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CHANGES IN THE STRUCTURES OF SMALL CITIES – A DOCUMENTATION OF LAND USE PATTERN CHANGES IN SELECTED REGIONS OF THE PROVINCE STYRIA (AUSTRIA)

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Abstract

The paper deals with the documentation of land use pattern changes in selected small urban regions in the Province Styria (Austria). The first part describes some useful definitions like “land consumption”, “built up area”, and “land cover and land use” in the context of Remote Sensing recording. In the following, different nomenclatures for Urban Remote Sensing Analyses from the Copernicus Land Monitoring Service such as the “CORINE Land Cover”, “Impervious Products”, “European Settlement Map” and the “Urban Atlas” will be documented and compared with the “Land Information System Austria – LISA” and local “Land Use Classification System” for the city of Graz. Several selected case studies/maps of small cities (Fohnsdorf/Judenburg, Liezen, Leibnitz and Deutschlandsberg) in Styria are proofing that a continuously observation of land consumption and land use pattern changes can be guaranteed by the analyses of different remote sensing data sets.

Keywords: *land use pattern changes, Remote Sensing, small cities, Styria*

Introduction

The application of Remote Sensing in urban research has progressed rapidly in recent years. The evaluation of urban development processes is a frequently asked question in the field of urban planning. The emphasis is increasingly on the development of new methods of urban remote sensing for use in politics and administration. Analysis of urban growth from Remote Sensing data, as a pattern and process, helps us understand how an urban landscape is changing through time. This understanding includes (GUPTA 2014):

- the rate of urban growth,
- the spatial configuration of growth,
- whether there is any discrepancy in the observed and expected growth,
- whether there is any spatial or temporal disparity in growth, and
- whether the growth is sprawling or not.

Remote Sensing, although challenged by the spatial and spectral heterogeneity of the urban environments (HEROLD et al. 2005, JENSEN – COWEN 1999), seems to be an appropriate source of urban data to support such studies (DONNAY et al. 2001). The city planning and the field of activity of individual offices of the city is based on heterogeneous data sets such as digital cadastre, topographical maps, aerial data, technical data, surveys, etc. Aerial images have been successfully used for a variety of issues for several decades. Since the availability of modern Remote Sensing image data with different spectral, radiometric, geometric and temporal resolutions, their application possibilities and the comparisons of the evaluation methods are analysed in numerous projects. In addition to method development such as the linking of additional information (e.g. digital surface models from laser scanner or digital cadastre), the operational use of Remote Sensing data in planning (such as the repeated use of aerial image surveys by means of DAEDALUS or ULTRACAM data for the city monitoring Graz (SULZER et al. 2008, SULZER – KERN 2009, SULZER 2016).

The urban environment is a highly dynamic system with a permanent change in shortest time intervals. It shows persistent and constantly changing structures, which are extremely heterogeneous and small-structured. There is a continuous change of artificial and natural (vegetated/water) surfaces, a constant change in the (city) relief (SULZER 2018). Remote Sensing is therefore challenged by the spatial and spectral heterogeneity of urban elements/features. It is proved that Earth observation is a modern science, which studies the Earth's changing environment through remote sensing tools such as satellite imagery and aerial photographs (EUROPEAN ENVIRONMENT AGENCY 2002).

Urbanization process is a major factor of change in Central European cities and causes land use and land cover changes, which can lead to deeper social, economic and especially to environmental changes. Because of its negative effect on the soil water balance, microclimate, flora and fauna (destruction of habitats), noise and the urban heating, monitoring in soil sealing provides basic indicators of urban ecology. Multitemporal analyses of remotely sensed data provide time-series information to define and locate the urban sprawl trends in sealing processes.

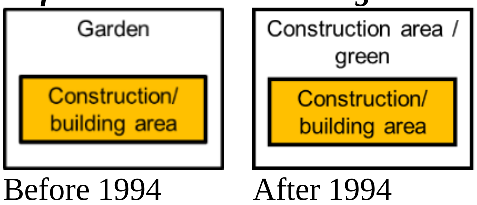
1. Some Definition of Terms

Land is a scarce resource, whose supply is fixed for all practical purposes at the same time. The demand for land for various competing purposes is continuously increasing with the increase in human population and economic growth. The concept of land consumption, a very important current environmental issue, developed in backgrounds where the urbanized area appeared extended, fragmented and widespread (BATTY – LONGLEY 1994).

