



# Mapping ecosystem services

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**INRAE**

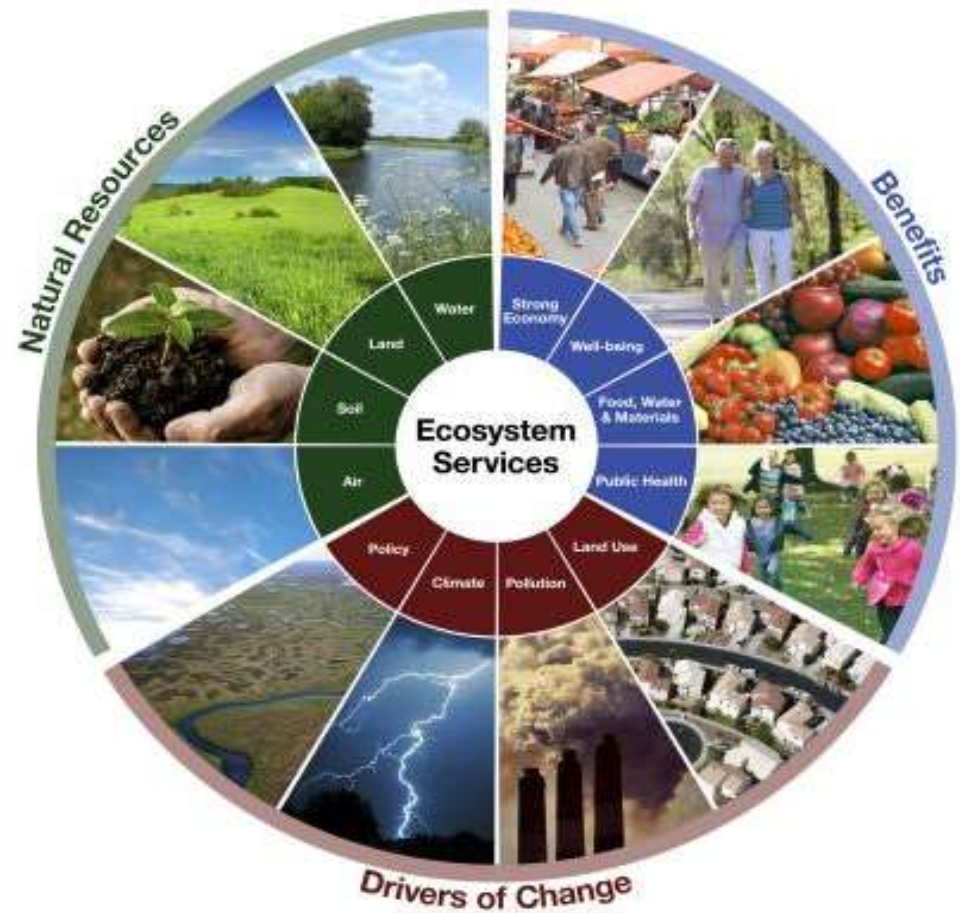


*EJP Doctoral School  
April 11 to 14th 2023*

# Introduction

- Ecosystem services (ES) as a concept to increase people's awareness on the contribution of nature to human well-being
- ES also as a tool for policy and decision-making from global to local levels.
  - Sustainable management of natural resources
  - Environmental protection
  - Nature conservation and restoration
  - Territorial and landscape planning
  - Nature-based solutions
  - Climate change mitigation
  - Disaster risk reduction

-> need for ES assessment maps



# Outline

1. Interest and risk of ES mapping
2. Early experiences of “ES-like” concepts mapping
3. The MAES program: Mapping and Assessment of Ecosystems and their services
4. Discussion on scientific papers:
  - Kandziora et al. 2013 – Mapping provisioning ecosystem services...
  - Baro et al. 2016 – Mapping ecosystem service capacity, flow and demand...

# Interest of *Ecosystem services* mapping?

- **ES maps to test and evaluate ES assessment procedures**
  - Taking account the spatial variability of the ES drivers
  - Sensitivity of ES assessment to spatial variability
- **ES maps as a tool to bring ES into practical application**
  - Efficiently communicate complex spatial information, raising awareness
  - Mandatory instruments for planning and protection
  - Portray trade-offs and synergies
  - Enable budgets for ES supply and demand at different spatio-temporal scales



# Risk linked to ES mapping

## 1. Risks linked to the mapping process

- Ambiguity on the concepts
- Over simplification of ES assessment based on existing spatial data (*See the biophysical realism gap in ES mapping, S. Lavorel et al., 2017*)
- Uncertainty of the maps

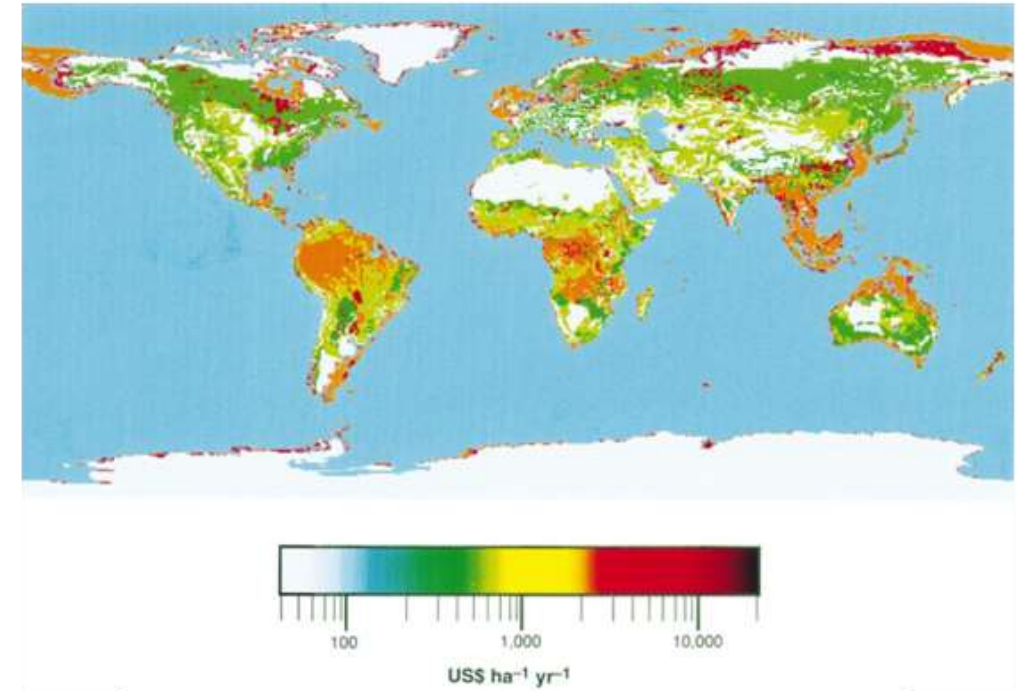
## 2. Risks linked to the mapping finality

ES maps enhance further exploitation (commodification, privatization) of natural resources  
(*See Maris V. 2014, Nature for sale ; Ed. Quae*)

## 3. A priori responses

- Develop research in ES mapping
- Stop the mapping process when uncertainty too high
- Produce well documented maps with explanations of procedures and uncertainties

