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LAND USE DATASET COLLECTION AND PUBLICATION BASED ON LUCAS AND HILUCS

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Spatial data have become very important phenomena within the last decade in Europe due to a strong support from the political spectrum with regard to related legislation and resulting in financial support to several research, educational, and enlargement projects. INSPIRE (Infrastructure for Spatial Information in the European Community) Directive indeed defines the principles for the harmonization of spatial data infrastructure in the European community, including Land Use and Land Cover data themes. INSPIRE defines a methodology on how to transform datasets to common data models, but it does not cover the process of data collection and update, because it is out of its scope. Evaluation of the Land Use dataset derived from remote sensing products complemented by fieldworks has been realized since 2006 by Eurostat within the LUCAS (Land Use and Cover Area frame Survey) project. The work presented in this paper follows the LUCAS fieldwork methodology, which was applied during the fieldwork in July 2014 in the City of Zagreb (Croatia), to use at the local (municipal) geoportal level. The surveying groups collected point features with the following data type attributes: Land Use codes defined by HILUCS (Hierarchical INSPIRE Land Use Classification System) and optional Land Cover codes defined by LUCAS classification. In addition, photographs representing the observed areas were collected by cameras embedded in the mobile GIS platforms. An update of original topological layer was performed and Web GIS components for sharing the newly developed datasets were implemented. The results presented provide a suitable proposal for fieldworks methodology and updates of a land use database in line with the INSPIRE directive applicable at a local spatial data infrastructure level.

Keywords: Land Use, INSPIRE, LUCAS, Web GIS, Local SDI

Urban planning is a complex task requiring multidimensional urban information (spatial, social, economic, etc.). The need for assistance in performing urban planning tasks has led to the rapid development of urban information systems, especially “e-Planning” systems, with the support of government policy and emerging information and communication technologies (Wang et al., 2007). One of the important datasets required for local planning is data about the land: land use by type – residential, commercial, industrial, recreational and open space, institutional, etc.; by density / intensity; ownership; land supply/demand; development potential (Nedovic-Budic et al., 2004). Land use (LU) and Land cover are core information layers for a variety of scientific activities as well as administrative tasks (e.g. hydrological modelling, climate models, LU planning, integrated land management, agricultural crop mapping) usually covered by state public agencies. In the last decades, the LU coverage change has become an additional irreplaceable observation feature not only in Europe, but across the whole globe. LU and land cover mapping products are mandatory baseline datasets usually required for large areas with different levels of detail. Since, they should be provided in an interoperable way by applying harmonized, reliable, effective and efficient methods. To ensure this, space and aero remote sensing techniques integrated with field information collected by citizen sensors have been gaining ground against large scale statistical surveys based on in-situ observations (Manakos and Braun, 2014). Interoperability bridges the heterogeneity of datasets by transformation; a process, which switches from one state to another. These

procedures can be expressed by a simple change, but terms as converting, remodelling, reshaping are also used in the scientific terminology for transformation. In an established ‘Spatial Data Infrastructure’, SDI, a data provider publishes the data according agreed standardised data presentation to achieve the interoperability. The theoretical approach in an SDI for interoperability should be conducted, to keep the original data structure and publish data via transformation procedures with predefined mapping rules following the target specification (Granell et al., 2009).

The Directive 2007/2/EC establishing the Infrastructure for Spatial Information in the European Community (INSPIRE) entered into force on the 15th of May 2007. The main objective of the Directive is to establish the infrastructure for spatial information in Europe to support Community environmental policies. The INSPIRE addresses 34 spatial data themes organized in three groups reflecting different levels of harmonization efforts expected and a staged phasing (Cooper et al., 2011). Groups I and II focus on reference data, while Group III focuses on data for environmental analysis and impact assessment, including the LU data theme defined as territory characterised according to its current and future planned functional dimension or socio-economic purpose (e.g. residential, industrial, commercial, agricultural, forestry, recreational). The hierarchical INSPIRE Land Use Classification System (HILUCS) is a multi-level classification system developed for application to the existing and planned land use to ensure that the spatial data infrastructures of the Member States are compatible and usable in the European community and

