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Assessment of Ecosystem Services for Planning of Green Infrastructure at the Regional Level

Maija Ušča
Institute of Agricultural Resources and Economics
Riga, Latvia
maija.usca@arei.lv

Ivo Vinogradovs
University of Latvia
Faculty of Geography and Earth Sciences
Riga, Latvia
ivo.vinogradovs@lu.lv

Agnese Reķe
University of Latvia
Faculty of Geography and Earth Sciences
Riga, Latvia
agnese.reke@lu.lv

Dāvis Valters Immurs
University of Latvia
Faculty of Geography and Earth Sciences
Riga, Latvia
davis.immurs@lu.lv

Anita Zariņa
University of Latvia
Faculty of Geography and Earth Sciences
Riga, Latvia
anita.zarina@lu.lv

***Abstract*—Ecosystem services (ES) are defined as the benefits that human beings derive from ecosystem functions. Assessment and mapping of these benefits are crucial for sustainable environmental planning and future natural capital. Green infrastructure (GI) is natural or semi-natural territories that provide wide range of ES. Human affected ecosystems tend to fail to provide certain sets of ES due to the trade-offs among those services, which could be mitigated through implementation of GI. Mapping of ES, as well as assessing the interactions among various ES and analysing their supply potential's cold/hot spots considerably enhances and substantiates the planning process of GI, particularly at the regional scale and for the territories with diverse landscape potential.**

The aim of this paper is to discuss the assessment of ES supply potential and analyse its spatial distribution to reveal cold/hot spots of ecosystem capacity to provide wide range services and functions for GI. The study presents GIS based assessment of ES in a case study of Zemgale Planning Region. ES supply potential was assessed for 27 Corine land use classes (CLC2018) together with 10 regulatory, 12 provisioning and 6 cultural ES. An expert-based ranking approach using a two-dimensional ES matrix and a geospatial analysis was applied to determine total ES supply potential, spatial patterns and relations among multiple ES. Additional statistical analysis (Getis-Ord Gi*) was performed on spatial distribution of regulatory ES to disclose statistically significant capacity of ecosystems to function as GI in given surroundings. Preliminary results show uneven distribution of ES, trade-offs between regulatory and provisioning ES and landscape dependent spatial clustering of these trade-offs supported by result of Getis-Ord Gi* analysis, thus laying a foundation for further planning of GI at the regional scale.

Keywords*—*ecosystem services, green infrastructure, Zemgale Planning Region.

Introduction

Ecosystem services (ES) are benefits that human obtain directly or indirectly from ecosystems [1]. In the Millennium Ecosystem Assessment all of the ES are classified into four categories: (1) supporting ES that are essential to provide other ecosystem services e.g., maintenance of biodiversity or habitat for species, biomass production, nutrient cycling and soil formation, (2) provisioning ES that provide people with direct benefits and can be identified as market value, e.g., hay for animal feeding, biomass for energy production, herbs for medical treatment, genetic resources, (3) regulating ES that are of paramount importance for the well-being of humanity, e.g., climate regulation, pollution reduction, erosion protection, (4) cultural EC that contribute to personal growth, raise knowledge, provide aesthetic enjoyment and recreational facilities, e.g., landscape and its aesthetic qualities and cultural heritage, providing the basis for recreation and tourism, as well as quality of life for living in that area [1], [2]. The concept of ES was introduced in 1980, but only during the last years the inclusion of ES in policy and decision-making processes has been advocated for promoting sustainable development [3].

The idea of ES is closely linked to other definitions of natural components and their multiple functions. In the course of development ideas of ES have been followed by concepts of green infrastructure (GI) as well as nature-based solutions [4]. The European Commission defines GI as "a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services such as water purification, air quality, space for recreation and climate mitigation and adaptation" [5]. GI also plays a vital role in the conservation and enhancement of biodiversity and in tackling habitat fragmentation [6]. In this research we use quantitative assessment of ES to

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define areas at the regional level where GI (e.g. value of biodiversity, watershed protection etc.) is insufficient of lacking in order to support policy decisions about further planning process of GI. Thus, the aim of this paper is to discuss the assessment of ES supply potential and analyse its spatial distribution to reveal cold/hot spots of ecosystem capacity to provide wide range services and functions for GI.

