| | |
|---|---|
| **Ecosystem Service** | **Chemical composition of atmosphere and oceans** |
| **CICES class name** | Regulation of chemical composition of atmosphere and oceans |
| **CICES Section** | Regulation & Maintenance (Biotic) |
| **CICES Class code** | 2.2.6.1 |

## Brief Description

- Regulating our global climate
- Regulation of the concentrations of gases in the atmosphere that positively impact in global climate
- Regulation of the concentration of chemical substances in the oceans, which has a positive impact on humans

## Sample Indicators

| **Indicator values from** | | | |
|---|---|---|---|
| Experiment or direct measurement | | Survey | |
| Expert assessment | | Statistical- or census data | |
| Model or GIS | | Literature values | |
| Stakeholder participation | | Not provided | |

*Table 1: Field Scale*

| **Indicator** | **Unit** | **Indicator values from** |
|---|---|---|
| [29] Long term carbon stabilization: Carbon content in microaggregate-within-macroaggregate fraction (c.f. Six & Paustian, 2014. DOI: 10.1016/j.soilbio.2013.06.014) | Not provided | |
| [42] Soil organic carbon content (0–10 cm) | Not provided | |
| [55] Soil organic carbon (SOC) stock (0-20cm) | Mg * $ha^{-1}$ | , |
| [14] Carbon stock in soil (0-30 cm) | Mg * $ha^{-1}$ | |
| [24] Soil organic carbon (0–30 cm) after 20 years of management | Mg * $ha^{-1}$ | |
| [25] Soil organic carbon (0–30 cm) after 20 years of management | Mg * $ha^{-1}$ | |
| [14] Carbon in trees (dbh≥10 cm) and bushes (dbh <10 cm, height >2 m) | Mg * $ha^{-1}$ | |
| [37] Carbon stored in aboveground woody biomass; carbon stored in topsoil (0–20 cm) | Mg * $ha^{-1}$ | |

| | | |
|---|---|---|
| [38] Carbon storage in aboveground biomass (sum of herbaceous and tree components) and soils (upper 20 cm) | Mg * $ha^{-1}$ | |
| [44] Amounts of carbon fixed in the soil and in the annual organs of orchard trees | kg * $ha^{-1}$ * $yr^{-1}$ | |
| [33] Carbon sequestered in soil and orchard-trees | kg * $ha^{-1}$ * unit $time^{-1}$ | |
| [51] Climate regulation: annual net ecosystem exchange (NEE) of carbon | Mg C * $ha^{-1}$ | |
| [44] Prevention of N denitrification: yearly amount of denitrified nitrogen | kg $N_2O$-N * $ha^{-1}$ * $yr^{-1}$ | |
| [33] Greenhouse gas mitigation: Cumulative denitrified nitrogen | kg $N_2O$-N * $ha^{-1}$ * unit $time^{-1}$ | |
| [54] Greenhouse gas emissions | CO2 equ. * $ha^{-1}$ | |
| [23] Net global warming impact of soil carbon sequestration, agronomic N fertilizer application, lime application, fuel usage, nitrous oxide (N2O) emissions, and methane (CH4) oxidation | g $CO_2$e * $m^{-2}$ * $yr^{-1}$ | , |
| [33] Greenhouse gas mitigation: Cumulative amounts of $CO_2$ emitted by agricultural operations | kg C * $ha^{-1}$ * unit $time^{-1}$ | , |
| [38] Emissions of GHG ($CO_2$, $CH_4$, $N_2O$) measured by static chamber techniques in the field | $CO_2$ equ. | |
| [43] Emissions of $CO_2$ and $N_2O$ | Not provided | |
| [41] Indicator value calculated as: $$I = \frac{\sum \; \lvert \log\left(\frac{i}{i_{max}}\right)\rvert}{n}$$ With: i – variable i measured, $i_{max}$ – maximum ecologic potential of variable i in benchmark reference, n – number of variables. Where performance is considered better than in the benchmark and deviation, therefore, has a positive effect, $\lvert \log\left(\frac{i}{i_{max}}\right)\rvert$ is subtracted from the sum instead of added. For this ecosystem service, variables were:<br><br>-Soil organic matter [% dw]<br>-Bacterial biomass [mg C /g dw]<br>-pH in KCl<br>-Physiological diversity bacteria [biolog. CLPP: Hill's slope] | - | , |
| [58] SOC in top soil (0–20 cm) at the end of a 30-year simulation period | Mg of carbon / hectare | |
| [59] SOC in top soil (0–20 cm) | tons / hectare | |