„***Land consumption***” refers to the irreversible use of agricultural and forestry land for settlement, traffic and economic purposes as well as for the disposal and energy generation. Characteristic of the land use is an irreversible change of use of "fertile" soil (in the sense of "where something grows", e.g. agricultural and forestry areas, gardens and recreational areas, semi-natural areas) to “infertile” soil (in the sense of "where nothing grows", e.g. buildings, paved are "barren" soil as, roads, railways, mining areas, landfills, power plants). This process is irreversible because the dismantling of buildings or road systems is only carried out in exceptional cases and even then the soil functions can usually no longer be produced. The term land consumption is thus used as a synonym for the direct consumption of space/soil (UMWELTBUNDESAMT 2019). The term land consumption is used for planning and cadastre purposes: This type of use "construction area" with all uses ("buildings", "attached", "green" and "no differentiation"), "gardens" with use of "recreational areas". The type of "others" includes "road facilities", "railway facilities", "mining areas" and "no differentiation".

Built up area includes "construction area" with all uses ("buildings", "attached", "green" and "no differentiation"). The definitions of built up areas and gardens changed in 1994. Before 1994, only the area that was actually developed, e.g. permanently constructed buildings, was referred to as "construction area". The areas around the buildings, but on the same property (for example, the garden around the house) were referred to as "gardens". From 1994 on, the entire property was designated as a construction area; this was then further subdivided into the types of use of "building", "attached", "green" and "no differentiation" (Figure 1).

Figure 4: Definition of Construction / Building Area before and after 1994



Land consumption (ÖROK 2001) is an indicator for continued urban sprawl and high land and resource consumption through:

- Dynamic construction activity and settlement expansion,
- Space intensive building construction (high percentage of single houses) and remote settlement structures,
- Space intensive industrial zones (single floors),
- Trends towards huge land consuming shopping centres and recreation areas with connected parking lots,
- Space intensive traffic areas.

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The daily land consumption in Austria is 12.9 ha/day on average for the three-year period 2015-2017 and is thus still well above the reduction target of the sustainable development strategy of 2.5 ha/day. The daily consumption in 2017 was 5.7 ha/day for construction and traffic areas, 5.5 ha/day for operational areas and 1.2 ha/day for recreational and mining areas (UMWELTBUNDESAMT 2018).

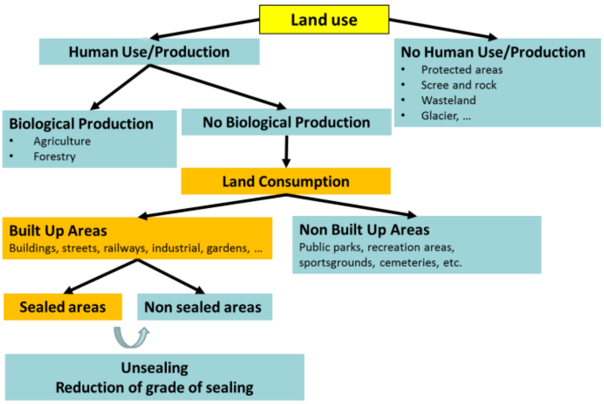

Figure 5: Structure of land use according to the model of the intensity of human land use
(Source: Umweltbundesamt, 2018)

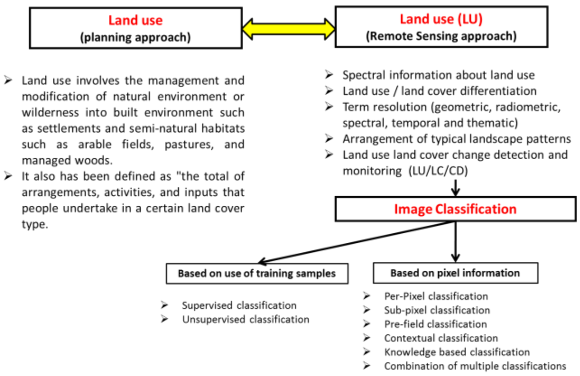

Figure 6: Land use and land cover by means of Remote Sensing

Figure 2 documents the structure of land use according to the model of the intensity of human land use and shows the potential inclusion of remotely sensed methodologies by analysing the land consumption via detecting built up areas, sealed areas etc. Figure 3 tries to document the different approaches of the term land uses for planning and Remote Sensing techniques.

