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Ecosystem services provided by the bio-physical structure of natural capital in the Danube Delta Biosphere Reserve Romania

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Abstract

The Danube River is the second largest in Europe and the most international river of the world, before flowing into the Black Sea, it creates a delta covering 5,165 km² that is one of the best preserved in the world. Bio-physical structure of Danube Delta natural capital consist of 38 different ecosystem types supporting a very rich biodiversity area. We matched the ecosystems types to their potential services then ranked them with local, regional and national stakeholders using a participatory GIS approach.

Keywords

Danube Delta Biosphere Reserve, ecosystem services, GIS

Introduction

As defined by millennium ecosystem assessment, the ecosystem services are the benefits people obtain from ecosystems (MEA 2005, TEEB 2010). Thus, knowing the biophysical structure of natural capital (i.e. type of ecosystems, their state, dynamics and the complex interrelations established inside and between them, availability and type of resources etc.) it is very important for the assessment and mapping of ecosystem services.

The Danube River is the second largest in Europe and the most international river of the world. Its basin, covering an area of 8,684 km², comprises 19 countries, its springs lay in Germany, and it ends up at the border between Romania and Ukraine after having passed through Austria, Slovakia, Hungary, Croatia, Serbia, Bulgaria, and having touched four capitals: Vienna, Bratislava, Budapest and Belgrade before reaching the Black Sea.

At the end of its catchment, the Danube River forms a huge delta covering a surface of 5,165 km², an area covered by 38 different ecosystem types (EEA 2015). The Danube Delta is the second largest delta in Europe, after the one of the Volga River, and it is shared between Romania (86%) and Ukraine (14%).

The dynamics of the river arms, transported sediment, low altitudes and the presence of the sea is creating a complex landscape formed by freshwater ecosystems (canals, shallow lakes, and wetlands), flood plains, alluvial forests, reed-beds, lagoons and coastal area. Delta's territory is still spreading seaward at a rate of 24 to 30 meters annually, despite the sediment deficit due to the construction of dams on the river and its tributaries in the last 70 years (RAFFERTY 2011)

The complex biophysical structure of the Danube Delta landscape sustain a large variety of habitats for many species. More than 300 species of birds and 80 species of fish can be found in the Delta. About 160 species of migratory bird species are here because the Delta is located on the major migratory routes, and its environment provides favorable conditions for nesting and hatching. Flora is composed by almost thousand species, and more than three thousands species of invertebrates were found here. The Danube Delta is home to over 60% of the world's population of pygmy cormorants (Phalacrocorax pygmeus), 50% of red-breasted geese (Branta ruficollis) and the largest number of white pelicans (Pelecanus onocrotalus) and Dalmatian pelicans (Pelecanus crispus) in Europe (NANKINOV 1996).

Being a wetland dominated landscape, the reed forms one of the largest compact areas in the world, covering about 2400 km2. Other notable ecosystem types are Letea and Caraorman forests that are located at the northern limit of the two rare species of oak found more frequently in the south of the Italian and Balkan peninsulas.
There are about 14,000 inhabitants (INS 2002) in the Danube Delta, living in 25 settlements (a town – Sulina), concentrated along the Danube arms on the areas of dry land, most of them being reachable only by boat. Thus, the area is one of the less populated in Europe with a population density of about 2.8 inhabitants per square kilometers. Also, due to the historic set-up of the area, cultural heritage is also notable.

Because of its rich diversity, both biological and cultural, the entire delta area gained a triple international conservation designation: UNESCO World Heritage Sites, Biosphere Reserve since 1990 and Ramsar site due to its importance for migratory birds. At EU level, the Danube Delta is recognized as part of Natura 2000 network for the great diversity of birds listed on the Bird directive, as well as for the habitats and other species listed on the annexes of Habitat directive.

In the current work, we are exploring the potential of this unique complex of ecosystems to generate services. We used high resolution maps of ecosystem types that were matched with their potential of generating services. Then, this potential was assessed on the bases of stakeholders' knowledge that ranked their importance. Maps with ranked values of general categories of ecosystem services were produced. The assessment and mapping of ecosystem services from a protected area is a valuable asset for a sustainable management and informed decision.