*Table 2: Farm Scale*

| **Indicator** | **Unit** | **Indicator values from** |
|---|---|---|

| | | |
|---|---|---|
| [34] Climate regulation: Vegetation cover [%], expressed as a four-level index | poor-fair-good-excellent] | |
| [53] Vegetation carbon stock: Above ground dry biomass of trees, bushes, and herbaceous plants | Mg C * $ha^{-1}$ | |
| [53] Topsoil carbon stock: calculated from bulk density and total C content at 0–10, 10–20, and 20–30 cm depths | Mg C * $ha^{-1}$ | |

*Table 3: Regional Scale*

| **Indicator** | **Unit** | **Indicator values from** |
|---|---|---|
| [1] Carbon sequestration | kg * $ha^{-1}$ * $yr^{-1}$ | , |
| [15] Carbon sequestration rate (above and belowground) | Mg * $ha^{-1}$* $yr^{-1}$ | |
| [36, 47] Carbon sequestration rate:  sum of above and below ground crop and tree biomass and soil organic carbon (SOC) | t * $ha^{-1}$ * $yr^{-1}$ | |
| [5] Carbon sequestration: annual change in above- & below ground biomass. Values are monetarized based on an estimated social cost of carbon of $43/ton. | $ * $ha^{-1}$ * $yr^{-1}$ | |
| [4] Carbon sequestration in soil & biomass | kg C *$ha^{-1}$ | |
| [9] Organic carbon stored in soils and above- and belowground biomass, divided by area | kg * m-2 | |
| [3] Carbon sequestered in above- and belowground biomass of woody species | t CO2 eq. * $ha^{-1}$ * $yr^{-1}$ | |
| [16] Carbon sequestration: Amount of carbon that is sequestered from land use, land use change and forestry | C * $km^{-2}$ * $yr^{-1}$ | |
| [52] Above- and belowground carbon stored in living plant material. | t C * $ha^{-1}$ * $yr^{-1}$ | |
| [31] Carbon sequestration: identification of areas with peat soils or carbon-rich semi-terrestrial areas | Not provided | |
| [21] Carbon sequestration: Values based on land use by assigning a country-specific, land use type specific emission factor to each land use type. The emission factor also considers forest age and soil carbon stock. | Not provided | |
| [49] Soil organic carbon stock, values for CORINE land cover classes | t C * $ha^{-1}$ | , , |
| [26] Carbon stock of above- and below ground phytomass within different land cover classes | Mg C * $ha^{-1}$ | , |
| [35] Carbon storage: Carbon stored in aboveground biomass, belowground biomass, and soils; calculated by combining the InVEST model with wood production figures. | Mg * $ha^{-1}$ | , |
| [36] Carbon stock: sum of above and below ground crop and tree biomass and soil organic carbon (SOC) | t C * $ha^{-1}$ | |