transboundary context, the Directive requires that common Implementing Rules (IR) or components adopted in a number of specific areas (Metadata, Data Specifications, Network Services, Data and Service Sharing and Monitoring and Reporting) (Cetl et al., 2009). The European statistical office Eurostat carries out a survey on the state and the dynamics of changes in LU and land cover in the European Union called the LUCAS survey. The aim of the LUCAS survey is to gather harmonised data on land use/cover and their changes over time. In addition, the survey provides territorial information facilitating the analysis of the interactions between agriculture, environment and countryside. The surveys are done every three years. The LUCAS surveys are carried out in-situ; this means that observations are made and registered on the ground all over the EU. From LUCAS survey, 3 types of information are obtained: micro data (land cover, land use and environmental parameters associated to the single surveyed points, including transect information), point and landscape photos in the four cardinal directions and statistical tables with aggregated results by land cover, land use at geographical level. The land cover and the visible land use are classified according to the harmonized LUCAS land cover and land use nomenclatures, which is similar with INSPIRE's HILUCS nomenclature. The latest LUCAS survey (2012) covers all 27 EU countries. LUCAS points belong to the intersections of a 2 km grid that includes around 1 million points all over the EU. During the LUCAS 2012 survey, a sample of 270,000 of these points was visited on the spot by 750 field surveyors (Eurostat, 2013).

The manuscript describes the application of LUCAS observation methodology concepts and INSPIRE existing land use categories definitions. The practical exercise was carried out at the local SDI level during the summer GIS school held in Zagreb (July 2014). The work performed consisted in LU dataset collection, processing and publication. The material and methods chapter defines the study area details and reference input datasets provided by the city of Zagreb. Information about the methodology used during

the fieldworks, software used for data processing and publication is described further on. The results chapter reports basic statistics and final products produced by the project. Individual problems discovered during the newly developed dataset life cycle are discussed and conclusions are drawn.

Material and methods

Study area

The central part of the city of Zagreb was chosen as the territory of the LU dataset definition, with the Sava River as a natural boundary suitable for the allocation of survey zones. The selected area of Zagreb was divided into six survey zones (Figure 1) with various character of land usage. Briefly, Zone 1 is characterized by its recreational and sporting facilities. Zone 2 is

mainly residential. In Zone 3, there are administrative and commercial headquarters, with a distinctive urban character. Zone 4 has a varied distribution of agricultural, industrial and natural environments. Zones 5 and 6 are characterized by residential-commercial use with high amount of recreational areas (Figure 2).

The reference input spatial data were represented by a topographical dataset provided by the city of Zagreb, created as a product of remote sensing. The total area of observation was 1,825.4 hectares. The overall amount of polygon features that were present in the reference topographic dataset was more than 11,000. Original LU classification available in input dataset contained 23 categories. The basic statistics of the input dataset is reported in Table 1.

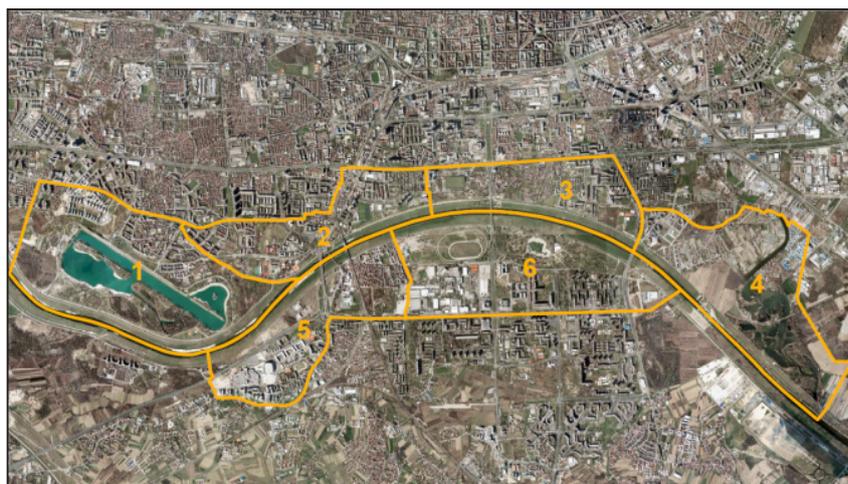


Figure 1 Study area – digital orthophoto with surveying zones boundary definition



