This item is the archived peer-reviewed author-version of:

Evaluation of the accuracy of land-use based ecosystem service assessments
for different thematic resolutions

Reference:

Van der Biest Katrien, Vrebos Dirk, Staes Jan, Boerema Annelies, Berenguer Bodí Mercedes, Franssen Erik, Meire Patrick.-
Evaluation of the accuracy of land-use based ecosystem service assessments for different thematic resolutions
Journal of environmental management - ISSN 0301-4797 - 156(2015), p. 41-51
Full text (Publishers DOI): <http://dx.doi.org/doi:10.1016/j.jenvman.2015.03.018>
To cite this reference: <http://hdl.handle.net/10067/1239280151162165141>

Evaluation of the accuracy of land-use based ecosystem service assessments for different thematic resolutions

---

Van der Biest K.*¹, Vrebos D.¹, Staes J.¹, Boerema A.¹, Bodí M.B.¹, Fransen E.² and Meire P¹.

*: Corresponding author

¹: Ecosystem Management Research Group, University of Antwerp, Universiteitsplein 1C, 2610 Wilrijk, Belgium. 32(0)32652261

²: StatUa Center for Statistics, University of Antwerp, Prinsstraat 13, B-2000 Antwerp, Belgium

katrien.vanderbiest@uantwerpen.be; dirk.vrebos@uantwerpen.be; jan.staes@uantwerpen.be;
annelies.boerema@uantwerpen.be; mercedes.berenguerbodi@uantwerpen.be;
erik.fransen@uantwerpen.be; patrick.meire@uantwerpen.be

Supplementary data

A) Applied scores for ES delivery per land use classification system

ESLUC land use	Crops	Livestock	Wood fuel	Global climate regulation	Groundwater recharge	Nutrient retention	Denitrification	Pollination
Building	0	0	0	0	0	0	0	1
Non-built up paved surface	0	0	0	0	0	0	0	0
Garden, grass or bush	2	0	0	1	4	2	2	3
Garden, trees	0	0	3	2	3	2	3	3
Park, grass or bush	0	1	0	1	4	2	2	4
Park, trees	0	0	3	2	3	3	3	2
Bare ground	0	0	0	0	4	0	0	0
Cemetery	0	0	1	1	1	1	0	2
Railway	0	0	0	0	0	0	0	1
Road	0	0	0	0	0	0	0	0
Dike	0	3	1	1	0	2	2	2
Sports- or recreational building	0	0	0	0	0	0	0	0
Sports or recreational terrain	0	0	1	1	0	0	0	0
Sports or recreational terrain, grass or bush	0	0	0	1	4	2	2	2
Sports or recreational terrain, trees	0	0	3	2	3	2	3	2
Golf terrain	0	0	1	1	4	2	2	2
Quarry	0	0	0	0	3	0	0	0
Dump	0	0	0	0	0	0	0	0
Cropland	5	0	0	1	2	0	2	1
Corn	5	0	0	1	1	0	1	1
Floriculture + nursery	0	0	0	1	2	0	2	3
Fruit	5	0	0	1	2	1	2	4
Orchard	5	1	2	1	2	1	2	4
Greenhouse	5	0	0	0	0	0	0	0
Fallowland	0	0	0	1	2	1	2	4
Permanent cultivated grassland	0	3	0	2	3	1	2	0
Temporary cultivated grassland	0	2	0	2	3	1	2	0
Forested cultivated grassland	2	3	1	2	3	1	2	3
Natural grassland, agricultural use	0	2	0	2	3	2	2	4
Mixed deciduous forest	0	0	2	3	3	3	3	2
Mixed deciduous forest, nature management	0	1	1	4	3	3	4	3
Mixed coniferous forest	0	0	4	2	2	2	2	1
Mixed coniferous forest, nature management	0	0	1	3	2	2	3	1
Mixed forest	0	0	3	3	3	3	3	2
Mixed forest, nature management	0	1	1	4	3	3	4	3
Alder	0	0	3	2	3	3	2	2
Ash	0	0	3	2	3	3	2	2
Beech	0	0	3	2	3	3	2	1
Birch	0	0	3	2	3	3	2	2
Linden	0	0	3	2	3	3	2	3
Poplar	0	0	3	2	3	3	2	2
Willow	0	0	3	2	3	3	2	2
Oak	0	0	3	2	3	3	2	2
Pine	0	0	3	2	2	2	2	1
Dry heathland	0	1	0	2	4	1	1	3
Wet heathland	0	0	0	4	1	2	1	3
Natural grassland (excl. valley and marsh natural grassland)	0	1	0	3	3	2	2	4
Other bush	0	0	0	3	3	3	2	4
Other shrub	0	0	1	3	3	3	3	3
Bare land dune	0	0	0	0	5	0	0	0
Vegetated, non-forested land dune	0	1	0	1	4	1	1	2
Forested land dune	0	1	2	2	3	2	1	1
Alder brook forest	0	0	1	5	3	4	4	2
Other valley and marsh forest	0	0	1	5	3	4	4	2
Fen	0	0	0	5	1	4	4	2
Reed	0	0	0	4	3	4	4	2
Valley and marsh bush	0	0	0	4	3	3	3	4
Valley and marsh natural grassland (excl. reed)	0	0	0	4	3	3	3	4
Valley and marsh shrub	0	0	1	4	3	4	4	3
Vegetated intertidal flat ('schorre')	0	1	1	3	0	3	3	3
Navigable water course	0	0	0	1	3	1	2	0
Non-navigable watercourse	0	0	0	2	3	2	3	1
Pond	0	0	0	3	3	3	2	1
Water basin	0	0	0	1	2	1	1	0
Dock	0	0	0	1	2	1	1	0