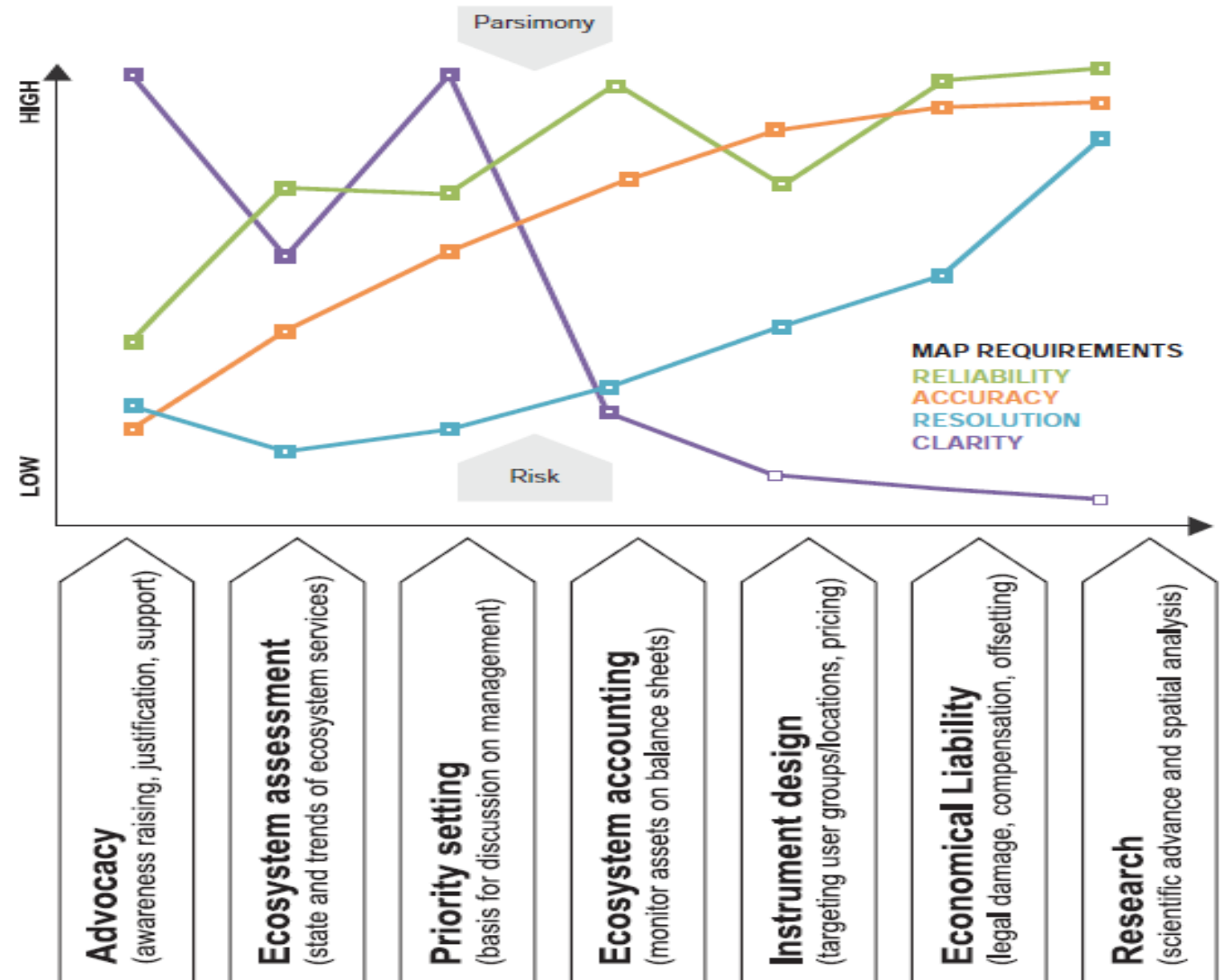
Global map of values of estimated ecosystem services in 1997.



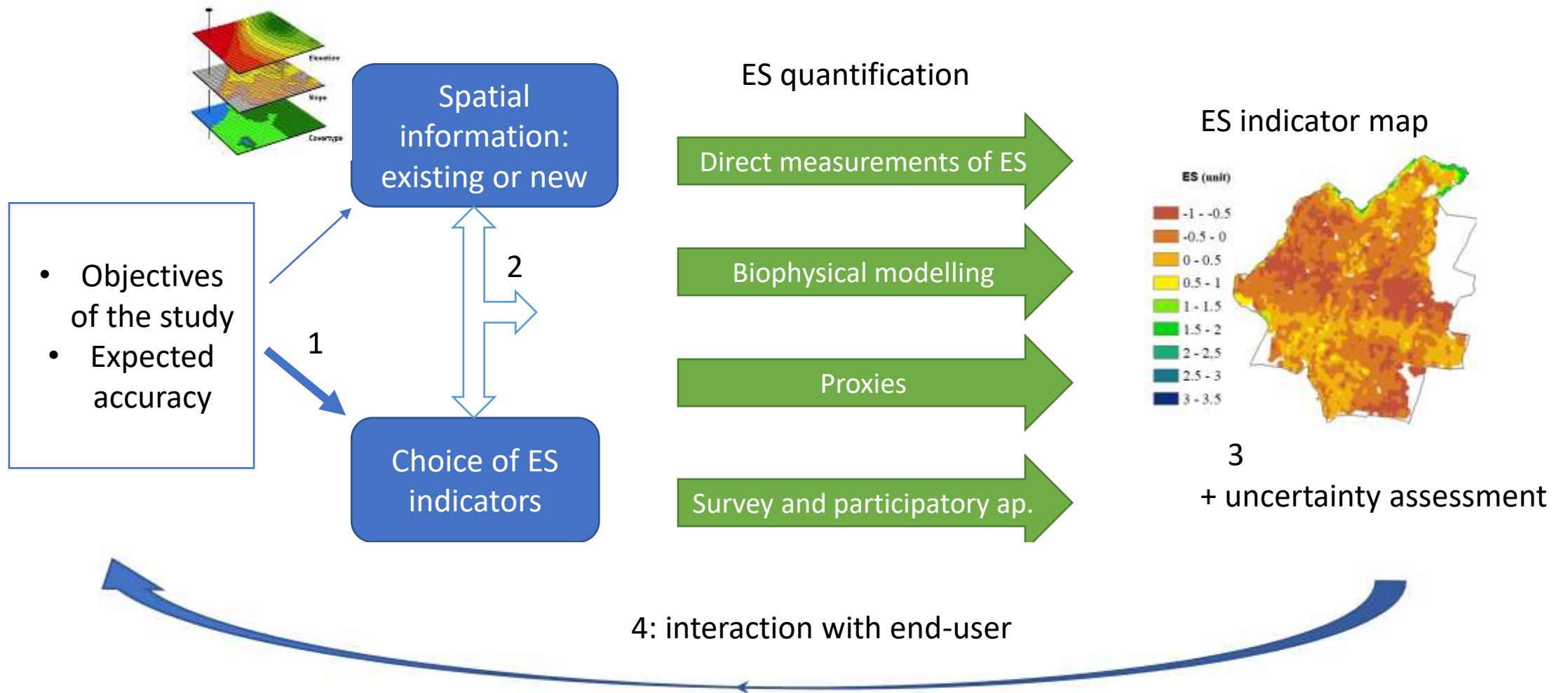
Source: Costanza et al., 1997.

# ES mapping related to mapping objective

Purpose of ES mapping should influence the quality requirements of the mapping procedure (Jacobs et al., 2017)



# The main steps of ES mapping



Early experiences of « ES-like »  
mapping



# Early experiences of « ES-like » mapping

- **Canada Land Inventory (1960-1971)**

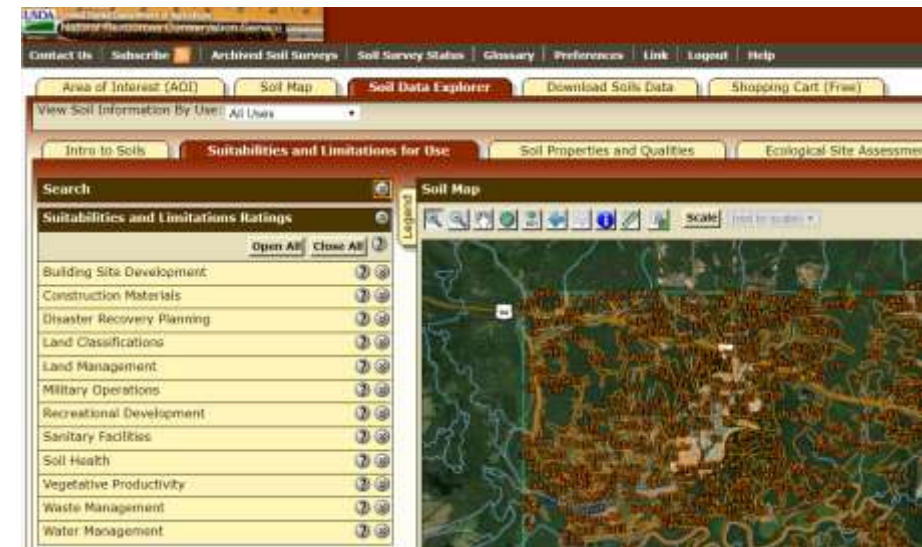
- A federal survey of land capability
- 2.6 million km<sup>2</sup> (25 % of Canada)

- **France: CDTA maps of agricultural land (1981-1987)**

- Aim: « Protecting agricultural land, fixing loans, planning land improvement »
- 10 % of France at 1:50 000 scale

- **USA: Suitabilities and limitations ratings derived from soil survey (NRCS)**

- 90 % of US area at 1:63 000 scale
- <https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx>



# Early experiences of ES mapping

- Canada Land inventory – scale : 1:250,000



# Early experiences (2): Canada Land Inventory

- Land capability for outdoor recreation



**CLASS 1** LANDS IN THIS CLASS HAVE VERY HIGH CAPABILITY FOR OUTDOOR RECREATION.

Class 1 lands have natural capability to engender and sustain very high total annual use based on one or more recreational activities of an intensive nature. Class 1 land units should be able to generate and sustain a level of use comparable to that evident at an outstanding and large bathing beach or a nationally known ski slope.

**CLASS 2** LANDS IN THIS CLASS HAVE A HIGH CAPABILITY FOR OUTDOOR RECREATION.

Class 2 lands have natural capability to engender and sustain high total annual use based on one or more recreational activities of an intensive nature.