Figure 2 Study area – Zone 6 input topographic database

Table 1 Land use categories and related spatial objects available in reference topographic dataset

Original nomenclature	Area in ha	Part from whole area in %	Feature count	Ø area of feature in ha
Residential and combined objects	74.76	4.10	3751	0.02
Public objects	13.48	0.74	213	0.06
Economical objects	45.87	2.51	844	0.05
Cultural objects	0.01	0.00	1	0.01
Religious objects	0.43	0.02	12	0.04
Other objects	15.7	0.86	2543	0.01
Road transportation	121.02	6.63	449	0.27
Railway transportation	3.2	0.18	6	0.53
Public transportation	6.07	0.33	29	0.21
Arable land	119.44	6.54	74	1.61
Grassland	416.09	22.79	1349	0.31
Fruit plants and vineyard	17.75	0.97	44	0.40
Park	229.13	12.55	654	0.35
Forests	98.97	5.42	20	4.95
Shrubland	40.72	2.23	43	0.95
Abandoned area	3.69	0.20	6	0.62
Public build up area	246.15	13.48	689	0.36
Economic build up area	47.13	2.58	30	1.57
Transportation build up area	0.17	0.01	1	0.17
Courtyard	117.46	6.43	306	0.38
Areas under construction	6.27	0.34	11	0.57
Water streams	84.05	4.60	13	6.47
Backwater	117.84	6.46	23	5.12
Total	1825.4	100.00	11 111	0.16

Data collection – field works

LU mapping has been already a subject of many scientific works, always depending on the context of use. For instance, agricultural land can be used for land consolidation projects and its impact on the visual

scenery of a landscape (Muchová and Petrovič, 2014), for soil bonitation and determination of soil prices (Stredánská et al., 2013), or for soil erosion determination and modelling (Lackóová et al., 2013; Urban et al., 2013). However, mapping in urban

spaces is applied in a different way, e.g. remote sensing data are more difficult to be used, and additional field works are required.

Mobile GIS devices Trimble Juno 3B with integrated, highly sensitive GPS receiver with Real-time measurement accuracy 2–5 meters and integrated 5Mpix camera and pre-installed mobile GIS software ESRI ArcPad were used for the field works. Custom form for creating and editing the feature attributes was developed with ArcPad Studio (Rusmore, 2002) utility and attached to the dataset observation points. Attributes such as HILUCS (Benner et al., 2013) LU and LUCAS LC codes (Gallego et al., 2008) together with cardinal direction photographs were implemented into the data model for field observations dataset. Surveying groups were taking observation for each accessible

**Figure 3** Example of a suitable position of observed points

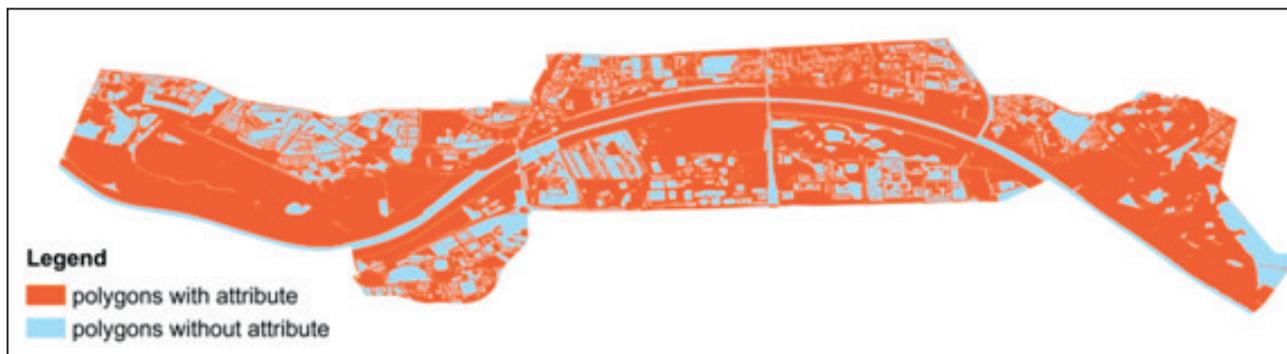


Figure 4 Map of polygons with attributes directly transposed from observed points

polygon present in the reference input topographic dataset (Figure 3); evaluating possible aggregation of the topographical features into a new LU feature based on HILUCS categories definitions and adapts the observation point for this purpose. For each observed point, a surveyor took one photograph for each cardinal orientation. The photographs aimed at capturing the observed areas in the best possible way.