Table S.1– Capacity of the ESLUC land use types to deliver ES

CORINE land use	Crops	Livestock	Wood fuel	Global climate regulation	Groundwater recharge	Nutrient retention	Denitrification	Pollination
Continuous urban fabric	0	0	0	0	0	0	0	0
Discontinuous urban fabric	1	0	0	0	0	0	0	0
Green urban areas	0	0	1	1	4	2	2	3
Road and rail networks and associated land	0	0	0	0	0	0	0	1
Sport and leisure facilities	0	0	0	1	2	1	1	1
Mineral extraction sites	0	0	0	0	0	0	0	0
Dump sites	0	0	0	0	0	0	0	0
Non-irrigated arable land	5	0	0	1	2	0	2	1
Fruit trees and berry plantations	5	0	0	1	2	1	2	4
Pastures	0	3	0	2	3	1	2	0
Broad-leaved forest	0	0	2	3	3	3	3	2
Coniferous forest	0	0	4	2	2	2	2	1
Mixed forest	0	0	3	3	3	3	3	2
Moors and heathland	0	1	0	3	3	2	1	3
Natural grassland	0	1	0	3	3	2	2	4
Transitional woodland-shrub	0	0	1	3	3	3	3	3
Inland marshes	0	0	1	4	3	4	4	3
Intertidal flats	0	1	1	3	0	3	3	3
Water courses	0	0	0	1	3	1	2	0
Water bodies	0	0	0	3	3	3	2	1

Table S.2– Capacity of the CORINE land use types to deliver ES

Governmental land use	Crops	Livestock	Wood fuel	Global climate regulation	Groundwater recharge	Nutrient retention	Denitrification	Pollination
Residential and commercial fabric	1	0	2	1	1	1	1	1
Park	0	1	2	2	3	2	2	3
Business and industrial site	0	0	0	0	0	0	0	0
Infrastructure	0	0	0	0	0	0	0	0
Agricultural grassland	0	3	0	2	3	1	2	0
Recreation and sports facilities	0	0	2	1	3	2	1	1
Cropland	5	0	0	1	2	0	0	1
Cropland with an environmental target	4	0	0	1	3	0	1	1
Agricultural grassland (with an environmental or a biodiversity target)	0	2	0	2	3	2	2	4
Multifunctional forest	0	1	3	3	2	3	4	3
Forest (biodiversity management)	0	1	1	4	2	3	3	2
Heathland (biodiversity management)	0	1	0	3	3	2	1	3
High nature value grassland (biodiversity management)	0	1	0	3	3	3	3	4
High nature value grassland (no biodiversity management)	0	1	0	3	3	3	3	4
Beaches and dunes (biodiversity management)	0	1	0	0	3	1	1	1
Marshland (biodiversity management)	0	0	1	5	3	3	4	3
Mud flat and salt marshes	0	1	0	2	0	2	3	2
Water	0	0	0	2	3	2	2	1
Port area	0	0	0	1	2	1	1	0

Table S.3 – Capacity of the governmental land use types to deliver ES

B) Background information on the process-based ecosystem service models

Information on the variables and processes driving the ES quantitative models.

