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PROBLEMS OF MAPPING PROVISIONING AND RECREATION ECOSYSTEM SERVICES IN METROPOLITAN AREAS

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PROBLEMY MAPOWANIA USŁUG EKOSYSTEMÓW ZAOPATRZENIOWYCH I REKREACYJNYCH W OBSZARACH METROPOLITALNYCH

STRESZCZENIE: Mapowanie potencjału usług ekosystemowych jest ważnym etapem identyfikacji korzyści prowadzonych przez ekosystemy i ich wyceny ekonomicznej. W artykule przedstawiono analizę dwóch kategorii usług ekosystemowych: zaopatrzeniowych oraz rekreacyjnych, które przeprowadzono dla trzech europejskich obszarów metropolitalnych, które łączy zastosowanie narzędzi planistycznych służących ochronie terenów otwartych. Badano obszary zielonych pierścieni rozciągające się w promieniu 20 km od granicy obszarów zwartej zabudowy. Jako podstawę analizy wykorzystano ogólnodostępne dane CORINE Land Cover. Badano w jaki sposób dane o pokryciu/użytkowaniu terenu powinny zostać wykorzystane do scharakteryzowania obszarów określonych jako zielone pierścienie. W granicach analizowanych buforów dominują usługi zaopatrzeniowe głównie produkcji rolnej. Określenie udziału obszarów usług rekreacyjnych jest w mniejszym stopniu zależne od cech użytkowania terenu i trudniejsze do oszacowania. Na przykładzie wykazano że ich udział może się wahać od dominującego do nieistotnego w zależności od przyjętych kryteriów. Zaproponowano uzupełnienie kryteriów definiujących tereny wykazujące potencjał dla tej usługi o informacje jakościowe dotyczące struktury własnościowej, intensywności produkcji rolnej oraz założeń rozwoju infrastruktury turystycznej. Wykazano że zastosowane podejście jest przydatne w porównaniach struktury przestrzennej potencjału dla serwisów ekosystemowych.

SŁOWA KLUCZOWE: usługi ekosystemów, mapowanie usług ekosystemów, kształtowanie obszarów metropolitalnych, zielony pierścień

Introduction

The two main approaches to research on Ecosystem Services (ES) mapping can be found in the literature during last few years mainly in special issue of Ecological Indicator no. 21 (2012). First1 mapping of ES through analyses of land cover or/and land use (LULC), where in the result one can get indirect information about Ecosystem Services potential. This makes possible to map benefits that come through general land management, but doesn't provide information on kind of ES and benefits that we can gain from particular ecosystem. The information is related usually to more than one type of Ecosystem Service, sometimes even to whole group as provisioning, regulating, cultural. As an example Burkhard[1] provisioning ES can be mapped through reduced information about land use as agricultural lands and forests. Second approach[2] is based on mapping of particular ES to capture relation between particular benefits and it's area of supply (sometimes also demand). This approach helps to define the actual area that brings the benefit to the very well defined category of ES. The disadvantage of such approach may be relatively narrow understanding of interrelations of the particular ES with other factors. As an example one can map flood regulating ES or fiber supply usually these kind of research refer to local scale because of very specify detail data.

In this paper we follow first of the mentioned approaches and focus on multifunctional aspect of ES mapping. Although mapping of ES based on LULC data was applied in some studies mentioned before, it hadn't been used such approach applied to the green belts.

We assess the areas that provide ES in metropolitan areas of selected European cities: London, Vienna and Randstad. For all of them tools were proposed to apply for open space protection in the surroundings of the city/cities to control urban sprawl. This kind of planning instrument is used to be called *green belt*. The concept of green belt for more than 100 years inspired city planners to keep the outskirt of the cities out of built up areas, that mean areas with strong limitation of new development[3] The list of main goals to use this planning instrument for these cities is presented in Table 1. There are different reasons to protect open spaces around analyzed cities related to various roles to sustain them.

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[1] B. Burkhard, F. Kroll, B. Nedkov, F. Müller, *Mapping ecosystem service supply, demand and budgets*, "Ecological Indicators" 2012 no. 21, p. 17-29; L. Koschke, C. Fürst, S. Frank, F. Makeschin, *A multi-criteria approach for an integrated land cover based assessment of ecosystem services provision, "*Ecological Indicators" 2012 no. 21, p. 54-66.