**CLASS 3** LANDS IN THIS CLASS HAVE A MODERATELY HIGH CAPABILITY FOR OUTDOOR RECREATION.

Class 3 lands have natural capability to engender and sustain moderately high total annual use based usually on intensive or moderately intensive activities.

**CLASS 4** LANDS IN THIS CLASS HAVE MODERATE CAPABILITY FOR OUTDOOR RECREATION.

Class 4 lands have natural capability to engender and sustain moderate total annual use based usually on dispersed activities.

**CLASS 5** LANDS IN THIS CLASS HAVE MODERATELY LOW CAPABILITY FOR OUTDOOR RECREATION.

Class 5 lands have natural capability to engender and sustain moderately low total annual use based on dispersed activities.

**CLASS 6** LANDS IN THIS CLASS HAVE LOW CAPABILITY FOR OUTDOOR RECREATION.

Class 6 lands lack the natural quality and significant features to rate higher, but have the natural capability to engender and sustain low total annual use based on dispersed activities.

**CLASS 7** LANDS IN THIS CLASS HAVE VERY LOW CAPABILITY FOR OUTDOOR RECREATION.

Class 7 lands have practically no capability for any popular types of recreation activity, but there may be some capability for very specialized activities with recreation aspects, or they may simply provide open space.

Available for whole Canada: 195 sheets

<http://sis.agr.gc.ca/cansis/publications/maps/cli/250k/rec/index.html>

# Early experiences (3): Canada Land Inventory

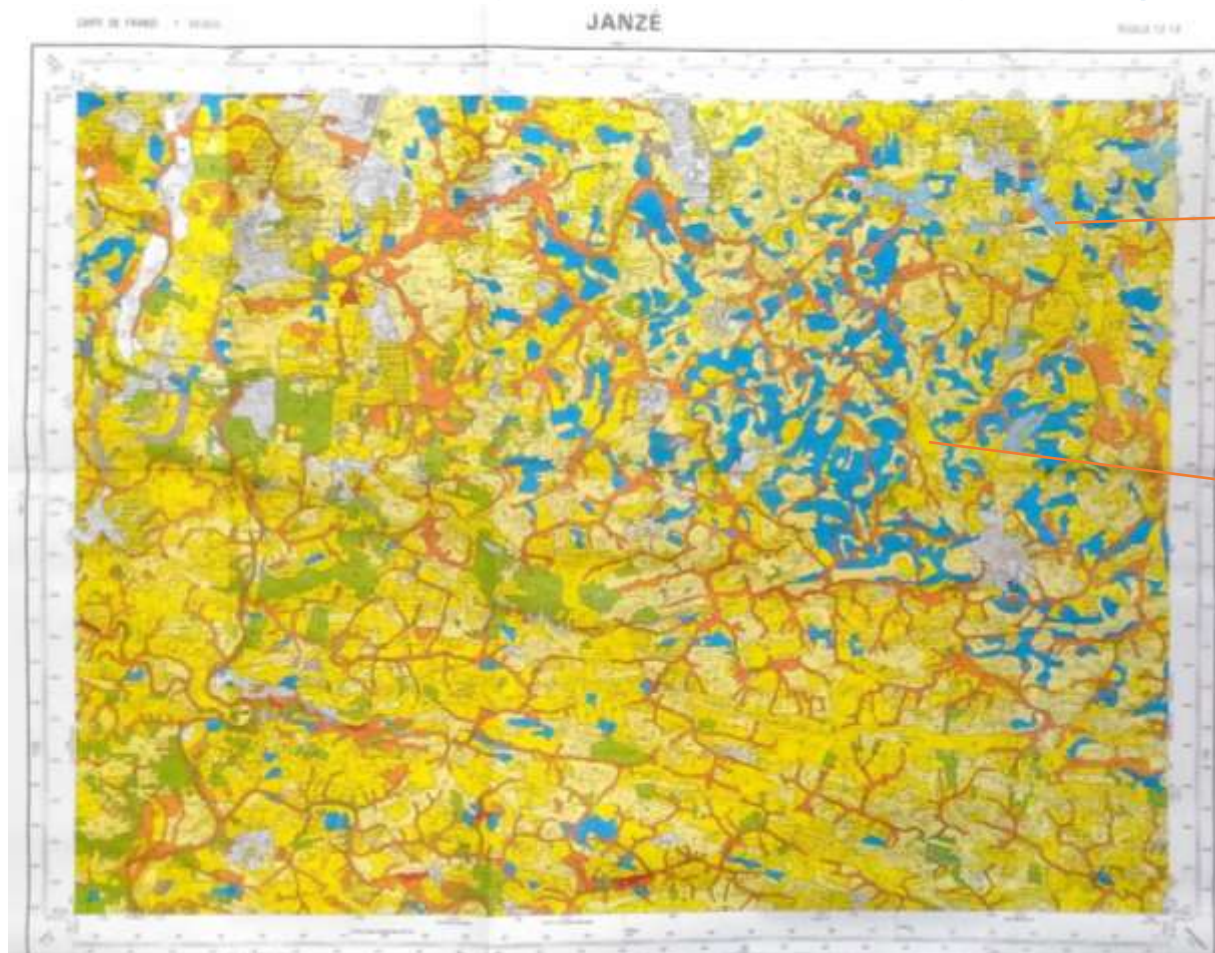
- A program started in 1961 and ended in the early 1990
- Over one million copies of maps were printed
- Still available on Cansis website: <http://sis.agr.gc.ca/cansis>







“Although the information is old, and better information is available for some areas, the interpretations are still largely valid, and many jurisdictions still use them for land use planning purposes.”

(Government of Canada, 2023)

# Early experiences of ES mapping (4)

- France: Departmental map of agricultural land



CLASSEMENT DES TERRES	
	<b>Classe 1</b> Terres de très haute productivité Potentialités élevées du milieu naturel. Système d'exploitation adapté aux conditions économiques et naturelles du milieu.
	<b>Classe 2</b> Terres de bonne productivité Potentialités du milieu naturel bonnes à moyennes, mais légères contraintes. Système d'exploitation adapté aux conditions économiques et naturelles du milieu, mais dans certains cas, possibilité d'investissements pour une meilleure valorisation des terres.
	<b>Classe 3</b> Terres de productivité moyenne Potentialités du milieu limitées par des contraintes assez importantes. Système d'exploitation adapté aux conditions naturelles et économiques du milieu mais, dans certains cas, nécessité d'améliorations foncières pour une meilleure valorisation des terres.
	<b>Classe 4</b> Terres de productivité médiocre Potentialités du milieu naturel limitées par des contraintes importantes souvent difficilement améliorables. Investissements très importants justifiés ou injustifiés suivant le système d'exploitation adopté.
	<b>Classe 5</b> Terres de productivité faible Potentialités faibles, très fortes contraintes limitant ou interdisant toutes améliorations foncières.
	<b>Classe 6</b> Terres de productivité très faible ou nulle Améliorations foncières inutiles ou impossibles, sauf dans quelques cas exceptionnels.

**Class 1: very high productivity land**

- High productivity potential enabled by soil and climate
- Production system adapted to economical and environmental conditions

**Class 3: medium productivity land**

- Existing constraints to productivity
- Need for land improvement (drainage, land consolidation...) in some cases

# Early experiences : Departmental map of agricultural land (5)

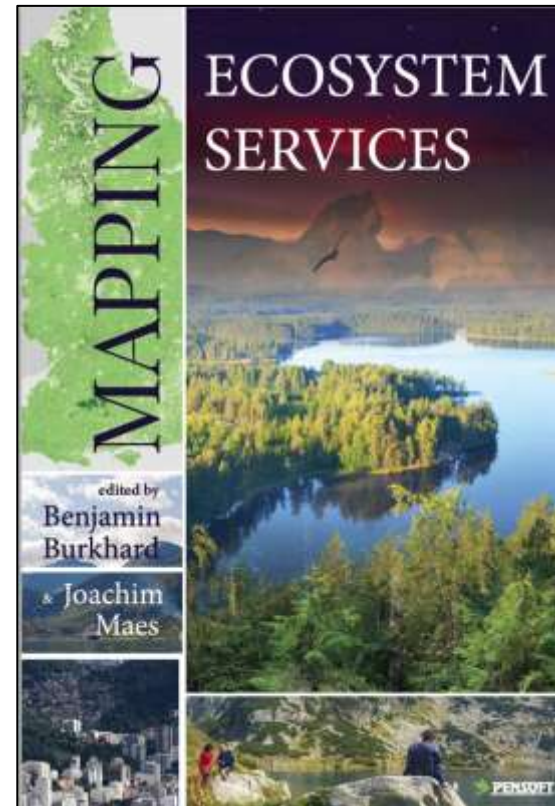
- A land capability concept integrating natural constraints and socio-economical conditions of the agricultural production:
  - Publication of 133 sheets at 1:50,000 scale: 10 % of France
  - A monofactorial approach: agricultural productivity as unique service
  - Strong heterogeneity between maps (data availability, assessment methodology)
- Only available in paper format maps today

