Land take in the Alpine region: the data perspective

Contribution to IP_S2, Step 1
of the Alpine Climate Target System

Working Group Spatial Planning and Sustainable Development of the Alpine Convention

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1. Background

As a contribution to the Alpine Climate Target System, this overview of statistical data on land take in the Alps contributes to Step 1 “Define land-take/sealing and the need to stop both” of the Soil Implementation Pathway 2 “Defining Alpine wide guidelines for minimised land-take and sealing”. Regarding the task of developing an Alpine-wide definition and shared understanding of monitoring of land-take and land-sealing, the paper provides an overview of theoretical concepts, an explanation of data origins but also a comparison of the data situation at different levels and in different national contexts.

2. Introduction

The challenge: varying concepts, methods and indicators

The issue of land take is highly complex for two reasons. Firstly, the understanding of the overlapping concepts as land take, soil sealing, or land use change are not defined in unambiguous ways. Instead, differing and sometimes contradictory understandings exist in parallel. Secondly, the data situation is incomplete and complex, in particular on the transnational scale of the Alpine region. A series of indictors and data gathering methods aim to address issues of land take in the wider sense, but harmonised, meaningful analyses are difficult to produce (Alpine Convention 2017: 102ff.).

When structuring the numerous approaches, the following differentiation can be helpful:

a) The quantitative perspective: Some concepts focus on the question *if* or to what *extent* a natural soil loses its quality due to sealing or severe derogation. This is in particular covered by the concepts of ‘soil sealing’, ‘artificialization’, ‘land consumption’ or ‘land take’.
b) The qualitative perspective: Several approaches focus rather on the *qualitative differences*. ‘Land cover’ focusses on the material dimension and ‘land use’ (also) considers human activity on the respective areas. The two perspectives differ largely in the underlying survey methodology, as we will illustrate in the next section (Meinel & Hennersdorf 2002: 2f.).

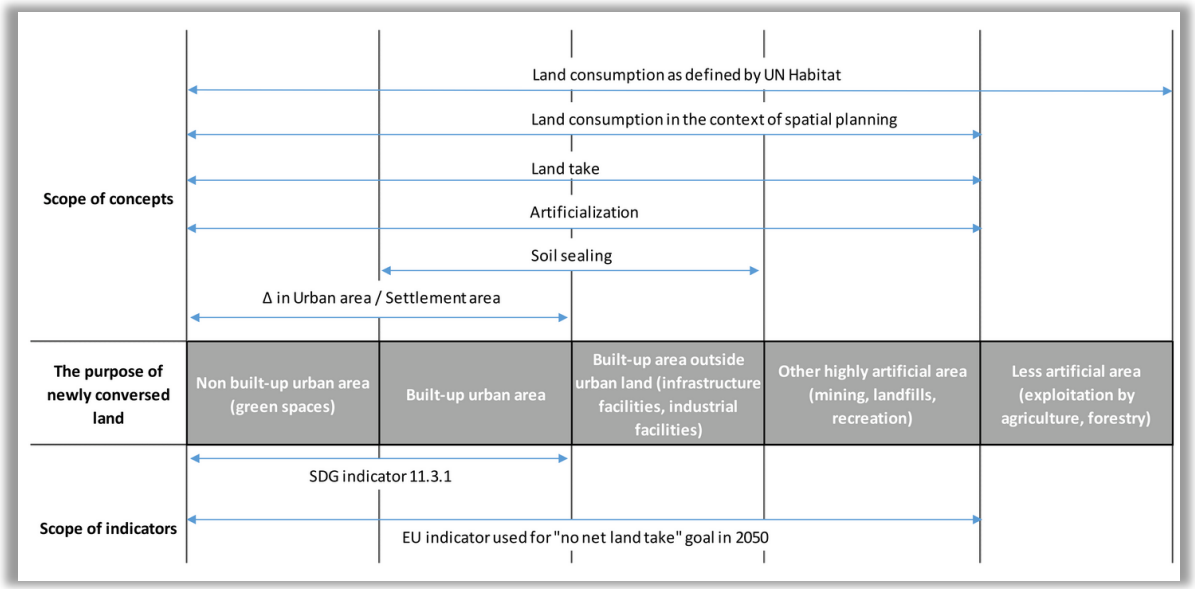

Fig. 1 Different understandings of 'land take' in the broad sende (Marquard et al. 2020:12)

Fig. 1 illustrates the multitude of concepts and indicators that are relevant both in political debates and in analytical work. The latter perspective is reflected in the paper at hand, focussing on the current data situation. The difficulty lies in the fact that the data situation differs across the countries and political levels. As it is often the case in data analysis, there is a grey area between data availability, data homogeneity and spatial resolution.