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| [21] Carbon stocks in soil and vegetation. Based on land use by assigning a region-specific, age-specific biomass carbon stock to the land use types "forest" and "(semi-)natural vegetation" | Not provided | |
| [40] Carbon stored in soil and biomass. Values were normalized [0-1] using benchmark values where available and observed values otherwise. | t C * $ha^{-1}$ | |
| [46] Carbon stock in living biomass, deadwood, litter, and soils | t C * $ha^{-1}$ | |
| [47] Annual carbon stock: above and below ground biomass, soil organic carbon | t C * $ha^{-1}$ | |
| [45] Carbon stored in aboveground biomass, belowground biomass, soil and dead organic matter (calculated with InVEST's Carbon Storage and Sequestration model). Values for all pools per land-use class were taken from Japans National Greenhouse Gas Inventory Report. | t * $ha^{-1}$ * grid $cell^{-1}$ | |
| [49] Total carbon stock for CORINE land cover classes, calculated as the sum of aboveground biomass, belowground biomass, litter and soil organic carbon | t C * $ha^{-1}$ | , , |
| [27] Total carbon stored in landscape, calculated with InVEST model | Mg | |
| [12] Carbon storage capacity | t C * $ha^{-1}$ | |
| [17] Carbon flow change: Carbon stock in vegetation (above- and belowground) + soil organic carbon stock (1 m). Values are compared to values for a reference situation. | t C * $ha^{-1}$ | , |
| [10] Greenhouse gas emissions | 1000 t CO2eq. | |
| [19] Greenhouse gas balance of entire agricultural production system, including emissions from soils and fabrication of fertilizers and machinery | CO2 eq. * $ha^{-1}$ * $yr^{-1}$ | , |
| [8] Climate change mitigation: Annual carbon sequestration and GHG emissions, using the methodology for the LULUCF sector in Finland's National Inventory of greenhouse gases | CO2 equ. * $km^{-2}$ | , |
| [49] Annual Gross Primary Production, based on "Moderate Resolution Imaging Spectroradiometer (MODIS) 17" satellite datasets | t C * $ha^{-1}$ * $yr^{-1}$ | , , |
| [49] Annual total Net Primary Production, based on "Moderate Resolution Imaging Spectroradiometer (MODIS) 17" satellite datasets | t C * $ha^{-1}$ * $yr^{-1}$ | , , |
| [18] Carbon capture: NPP × $(1–VC_{NNP})$ × (1–Ow); where NPP: Net Primary Production calculated from NDVI-values and expressed on a relative scale set to (0 - 1000), $VC_{NPP}$: coefficient of variation of NPP (0 - 1), Ow: water bodies occupancy percentage and flat floodplain area (0 - 1). Ow is used to reflect that water cover is negatively correlated with plant cover and therefore by proxy with carbon capture | - | |
| [50] Carbon sequestration and oxygen production: net primary productivity | t C * $area^{-1}$ * $yr^{-1}$ | |
| [51] Climate regulation: annual net ecosystem exchange (NEE) of carbon | Mg C * $ha^{-1}$ | |

| | | |
|---|---|---|
| [52] Net ecosystem productivity | t C * $ha^{-1}$ * $yr^{-1}$ | |
| [48] Carbon sequestration: net primary productivity (NPP) using CASA (Carnegie-Ames-Stanford Approach) ecosystem model | gC * $ha^{-1}$ | |
| [8] Airborne nutrient input: Exceedance of empirical critical loads of nitrogen in Natura 2000 sites | mg N * $m^{-2}$ | , |
| [13] "Emergy" of $O_2$ release by crops (derived from yield and a dollar price for $O_2$) and "emergy" of $CO_2$ absorption soils (based on organic matter accumulation) | solar equivalent Joules | |
| [20] Index based on:<br>a) Carbon storage: aboveground carbon in living biomass and soil carbon in the surface layer (0–20 cm) [tons C/ha]<br>b) Greenhouse gas emissions: Emissions of $CO_2$, $CH_4$, and $N_2O$ measured at monthly intervals [CO2 equ. flux]<br>Both a and b were scaled to a range of 0.1-1 (whereby 0.1 denotes the highest GHG emissions) and averaged. | - | |
| [20] Bio-indicator: Presence of specific ant species is used as an indicator for high, medium or low provision of this ES. Suitable indicator species must first be identified by a correlation between the presence of species and ES provision. | low-medium-high | |
| [28] Global climate regulation: values for ecosystem service supply based on land cover classes. The matrix defined by Burkhard et al., 2012 (DOI:10.1016/j.ecolind.2011.06.019) was adapted and used in this study. | Index 0-5 | |
| [49] Global climate regulation service, expert-based index values for CORINE land cover classes published by Burkhard et al. (2014, DOI: 10.3097/LO.201434). | Index 0-5 | , , |
| [1] $NO_2$ dry deposition velocity | mm * $s^{-1}$ * $ha^{-1}$ | , |
| [57] Amount of carbon stored in the above/below ground biomass and soil over a specified amount of time (e.g. 20-years) | ton / $km^2$ | |

*Table 4: National Scale*

| Indicator | Unit | Indicator values from |
|---|---|---|
| [2] GHG emissions: methane ($CH_4$) from livestock (both through the production of manure and enteric fermentation); nitrous oxide ($N_2O$) from the application of inorganic fertilizers; and carbon dioxide ($CO_2$) associated with changes in carbon stocks in above and below ground biomass (making allowance for soil type) and from the burning of fossil fuels to power agricultural machinery and production of fertilizers and pesticides | $CO_2$ equ. * $area^{-1}$ * $yr^{-1}$ | |
| [2] GHG emissions: as above, valuation based on UK official non traded carbon value | Money * $area^{-1}$ * $yr^{-1}$ | |