Data processing

The main tool used for the data processing was GIS client Quantum GIS (QGIS) as a most advanced open source GIS editor, described by Tsou and Smith (2011). QGIS is freely downloadable and is distributed with open code with many available custom modules for integration, topological cleaning and processing of data of various types. To perform an update of the topological dataset with the newly collected LU code attributes, it has been necessary to match the observed characteristics from the survey points and merge it with the source polygon features. Taking the attributes of different layers into the target dataset was realized by joining the attributes of features by location. Join algorithm is based on the rule that the polygon which does not contain a point takes an attribute from the nearest point. But the rule of taking attributes based on the distance weight is not in the relationship with distribution of LU in the real world. For this reason, the joining algorithm from the observed points was restricted only for the polygons which contained a specific point. Before this process, each of the six working groups verified the accuracy of observed points and additionally adjusted or discarded the points from the next data processing.

Topology checking functionality provided by a custom QGIS module was used to verify the correctness of topological relation among features according to predefined rules.

Data publication – Web GIS

Geospatial data were published using the following Web GIS components:

- **GIS database** – The underneath GIS database was implemented using PostgreSQL, which is an open source object-relational database management system (ORDBMS) with an emphasis on extensibility and standards-compliance. Additionally, it allows managing geographic objects through its extension – PostGIS, which is an open source software product freely available to download and install. PostGIS adds extra data types (geometry, geography and others) to the PostgreSQL database. It also adds functions, operators, and index enhancements that apply to these spatial data types. These additional functions, operators, index bindings and types augment the power of the core PostgreSQL DBMS, making it a

fast, feature-plenty, and robust GIS database management system (Obe, 2011).

- **Web GIS server** – In order to accomplish the requirements for a Web GIS server component, we have used GeoServer open source software, which is designed to ensure interoperability by publishing data from any major spatial data source using open standards (Giannecchini and Aime, 2013).
- **Web GIS client** – Mapshup is a Web GIS client based on standard web technologies (i.e. JavaScript/CSS/HTML). The user interface is designed to work both on desktop and portable touchscreen devices through a standard web browser. It is able to connect to a large range of web services including: OpenStreetMap/Bing/Google maps as base maps layers, OGC services (WMS, WFS, CSW and WPS), Google Earth plugin, Google Streetview, Google Elevation, Flickr API, YouTube API, Wikipedia API, Geonames, RSS and Atom feeds, and other services. Out of the box functionalities, the following are included: auto-detection of data

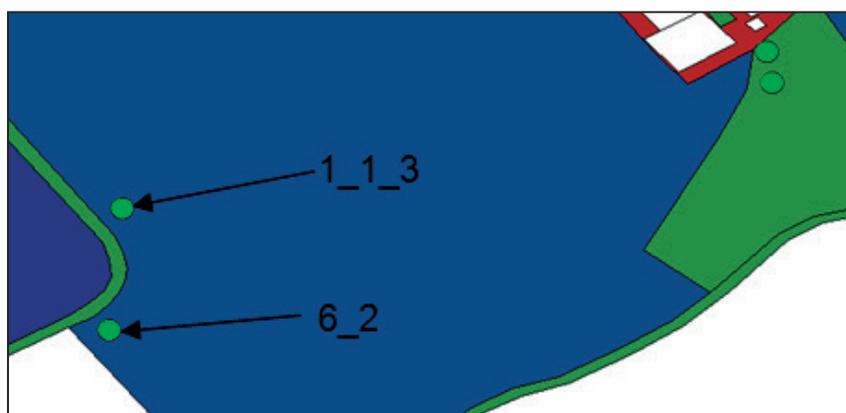


Figure 5 Surveying errors – Duplicated observed points with different HILUCS attribute values