-> a failure, but maps would today be useful to protect agricultural land against urban sprawling

# The MAES and JRC approaches for Europe

MAES : Mapping and Assessment of Ecosystems and their services

JRC : Joint Research Centre



Burkhard B, Maes J (Eds.)  
(2017) Mapping Ecosystem Services. Pensoft Publishers, Sofia,

<https://ab.pensoft.net/article/12837/download/pdf/>



Vallecillo et al, (2022) - EU-wide methodology to map and assess ecosystem condition, EUR 31226 EN, Publications Office of the European Union, doi:10.2760/13048

# The MAES program (1)

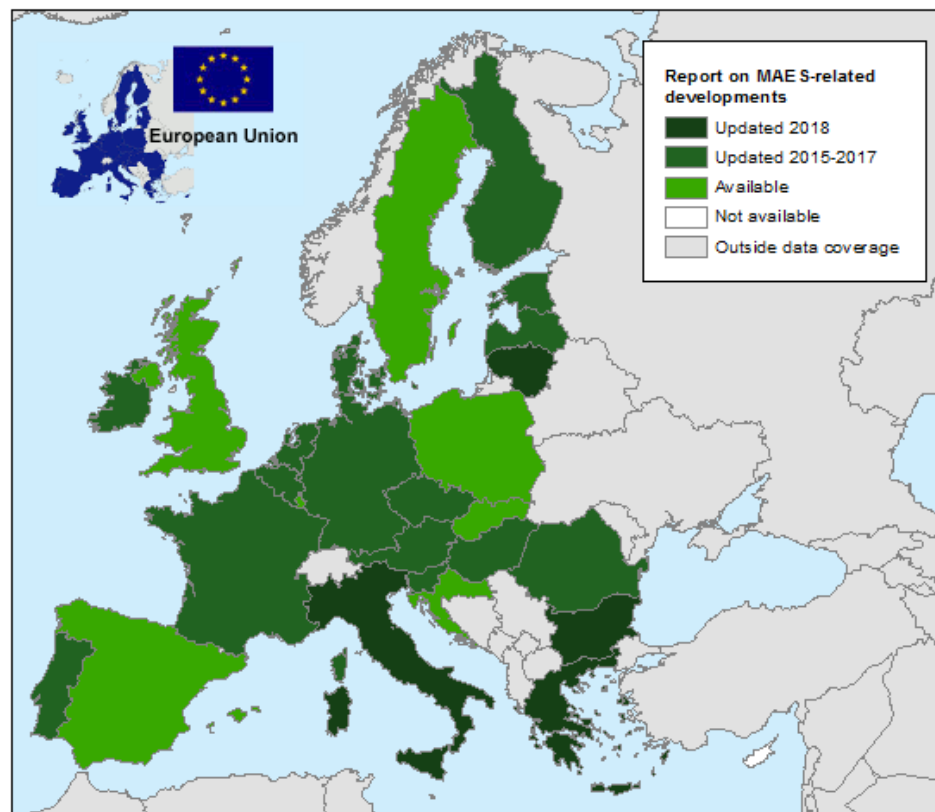
- **MAES initiated in 2011 by the EU biodiversity strategy:**
  - “halt the loss of biodiversity and ecosystem services in the EU and help stop global biodiversity loss by 2020”
- **Action 5 of the strategy: improve knowledge of ecosystems and their services in the EU**

“ Member States, with the assistance of the Commission, will map and assess the state of ecosystems and their services in their national territory by 2014, assess the economic value of such services, and promote the integration of these values into accounting and reporting systems at EU and national level by 2020.”



# The MAES program (2)

- **A common framework of ES assessment and a common classification of ES**
- **Methodological work by European agencies**
  - 5 reports from 2012 to 2017: (1) framework, (2) ES indicators, (3) Ecosystem conditions, (4) urban ecosystems, (5) final framework
- **a typology of ecosystems in three major types: terrestrial, freshwater and marine environment**
- **Common classification of ecosystem services: CICES classification v5.1**
  - <https://cices.eu/>
- **The member states are in charge of the detailed methodology and final mapping**
  - <https://biodiversity.europa.eu/countries/>



# The CICES Classification (1)

- **Intended as a reference classification of final ecosystem services: contribution that ecosystems make to human well-being.**
- **3 major sections of ES:**
  - Provisioning
    - Nutritional material, non-nutritional material, energetic outputs, abiotic outputs
  - Regulation and maintenance
    - Transformation of biochemical or physical inputs to ecosystem
    - Regulation of physical, chemical and biological conditions
  - Cultural
    - All the non-material outputs of ecosystems (biotic and abiotic) that affect physical and mental states of people

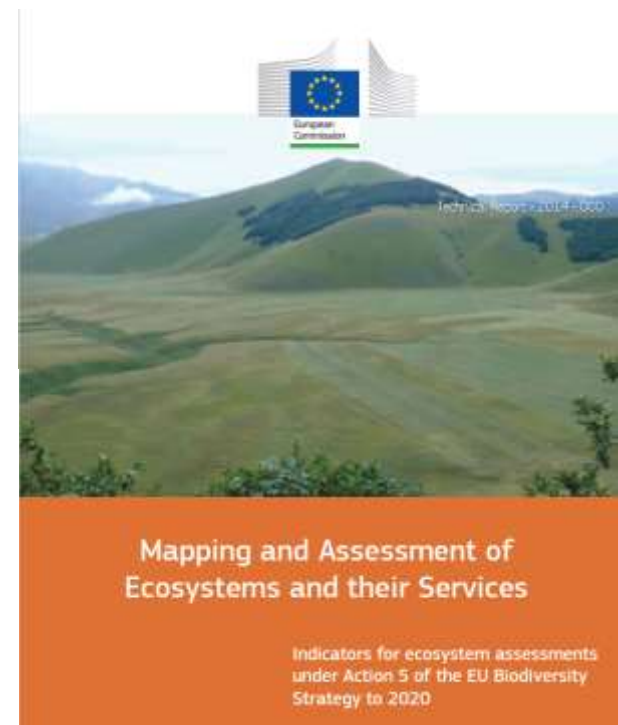
# Indicators of Ecosystem services

## • A proposal of ES indicators for:

- Forest services
- Cropland and grassland services
- Freshwater services

**Table 8.** Indicators for provisioning services delivered by agro-ecosystems.

Division	Group	Class	Cropland	Grassland
Nutrition	Biomass	Cultivated crops	<ul style="list-style-type: none"> <li>• Yields of food and feed crops (ton/ha; ton dry matter/ha; MJ/ha)</li> <li>• Food and feed crop area (ha)</li> </ul>	<ul style="list-style-type: none"> <li>• Yields (ton/ha; ton dry matter/ha; MJ/ha)</li> <li>• Grassland area (ha)</li> </ul>
		Reared animals and their outputs	<ul style="list-style-type: none"> <li>• Livestock data (LU/ha, Ton/yr/region)</li> </ul>	
		Wild plants, algae and their outputs		
		Wild animals and their outputs	<ul style="list-style-type: none"> <li>• Wild game bag data (merged with forest ecosystems)</li> <li>• Wild game population estimates</li> </ul>	
		Plants and algae from in-situ aquaculture		
		Animals from in-situ aquaculture		
	Water	Surface water for drinking	<ul style="list-style-type: none"> <li>• High Nature Value farmland</li> </ul>	
		Ground water for drinking	<ul style="list-style-type: none"> <li>• Areas important for groundwater abstraction in agro ecosystems</li> </ul>	



# Global Datasets to mapping ES

Ecosystem service	Global dataset	Resolution	URL
Food production	Land Cover	250 m	<a href="http://www.eea.europa.eu/data-and-maps/data/global-land-cover-250m">http://www.eea.europa.eu/data-and-maps/data/global-land-cover-250m</a>
	Land Use Systems	8 km	<a href="http://www.fao.org/geonetwork/srv/en/metadata.show?id=37139">http://www.fao.org/geonetwork/srv/en/metadata.show?id=37139</a>
	Net Primary Productivity	10 km	<a href="http://neo.sci.gsfc.nasa.gov/view.php?datasetId=MOD17A2_M_PSN">http://neo.sci.gsfc.nasa.gov/view.php?datasetId=MOD17A2_M_PSN</a>
	Global Livestock Densities	5 km	<a href="http://www.fao.org/ag/againfo/resources/en/glw/GLW_dens.html">http://www.fao.org/ag/againfo/resources/en/glw/GLW_dens.html</a>
Fresh water	FAO Global Water Database (AQUASTAT)	Country	<a href="http://www.fao.org/nr/water/aquastat/main/index.stm">http://www.fao.org/nr/water/aquastat/main/index.stm</a>
Timber harvesting	Global Tree Cover Loss	30 m	<a href="http://earthenginepartners.appspot.com/science-2013-global-forest/download_v1.2.html">http://earthenginepartners.appspot.com/science-2013-global-forest/download_v1.2.html</a>
Carbon sequestration	Global Biomass Carbon	1 km	<a href="http://cdiac.ornl.gov/epubs/ndp/global_carbon/carbon_documentation.html">http://cdiac.ornl.gov/epubs/ndp/global_carbon/carbon_documentation.html</a>