MATERIALS AND METHODS

A. Study area

The study area is an administrative territory – Zemgale Planning Region (ZPR) that covers 10 742 km² and is situated in the central part of Latvia. It is comprised by diverse landscape regions: large tracts of intensive agricultural fields, mosaic type landscapes, as well as areas with large forest or wetland areas. The distribution of landscape types is related mainly to geo-ecological potential of the area, such as soil fertility, topography, drainage conditions. However, socio-economic processes, such as land abandonment and depopulation, have also affected landscape functions in the last decades, especially in the territories of marginal locations and of low agricultural potential. There are several natural features of historical value, such as, the River Daugava and the River Lielupe, which determine the largest settlement areas (towns of Jelgava, Bauska, Jēkabpils and others), while the nature protection areas are related to the distribution of natural wetlands (mires and bogs), but also – river valleys.

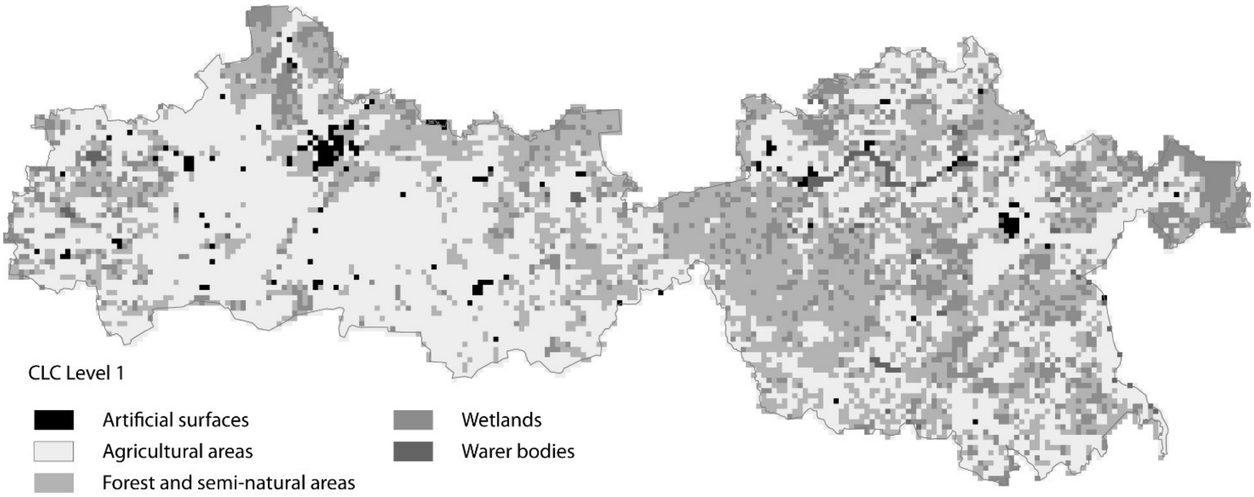

Fig. 1. Land use in ZPR according to (CLC2018)

According to the level 1 of Corine land use classes (CLC2018), the territory of ZPR is composed by 1.75% of artificial surface, 49.31% agricultural area, 45.11% forest and semi-natural area, 2.63% wetlands and 1.21% of water bodies (Fig. 1).

B. Methods

This study used the CICES v.4.3, the most widely used classification of ecosystem services, where support services are not considered separately, as they are assumed to be a prerequisite for other service categories. The ES matrix method, developed by Burkhad et al. [8] – [10], was used to assess the ES. It is a semi-quantitative, adaptive and efficient GIS technique to assess the potential of ecosystems to provide certain services based on the type of Land Cover / Land Use (LCLU). This method uses the CORINE LCLU type class as a basis for expert judgment on the potential of this class to provide a separate service. A list of ES that included regulatory ES and supply ES (Table 1) was adapted from previous studies [1], [11] – [13] and adjusted to the specifics of the ZPR. The expert assessment was based on the ES assessment study [14] in the territory of Lithuania. The ES potential was mapped using a 1x1 km grid to provide further data analysis capabilities, especially hot and cold spots, ES clusters, and ES interactions. The grid used is fully in line with the grid of data collection of the Central Statistical Bureau of Latvia, thus it contains the potential to link the analysis of the spatial distribution of ES supply potential to the socio-economic indicators.