[2] F. Eigenbrod et al., *The impact of proxy-based methods on mapping the distribution of ecosystem services,* "Journal of Applied Ecology" 2010 no. 47, p. 377-385; S. Frank, Ch. Fürst, L. Koschke, F. Makeschin, *A contribution towards a transfer of the ecosystem service concept to landscape planning using landscape metric, "*Ecological Indicators" 2012 no. 21, p. 30-38.

[3] P. Hall, *Cities of Tommorow,* Oxford 1990; M. Amati, M. Yokohari, *The establishment of the London Greenbelt: Reaching consensus over, "*Journal of Planning History" 2007 no. 6, p. 311-337; H.W. Frey, *Not green belts but green wedges: the precarious relationship between city and country*, "Urban Design International" 2000 no. 5, p. 13-25.

In Vienna the main goal was to protect nearby forest for recreation needs, then also to conserve traditional agriculture as vineyards and to keep agriculture on the best Austrian soils in Danube valley[4]. Similar motivation was to establish the green heart of the Netherlands in Randstad consisting of agricultural lands. The iconic example of greenbelt in London had been set to control urban sprawl but also to preserve productive agricultural areas and green open spaces suitable for recreation[5]. Additionally the table shows difference between functions that are fulfilled by open spaces in the surrounding of the analyzed ten cities. Functions of greenbelt and the like instruments had been analyzed by Yokohari, Yang and Jinxing, Bengston and Youn, Amati and Yokohari[6].

Open spaces within greenbelts mostly consist of natural and seminatural ecosystems that provide variety benefits to cities inhabitants[7,8]. Benefits provided by green belts are contemporary understood through the ES concept. Discussion how functions of landscape or environment can be transmitted to ecosystem services is still quite dynamic starting from Jax, Wallace, Bollinger and Kienast, till Haines-Young, Potschin and Kienast and also Burkhard et al.1[9]. Additionally the problem can be understood wider – while functions are mainly understood by environmentalist as natural processes by planners or urbanists functions are more recognized as management (uses) of the land (landscape).

Main aim of this paper is to find out how (or if) the differences in the LULC between the compared areas influence green belt functions. For this reason we selected those which occur in almost all European metropolitan areas: recreation and protection of agricultural land. We investigate how much of the metropolitan area provides potential two groups of ES: provisioning and cultural. To reach this

[4] M. Breiling, G. Rulad, *The Vienna Green Belt: From Localized Protection to a Regional Concept,* in: M. Amati (ed.), *Urban green belts in the Twenty-first Century*, Ashgate 2012.
[5] M. Amati (ed.), op. cit.
[6] M. Yokohari, K. Takeuchi, T. Watanabe, p. Yokota, *Beyond greenbelt and zoning: A New planning concept for environment of Asia mega-cities,* "Landscape and Urban Planning" 2000 no. 47, p. 159-171; J. Yang, Z. Jinxing, *The failure and success of greenbelt program in Beijing,* "Urban Forestry&Urban Greening" 2007 no. 6(4), p. 287-296; D. Bengston, T-C. Youn, *Urban Containment Policies and the Protection of Natural Areas: The Case of Seoul's Greenbelt*, "Ecology and Society" 2006 no. 11(1). M. Amati, M. Yokohari, *Temporal changes and local variations in the functions of London's Greenbelt*, "Landscape and Urban Planning" 2006 no. 75(1-2), p. 125-142.
[7] R.S. de Groot, M. Wilson, R. Boumans, *A typology for the description, classification and valuation of Ecosystem Functions*, "Goods Services Economics" 2002 no. 41(3), p. 393-408.
[8] R.S. de Groot, *Function-analysis and valuation as a tool to assess land use conflicts in planning for sustainable, multi-functional landscapes*, "Landscape and Urban Planning" 2006 no. 75, s. 175-186.
[9] K. Jax, *Function and "functioning" in* ecology*: what does it mean?,* "Oikos" 2005 no. 111, p. 641-648; K.J. Wallace, *Classification of ecosystem services: problems and solutions*, "Biological Conservation" 2007 no. 139, p. 235-246. J. Bollinger, F. Kienast, *Landscape Functions in a Changing Environment,* "Landscape Online" 2010 no. 21, p. 1-5. R. Haines-Young, M. Potschin, F. Kienast, *Indicators of ecosystem service potential at European scales: Mapping marginal changes and trade-offs*, "Ecological Indicators" 2012 no. 21, p. 39-53. F. Kienast et al., *Assessing landscape functions with broad-scale environmental data: insights gained from a prototype development for Europe*, "Environmental Management" 2009 no. 44, p. 1099-1120.