# Where are we today?

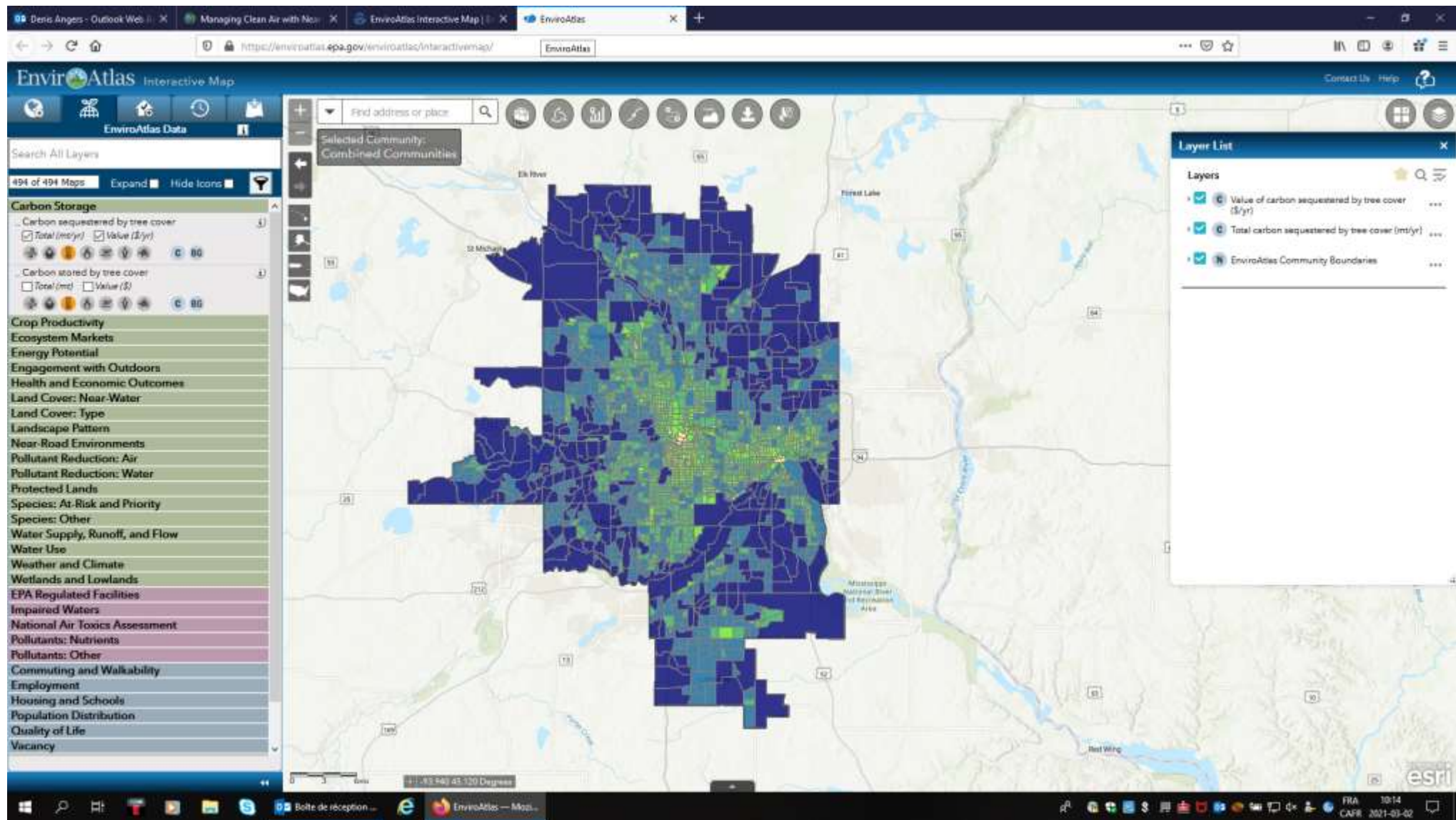
## The INCA ES mapping platform for Europe

- <https://ecosystem-accounts.jrc.ec.europa.eu/>

The screenshot shows the INCA Platform website. At the top left is the European Commission logo. To its right is a search bar with a 'Search' button. Below the logo is the text 'Energy, Climate change, Environment'. The main header is a dark blue bar with the text 'INCA Platform' and a navigation menu with links: 'Home', 'About', 'Publications', 'News', 'Data Catalogue', 'Map Tool', 'Glossary', and 'Contact Us'. The main content area is light blue and features a section titled 'How ecosystem services are assessed in INCA'. This section has two yellow boxes: 'Ecological supply' with icons of a butterfly, trees, and a water drop; and 'Socio-economic needs' with icons of people and a power line. On the right side, there is a dark blue sidebar with a 'START' button, a map of Europe, and a section for 'Accounting tables' with a dropdown menu.

# Conclusion

- ES maps are intended to help decision-making, but are still complex to establish and their validity must often be questioned
- Poor maps should not lead to wrong decisions
- MAES framework is as a solid reference but should not be considered as a definitive methodology of ES assessment
- Recent progress in information availability and processing, but still research needed for harmonized ES quantification and uncertainty assessment
- See also the US experience of ES mapping (Enviroatlas, US EPA):
  - <https://enviroatlas.epa.gov/enviroatlas/interactivemap/>



<https://www.epa.gov/enviroatlas/enviroatlas-interactive-map>

EnviroAtlas Interactive Map

Find address or place

Selected Community: Combined Communities

494 of 494 Maps

**Carbon Storage**

- Carbon sequestered by tree cover
  - Total (mt/yr) Value (\$/yr)
- Carbon stored by tree cover
  - Total (mt) Value (\$)

**Crop Productivity**

**Ecosystem Markets**

**Energy Potential**

**Engagement with Outdoors**

**Health and Economic Outcomes**

**Land Cover: Near-Water**

**Land Cover: Type**

**Landscape Pattern**

**Near-Road Environments**

**Pollutant Reduction: Air**

**Pollutant Reduction: Water**

- Biological nitrogen fixation (kg N/ha/yr)
  - Natural  Cultivated
- Crop phosphorus removal (kg P/ha/yr)
- Net agricultural phosphorus balance (kg P/ha/yr)
- Percent of agriculture that is buffered
- Reduction in biochemical oxygen demand [BOD5] due to tree cover (kg/yr)
  - Mean  Median
- Reduction in chemical oxygen demand [COD] due to tree cover (kg/yr)
  - Mean  Median

Layer List

**Layers**

- Cultivated biological nitrogen fixation (kg N/ha/yr)
- Natural biological nitrogen fixation (kg N/ha/yr)
- EnviroAtlas Community Boundaries

esri

79 310 48.030 Degrees

FRA 11:17 2021-03-02

<https://www.epa.gov/enviroatlas/enviroatlas-interactive-map>



# Discussion on examples of ES mapping studies

# Mapping provisioning ecosystem services at the local scale... (Kandziora et al., 2013)



Ecosystem Services  
Journal homepage: www.elsevier.com/locate/ecoser

## Mapping provisioning ecosystem services at the local scale using data of varying spatial and temporal resolution

Marko Kandziora\*, Benjamin Burkhard, Felix Müller

Abstract for Research Resource Consortium, Christian-Albrechts-University of Kiel, 2013, 1-14, 1-14

**ARTICLE INFO**

**Article history:**  
Received 10 May 2012  
Received in revised form 27 March 2013  
Accepted 1 April 2013  
Available online 11 May 2013

**Keywords:**  
Spatial resolution  
Temporal resolution  
Data quality  
GIS  
ES  
Land use

**ABSTRACT**

Spatial data on land use and land cover (LULU) are broadly available on different scales and are used widely for mapping ecosystem services at LULU and their changes impact on the provision of multiple ecosystem services. Here, two spatial data sets were compared for their practicality as input data for the GIS-based assessment method in the Bornhöved Lakes study area. The results for the 60 km<sup>2</sup> study area are that more detailed land use information (FRS) and a combined ATN2010/WerkLandul data sets are preferred to CORINE land cover data due to the possibility of including spatial details (e.g. number of LULU classes and crop information) in the assessment of provisioning ecosystem services. The CORINE data set overestimated the supply of the two analyzed provisioning services crops and fodder in comparison to the combined data set which provided information on the specific crops, making quantification with statistical information on yields easier. Spatial input data quality has an effect on the resulting provisioning service maps and quantifications of ecosystem services in the study area due to the identification of ecosystem services, their extent and change. Consequently they also influence decision making and the development of the ecosystem services concept in the future.