| | | |
|---|---|---|
| [11] GHG emissions from agriculture | t $CO_2$ eq. | |
| [21] Carbon sequestration. Based on land use by assigning a country-specific, land use type specific emission factor to each land use type. The emission factor also considers forest age and soil carbon stock. | Not provided | |
| [22] Carbon sequestration by farm afforestation | t $CO_2$ eq. * $ha^{-1}$ * $yr^{-1}$ | |
| [39] Carbon sequestered by permanent crops and grassland | Not specified | |
| [7] Carbon stored in vegetation and soils | kg C * $m^{-2}$ | , |
| [21] Carbon stocks in soil and vegetation. Based on land use by assigning a region-specific, age-specific biomass carbon stock to the land use types "forest" and "(semi-)natural vegetation" | Not provided | |
| [6] Global climate: Expert assessment for each land use class based on the indicators: $CO_2$, $CH_4$, $N_2O$, NO, and soot emissions | very negative (−3) to very positive (+3) | |
| [6] Air quality: Expert assessment for each land use class based on the indicators: nitrous oxide, ammonia, and soot emissions; trees | very negative (−3) to very positive (+3) | |
| [56] $NO_2$ deposition velocity: calculated as as a linear function of wind speed at 10m height and land cover type. | mm/s | |
| [56] $NO_2$ removal flux calculated as the product of modelled $NO_2$ concentration and deposition velocity. Deposition velocity is calculated as as a linear function of wind speed at 10m height and land cover type. | t/(ha*year) | |

*Table 5: Multinational Scale*

| **Indicator** | **Unit** | **Indicator values from** |
|---|---|---|
| [16] Carbon sequestration: Amount of carbon that is sequestered from land use, land use change and forestry | C * $km^{-2}$ * $yr^{-1}$ | |
| [32] Global climate regulation: values for Corine land cover classes, based on values published by Burkhard et al. (2009; DOI: 10.3097/LO.200915) and modified for the context of riparian zones. | Index 0-5 | |

## References

| No. | Citation |
|---|---|
| 1 | Baro F, Gomez-Baggethun E, Haase D (2017) Ecosystem service bundles along the urban-rural gradient: Insights for landscape planning and management. Ecosystem Services 24: 147-159. DOI: 10.1016/j.ecoser.2017.02.021 |
| 2 | Bateman IJ, Harwood AR, Abson DJ, Andrews B, Crowe A, Dugdale S, Fezzi C, Foden J, Hadley D, Haines-Young R, Hulme M, Kontoleon A, Munday P, Pascual U, Paterson J, Perino G, Sen A, Siriwardena G, Termansen M (2014) Economic Analysis for the UK National Ecosystem Assessment: Synthesis and Scenario Valuation of Changes in Ecosystem Services. Environmental & Resource Economics 57(2): 273-297. DOI: 10.1007/s10640-013-9662-y |
| 3 | Felipe-Lucia MR, Comin FA (2015) Ecosystem services-biodiversity relationships depend on land use type in floodplain agroecosystems. Land Use Policy 46: 201-210. DOI: 10.1016/j.landusepol.2015.02.003 |