The European Environment Agency (EEA) introduced in 1990 and 2000 the indicator land uptake, defined as a measure of the surfaces employed for urban growth, in order to monitor land consumption in all European countries starting from the data collected in the project CORINE Land Cover. The measure of land consumption requires the quantification of the phenomenon of settlement dispersion. Numerous studies in literature use different metrics regarding landscape ecology for the analysis of urban configurations (GERUNDO – GRIMALDI 2011). Urban configuration / urban metrics can be achieved by using information from Remote Sensing. It describes urban land use structures and land cover changes that result from urban growth. Landscape metrics can be calculated for segmented areas of homogeneous urban land use to allow a further characterization of the land use of urban areas (HEROLD et al. 2002).

Land cover is the physical material at the surface of the earth and includes grass, asphalt, trees, bare ground, water, etc. **Land use** is a description of how people utilize the land and of socio-economic activity. Urban and agricultural land uses are two of the most commonly known and use classes. At any one point or place, there may be multiple and alternate land uses, the specification of which may have a political dimension. "Land cover" is distinct from "land use", despite the two terms often being used interchangeably (UN FAO, 1998).

2. Nomenclatures for Urban Remote Sensing Analyses

A number of national, regional and global land cover classification systems have been developed to meet specific user requirements for land cover mapping projects, independent of scale, nomenclature and quality (Yang et al., 2017). The classifications which describe the systematic frameworks with the name of the classes and the criteria used to distinguish them and the relation between classes depend on a specific user's requirements, including biodiversity, planning, monitoring and statistics (Meinel & Hennersdorf, 2002). For urban analyses the following classification schemes/examples will be used for smaller towns (not megacities):

The Pan-European component is coordinated by the European Environment Agency (EEA) and produces satellite image mosaics, land cover / land use (LC/LU) information in the CORINE Land Cover data, and the High Resolution Layers (HRL) and the related Pan-European products:

CORINE Land Cover (*https://land.copernicus.eu/pan-european/corine-land-cover*)**:** The main European Environmental Agency (EEA) data source is the Copernicus Land Monitoring Service which includes the CORINE Land Cover data set (European Environmental Agency 2017; Copernicus Programme, 2017). The CORINE Land Cover (CLC) inventory was initiated in 1985; the data sets themselves were first elaborated in 1990. Updates have been produced in 2000, 2006, and 2012 (see Fig. 4) and are based on the cooperation between EEA members, collaborating countries, and the Copernicus Program. In 2018, a new inventory was planned, but is still not available. The concept and nomenclature of CLC is used as the quasi-standard for land cover and land use mapping in Europe. The data consists of an inventory of 44 classes. CLC uses a Minimum Mapping Unit (MMU) of 25 hectares (ha) for areal phenomena and a minimum width of 100m for linear phenomena. The time series are complemented by change layers, which highlight changes in land cover with an MMU of 5 ha. The CORINE Land Cover is a vector map with a scale of 1:100 000, a minimum cartographic unit (MCU) of 25 ha and a geometric accuracy better than 100m. It maps homogeneous landscape patterns, i.e. more than 75% of the pattern has the characteristics of a given class from the nomenclature. This nomenclature is a 3-level hierarchical classification system and has 44 classes at the third and most detailed level. In order to deal with areas smaller than 25ha a set of generalization rules were defined. The CORINE Land Cover (CLC) inventory can be used for the analyses of larger areas and their recent changes which allows a multitemporal analysis for the time period 1990-2012 (Lieb & Sulzer, 2019).

The **Imperviousness Products (***https://land.copernicus.eu/pan-european/high-resolution-layers/imperviousness*) as the High Resolution Layers (HRL) is a capture the percentage and change of soil sealing (see Fig. 4.). Built-up areas are characterized by the substitution of the original (semi-) natural land cover or water surface with an artificial, often impervious cover. These artificial surfaces are usually maintained over long periods of time. The imperviousness HRL captures the spatial distribution of artificially sealed areas, including the level of sealing of the soil per area unit. The level of sealed soil (imperviousness degree 1-100%) is produced using a semi-automated classification, based on calibrated NDVI.