Agricultural production and livestock

Agricultural production is expressed in % yield. Areas with optimal soil conditions (soil texture, profile development and groundwater level) for agricultural practices have an estimated yield of 100 %, while areas with less suitable soil conditions suffer from certain yield losses. Information on yield losses is derived from experimental studies on the effects of desiccation and rewetting on crop-specific productivity (Moens et al. 2008 and Brouwer and Huinink 2002). How sensitive a soil is to these effects depends on soil texture, where sandy soils are more sensitive to hydrological effects than loamy soils. Furthermore, the effects of profile development and substrate on chemical and physical soil fertility are accounted for (Bollen 2012).

Wood production

Wood production is expressed in mean annual volume increment ($\text{m}^3 \text{ ha}^{-1} \text{ yr}^{-1}$). It depends on soil characteristics (De Vos 2009) and the harvest regime applied. The specific potential of some species to produce wood volumes (Moonen et al. 2011; Jansen et al. 1996) can be found in Table S.1 where differentiation is made according to soil suitability (soil texture and moisture).

Soil suitability	Tree species							
	<i>Fagus sylvatica</i>	<i>Quercus (Robur and Rubra)</i>	<i>Populus sp.</i>	<i>Larix decidua</i>	<i>Pinus sylvestris</i>	<i>Pinus Nigra</i>	<i>Picea abies</i>	<i>Pseudotsuga menziesii</i>
4	4.0	3.0	9.0	6.0	4.0	6.0	6.0	8.0
3	6.7	5.0	11.0	8.7	6.0	9.3	9.0	10.7
2	9.3	7.0	13.0	11.3	8.0	12.7	13.0	13.3
1	12.0	9.0	15.0	14.0	10.0	16.0	16	16.0

Table S.1 - Overview of the relationships between soil suitability and the maximal mean growth of stemwood ($\text{m}^3 \text{ ha}^{-1} \text{ yr}^{-1}$), based on Moonen et al. (2011) and Jansen et al. (1996)

Depending on management and ownership structure (private or public), a harvest factor is applied that estimates the proportion of the maximal mean growth that is harvested annually. The harvested volumes are available from recent data (2009-2012) on timber selling from public (state-owned) forests and from forest owner cooperatives (privately-owned but the management is state-coordinated). This database has about 80,000 records of volumes sold per tree species and circumference. For state-owned forests, the harvest factor is 0.54. Privately-owned forests and forests under nature management often have a lower (0.15) harvest factor. For private forests, there is an unknown fraction of harvest for private use and informal markets (especially for firewood).

Infiltration

Water infiltration is the movement of water from the soil surface into the soil profile (l.m^{-2}). Potential infiltration is determined by soil infiltration capacity (influenced mostly by soil texture) and groundwater level (Batelaan and Desmedt 2007). Data on soil texture was obtained from the Belgian national soil classification system (AGIV 2001). Soil hydrology data was generated by updating the drainage classification system from the soil map based on the most recent digital elevation model with 25m resolution (AGIV 2011). Groundwater depth has a limited effect. More important variables are interception by vegetation and runoff from paved surface to storm drain infrastructure. Both parameters were mapped at high resolution (5m cells), using detailed data on vegetation (INBO 2010), paved surface (NGI 2007) and sewerage infrastructure (Dirckx et al. 2009; Vrebos et al. 2013).

Carbon sequestration in soils

Soils in unmanaged, natural vegetation types typically have larger carbon stocks than in managed vegetation types. Soil hydrology also plays a crucial role in the creation of soil organic carbon (SOC) stocks. Soil organic carbon is especially high in forests and/or hydric soil. The potential equilibrium state for soil organic carbon stocks can be calculated using the regression formula developed by Meersmans et al. (2011), which includes as parameters soil water content, soil texture and vegetation type. De Vos B. (2009) revealed that this function systematically underestimated SOC stocks in forest soils by 32 %. This correction factor to Meersmans's regression formula is applied to all forests. Peatlands, wetlands and freshwater ecosystems can sequester higher carbon stocks than terrestrial ecosystems (Altör and Mitsch 2008).