The results of the identification of the ES supply potential were used to identify ES clusters - ES bundles within which the ES interacts. The analysis was performed in SPSS software using the Principal Component (PCA) statistical procedure, which is able to divide the dataset into components, thus highlighting potential ES bundles. Sums of ES supply potentials of the ES Group (Regulatory, Production, Cultural) were used as a basis for spatial-statistical analysis in ArcGIS software using the Hot Spot Analysis (Getisi-Ord Gi *) procedure, thus separating statistically significant cold and hot spots of the ES group's supply potential.

TABLE I. Ecosystem services used in the study and indicators describing them (CICES)

Ecosystem services	Potential indicators
Regulating EC	
Global climate regulation (GCR)	Emitted-associated CO^2, methane, water vapours, etc..
Local climate regulation (LCR)	Temperature (amplitudes), albedo, precipitation, evaporation.
Air quality regulation (AQR)	Leaf area index, amplitude of pollution indicators.
Water flow regulation (WFR)	Amount of water on hold
Water purification (WP)	Water quality and quantity
Nutrient regulation (NR)	Balance of N, P and other substances
Erosion regulation (ER)	Quantity of particles on hold, ground coverage
Natural hazard regulation (NHR)	Quantity of floods, fires, frequency pf them
Pollination (POL)	Number of pollinators
Pest and disease control (PDC)	Diversity of landscape and species, spreading of diseases and pest sites
Provisioning EC	
Crops (CRO)	Harvest, t/ha
Biomass for energy (BFE)	Biomass t/ha, kJ/ha
Fodder (FOD)	Fodder t/ha
Livestock (LST)	Animal units /ha
Fibber (FBR)	Fibber t/ha
Timber (TBR)	Timber m^3/ha
Wood fuel (WDF)	Wood m^3/ha
Fish (FSH)	t/ha
Aqua culture (AQC)	t/ha
Wild foods and resources (WDR)	t/ha
Biochemicals and medicine (BCM)	t/ha
Fresh water (FRW)	m^3/ha
Cultural EC	
Recreation and tourism (RCT)	Relative fitness of the ecosystem for recreation and tourism
Landscape aesthetics and inspiration (LAI)	Relative suitability of the ecosystem for enjoyment and inspiration
Knowledge systems (KNS)	Relative relevance of the ecosystem to the maintenance of knowledge systems
Religious and spiritual experience (RSE)	The relative capacity of the ecosystem to provide religious and mental experience
Cultural heritage and cultural diversity (CHD)	Relative relevance of the ecosystem to the maintenance of cultural heritage and diversity
Natural heritage and natural diversity (NHD)	Relative relevance of the ecosystem to the maintenance of cultural heritage and diversity

RESULTS AND DISCUSSION

Assessment of ecosystem services was based on CORINE CLC type classes. The assessment was carried out on a relative scale of 1-5, indicating the potential of the given ES collateral (1-very low, 2-low, 3-average, 4-high, 5-very high). 0 is given in a situation where the service is not provided (Table 2).