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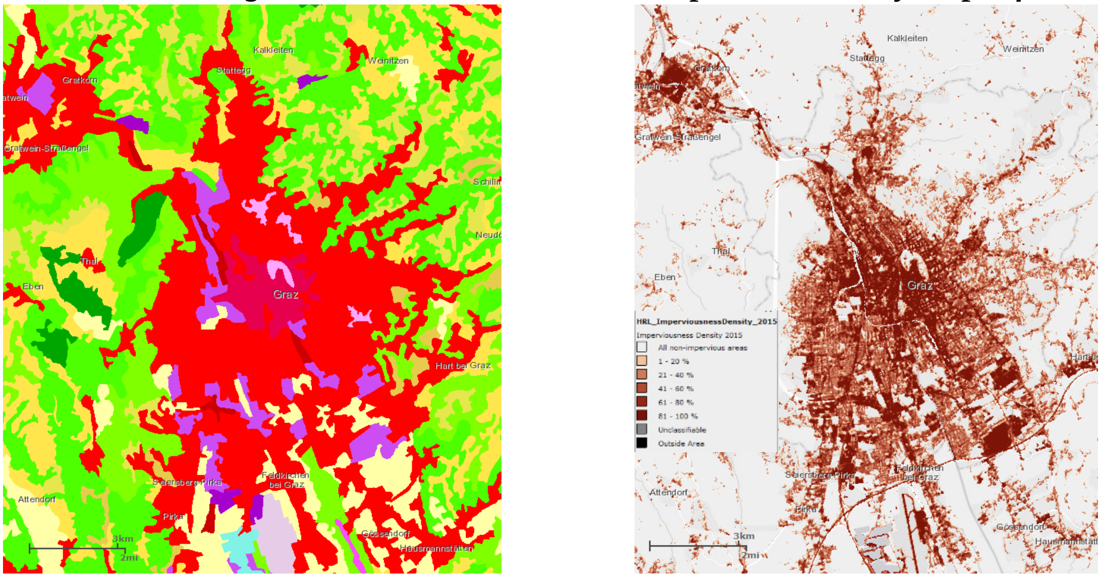
The **European Settlement Map** (*https://land.copernicus.eu/pan-european/GHSL/european-settlement-map*) as part of the "Related Pan-European products" is a spatial raster dataset that is mapping human settlements in Europe based on SPOT5 and SPOT6 satellite imagery. The map represents the percentage of built-up area coverage per spatial unit. The GHSL method uses machine learning techniques in order to understand systematic relations between morphological and textural features, extracted from the multispectral and panchromatic (if available) bands, describing the human settlement. The thematic content of this product is similar to the imperviousness HRL.

Figure 7: Corine Landcover and Impervious Density Maps of Graz



Corine Landcover Map 2012 of Graz Area
(https://land.copernicus.eu/pan-european/corine-land-cover)

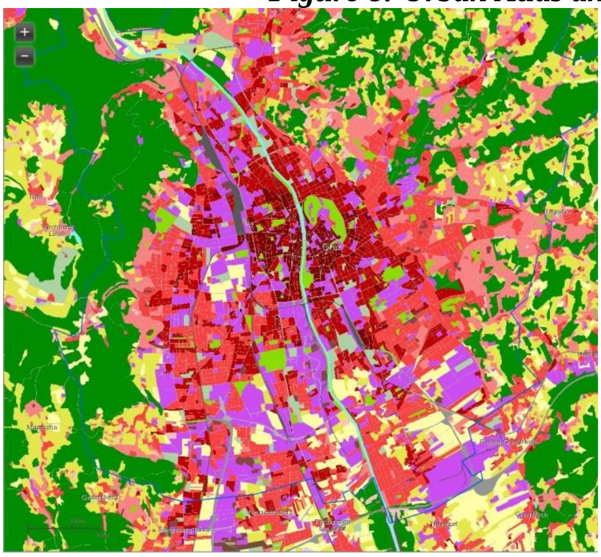
Impervious Density Map of Graz
(https://land.copernicus.eu/pan-european/high-resolution-layers/imperviousness)

Urban Atlas (*https://land.copernicus.eu/local/urban-atlas*): The "local component" is coordinated by the European Environment Agency and aims to provide specific and more detailed information that is complementary to the information obtained through the Pan-European component. The local component focuses on different hotspots, e.g. areas that are prone to specific environmental challenges and problems. It will be based on very high resolution imagery (2,5x2,5 m pixels) in combination with other available datasets (high and medium resolution images) over the pan-European area. The three local components are: Urban Atlas, Riparian Zones and Natura 2000. EU regional policy justifies the production and maintenance of detailed land cover and land use information over major EU city areas. The Urban Atlas provides pan-European comparable land use and land cover data covering a number of Functional Urban Areas (FUA). In 2012, additional layers (Street Tree Layer, Building Height and Population Estimates) were produced, too