Nutrient storage in soils

Changes in soil organic carbon also affect soil nutrient stocks. It is known that soil organic matter contains a certain percentage of nitrogen (N). Land use change and especially drainage of historically water-logged soils can increase mineralization of the SOC and result in additional supply of N to the environment. The ratio of

carbon to nitrogen (C/N ratio) is typically associated with vegetation type and land use. Higher C/N ratios in the SOC can be explained by litter production that is more difficult to decompose (high C/N, high lignin concentration). Parameter values for the C/N ratio in SOC can be found in Table S.2. Estimates of the total N stocks in the soil are corrected for input through manuring, based on the data of nutrient leaching in Flemish soils (Coppens et al. 2007).

Vegetation type/ land-use	Upper and lower estimates	Central value
Cropland and production grassland	8-12	10
Floristic and species rich grasslands	10-14	12
Broad leaf forest	15-25	20
Mixed forest	20-25	22
Coniferous forest	25-30	27
Heathland	25-35	30
Phragmites wetlands	25-35	30
Wetlands (sedges and tall herbs)	15-25	20
Eutrophic alluvial forests	15-20	17
Mesotrophic wetland forest	20-25	22
Oligotrophic wetland forest	25-30	27
Peat bogs	25-35	30

Table S.2 – SOC C/N ratio for several vegetation types

Nutrient removal by denitrification

Nutrient removal by denitrification is expressed in % removal of nitrogen (N). In conditions of (temporary) waterlogging, bacterial processes enable the removal of nitrogen from ground and surface water. The most important variables are the soil moisture, supply of nitrate and soil organic carbon. As a proxy for nitrate removal efficiency, combinations of the mean highest (MHG) and mean lowest groundwater (MLG) levels were converted to an estimated nitrate removal efficiency (% of available nitrate removed), based on the results from Pinay et al. 2007.

	MLG	>50	45	40	35	30	25	20	15	10	5-0
MHG											
>50		10	13	17	20	23	27	30	33	37	40
45			20	23	27	30	33	37	40	43	47
40				30	33	37	40	43	47	50	53
35					40	43	47	50	53	57	60
30						50	53	57	60	63	67
25							60	63	67	70	73
20								70	73	77	80
15									80	83	87
10										90	93
0-5											100

Table S.3 - Estimated removal efficiency (%) for combinations of mean highest (MHG) and mean lowest groundwater (MLG) levels (in cm below soil surface).

Pollination

Pollination is a regulating service crucial to sustain certain types of agricultural production. In situ (cell-based) quantification of pollination is not straightforward as it depends on the presence of pollination-dependent crops near pollinator-providing habitat. As this study evaluated the suitability of a habitat to provide services,

independent of the surrounding land use, a semi-quantitative method was applied. This method is based on only one input parameter (vegetation), for which experts provided a score on the capacity of the habitat to provide pollinators. This was done for the nearly 1000 classes of the biological valuation of Flanders (INBO 2010). The pollination probability by wild pollinators for a particular habitat is derived by mapping the suitability score onto a relative surface area. The surface of high quality pollinator habitat (score 4) accounts for 100 % of the surface area, while low quality pollinator habitat (e.g. score 2) would only be accounted for 50 % of the surface area.

References

Coppens G., Elsen F., Ver Elst F. and Bries J. (2007). Estimation of nitrate residual and manuring standards for a selection of agricultural fields. Bepalen van nitraatresidu en bemestingsadvies voor een selectie van landbouwpercelen gedurende het voorjaar van 2007 en opmaken van een bodembalans. Bodemkundige Dienst van België vzw (Belgian Soil Service NGO)

De Vos B. (2000). Soil suitability for trees – Flood tolerance. Test version. Bodemgeschiktheidsprogramma voor boomsoorten, Overstromingstolerantie. Testversie. Institute for Nature and Forest Research, Flemish Government.

Dirckx G., Bixio D., Thoeye D., De Gueldre G. and Van De Steene B. (2009). Dilution of sewage in Flanders mapped with mathematical and tracer methods. Urban Water Journal 6(2): 81-92.

Tallis H. and Polasky S. (2009). Mapping and Valuing Ecosystem Services as an Approach for Conservation and Natural-Resource Management. Ann. N.Y. Acad. Sci. 1162 (2009): 265–283.

Vrebos D., Vansteenkiste T., Staes J., Willems P. and Meire P. (2013). Water displacement by sewer infrastructure in the Grote Nete catchment, Belgium, and its hydrological regime effects. Hydrol. Earth Syst. Sci. Discuss. 10(6): 7425-7467.