Table 1
Goals and instruments used to protect open spaces within analyzed metropolitan areas

Goals to protect open spaces within metropolitan areas	Tool to protect open space within metropolitan areas	City
Recreation areas Tradition of agriculture Limitation of urban sprawl	System of protected open spaces within metropolitan area	Vienna
Control urban sprawl Physiognomic/ landscape protection Protection of agricultural land Recreation areas	System of open spaces that surrounds the city	London
Productivity of agricultural land Limitation of urban sprawl Recreation areas	System of open spaces is located inside the group of cities (polycentric region of Amsterdam, Rotterdam, the Hague and Utrecht)	Randstad

Source: own elaboration based on planning documents for London, Vienna and Randstad metropolitan areas.

objective we test how the information on potential for these ES might be represented with simple and widely accessible data from European databases (LULC and protected areas). If successful, such approach might be useful tool for comparisons made over a large number of compared metropolitan areas across the Europe, where completing the detailed data for all of these is almost impossible.

Methods

Three European metropolitan areas: Vienna, London and Randstad were chosen for analysis. They represent different types of greenbelts (Table 1), similar goals to set this planning tool and some dissimilarities between the local conditions reflected in the LULC structure within their green belts. The second criterion was similarity of the goals and applied tools for open spaces protection. The area of green heart within conurbation of Randstad (Amsterdam, Rotterdam, The Hague) was added to the analysis because of its specific unique character non comparable to the other European green belt areas, especially related to the cultural functions fulfilled (for details see discussion section).

The green belt areas were analyzed as buffer zones of the fixed radius of 20 kilometers around main urban areas of the cities. Such approach, in opposite to the use of legal borders of protected greenbelts of various sizes and character, facilitates comparison of the analyzed areas. The radius of 20 km was determined through the landscape structure analysis, which result was that the configuration specific for the green belt areas can be mostly found within this distance. This extent is also comparable to the areas considered as green belt around most of the European cities.

For mapping of the ES the widely accessible European datasets were used: Corine Land Cover 2000 (CLC) and EU nature protection areas Natura 2000 sites (EEA). The reference scale of CLC database is 1:100 000, which is widely agreed as appropriate for comparisons of such large areas. The thirty five LULC categories are provided for the analyzed metropolitan areas. These were grouped to characterize the potential for the two main benefits: provisioning and recreation ES.

The Provisioning Ecosystem Services or production functions are understood in this study according to de Groot as biomass production – agriculture, timber production and also other energy resources. The group of provisioning ES we refer to the feeding function of green belt – preserving farmland, best soils and traditional farming types as vineyards, pastures or simply preserving economic value of agriculture, but also to keep forest for timber production, and some areas suitable for mineral extractions. This approach was also presented by de Groot, Koschke and Burkhard1215. Similar to Koschke and Burkhard12. As offering potential for the provisioning ES the following categories were used: all classes of agricultural areas (CLC 211-244), mineral extraction sites (CLC 131) as well as nonproductive forest. To delimit the last category protected areas of Natura 2000 sites were excluded from combined three kinds of forest: broad leaved (CLC 311), coniferous (CLC 311) and mixed (CLC 312).