Acknowledgments

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Methods

Study area

Our research was focused on the Danube Delta Biosphere Reserve that lies between 44°80 ' and 45°27 ' N and 28°45 , and 29°46 ' E, and is approximately 100 km long. The delta shape starts were the river divides into three main arms that enclose an area dominated by marshes and lakes of varying sizes and depths, most of them shallow. Numerous channels are natural while others have been cut through the marshes mainly to facilitate the access to these lakes for fishing. Also, the main arms were dredged and straightened for navigation purposes (Fig. 1), the northern one, named Chilia, being preserved as close as its natural regime, while Sulina arm, the one in the middle is managed as a maritime shipping lane.

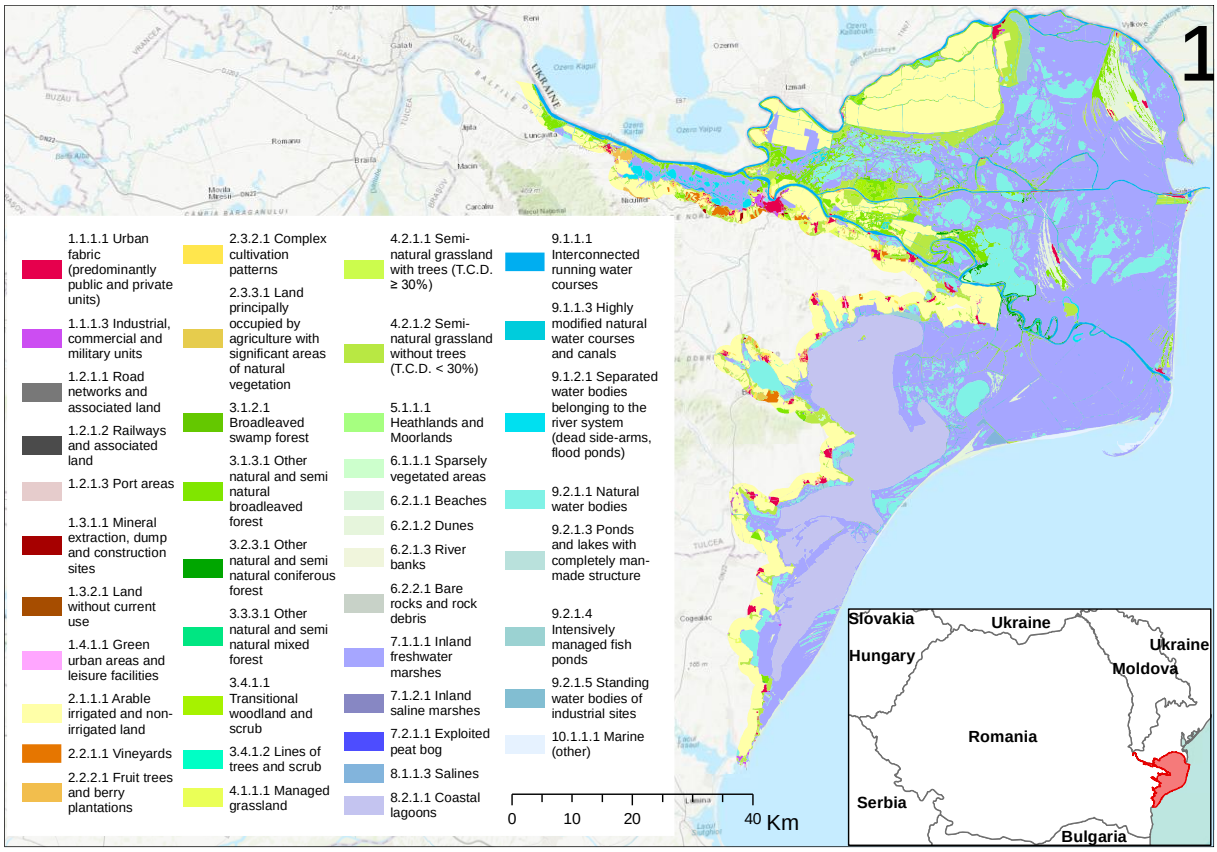

Figure 1: Location of the Danube Delta and the distribution of ecosystem types according to MAES level 4 classification.