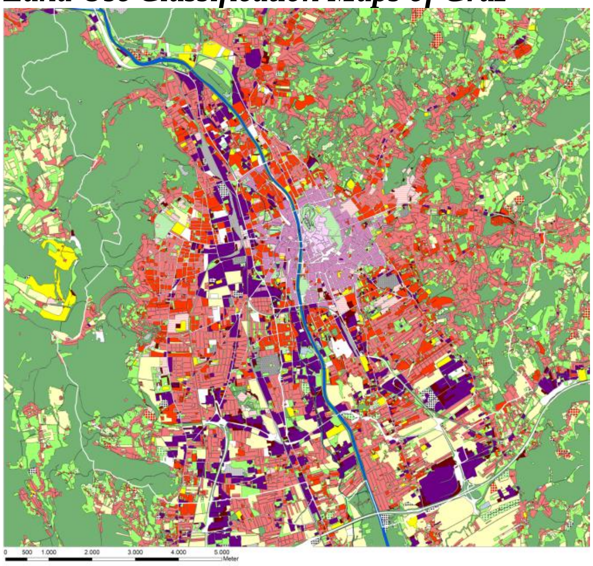
(European Environmental Agency, 2016). Building Height is available for core urban areas of selected cities (capitals in EU28 + EFTA), the Street Tree Layer (STL) within selected FUAs (depending on availability of suitable satellite imagery).

Land Information System Austria – LISA (*https://www.landinformationsystem.at*): The overall aim of the Land Information System Austria is to provide current and detailed geospatial information of the status and development of land cover and land use in Austria to public authorities and the private sector. LISA reduces the existing lack of information of different special fields such as spatial planning, forestry, agriculture, water and natural hazard management, as well as environmental protection and conservation. Deficits of available data like too large scales, insufficient informational content of object classes, a lack of international standardization and topicality will be cleared out with LISA data sets (BANKO et al. 2014).

Figure 8: Urban Atlas and Land Use Classification Maps of Graz



Urban Atlas Graz
(https://land.copernicus.eu/local/urban-atlas/urban-atlas-2012)



Land Use Classification Graz
(SULZER, 2016 and 2018)

3. Case studies in Styria

Methodology: The methodology adopted here for detecting land cover changes was based on the comparison between the orthophoto imageries of different years. The visual interpretation of the aerial data took place in ArcGIS. At the beginning of the evaluations, all data records should be completely present in order to avoid misinterpretations. The selection of the image data was made according to the available offer, whereby it was attempted to achieve as far as possible a constant time of about 10 to 15 years. The basis of such analysis is the interpreter's knowledge of spatial arrangements of urban land-cover features (for example, pattern shapes, frequencies) that are used to characterize urban land use (HEROLD et al. 2002).

Description of the Land use classes: The differentiation of the individual classes depends on the quality of the image material. Geometric high-resolution aerial image data allow a very accurate and reliable interpretation, while the older panchromatic aerial image data are only available in a panchromatic channel, and have lower geometric resolutions which offer significantly less possibilities of interpretation. However, a targeted image enhancement can improve the contrast of this data. The construction of the legend is based essentially on the proposal of the Austrian Conference on Spatial Planning - ÖROK (1990). Here, an attempt was made - in cooperation with the City Surveying Office and the City Planning Office - to develop a supra-regional legend. The Austrian Spatial Planning Conference (ÖROK, 1990) introduces a catalogue of uses for recording current land use and zoning. This recommendation also draws attention to the lack of uniform documentation of land use or land cover in Austria. Official surveys (Austrian Official Statistics: Land Use Survey, Federal Office for Metrology and Surveying: Cadastre, Land Database) serve different purposes, often incompatible survey methods and terminologies. Moreover, not always the actual land use aimed at zoning (see Fig. 3.). The data for the type of land use catalogue should be recorded at least in a community-based manner (possibly catastrophic / count-splitting way).

On closer examination, the land use categories proposed by ÖROK (1990) make it clear that only a part can be directly derived from aerial or satellite imagery. The classes can therefore be divided into two groups, functional and non-functional classes. The non-functional classes are directly related to objects on the Earth's surface. On the one hand there are objects including artificial objects such as buildings and parking lots, and on the other hand they include also various types of natural surface cover such as meadow, field, vineyard, etc. A class may also consist of various objects. The detailed definition of the individual classes, e.g. for rivers, not only the immediate surface of the water but also the shore area is included. The other land use classes can be referred as functional classes. They are defined by the function of the objects. For example, buildings can be used as residential buildings. This information is difficult or impossible to obtain from an aerial or satellite image. Furthermore, the assignment to the individual classes cannot always be assigned unambiguously. For example, a green area can sometimes be used as a meadow, or as a recreational area.