The pan-European land monitoring systems provide at least a good starting point (Arnold 2015: 201f., Sleszynski et al. 2020: 2) that will be outlined in the following sections.

Two types of data gathering

There are a series of data gathering methods available at different levels. Simplifying the situation to a certain extent, one can differentiate remote sensing data and general statistical information (see Fig. 2):

- Remote sensing data is the most prominent approach on the EU level, linked to the Copernicus programme (for details see next chapter). The necessary facilities for an aerospace programme are enormous and can only be ensured on the international level. The delivered raw data provide a fine scale information set. The challenges are not in harmonisation – as it is the case for statistical data – but in the processes of interpretation. Representative in-situ investigations help to calibrate the data and to deliver information on land use.
- On the domestic level, a series of national and regional statistical offices provide official information on a number of sectoral fields. Many of them are of high relevance for land take in the broader sense, in particular land use statistics, agricultural statistics, building statistics or real estate statistics. In this case the problem is, that the data are not harmonised on the cross-border or transnational level and they are hardly combinable due to different survey methods. Those data sets that are harmonised and provided by

Eurostat, are not available on a spatial level that would be meaningful for questions of land take. Switzerland and Liechtenstein work with a 'remote-sensing' like approach: They use aerial photo data to generate their 'Arealstatistik' and thus form a compromise between purely statistical and satellite data.

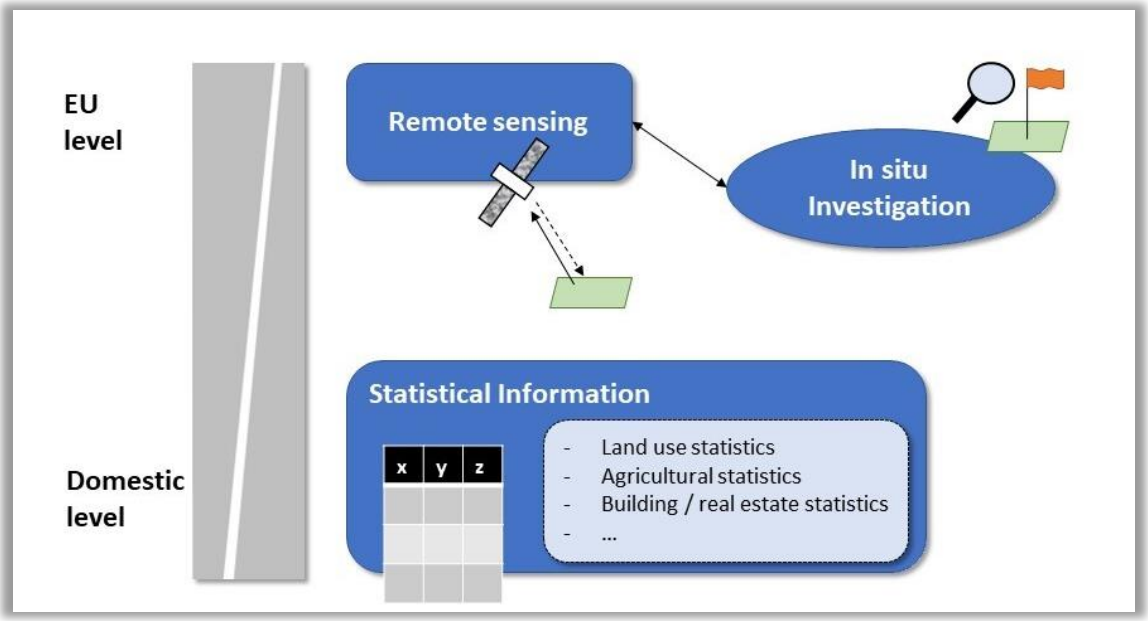

Fig. 2 Data gathering on different levels (Lambracht & Chilla 2021)

The institutional perspective: European and domestic initiatives

The available data are based on programmes and initiatives that are often interlinked. Fig. 3 provides a simplified overview.