Ecosystem identification

Ecosystem identification was based on semi-automatic classification of satellite data with pixel resolution varying from 1.5 to 2.5 m that were acquired during 2010-2014. Ecosystem types were named following the MAES level four classification scheme (MAES et al. 2016). The Minimum Mapping Unit (MMU) is 0.5 with a Positional Accuracy less than 5 m (RMSE > 5m). Such level of spatial resolution allow us to capture the most important ecological features on the ground.

Ecosystem services

Each ecosystem type was associated to a potential list of ecosystem services in accordance to common international classification of ecosystem services (CICES) (HAINES-YOUNG & POTSCHIN 2013). We used high resolution maps of ecosystem types and matched these with their potential in providing different services considering their functions and stakeholders opinion. Each ecosystem type received a rank between 0 – not provided to 5 - maximum provided in accordance with the type and importance of providing a specific service (BURKHARD et al. 2014). Median value of specific ecosystems service ranks were mapped as general category of ecosystem service. Subcategories of services are presented in the Tab. 1.

Ecological Integrity	Provisioning services
Exergy Capture (Radiation)	Crops
Entropy production	Energy (Biomass)
Storage capacity (SOM)	Fodder
Reduction of Nutrient loss	Livestock
Biotic waterflows	Fibre
Metabolic efficiency	Timber
Abiotic heterogeneity	Wood Fuel
Biodiversity	Capture Fisheries
Regulating services	Aquaculture
Global climate regulation	Wild Foods
Local climate regulation	Biochemicals / Medicine
Air Quality Regulation	Freshwater
Water flow regulation	Mineral resources
Water purification	Abiotic energy sources
Nutrient regulation	**Cultural services**
Erosion Regulation	Recreation & Tourism
Natural hazard protection	Landscape aesthetics, amenity and inspiration
Pollination	Knowledge systems
Pest and disease control	Religious and spiritual experiences
Regulation of waste	Cultural heritage & cultural diversity
	Natural Heritage & natural diversity

Table 1: List of ecosystem services and their categories. Ecological integrity can be understood as structures and processes relevant for ecosystem self-organization (MÜLLER 2005)

Results

Weight and distribution of ecosystem types

We identified nine main categories of ecosystems in the Danube Delta, the most dominant ones are, as expected, the aquatic ecosystems (formed by wetlands, rivers and lakes, marine inlets and transitional waters, and marine) that are cumulating about 72% of the entire surface, followed by man dominated ecosystems (cropland and urban) with a cumulated surface of about 17%, the rest are woodland and forest, grassland, sparsely vegetated areas, and heathland and shrub (Fig. 2, Tab. 2). Increasing the spatial resolution and classification level we can distinguish 38 types of ecosystems (Tab. 2) from which the most important are inland freshwater marshes covering 44.8 % of total area.