Table 2 Distribution of HILUCS Land Use categories in the final dataset

HILUCS code	Nomenclature	Area in ha	Feature count	Ø feature area in ha
1_1_1	Commercial agricultural production	39.37	7	5.62
1_1_2	Farming infrastructure	4.51	2	2.25
1_1_3	Agricultural production for own consumption	58.48	53	1.10
1_2_1	Forestry based on short rotation	1.07	1	1.07
1_2_3	Forestry based on continuous cover	0.71	1	0.71
2_1_1	Textile manufacturing	2.40	1	2.40
2_1_6	Manufacturing basic metals	0.68	1	0.68
2_1_7	Manufacturing of non-metal products	0.34	1	0.34
2_3_1	Food and beverage manufacturing	0.64	1	0.64
2_4	Energy production	24.38	4	6.09
2_4_2	Energy production based on fossil fuel	0.05	1	0.05
3_1_1	Accommodation and food services	26.91	30	0.90
3_1_3	Other commercial services	6.43	36	0.18
3_1_4	Financial and insurance services	38.22	10	3.82
3_2_1	Professional services	2.23	3	0.74
3_2_2	Information and communication	1.45	1	1.45
3_2_3	Administrative services	10.36	4	2.59
3_2_4	Other financial services	0.24	1	0.24
3_2_5	Public administration	0.05	1	0.05
3_3_1	Education	1.35	4	0.34
3_3_2	Health and social services	18.08	27	0.67
3_3_3	Religious services	1.08	5	0.22
3_3_4	Other public services	1.69	6	0.28
3_3_5	Cultural services	0.06	2	0.03
3_4_1	Sports infrastructure	1.79	2	0.89
3_4_3	Open air recreational areas	115.68	78	1.48
3_4_4	Other recreational services	226.90	332	0.68
3_4_5	Other services	4.13	7	0.59
3_5	Road transportation	9.77	72	0.14
4_1_1	Railway transportation	204.07	222	0.92
4_1_2	Water transportation	6.36	19	0.33
4_1_5	Other transport networks	17.96	62	0.29
4_2	Logistical and storage services	19.16	7	2.74
4_3_1	Electricity, gas and thermal power distribution	0.70	6	0.12
4_3_3	Waste treatment	0.58	1	0.58
4_3_4	Other utilities	0.03	12	0.00
5_1	Permanent residential use	194.29	249	0.78
5_2	Residential use with other uses	118.80	135	0.88
5_3	Other residential use	0.48	1	0.48
6_1	Transitional areas	13.90	6	2.32
6_2	Abandoned areas	17.61	22	0.80
6_3_1	Land areas not in economic use	433.21	269	1.61
6_3_2	Water areas not in economic use	198.54	13	15.27
6_5	Areas without any specified planned use	0.76	3	0.25
Total		1825.53	1721	1.06

layers through Drag & Drop of files and/or URL addresses to the map, 2D and 3D support, content creation, context saving and sharing through email/Facebook/twitter. The user interface is „map centric“ by default. All information is displayed within the map which represents 100% of the view except for the top header bar which may contain generic actions as a free text search input form, the map backgrounds switcher, the share button, the help button, the login information. The user interface is designed to be easy to use on touch devices. As a consequence, each functionality is accessible through one single touch and „hidden“ menu are avoided as possible, making the user experience very intuitive (Gasperi et al., 2013).

Results and discussion

The fieldwork lasted four days and resulted in the total number of 1,755 observation points collected by six working groups. Initial verification of observations during the data processing phase filtered a set of 132 points that were not used for the further classification due multiple and outlier measurement.

The results of an automatic attribute joining by location of observations with reference topographic dataset, represented 1,099 features (9.89% of the source dataset feature count). The total area classified by HILUCS codes covered 1,259.12 hectares (68.98% of the entire area of interest) (Figure 4).