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### 1. Introduction

Mapping of ecosystem services is an arising and significant topic in the scientific community, which is evident in the amount of publications and special issues on the topic in recent time (Dronau et al., 2012; Burkhard et al., 2012a, p.2) define ecosystem services as “the contributions of ecosystem structure and function—in combination with other inputs—to human well-being”. This definition includes the highly managed and human-influenced agroecosystems, which are extensively spread globally and provide bundles of ecosystem services (Kandziora-Mikome et al., 2010) or “agroecosystem services” (Pepelink et al., 2012). Maximizing only selected ecosystem services (e.g. agricultural production) causes effects and trade-offs concerning other ecosystem services, ecosystem functions and human well-being (Tallis and Polasky, 2009). Since the concept of ecosystem services has the potential to be brought widely into decision-making and planning (de Groot et al., 2010), the use of maps to visualize ecosystem services and their spatio-temporal distribution in local (Troy and Wilson, 2006), regional (Cheng et al., 2006; Burkhard et al., 2012; Krull et al., 2012; Villersgaard et al., 2010) and national (Rygh et al., 2008), continental (Hansen-Piisang et al., 2012; Man

et al., 2011) and global case studies (Costanza et al., 1997) are recognized as a key element. Being spatially explicit is a local requirement for ecosystem service maps and models, which is commonly considered to be of great importance (e.g. Nelson et al., 2009; Tallis and Polasky, 2009; Troy and Wilson, 2006). As a map can only communicate a limited amount of information, most mapping studies focus on selected ecosystem services (e.g. Cheng et al., 2006; Rygh et al., 2008; Egevedt et al., 2010; Galkin et al., 2011; Krull et al., 2012; Naidun et al., 2008; Nordén and Burkhard, 2012; Schulz et al., 2012; Tarnon et al., 2010; van Oudenhooven et al., 2012); these maps are a prerequisite for ecosystem or urban planning, management and the sustainable use of resources and ecosystem services (Burkhard et al., 2009; Cooper and Robinson, 2010; Cheng et al., 2006; Kuchta et al., 2012; Schulz and Altemark, 2011; Tallis and Polasky, 2009) and they also explicitly link ecosystem conservation to human well-being (Fisher et al., 2009; Erickson et al., 2009).

There are several approaches and methods to quantify, map and evaluate ecosystem services as the following short review reveals. Agrebotin and Kuytko (2008) give the example of participatory mapping of ecosystem/landscape service indicators in rural environments for a bottom-up management. Social and community values were mapped by Ryan et al. (2010) and Byers et al. (2008) in the Murray-Darling basin as a complement to economic and biophysical mapping. A GIS-based mapping approach for social values of ecosystem services was compiled by

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E-mail address: marko.kandziora@uni-kiel.de (M. Kandziora).

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http://dx.doi.org/10.1016/j.ecoser.2013.05.001

Kandziora et al., 2013

## ❖ Ecosystem services considered:

Provisioning ES: capacity for crop supply or fodder supply

## ❖ Aim of the study:

Influence of spatial and temporal resolution of input data on local ES assessment

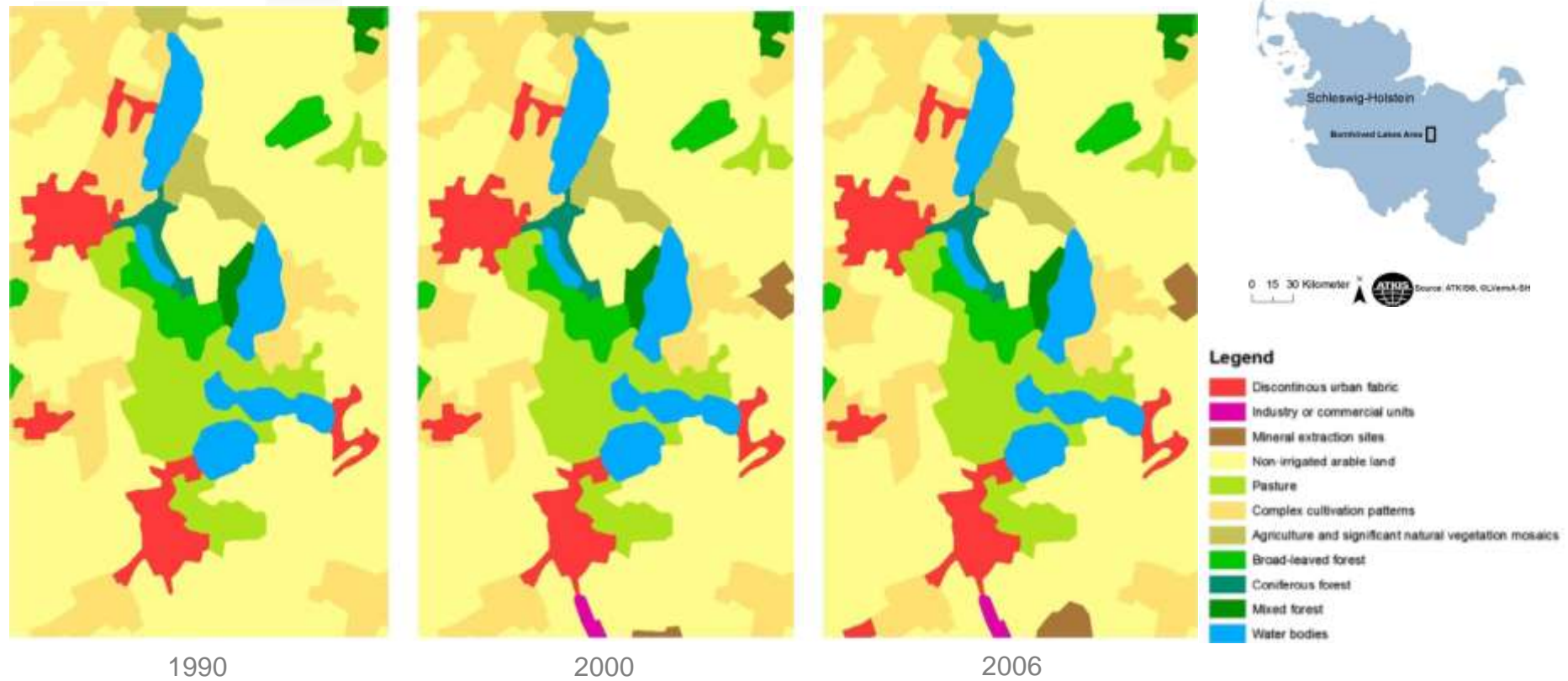
## ❖ Assessment methodology of ES

- Multiple input spatial data sets
- Proxy based assessment
- Statistical data

## ❖ Mapping of ecosystem services

- Mean value per land use or land cover class
- Local scale (northern Germany - 60km<sup>2</sup>)

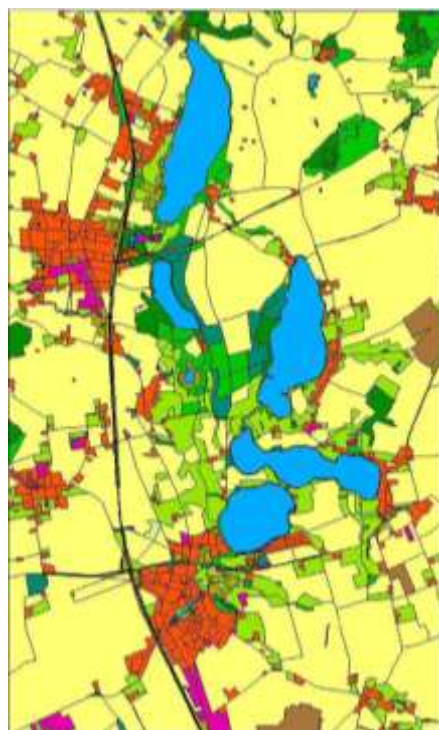
# Corine Land Cover as basis of ES mapping ?