TABLE II. Expert assessment by categories of EC

CLC type (Corine)	The sum of regulating ES	The sum of provision ES	The sum of culture ES	Total EP POTENCIĀLS
Discontinuous urban fabric	3	2	17	22
Industrial or commercial units	0	1	4	5
Road and rail networks	0	0	10	10
Airports	0	0	0	0
Mineral extraction sites	0	8	5	13
Dump sites	0	3	1	4
Sport and leisure facilities	14	0	9	23
Non-irrigated arable land	11	24	13	48
Fruit trees and berries	22	16	17	55
Pastures	20	19	16	55
Complex cultivation patterns	15	18	11	44
Agriculture & natural vegetation	25	21	19	65
Broad-leaved forest	49	22	20	91
Coniferous forest	46	22	22	90
Mixed forest	47	22	21	90
Natural grassland	28	14	19	61
Transitional woodland shrub	19	9	11	39
Inland marshes	29	9	13	51
Peatbogs	35	7	22	64
Water courses	21	17	22	60
Water bodies	24	20	22	66

The results obtained were analysed in the SPSS software, using the statistical procedure of the principle components analysis (PCA) and potential ES bundles were highlighted. Using the Hot Spot Analysis (Getisi-Ord Gi *) procedure in the ArcGIS software 1 x 1 km network grid, the cold and hot spots of statistically significant ES bundles potential were distributed. As the main trade-offs of ES in the context of green infrastructure are linked to benefits obtained from regulation of ecosystems, further in the research we will probe into one class of ES – regulating services. The map of regulating ES reveals the spatial distribution of hot and cold spots of the services (Fig. 2). The hotter the spot (red), the amount of service is higher, the colder the spot (blue), more statistically significant the lack of specific ES in the territory. Regional scale analysis of areas covered by forests (Fig. 1) reveal to be the hotspots of regulating ES (Fig. 2), while the areas intensively used for agriculture purposes as well as the territories with higher density of inhabitants reveal to be cold spots, i.e., spatial clustering of specific ES depends on the dominating land use.