Additionally, 566.4 hectares of Land Use (31.02% of features) were determined manually. In the source topographic dataset reference topographic dataset, the average area of available land use features represented 0.16 hectares for land use categories, which after data processing became 1.06 hectares. The number of objects was more than 11,000, which was processed to 1,721 what constitutes about 6.5-fold reduction. The representation of HILUCS Land Use categories classification in final dataset is presented in Table 2. Compared with the initial classification (Table 1), there is apparent higher resolution of the INSPIRE Land Use classification in the same areas, but with less polygon

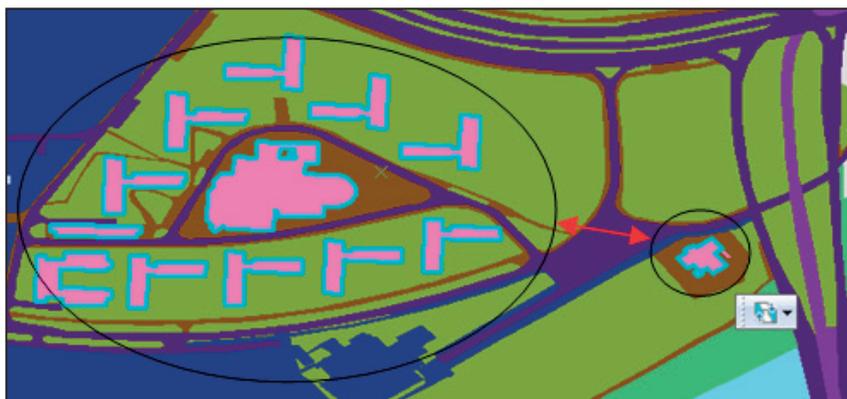


Figure 6 Merging features without the relationship in real world

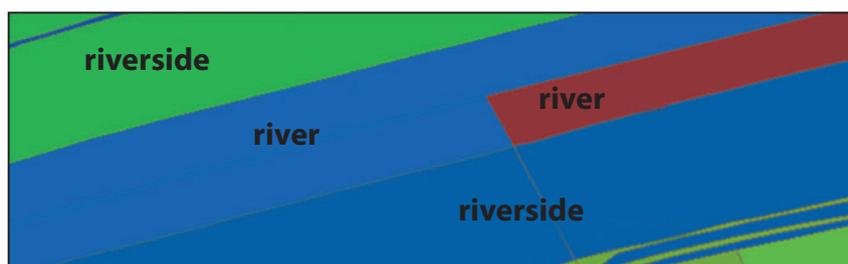


Figure 7 Assigning different categories of Land Use for identical objects by surveying groups

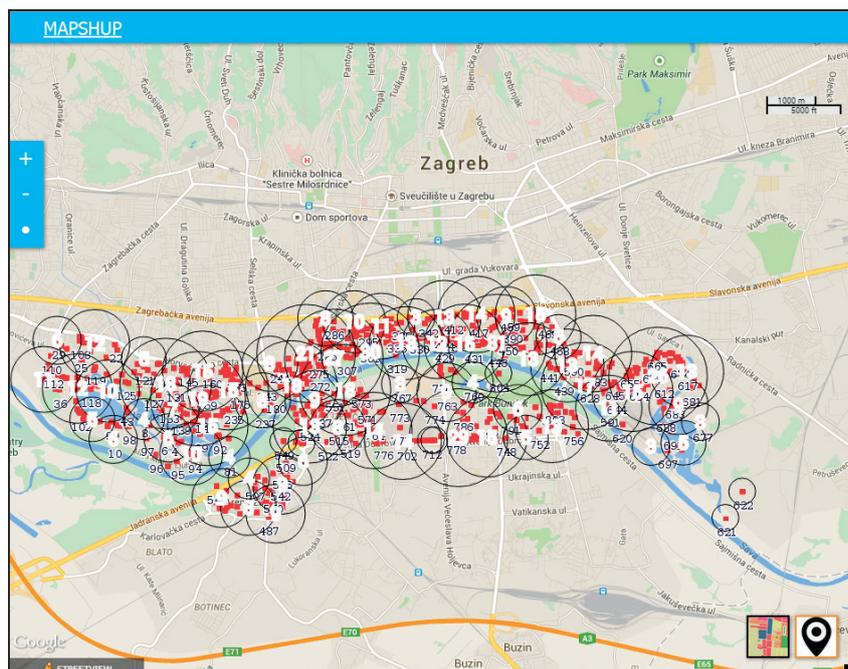


Figure 8 Zagreb Land Use 2014 mapshup viewer – clustered observation points

count and more homogenous representation.