The above mentioned problems proved that generating land use maps with methods of Remote Sensing is very often limited to the interpretable classes and has to integrate additional information from an existing GIS or from field work. The plot-type zoning can be taken from the official zoning plan and integrated into a GIS. During mapping current aerial image data, an accompanying field survey can provide improved information about the use of the buildings or areas. In historical aerial data, this is done by the knowledge of the evaluator, as without experience only a reduced mapping of the land cover is possible.

Finally, the classification consists of the different categories as follows:

Table 2: Landuse categories (SULZER 2016)

1. Agricultural Area: - Arable land - Open space/meadows - Vineyards - Fruit-growing/ plantation - Dispersed fruit trees - Market-garden - Allotment garden **2. Forested Areas** - Woodland **3. Surface Water** - River and rivulets - Lakes	**4. Traffic Areas** - Streets - Railway - Parking lots **5. Built up Areas** - Residential buildings - Middle-Age building structure - Promoterism building structure - Multi-storey buildings - Single familiy-residentials (1-2) - Open land building structure - Trade and industrial area - Other buildings	**6. Other Areas** - Recreation areas - Technical supply areas - Disposals - Mining areas - Hedges, alleys - Parks - Cemeteries - Sports fields - Other areas

Results of the study are different GIS-based maps with topics, which are related with time changes: land use / land cover maps and associated information about traffic network (streets and railways), drainage network, technical infrastructure, housing, relief, etc. The following figures are documenting some case studies of the project:

In SULZER (2016, 2018) the application for the capital town of Styria was documented. The land use of the individual research years and the development of the built-up areas of Graz (1944/45, 1952, 1968, 1974, 1984, 1990, 2002, 2004, 2007, 2011 and 2015) are documented in maps and land use statistics. Different Remote Sensing classification methodologies were used and generated specific information features for town planning (SULZER et al. 2016, SULZER et al. 2017, SULZER 2018). This analysis approach was widened to several district towns in Styria, to document the urban growth; respectively the land use changes in smaller urban areas, which are not covered/mapped by EU Copernicus initiatives.

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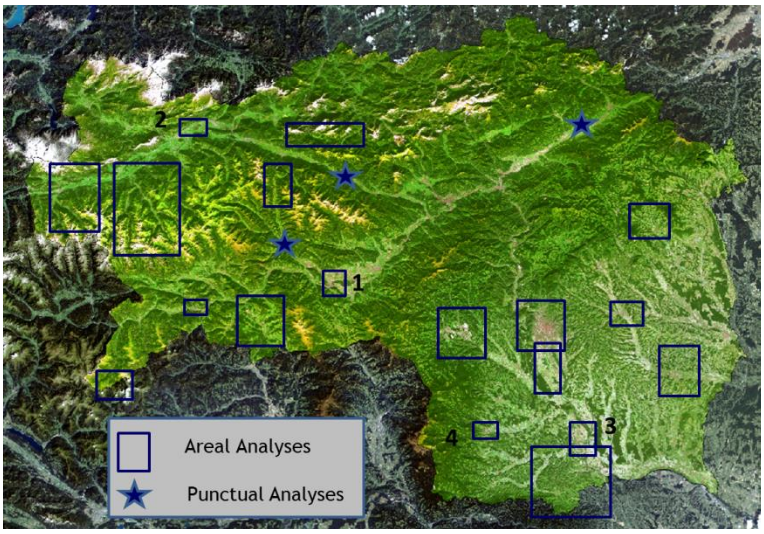
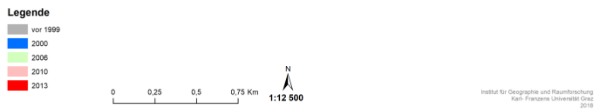
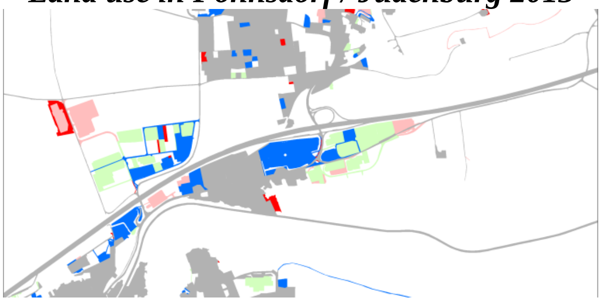


