystem service. As indicated, we will update this analysis in the follow-up phase of the project.

4. Recommendations

In order to carry out a more detailed, more inclusive analysis of hedonic ecosystem services, the distance to all facilities, including the distance to 'green areas' should be available at the level of individual houses. This would allow for the inclusion of the effect of 'having a view on', 'or being right next to' green areas. Moreover, distances should be calculated to all green areas including meadows, and not just to those that are publicly accessible. Importantly, these calculations should be made based on the LCEU map developed in this project. This would allow for a consistent interpretation of ecosystem services provided by these ecosystem units. Hence, the hedonic service provided by a forest or a meadow could be assessed independently, but the same would be true for the disservice in this respect from, for example, industrial areas and highways. In addition the dataset should be extended to include plot size.

The suggestions for improvement are all feasible for the Netherlands with data from CBS. Distances to facilities for individual houses will become available towards the end of 2015. Distances to LCEU units can be developed from this.

References

Bervaes, J.C.A.M., Vreke, J., 2004. De invloed van groen en water op de transactieprijzen van woningen. Alterra, Wageningen, the Netherlands, p. 33.

Luttik, J., 2000. The value of trees, water and open space as reflected by house prices in the Netherlands. Landscape and Urban Planning 48, 161-167 http://dx.doi.org/10.1016/S0169-2046(00)00039-6.