*Kandziara et al., 2013*

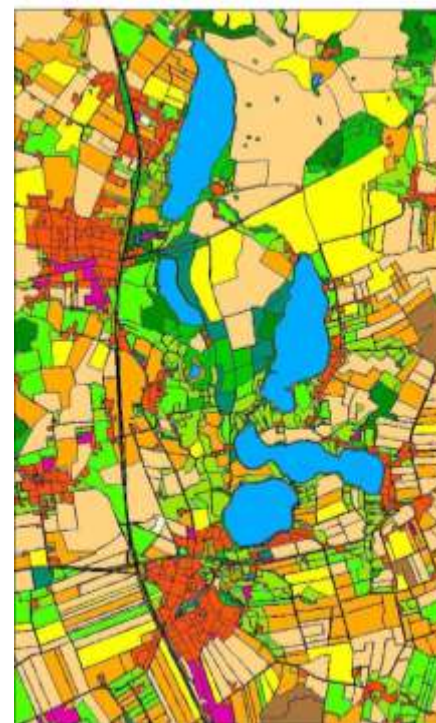
Very broad land cover classes, but freely available and existing at different dates

# More detailed information: cartographic information systems and remote sensing



- Legend**
- Discontinuous urban fabric
  - Industry and commerce
  - Open-cast mining
  - Arable land
  - Pasture and meadows
  - Tree nursery, garden land
  - Broad-leaved forest
  - Coniferous forest
  - Mixed forest
  - Grove, swamp, peat bog
  - Water bodies

ATKIS - 2010



- Legend**
- Discontinuous urban fabric
  - Industry and commerce
  - Open-cast mining
  - Tree nursery, garden land
  - Cereals
  - Maize
  - Rapeseed
  - Grassland
  - Pasture and meadows
  - Broad-leaved forest
  - Coniferous forest
  - Mixed forest
  - Grove, swamp, peat bog
  - Water bodies

ATKIS + InVeKoS + Landsat  
classification - 2010

*Kandziara et al., 2013*

# Results (1): Mapping ES capacity for crop production depending on the information source



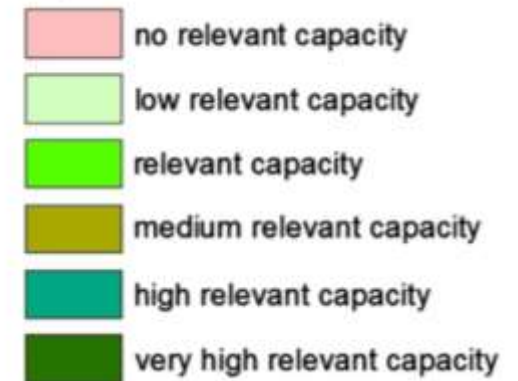
CORINE - Minimum mapping unit 25ha - 2006



ATKIS – 1:5000 2010



ATKIS – 1:5000 combined with landsat classification and InVeKos - 2010



*Kandziora et al., 2013*

Strong differences between ES capacity maps depending on spatial resolution of input data

## Results (2): Mapping ES capacity for crop production depending on the information source



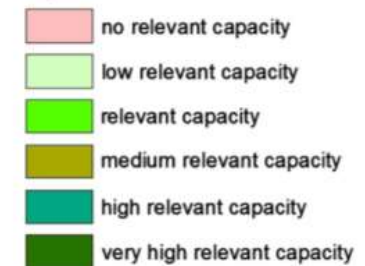
CORINE - Minimum mapping unit 25ha- 2006



ATKIS – 1:5000  
2010



ATKIS – 1:5000 combined  
with landsat classification  
and InVeKos - 2010



*Kandziara et al., 2013*

# Questions on this paper

- **Are statistics of annual average yields good indicators of provisioning ES ?**
- **Is the uncertainty associated to the ES maps known ?**
- **How can we improve the assessment?**

# Mapping ecosystem service capacity, flow and demand for landscape and urban planning (Baro et al, 2016)



## ❖ Ecosystem Services considered

- Regulation ES: air purification
- Cultural ES : Outdoor recreation

## ❖ Aim of the study:

compare ES capacity, flow and demand in the Barcelona Metropolitan area

## ❖ Assessment methodology

- ❖ Distinction between ES capacity, flow and demand
- Proxy-based and process-based assessment (ESTIMAP)
- Expert knowledge – Population analysis

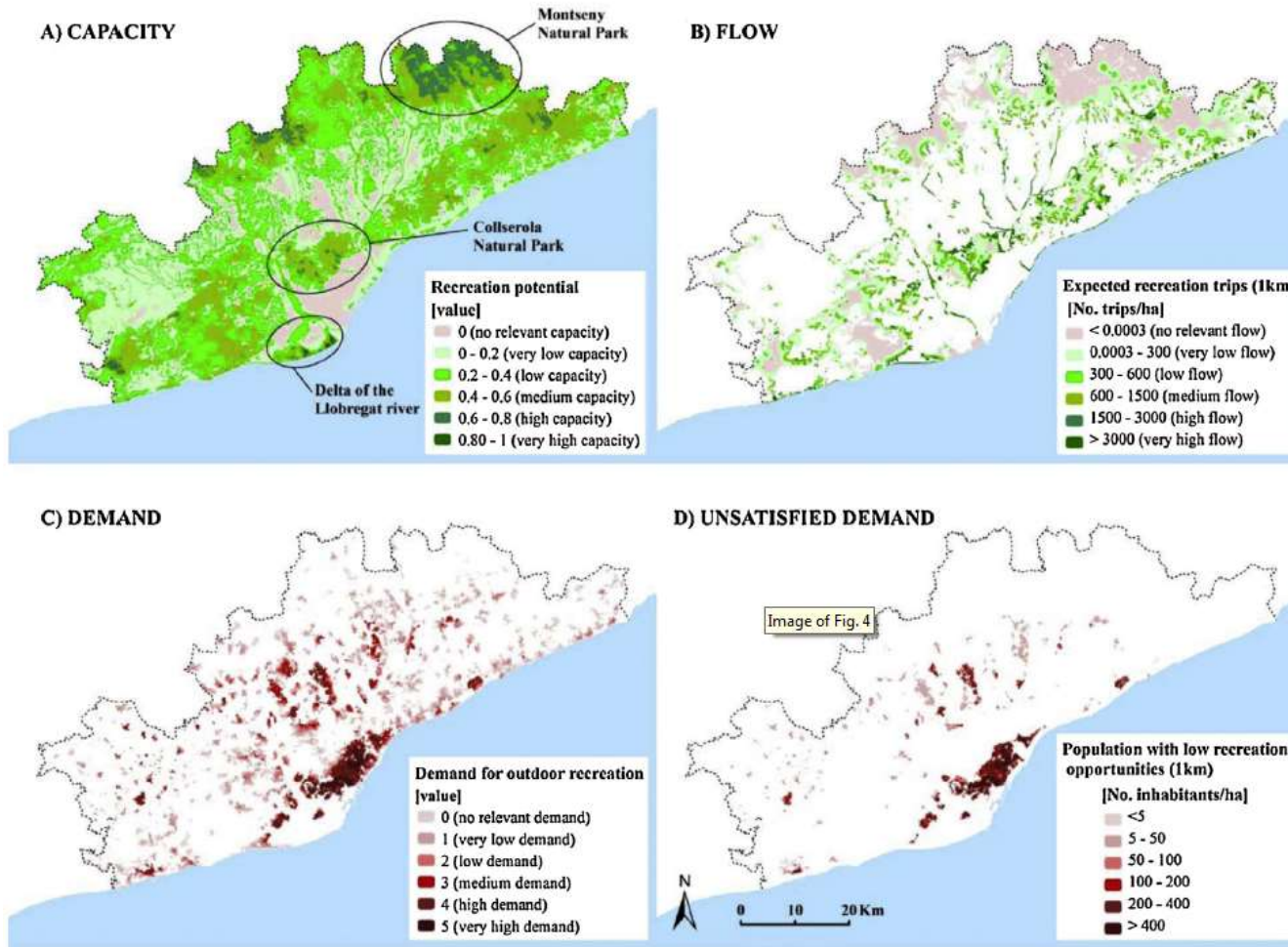
## ❖ Mapping of ecosystem services

- Composite-based mapping procedure
- Regional scale (3244 km<sup>2</sup>)