Among cultural ES we focus on areas suitable for recreation. Bengston and Youn12 as well as Amati and Yokohari13 bring emphasis to the substantial role of the metropolitan areas potential for recreation to supply leisure and sport areas in and out of the city limits. In definition of land use important for recreation we follow the approach proposed by Koshke et al.2 and Burkhard et al.1 and use the following classes: green urban areas (CLC 141), sport and leisure areas (CLC 142), water courses and water bodies (CLC 511, 512), from class of forest and seminatural areas we consider all forests groups, scrub and/or herbaceous vegetation associations, from class of open spaces we included beaches, dunes, sands (CLC 311, 312, 313. 321, 322, 323, 324, 331). Additionally, according to the recommendation these authors, selected agricultural lands classes were added with significant share of natural vegetation as: pastures, complex cultivation patterns, land principally occupied by agriculture with significant areas of natural vegetation, agro-forestry areas (CLC 231, 242, 243, 244) and one class of permanent crops vineyards (CLC no. 221).

The assessment of the metropolitan areas potential to fulfill the ES is performed separately for each group: provisioning and recreation. The percentage of the area is calculated occupied by the combined LULC classes within the whole green belt area. Also the configuration of the areas covered by these classes is visually analyzed. This allows us to check if there is a relation between these characteristics and declared green belt like instruments for these areas.

Results

The comparison of areas with potential for provisioning and recreation functions is provided in Figure 1a as percentage of the green belt areas of the three analyzed cities. The spatial distribution of these areas is presented on maps shown on Figure 2.

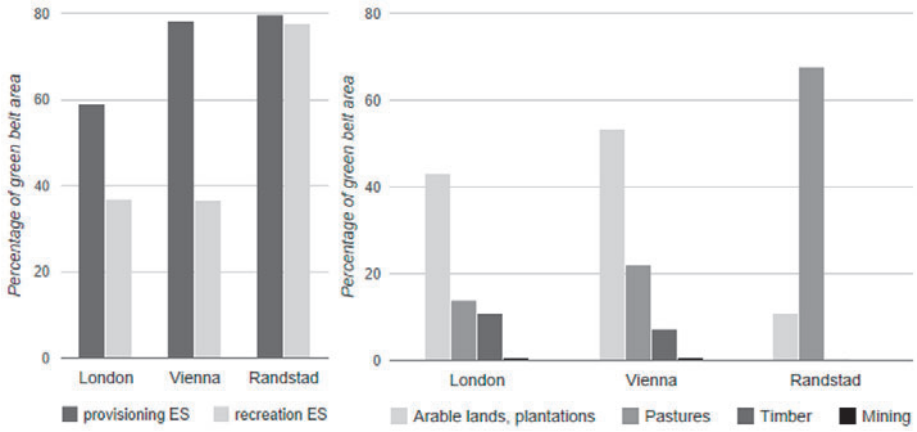
The areas of the provisioning ES are significant for all compared areas, especially for Randstad and Vienna (almost 80%) in London this area is relatively smaller (59%). From three ES types that contain provisioning group (Figure 1b) the food production prevails in metropolitan areas. In all buffer zones agricultural land that converts solar energy into edible plants and animals covers the highest area and fulfils the vital role to supply the city. These areas mainly consist of croplands in London and Vienna, and in Randstad pastures dominate. Substantial is small proportion of productive forest, particularly in conurbation of Randstad (the Netherlands) and London. Mineral extraction within analyzed areas has no significant role.

Predominant agricultural function suggests that the ecosystems within green heart of Randstad and in the surroundings of Vienna and London have a significant impact on city vitality. The spatial analyzes of the provisioning ES within all ten metropolitan areas clearly reflect goals of open space (green belt like instruments) protection proposed by planners. In addition, clearly marked by a lack of productive forests in vicinity of the Randstad and London.

ES related to recreation usually concern outdoor activities, but also provide leisure facilities i.e. those elements which enhance the recreation ability of the area. The largest area with potential of recreation arise in Randstad with almost