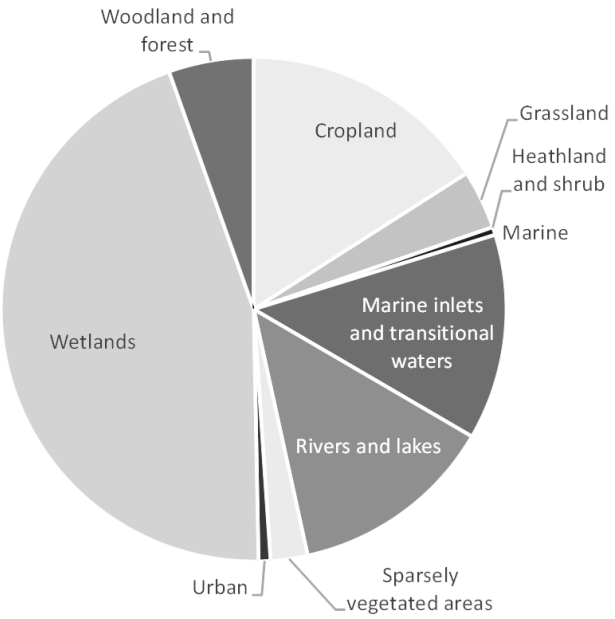

Figure 2: Wight of main categories of ecosystems from the Danube Delta

Ecosystems general categories	MAES Ecosystem level 4	%/subcategory %	Ecosystem integrity	Regulatory services	Production services	Cultural services
Cropland		**15.94**	**4**	**2**	**3**	**2**
	Arable irrigated and non-irrigated land	*97.73*	*4*	*2*	*3*	*2*
	Complex cultivation patterns	*0.79*	*3*	*2*	*3*	*2*
	Fruit trees and berry plantations	*0.60*	*3*	*2*	*4*	*3*
	Land principally occupied by agriculture with significant areas of natural vegetation	*0.25*	*3*	*2*	*3*	*2*
	Vineyards	*0.64*	*3*	*1*	*2*	*2*
Grassland		**3.78**	**4**	**2**	**3**	**4**
	Managed grassland	*2.93*	*4*	*1*	*5*	*2*
	Semi-natural grassland with trees (T.C.D. < 30%)	*0.85*	*4*	*2*	*3*	*4*
	Semi-natural grassland without trees (T.C.D. < 30%)	*96.22*	*4*	*2*	*3*	*4*
Heathland and shrub		**0.002**	**4**	**3**	**2**	**4**
	Heathlands and Moorlands	*100.00*	*4*	*3*	*2*	*4*
Marine		**0.50**	**2**	**3**	**3**	**4**
	Marine (other)	*100.00*	*2*	*3*	*3*	*4*
Marine inlets and transitional waters		**13.19**	**2**	**3**	**1**	**3**
	Coastal lagoons	*99.08*	*4*	*4*	*4*	*4*
	Salines	*0.92*	*1*	*2*	*0*	*2*
Rivers and lakes		**13.15**	**3**	**3**	**4**	**4**
	Highly modified natural water courses and canals	*5.99*	*3*	*3*	*4*	*4*
	Intensively managed fish ponds	*5.14*	*4*	*2*	*5*	*4*
	Interconnected running water courses	*16.51*	*3*	*3*	*4*	*4*
	Natural water bodies	*68.48*	*3*	*3*	*4*	*4*
	Ponds and lakes with completely man-made structure	*0.12*	*4*	*2*	*5*	*4*
	Separated water bodies belonging to the river system (dead side-arms, flood ponds)	*3.76*	*3*	*3*	*4*	*4*
Sparsely vegetated areas		**2.36**	**1**	**2**	**1**	**1**
	Bare rocks and rock debris	*0.29*	*3*	*1*	*0*	*4*
	Beaches	*6.43*	*1*	*2*	*1*	*2*
	Dunes	*77.87*	*1*	*2*	*1*	*2*
	River banks	*0.56*	*1*	*2*	*1*	*2*
	Sparsely vegetated areas	*14.84*	*1*	*1*	*0*	*0*
Urban		**0.77**	**1**	**0**	**1**	**2**
	Green urban areas and leisure facilities	*1.11*	*3*	*1*	*1*	*2*
	Industrial, commercial and military units	*8.56*	*1*	*0*	*1*	*1*
	Land without current use	*0.84*	*1*	*0*	*1*	*2*
	Mineral extraction, dump and construction sites	*3.10*	*2*	*0*	*5*	*1*
	Port areas	*4.66*	*1*	*3*	*0*	*1*
	Railways and associated land	*0.03*	*2*	*0*	*0*	*1*
	Road networks and associated land	*9.09*	*2*	*0*	*0*	*1*
	Urban fabric (predominantly public and private units)	*72.62*	*0*	*0*	*1*	*3*
Wetlands		**44.87**	**4**	**2**	**1**	**2**
	Inland freshwater marshes	*100.00*	*4*	*2*	*1*	*2*
Woodland and forest		**5.43**	**4**	**4**	**4**	**4**
	Broadleaved swamp forest	*0.23*	*4*	*5*	*5*	*5*
	Lines of trees and scrub	*0.05*	*3*	*2*	*1*	*2*
	Other natural and semi natural broadleaved forest	*80.20*	*4*	*5*	*5*	*5*
	Other natural and semi natural coniferous forest	*6.78*	*4*	*5*	*5*	*5*
	Other natural and semi natural mixed forest	*0.88*	*5*	*5*	*5*	*5*
	Transitional woodland and scrub	*11.86*	*3*	*2*	*1*	*2*