| 4[15*] | Fürst C, Frank S, Witt A, Koschke L, Makeschin F (2013) Assessment of the effects of forest land use strategies on the provision of ecosystem services at regional scale. Journal of Environmental Management 127: S96-S116. DOI: 10.1016/j.jenvman.2012.09.020 |
| 5 | Gret-Regamey A, Weibel B, Bagstad KJ, Ferrari M, Geneletti D, Klug H, Schirpke U, Tappeiner U (2014) On the Effects of Scale for Ecosystem Services Mapping. Plos One 9(12): e112601. DOI: 10.1371/journal.pone.0112601 |
| 6 | Helfenstein J, Kienast F (2014) Ecosystem service state and trends at the regional to national level: A rapid assessment. Ecological Indicators 36: 11-18. DOI: 10.1016/j.ecolind.2013.06.031 |
| 7 | Holland RA, Eigenbrod F, Armsworth PR, Anderson BJ, Thomas CD, Heinemeyer A, Gillings S, Roy DB, Gaston KJ (2011) Spatial covariation between freshwater and terrestrial ecosystem services. Ecological Applications 21(6): 2034-2048. DOI: 10.1890/09-2195.1 |
| 8 | Holmberg M, Akujarvi A, Anttila S, Arvola L, Bergstrom I, Bottcher K, Feng XM, Forsius M, Huttunen I, Huttunen M, Laine Y, Lehtonen H, Liski J, Mononen L, Rankinen K, Repo A, Piirainen V, Vanhala P, Vihervaara P (2015) ESLab application to a boreal watershed in southern Finland: preparing for a virtual research environment of ecosystem services. Landscape Ecology 30(3): 561-577. DOI: 10.1007/s10980-014-0122-z |
| 9 | Hou Y, Zhou SD, Burkharda B, Muller F (2014) Socioeconomic influences on biodiversity, ecosystem services and human well-being: A quantitative application of the DPSIR model in Jiangsu, China. Science of the Total Environment 490: 1012-1028. DOI: 10.1016/j.scitotenv.2014.05.071 |
| 10 | Huber R, Lehmann B (2010) Economies of Scope in the Agricultural Provision of Ecosystem Services: An Application to a High Cost Production Region. German Journal of Agricultural Economics 59(2): 91-105. |
| 11 | Kirchner M, Schmidt J, Kindermann G, Kulmer V, Mitter H, Prettenthaler F, Rudisser J, Schauppenlehner T, Schonhart M, Strauss F, Tappeiner U, Tasser E, Schmid E (2015) Ecosystem services and economic development in Austrian agricultural landscapes - The impact of policy and climate change scenarios on trade-offs and synergies. Ecological Economics 109: 161-174. DOI: 10.1016/j.ecolecon.2014.11.005 |
| 12 | Liu S, Crossman ND, Nolan M, Ghirmay H (2013) Bringing ecosystem services into integrated water resources management. Journal of Environmental Management 129: 92-102. DOI: 10.1016/j.jenvman.2013.06.047 |
| 13 | Ma FJ, Eneji AE, Liu JT (2014) Understanding Relationships among Agro-Ecosystem Services Based on Emergy Analysis in Luancheng County, North China. Sustainability 6(12): 8700-8719. DOI: 10.3390/su6128700 |
| 14 | Marichal R, Grimaldi M, Feijoo AM, Oszwaldd J, Praxedes C, Cobo DHR, Hurtado MD, Desjardins T, da Silva ML, Costag LGD, Miranda IS, Oliveira MND, Brown GG, Tselouiko S, |