In comparison with the LUCAS methodology reported in Gallego et al. (2008), the density of survey points was not predefined. Only a recommendation was made to observe each polygon available from

the original topographic dataset or aggregation of a group of polygons identified by observation point with photographs taken at the site. The observation depended on variability of land use distribution and density as well as accessibility of polygons. During the data processing phase, several problems

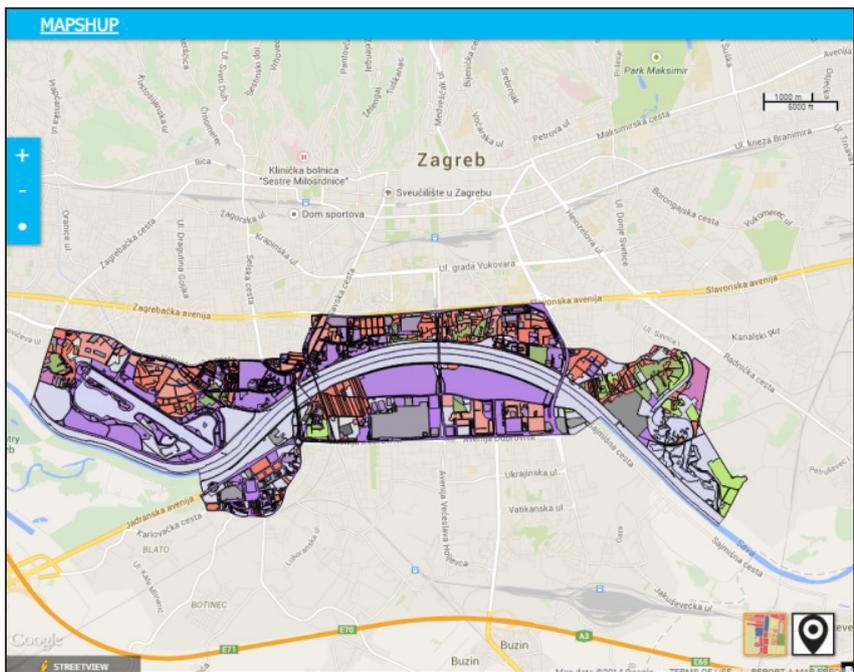


Figure 9 Zagreb Land Use 2014 mapshup viewer – LU dataset polygons

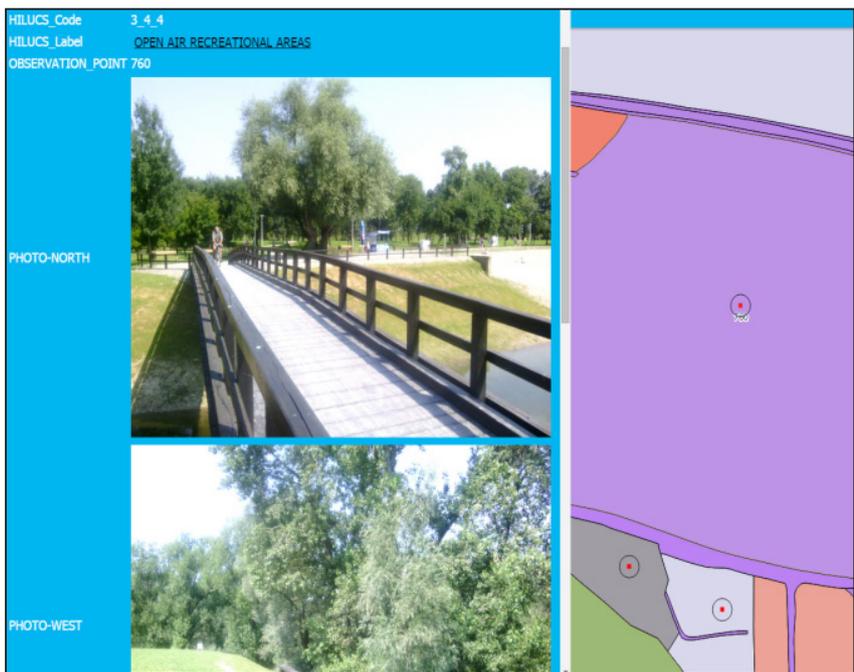


Figure 10 Identification of HILUCS and displaying photographs for selected map feature