Figure 1

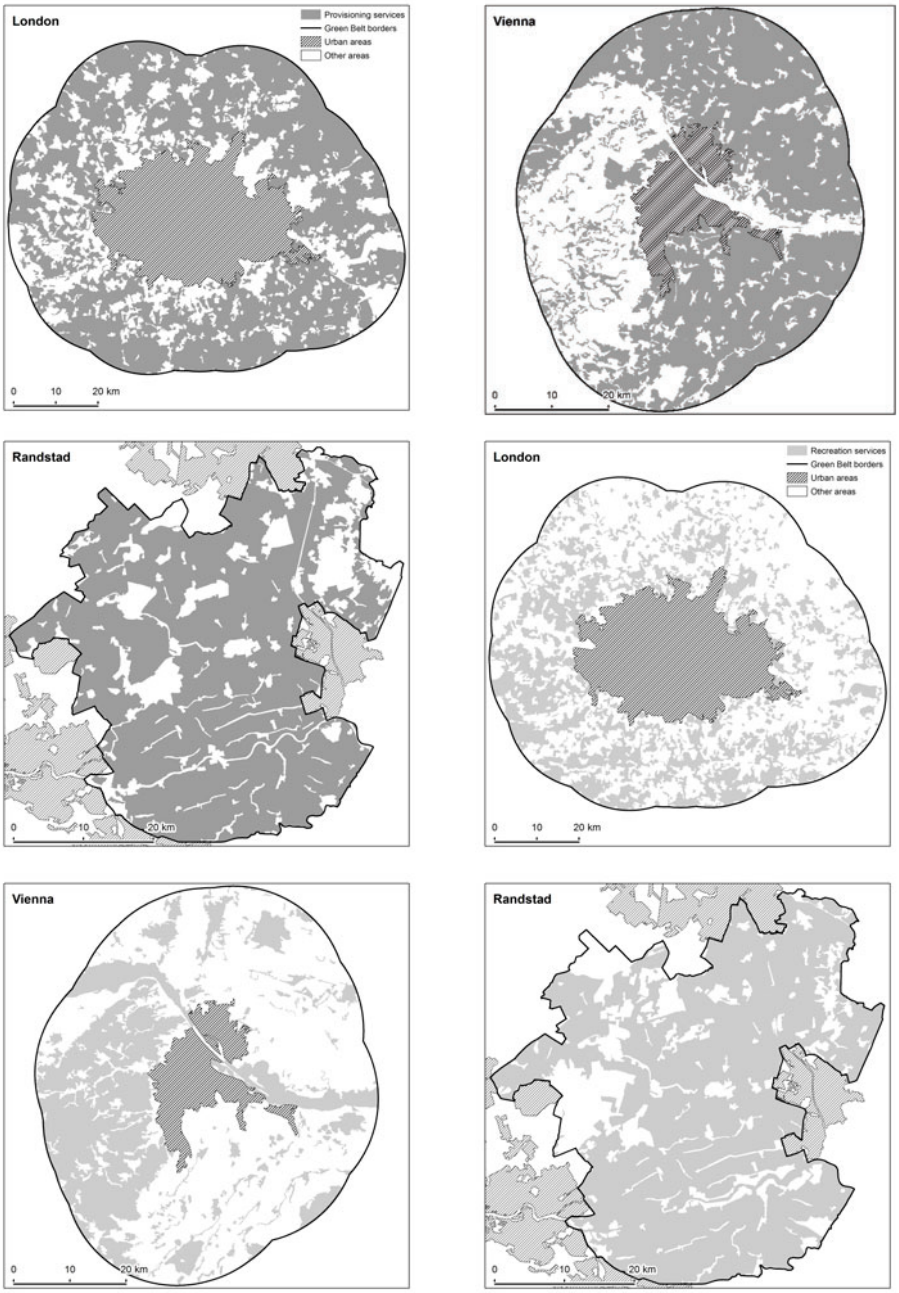
The percentage of the areas within buffer zones of metropolitan areas of London, Vienna and Randstad: a) comparison between provisioning and recreation ES, b) structure of provisioning ES



Source: own study.

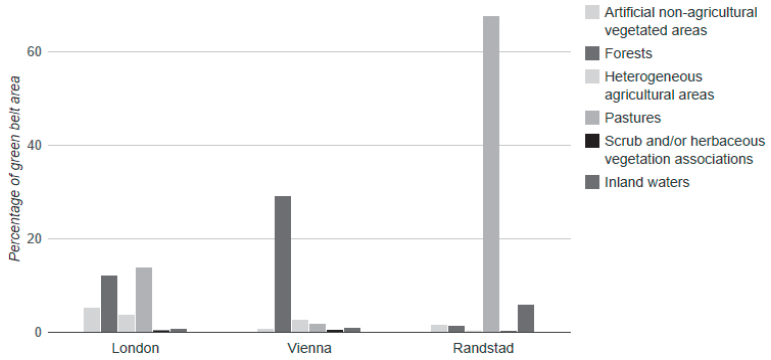
Figure 2

Areas with potential of providing two groups of ecosystem services (upper line) provisioning and (lower line) recreation within buffer zones of metropolitan areas of London, Vienna and Randstad



Source: own study.