[15*] The impact area discussed on this factsheet is not a focus of the cited paper

| No. | Citation |
|---|---|
| | Martins MB, Decaens T, Velasquez E, Lavelle P (2014) Soil macroinvertebrate communities and ecosystem services in deforested landscapes of Amazonia. Applied Soil Ecology 83: 177-185. DOI: 10.1016/j.apsoil.2014.05.006 |
| 15 | Marks E, Aflakpui GKS, Nkem J, Poch RM, Khouma M, Kokou K, Sagoe R, Sebastia MT (2009) Conservation of soil organic carbon, biodiversity and the provision of other ecosystem services along climatic gradients in West Africa. Biogeosciences 6(8): 1825-1838. DOI: 10.5194/bg-6-1825-2009 |
| 16 | Mouchet MA, Paracchini ML, Schulp CJE, Sturck J, Verkerk PJ, Verburg PH, Lavorel S (2017) Bundles of ecosystem (dis)services and multifunctionality across European landscapes. Ecological Indicators 73: 23-28. DOI: 10.1016/j.ecolind.2016.09.026 |
| 17 | Nordborg M, Sasu-Boakye Y, Cederberg C, Berndes G (2017) Challenges in developing regionalized characterization factors in land use impact assessment: impacts on ecosystem services in case studies of animal protein production in Sweden. International Journal of Life Cycle Assessment 22(3): 328-345. DOI: 10.1007/s11367-016-1158-x |
| 18 | Barral MP, Oscar MN (2012) Land-use planning based on ecosystem service assessment: A case study in the Southeast Pampas of Argentina. Agriculture Ecosystems & Environment 154: 34-43. DOI: 10.1016/j.agee.2011.07.010 |
| 19 | Posthumus H, Rouquette JR, Morris J, Cowing DJG, Hess TM (2010) A framework for the assessment of ecosystem goods and services; a case study on lowland floodplains in England. Ecological Economics 69(7): 1510-1523. DOI: 10.1016/j.ecolecon.2010.02.011 |
| 20 | Sanabria C, Lavelle P, Fonte SJ (2014) Ants as indicators of soil-based ecosystem services in agroecosystems of the Colombian Llanos. Applied Soil Ecology 84: 24-30. DOI: 10.1016/j.apsoil.2014.07.001 |
| 21 | Schulp CJE, Van Teeffelen AJA, Tucker G, Verburg PH (2016) A quantitative assessment of policy options for no net loss of biodiversity and ecosystem services in the European Union. Land Use Policy 57: 151-163. DOI: 10.1016/j.landusepol.2016.05.018 |
| 22 | Schulte RPO, Creamer RE, Donnellan T, Farrelly N, Fealy R, O'Donoghue C, O'HUallachain D (2014) Functional land management: A framework for managing soil-based ecosystem services for the sustainable intensification of agriculture. Environmental Science & Policy 38: 45-58. DOI: 10.1016/j.envsci.2013.10.002 |
| 23 | Syswerda SP, Robertson GP (2014) Ecosystem services along a management gradient in Michigan (USA) cropping systems. Agriculture Ecosystems & Environment 189: 28-35. DOI: 10.1016/j.agee.2014.03.006 |
| 24* | Tsonkova P, Bohm C, Quinkenstein A, Freese D (2015) Application of partial order ranking to identify enhancement potentials for the provision of selected ecosystem services by different land use strategies. Agricultural Systems 135: 112-121. DOI: 10.1016/j.agsy.2015.01.002 |
| 25 | Tsonkova P, Quinkenstein A, Bohm C, Freese D, Schaller E (2014) Ecosystem services assessment tool for agroforestry (ESAT-A): An approach to assess selected ecosystem services provided by alley cropping systems. Ecological Indicators 45: 285-299. DOI: 10.1016/j.ecolind.2014.04.024 |
| 26 | Vigl LE, Tasser E, Schirpke U, Tappeiner U (2017) Using land use/land cover trajectories to uncover ecosystem service patterns across the Alps. Regional Environmental Change 17(8): 2237-2250. DOI: 10.1007/s10113-017-1132-6 |
| 27 | Zarandian A, Baral H, Stork NE, Ling MA, Yavari AR, Jafari HR, Amirnejad H (2017) Modeling of ecosystem services informs spatial planning in lands adjacent to the Sarvelat and Javaherdasht protected area in northern Iran. Land Use Policy 61: 487-500. DOI: 10.1016/j.landusepol.2016.12.003 |
| 28* | Zhang ZM, Gao JF, Fan XY, Lan Y, Zhao MS (2017) Response of ecosystem services to socioeconomic development in the Yangtze River Basin, China. Ecological Indicators 72: 481-493. DOI: 10.1016/j.ecolind.2016.08.035 |