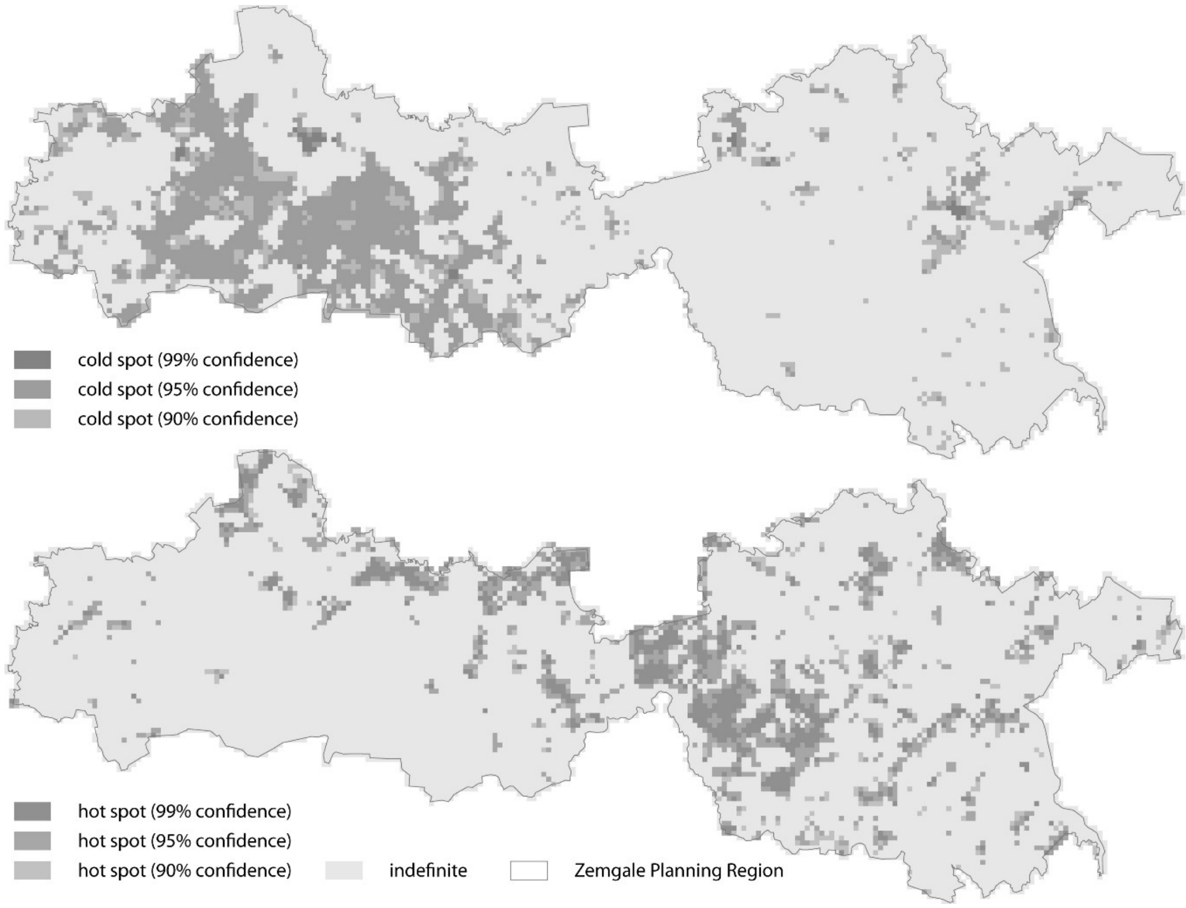

Fig. 2. The hot/cold spots of regulating ecosystem services supply potential in ZPR

The map of regulating ES reveals the spatial distribution of hot and cold spots of the services (Fig. 2). The hotter the spot (red), the amount of service is higher, the colder the spot (blue), more statistically significant the lack of specific ES in the territory. Regional scale analysis of areas covered by forests (Fig. 1) reveal to be the hotspots of regulating ES (Fig. 2), while the areas intensively used for agriculture purposes as well as the territories with higher density of inhabitants reveal to be cold spots, i.e., spatial clustering of specific ES depends on the dominating land use.

The central part of ZPR, where the landscape of agricultural lands with a dense network of rivers prevail, plays a crucial role in the warranty of provisional ES, but it lacks regulating ones. Thus, intensive farming practices result in contamination of surrounding water bodies and decline of biodiversity. It means that various components of green infrastructure dealing with the reduction of agricultural runoffs and pollution, e.g. buffer-zones between agricultural lands and water bodies that would minimize the negative impacts of agricultural pollution, should be planned and implemented in the agricultural landscape. At the same time trade-offs between provision ES and regulating ES should be analysed when planning green infrastructure.

More densely populated territories (towns and villages), disclose the lack of ES potential in both (regulating and provisioning) classes. In these areas cold spots of regulating as well as provisional ES prevail (Fig. 2). This is related to the continuous urban fabric, which significantly reduces the capacity of regulating and provisioning ES [14]. Therefore, when referring to green infrastructure, these territories should be taken into account primarily. Components of green infrastructure, e.g., buffer zones, green corridors and pathways, should be planned and implemented there.

In the context of the evaluation of the planning of GI, the main role is played by existing deployment and availability of regulatory ES. Previous researches have shown that management that attempts to maximize a particular ES often results in substantial declines in the provision of other ES [15]. Therefore, when assessing potential development areas of GI, deployment of provisioning and cultural ES should also be taken into account. This makes it possible to assess the relationship between all groups of ES and to find the best trade-offs between them.

CONCLUSIONS

The approach used in the research shows a capability to cover geographic areas at a regional scale in order to map ES. The results disclose the potential of ES assessment and mutual matching of them in order to find trade-offs between classes of ES in order to prioritize territories for GI development as well as to support and substantiate GI planning at the regional and national level. The method can support the decision-making processes in the field of regional planning, nature protection and GI development as a whole. Mapping of ES, as well as assessing the interactions among various ES and analysing their supply potential's cold/hot spots, considerably enhances and substantiates the planning process of GI, particularly at the regional scale and for the territories with diverse landscape potential.

This research is the first attempt to use the assessment of ES in GI planning at regional level in Latvia. The results reveal uneven distribution of ES thus showing the necessity to estimate trade-offs between regulatory and provisioning ES as well as landscape dependent spatial clustering of these trade-offs. Thus, the study is laying s a foundation for further planning of GI at the regional scale.

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