Figure 3
The percentage of the areas within buffer zones of metropolitan areas of London, Vienna and Randstad with detailed structure of recreation ES



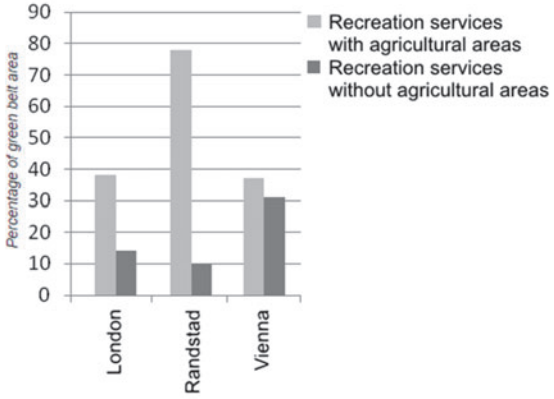
Source: own study.

80% cover of all the analyzed area. This area is mostly used as agricultural lands, particularly pastures. In other metropolitan areas less than 40% are covered by the recreation function. This is a result of different proportion between the pastures (London 14%, Vienna 22%) and arable lands which are not suitable for recreation. The detailed LULC structure (Figure 3) shows three kinds of areas playing main role within recreation areas of the green belts: pastures in Randstad (68%), forest in Vienna (29%), and both classes are significant in London (pastures 14%, forest 12%). In Randstad water bodies are also visible (6%). The results suggest that areas supplying the city with food and raw materials, are in parallel of the greatest potential for outdoor recreation.

It might be considered as a kind of surprising that Vienna area with more significant share of forest areas looks to be less suitable for recreation than Randstad where open spaces are dominant. Therefore further analysis was performed to investigate how the recreation function should be considered. For this reason we mapped it using changed criteria, namely without the most doubtful agriculture categories as pastures, complex cultivation patterns, land principally occupied by agriculture and agro-forestry areas. The result is compared to the hitherto considered percentage of land cover including these areas on Figure 4. Two kinds of metropolitan areas are visible in the results.

First, the differences in the mapped areas with capacity for recreation are major in the Randstad, London and in Vienna the difference is rather minor, less than the 10 percent points. The highest differences are noticeable in the Randstad where it reaches nearly 70% of the cover area. That means that the recreation function is determined by ecosystems created mainly by pastures, and also to a minor extent: complex cultivation patterns, land principally occupied by agriculture and agro forestry areas.

Figure 4
Two versions of percentage of the area with capacity to recreation ES.