| No. | Citation |
|---|---|
| 29* | Andrea F, Bini C, Amaducci S (2017) Soil and ecosystem services: Current knowledge and evidences from Italian case studies. Applied Soil Ecology 123: 693-698. DOI: 10.1016/j.apsoil.2017.06.031 |
| 31 | Bastian O, Lupp G, Syrbe RU, Steinháußer R (2013) Ecosystem services and energy crops - Spatial differentiation of risks. Ekologia Bratislava 32(1): 13-29. DOI: 10.2478/eko-2013-0002 |
| 32 | Clerici N, Paracchini ML, Maes J (2014) Land-cover change dynamics and insights into ecosystem services in European stream riparian zones. Ecohydrology and Hydrobiology 14(2): 107-120. DOI: 10.1016/j.ecohyd.2014.01.002 |
| 33 | Demestihas C, Plénet D, Génard M, Raynal C, Lescourret F (2017) Ecosystem services in orchards. A review. Agronomy for Sustainable Development 37(2): 12. DOI: 10.1007/s13593-017-0422-1 |
| 34 | Fleming WM, Rivera JA, Miller A, Piccarello M (2014) Ecosystem services of traditional irrigation systems in northern New Mexico, USA. International Journal of Biodiversity Science, Ecosystem Services and Management 10(4): 343-350. DOI: 10.1080/21513732.2014.977953 |
| 35 | Früh-Müller A, Hotes S, Breuer L, Wolters V, Koellner T (2016) Regional patterns of ecosystem services in cultural landscapes. Land 5(2): 17. DOI: 10.3390/land5020017 |
| 36 | Kay S, Crous-Duran J, Ferreiro-Domínguez N, García de Jalón S, Graves A, Moreno G, Mosquera-Losada MR, Palma JHN, Roces-Díaz JV, Santiago-Freijanes JJ, Szerencsits E, Weibel R, Herzog F (2018) Spatial similarities between European agroforestry systems and ecosystem services at the landscape scale. Agroforestry Systems 92(4): 1075-1089. DOI: 10.1007/s10457-017-0132-3 |
| 37 | Kearney SP, Fonte SJ, García E, Siles P, Chan KMA, Smukler SM (2019) Evaluating ecosystem service trade-offs and synergies from slash-and-mulch agroforestry systems in El Salvador. Ecological Indicators 105: 264-278. DOI: 10.1016/j.ecolind.2017.08.032 |
| 38 | Lavelle P, Rodríguez N, Arguello O, Bernal J, Botero C, Chaparro P, Gómez Y, Gutiérrez A, Hurtado MDP, Loaiza S, Pullido SX, Rodríguez E, Sanabria C, Velásquez E, Fonte SJ (2014) Soil ecosystem services and land use in the rapidly changing orinoco river basin of colombia. Agriculture, Ecosystems and Environment 185: 106-117. DOI: 10.1016/j.agee.2013.12.020 |
| 39 | Maes J, Liquete C, Teller A, Erhard M, Paracchini ML, Barredo JI, Grizzetti B, Cardoso A, Somma F, Petersen JE, Meiner A, Gelabert ER, Zal N, Kristensen P, Bastrup-Birk A, Biala K, Piroddi C, Egoh B, Degeorges P, Fiorina C, Santos-Martín F, Naruševičius V, Verboven J, Pereira HM, Bengtsson J, Gocheva K, Marta-Pedroso C, Snäll T, Estreguil C, San-Miguel-Ayanz J, Pérez-Soba M, Grêt-Regamey A, Lillebø AI, Malak DA, Condé S, Moen J, Czúcz B, Drakou EG, Zulian G, Lavalle C (2016) An indicator framework for assessing ecosystem services in support of the EU Biodiversity Strategy to 2020. Ecosystem Services 17: 14-23. DOI: 10.1016/j.ecoser.2015.10.023 |
| 40 | Rodríguez-Loinaz G, Alday JG, Onaindia M (2014) Multiple ecosystem services landscape index: A tool for multifunctional landscapes conservation. Journal of Environmental Management 147: 152-163. DOI: 10.1016/j.jenvman.2014.09.001 |
| 41 | Rutgers M, van Wijnen HJ, Schouten AJ, Mulder C, Kuiten AMP, Brussaard L, Breure AM (2012) A method to assess ecosystem services developed from soil attributes with stakeholders and data of four arable farms. Science of the Total Environment 415: 39-48. DOI: 10.1016/j.scitotenv.2011.04.041 |
| 42 | Daryanto S, Fu B, Zhao W (2019) Evaluating the use of fire to control shrub encroachment in global drylands: A synthesis based on ecosystem service perspective. Science of the Total Environment 648: 285-292. DOI: 10.1016/j.scitotenv.2018.08.140 |
| 43 | Daryanto S, Fu BJ, Wang LX, Jacinthe PA, Zhao WW (2018) Quantitative synthesis on the ecosystem services of cover crops. Earth-Science Reviews 185: 357-373. DOI: 10.1016/j.earscirev.2018.06.013 |