Figure 9: Study areas for multitemporal land use classification (1-4 case study areas)

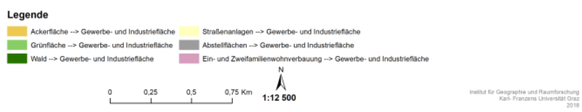
Land use in Fohnsdorf / Judenburg 1999

Land use in Fohnsdorf / Judenburg 2013





Change Sealed Areas 1999-2013



Change Trade and Industrial Areas (199-2013)

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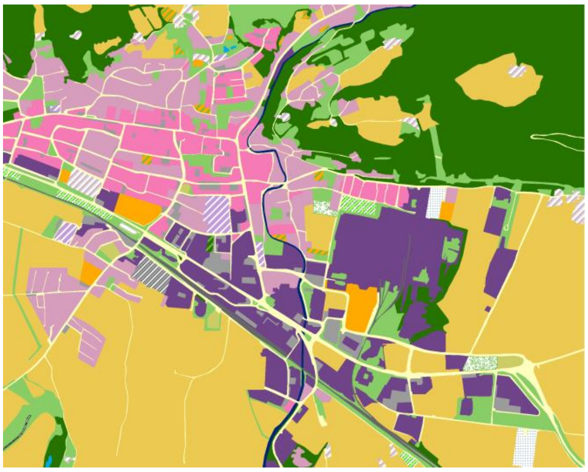
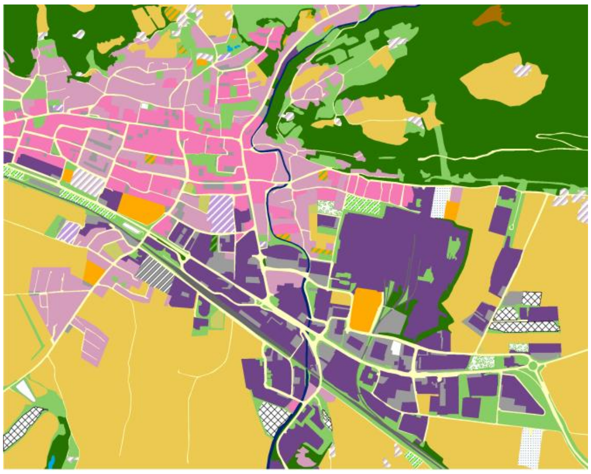
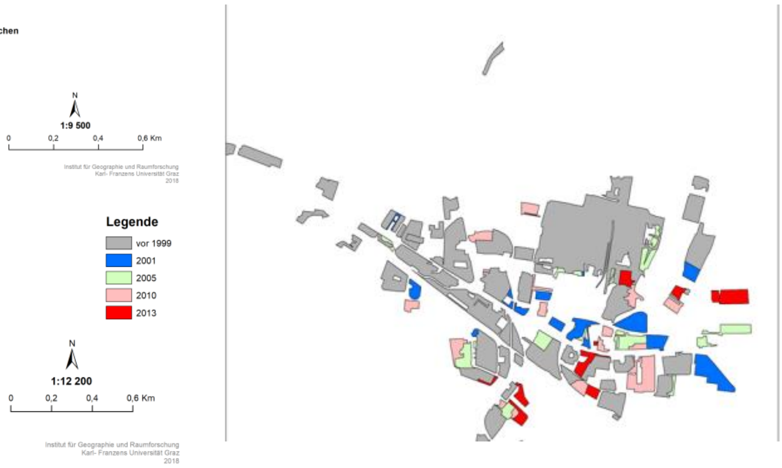
Figure 10: Land use Maps of Fohnsdorf / Judenburg (Area 1 in Figure 4)