Table 2: Weight of ecosystem general category and sub category and their associated categories of ecosystem services ranks (0 – no potential of services, 5 – full potential)

Ecosystem services

The biophysical structure of complex of ecosystems provide in different degree a set of ecosystem services. The importance of these ecosystems are reflected by their ranks (Tab. 2, Fig. 3).

Maps of ecosystem services

Ranks associated to different ecosystems where mapped so the distribution of different ranking values can be observed spatially (Fig. 4).

Discussion

We are considering that our exercise is useful for capturing in a participatory way the end-users perceptions regarding the services provided by ecosystem in an area. Linking the ecosystem distribution map with their services is important especially when communicating the importance of different ecosystems as well as for planning and making decisions.

We noticed that the knowledge and experience of experts or stakeholders involved in the ranking process of ecosystem services importance can greatly influence the final result. So that, analysis and selection of stakeholders are very important in such an approach.

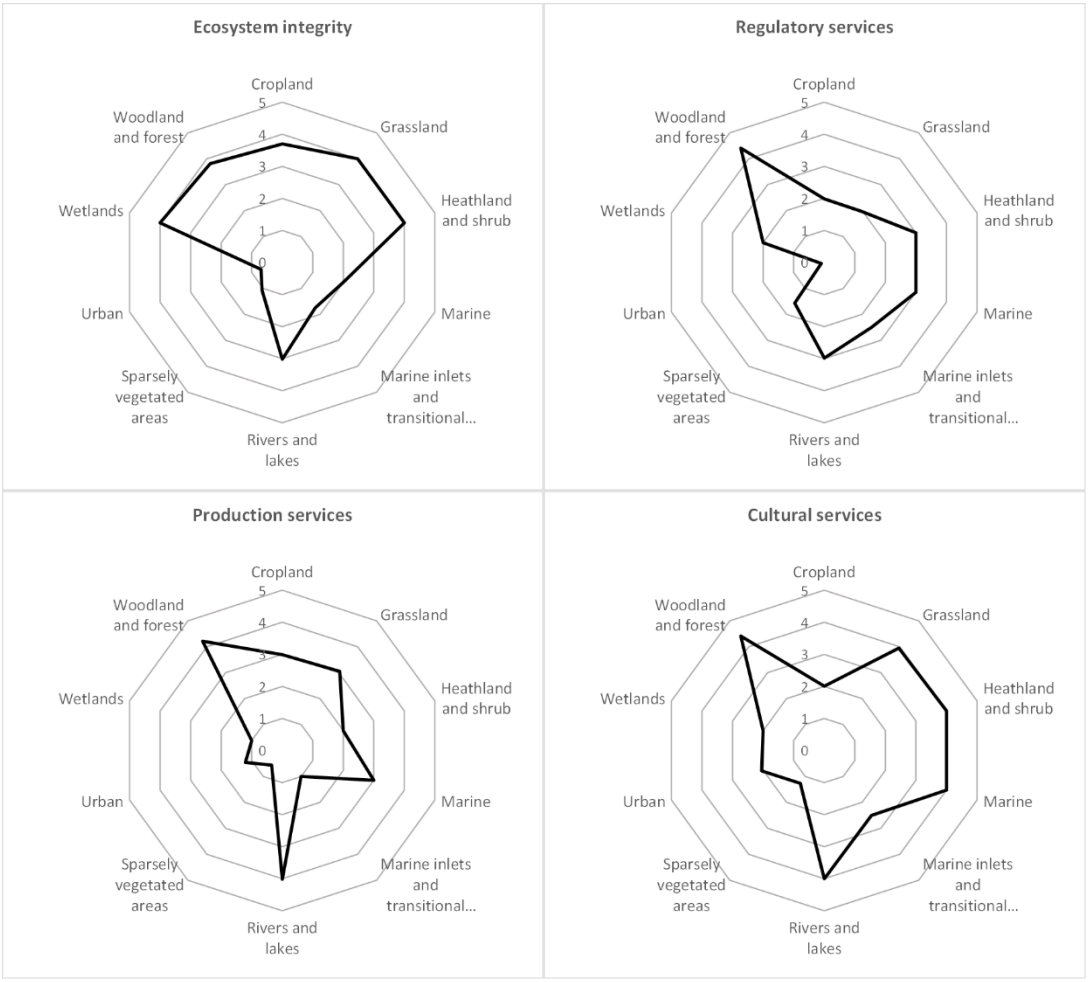

Figure 3: Importance of different ecosystem types for the provisioning of different services

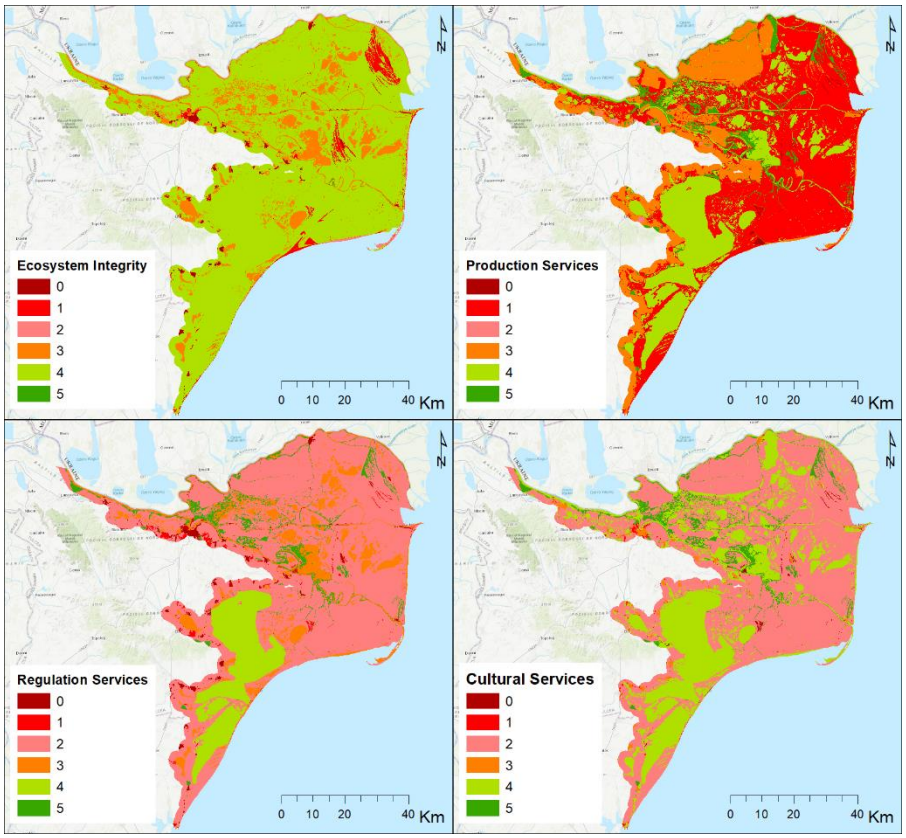

Figure 4: Maps of general categories of ecosystem services: a) ecosystem integrity, b) production services, c) regulatory services, d) cultural services (0 – not provided service, 5 – full provided service)

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