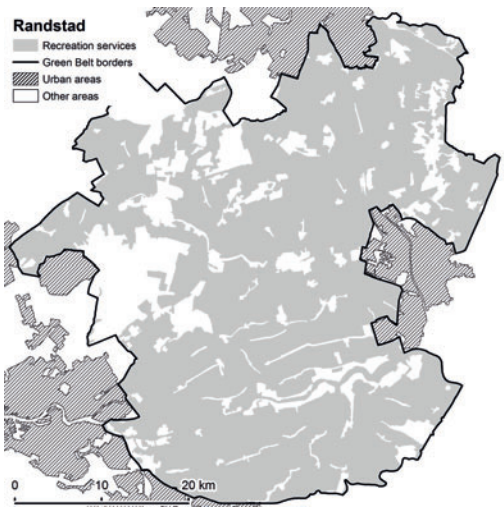


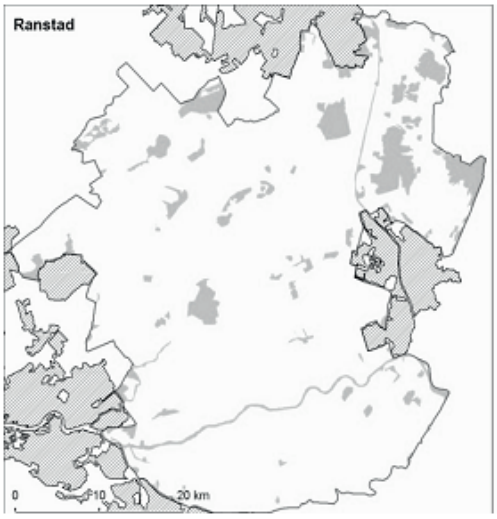
Source: own study.

Figure 5
Comparison of two approaches to Recreation ES mapping

5a – map that contains CLC categories as: green urban areas, sport and leisure areas, water courses and water, all group of forests scrub and/or herbaceous vegetation associations, beaches, dunes, sands and from agricultural categories: pastures, complex cultivation patterns, land principally occupied by agriculture, agro-forestry areas, vineyards and olive groves

5b – map that contains CLC categories as: green urban areas, sport and leisure areas, water courses and water, all group of forests scrub and/or herbaceous vegetation associations, beaches, dunes, sands and from agricultural categories: vineyards and olive groves





Source: own study.

The two versions of mapped recreation ES are presented in figure 5: a) shows the map obtained when meadows and pastures were included to the analysis, b) green heart zone with categories of recreation when the controversial categories are excluded. The comparison of these two approaches shows contrast in interpretation of existence of the potential for recreation ES within the Randstad area. In first figure this area is mostly suitable for outdoor activities, while according to the second, this area is not suitable.

Discussion and conclusions

In this paper we show that the proposed approach for mapping of the potential for provisioning and recreation ES using combined LULC classes provides satisfactory overview. This confirms findings of above cited authors. Although such comparison was not performed for green belt areas.

Further discussion is still needed on criteria used for definition of the ES groups. While provisioning ES are relatively accurately defined (the area of food and fiber production is rather clear), many doubts arise concerning ambiguously defined criteria that delineate categories of LULC suitable to recreation. In the literature main discordances are associated to the categories of agricultural areas. For example some authors consider the role of arable lands class (CLC 211) as ecosystems appropriate to outdoor recreation20, while others1 note their minor role. According to research of Koschke other classes: pastures, complex cultivation patterns, land principally occupied by agriculture, with significant areas of natural vegetation, agro-forestry areas, vineyards, and also olive groves seem to be proved as ecosystems that supply recreation activities.

Based on the provided comparison we suggest that one of solutions might be individual definition of recreation ES areas according to the following factors: intensity of agriculture, ownership structure, tradition of the recreation infrastructure development. First two factors might be considered as comparison of the Vienna area with Randstad and London. The most of Austrian agricultural areas are accessible for recreation and the intensity of agriculture is relatively lower than in the Randstad area as vineyards. In London area the habit of fencing parcels may limit accessibility of agricultural lands. The tradition of recreation infrastructure development in most of European countries causes concentration of the main tourist infrastructure (picnic areas, hiking nodes or starting tours places) near natural and seminatural areas: forests, watercourses. In the areas of accessible agricultural lands such elements are also present: biking or hiking trails and other elements as view towers or vista points. Nevertheless its presence corresponds to the goals of developments of the tourist infrastructure. Metropolitan buffer of Vienna is again different in this field than other analyzed areas, where long distance trails are kind of tradition. It seems that based on above provided conditions the three areas analyzed within this study might be accounted to two separate groups with different criteria of definition of the recreation

ES. Nevertheless such definition causes many doubts with comparisons of separately defined areas, what is subject to further research.

Within this paper we show that the proposed approach is useful for comparison between the different areas. The advantage is using data, which are widely accessible and standardized for the whole European Union. The proposition of grouping of the green belt areas with similar conditions for particular ES facilitates relation of the applied instruments to other areas where such solutions are under consideration, like most of Polish metropolitan areas.

The presented approach provides additional information about function of open spaces within outskirt of big cities and could be helpful for planners to define greenbelt or greenbelt like instrument to protect ecosystems that brings various benefits for human beings.

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