Land use Liezen 2001



Land use Liezen 2013

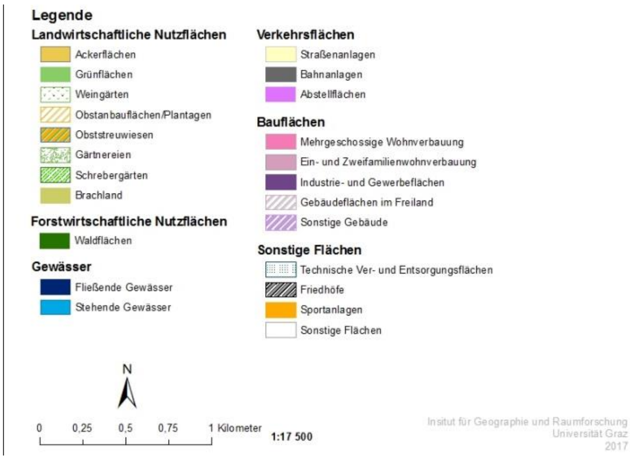


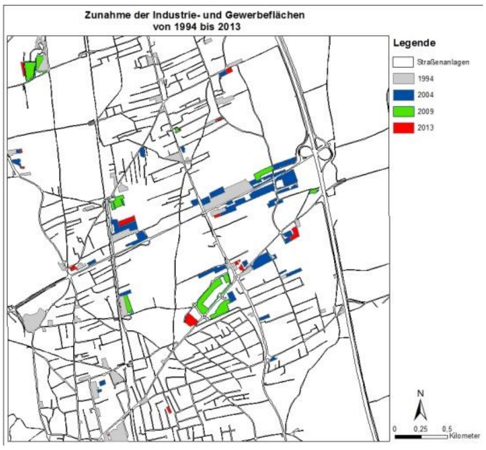
Change of Trade and Industrial Area (2001-2013)

Figure 11: Land use Maps of Liezen (Area 2 in Figure 4)

Land use Leibnitz 1994

Land use Leibnitz 2013





Change of Agricultural Area (1994-2013)

Figure 12: Land use Maps of Leibnitz (Area 3 in Figure 4)

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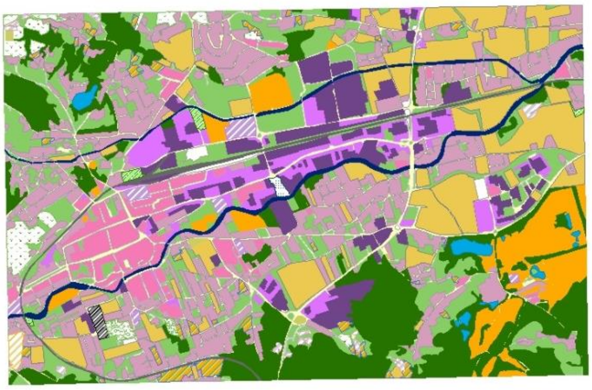
Land use Deutschlandsberg 1996

Land use Deutschlandsberg 2004



Land use Deutschlandsberg 2013

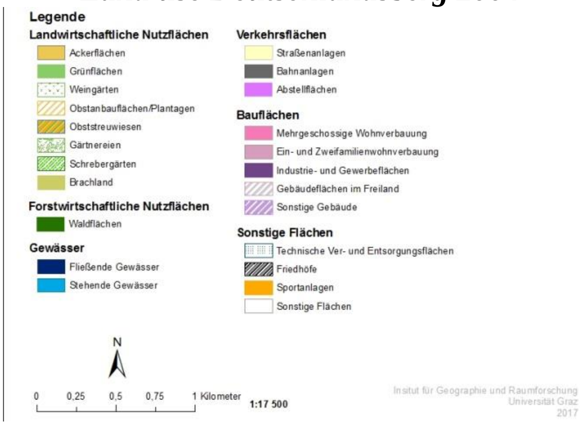


Figure 13: Land use Maps of Deutschlandsberg (Area 4 in Figure 4)

Conclusion

Visual land use classifications are still representative methods to obtain worthwhile information about small cities. CORINE land cover data (1:100.000) are suitable for larger cities; the demand of high resolution scales 1:10.000 for local planning purposes cannot be achieved. Detailed EU Copernicus local layers are still not available for the investigation areas in Styria. The multitemporal timescale for these high resolution EU Copernicus data ends back in the 2000, whereas aerial photographs are available back to 1952 (or in some cases to 1944/45, SULZER 2018). A hierarchical nomenclature, which is commonly used in land use / land cover mapping, obtains variable scale and a comparison opportunity for different investigation areas. It fits for local cities and rural areas, and can be extended on whole Styria and into open land, too. The methodology is repeatable with a high temporal resolution with different remote sensing data sets (aerial photographs and high resolution satellite images); so a continuous observation of land consumption can be guaranteed. These meet the needs of the demands of local and regional planning purposes, and finally can be semantically transferred to European nomenclatures.

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