were identified. Wrong or mismatching HILUCS attributes assignment for a single polygon (Figure 5). This may have been caused due measurement errors for neighbouring polygon or various land use interpretations by surveying groups. Furthermore, it is important to avoid duplication of observed points in a single polygon and redundancy of points in potential aggregation areas (Figure 5).

To maintain topological and logical structure of the final LU dataset, the following rules were defined: create homogeneous groups without merging the objects that have no relationship in the real world and do not create multipart features. However, several errors resulting from the data processing phase were identified as shown in Figures 6 and 7.

Multiple topological errors were detected in the initial version of the merged LU dataset. Most errors were inherited from the input topological dataset. Obviously, for the total area, the manual corrections would have been very difficult to manage, thus in order to make this process more effective, the LU dataset has been converted into a raster data model with the pixel resolution of 0.15m, which ensured that the original geometry has been preserved for the following vectorization. By automatic vectorization, a new layer has been created, with its topology independent from the original data. As a result, the numbers of topological errors have been reduced from thousands to dozens. These errors could have easily been corrected manually and the final LU dataset was prepared for publication on the web.

The products of the field works as well as the final product: Zagreb Land Use 2014 dataset were stored in the GIS database Postgres/Postgis, published on the web via Web Map Service provided by open source GIS server – GeoServer and made available for users on the Internet through open source Web GIS client mapshup (Figures 8 and 9).

Each observation point (Figure 8) and land use zone (Figure 9) map feature provides relevant attributes collected in the field and produced during the data processing phase. Each land use zone contains HILUCS code and its label, identifier of the observation point used to define HILUCS code, and the photographs taken at the point (Figure 10). HILUCS label attribute provides a link to the INSPIRE registry where the land use code definitions is provided in 23 European languages, including the Slovak and Croatian language (Figure 11).

Conclusions

By applying principles from the INSPIRE and LUCAS, we have shown how these two approaches can be used on a local SDI level in order to create a harmonized LU dataset, created from topographical and fieldwork data. These datasets are available for e-Planning and further developments on the select area of the city of Zagreb. The approach

The screenshot shows the INSPIRE Registry interface. At the top, there is the European Commission logo and the text 'INSPIRE REGISTRY Enhancing access to European spatial data'. Below this is a breadcrumb trail: 'European Commission > INSPIRE > INSPIRE registry > INSPIRE code list register > HILUCS > open air recreational areas'. The main content area is titled 'open air recreational areas' and contains the following information:

- ID:** http://inspire.ec.europa.eu/codelist/HILUCSValue/3_4_4_OpenAirRecreationalAreas
- This version:** http://inspire.ec.europa.eu/codelist/HILUCSValue/3_4_4_OpenAirRecreationalAreas:1
- Latest version:** http://inspire.ec.europa.eu/codelist/HILUCSValue/3_4_4_OpenAirRecreationalAreas
- Label:** open air recreational areas
- Definition:** Open air recreational areas, e.g. urban parks, playgrounds, national parks, and natural areas used for recreational purposes.
- Theme:** Land Use
- Application schema:** Land Use Nomenclature
- Code list:** HILUCS
- Status:** Valid
- Parent:** cultural entertainment and recreational services

At the bottom, there are icons for 'Other formats': XML, JSON, Atom, and RDF/XML beta.

Figure 11 HILUCS category multilingual definition in the INSPIRE Registry opened from mapshup viewer for selected map feature

described in the present document is novel and could be extended to other context.

These datasets could be a starting point for future investments and extension in spatial urban planning of the city of Zagreb.

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