| No. | Citation |
|---|---|
| 44 | Demestihas C, Plénet D, Génard M, Garcia de Cortazar-Atauri I, Launay M, Ripoche D, Beaudoin N, Simon S, Charreyron M, Raynal C, Lescourret F (2018) Analyzing ecosystem services in apple orchards using the STICS model. European Journal of Agronomy 94: 108-119. DOI: 10.1016/j.eja.2018.01.009 |
| 45 | Hashimoto S, DasGupta R, Kabaya K, Matsui T, Haga C, Saito O, Takeuchi K (2018) Scenario analysis of land-use and ecosystem services of social-ecological landscapes: implications of alternative development pathways under declining population in the Noto Peninsula, Japan. Sustainability Science 14: 53-75. DOI: 10.1007/s11625-018-0626-6 |
| 46 | Jaligot R, Chenal J, Bosch M, Hasler S (2019) Historical dynamics of ecosystem services and land management policies in Switzerland. Ecological Indicators 101: 81-90. DOI: 10.1016/j.ecolind.2019.01.007 |
| 47 | Kay S, Crous-Duran J, García de Jalón S, Graves A, Palma JHN, Roces-Díaz JV, Szerencsits E, Weibel R, Herzog F (2018) Landscape-scale modelling of agroforestry ecosystems services in Swiss orchards: a methodological approach. Landscape Ecology 33(9): 1633-1644. DOI: 10.1007/s10980-018-0691-3 |
| 48 | Li T, Lü Y, Fu B, Hu W, Comber AJ (2019) Bundling ecosystem services for detecting their interactions driven by large-scale vegetation restoration: enhanced services while depressed synergies. Ecological Indicators 99: 332-342. DOI: 10.1016/j.ecolind.2018.12.041 |
| 49 | Ma LW, Bicking S, Muller F (2019) Mapping and comparing ecosystem service indicators of global climate regulation in Schleswig-Holstein, Northern Germany. Science of the Total Environment 648: 1582-1597. DOI: 10.1016/j.scitotenv.2018.08.274 |
| 50 | Peng J, Tian L, Liu Y, Zhao M, Hu Y, Wu J (2017) Ecosystem services response to urbanization in metropolitan areas: Thresholds identification. Science of the Total Environment 607-608: 706-714. DOI: 10.1016/j.scitotenv.2017.06.218 |
| 51 | Qiu JX, Carpenter SR, Booth EG, Motew M, Zipper SC, Kucharik CJ, Loheide SP, Turner AG (2018) Understanding relationships among ecosystem services across spatial scales and over time. Environmental Research Letters 13(5): 054020. DOI: 10.1088/1748-9326/aabb87 |
| 52 | Santos-Martín F, Zorrilla-Miras P, Palomo-Ruiz I, Montes C, Benayas J, Maes J (2019) Protecting nature is necessary but not sufficient for conserving ecosystem services: A comprehensive assessment along a gradient of land-use intensity in Spain. Ecosystem Services 35: 43-51. DOI: 10.1016/j.ecoser.2018.11.006 |
| 53* | Solen LC, Nicolas J, de Sartre Xavier A, Thibaud D, Simon D, Michel G, Johan O (2018) Impacts of Agricultural Practices and Individual Life Characteristics on Ecosystem Services: A Case Study on Family Farmers in the Context of an Amazonian Pioneer Front. Environmental Management 61(5): 772-785. DOI: 10.1007/s00267-018-1004-y |
| 54* | Tang LL, Hayashi K, Kohyama K, Leon A (2018) Reconciling Life Cycle Environmental Impacts with Ecosystem Services: A Management Perspective on Agricultural Land Use. Sustainability 10(3): 630. DOI: 10.3390/su10030630 |
| 55 | Van Vooren L, Reubens B, Broekx S, Reheul D, Verheyen K (2018) Assessing the impact of grassland management extensification in temperate areas on multiple ecosystem services and biodiversity. Agriculture, Ecosystems and Environment 267: 201-212. DOI: 10.1016/j.agee.2018.08.016 |
| 56 | Balzan MV, Caruana J, Zammit A (2018) Assessing the capacity and flow of ecosystem services in multifunctional landscapes: Evidence of a rural-urban gradient in a Mediterranean small island state. Land Use Policy 75: 711-725. DOI: 10.1016/j.landusepol.2017.08.025 |
| 57 | Gasparatos A, Romeu-Dalmau C, von Maltitz GP, Johnson FX, Shackleton C, Jarzebski MP, Jumbe C, Ochieng C, Mudombi S, Nyambane A, Willis K (2018) Mechanisms and indicators for assessing the impact of biofuel feedstock production on ecosystem services. Biomass & Bioenergy 114: 157-173. DOI: 10.1016/j.biombioe.2018.01.024 |

| No. | Citation |
|---|---|
| 58 | Nguyen TH, Cook M, Field JL, Khuc QV, Paustian K (2018) High-resolution trade-off analysis and optimization of ecosystem services and disservices in agricultural landscapes. Environmental Modelling & Software 107: 105-118. DOI: 10.1016/j.envsoft.2018.06.006 |
| 59 | Van Vooren L, Reubens B, Ampoorter E, Broekx S, Pardon, P, Van Waes C, Verheyen K (2018) Monitoring the Impact of Hedgerows and Grass Strips on the Performance of Multiple Ecosystem Service Indicators. Environmental Management 62: 241-259. DOI:10.1007/s00267-018-1043-4 |