# Maps of ES outdoor recreation

Cultural ES outdoor recreation

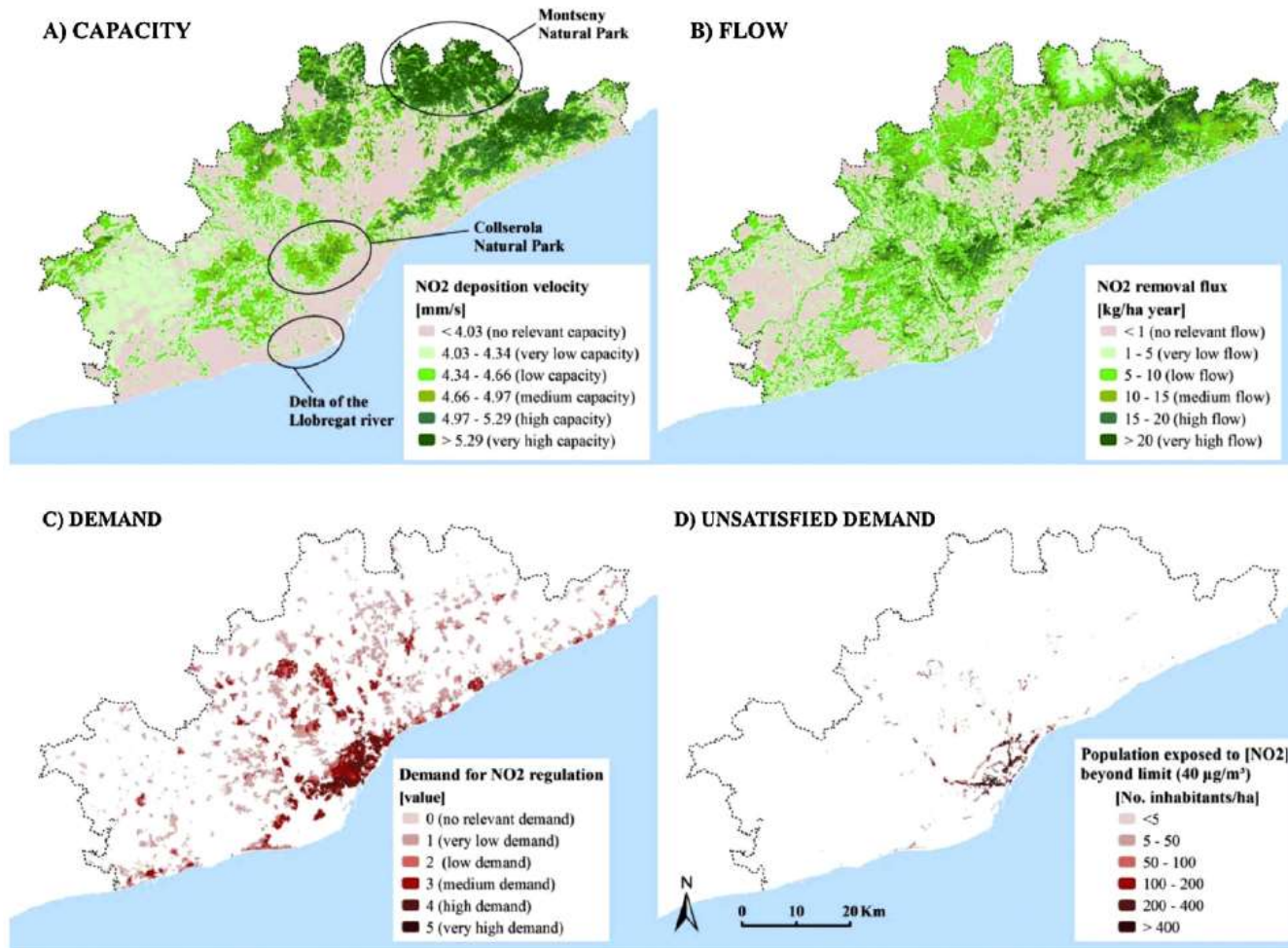


Outdoor recreation:

- **Capacity:** human influence x protected areas x water bodies
- **Flow:** distance analysis
- **Demand:** population density to distance to recreational sites

Baro et al., 2016

# Maps of air purification ES



Abatement of N<sub>2</sub>O air pollution by vegetation

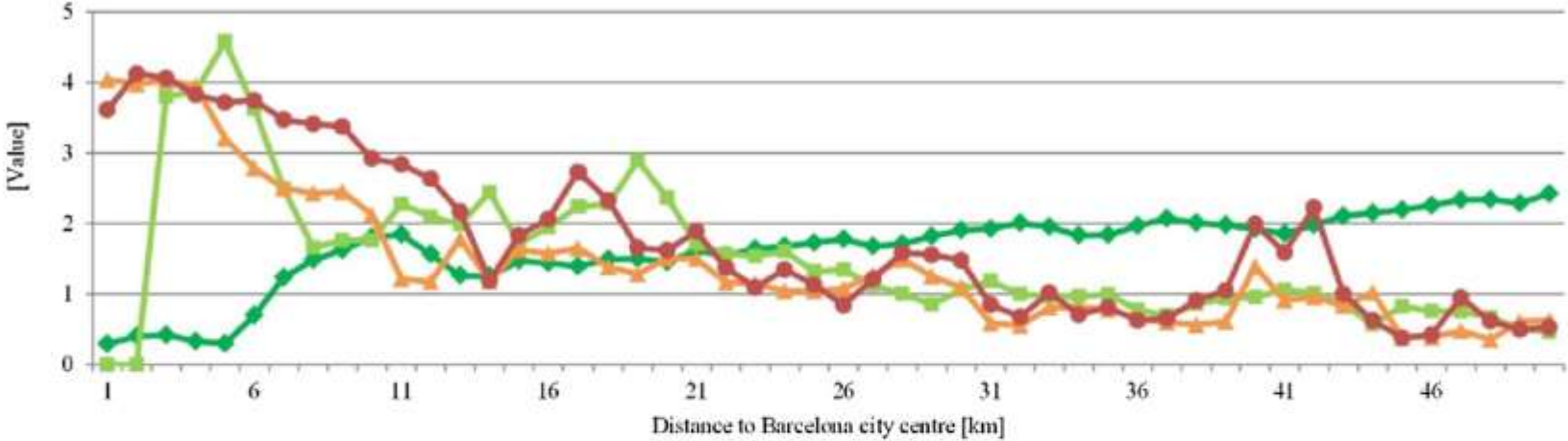
Multi component assessment :

- « **Capacity** » : NO<sub>2</sub> dry deposition velocity
- « **Flow** »: Modeled NO<sub>2</sub> removal by vegetation
- « **Demand** »: population density and exposure to NO<sub>2</sub> concentrations

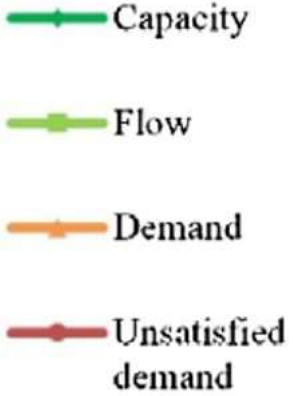
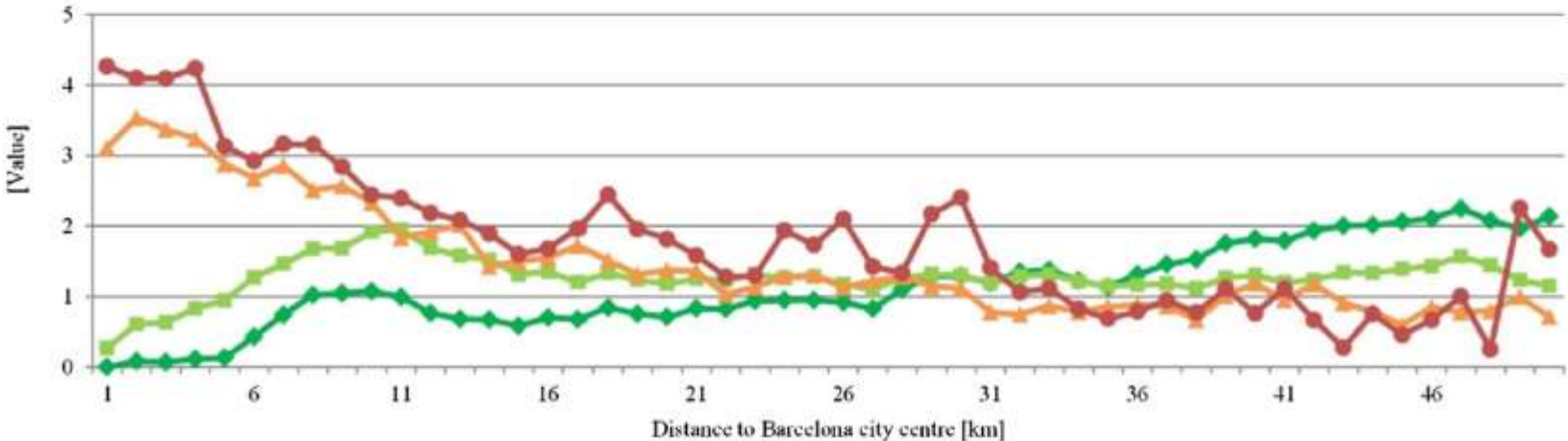
Baro et al., 2016

# Comparison of the ES capacity, flow and demand

A) OUTDOOR RECREATION



B) AIR PURIFICATION



# Questions on this study

- **Indicators of capacity, flow and demand?**
- **Can we compare easily ES capacity, flow and demand ?**
- **How to improve the approach ?**