As mentioned before, the Copernicus programme offers data in particular from the CORINE (Coordination of information on the environment) Land Cover (CLC) initiative and the HR (High Resolution) Layers. Both are explained in more detail below. They offer standardised data for all EEA39 countries and thus also for the entire Alpine Region. The urban Atlas provides interesting data but is limited to large cities and their suburban surrounding (e.g. Innsbruck and Bolzano/Bozen).

The BioPhysPar data, the Land Use and Coverage Area frame survey (LUCAS) and the land parcel identification system (LPIS) of the International Association of Classification Societies (IACS) complement the European initiatives.

On the domestic level, there are several national databases which combine the European CLC data with own data. They are the bases for further calculations and visualizations for national or regional purposes (e.g. the LISA database in Austria, the Arpa Piemonte in Italy, the Tiris in Tyrol or areal statistics in Slovenia). There are also national reference centres, which support the European data.

Also on the domestic level, there are some national databases which do not use the CLC data (e.g. ALKIS in Germany, Arealstatistik in Switzerland and Liechtenstein). These databases are

fed from official statistical data and surveys e.g. the real estate cadastre information system in Germany.

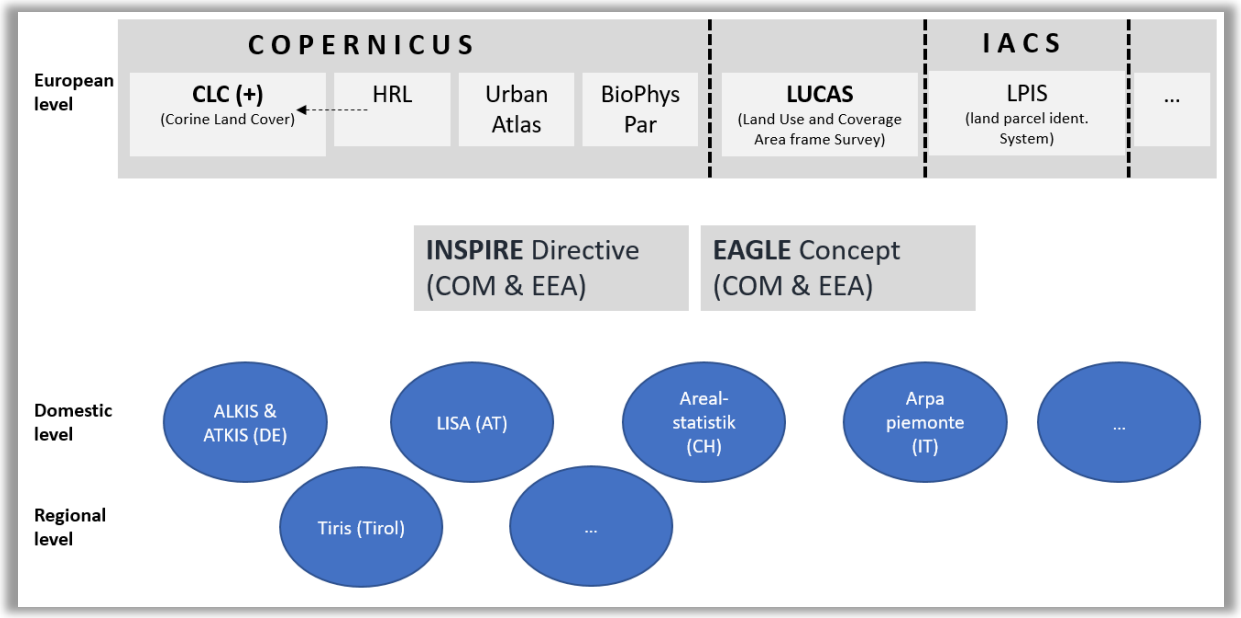

Fig. 3 Databases at different levels and homogenization concepts (source: https://land.copernicus.eu/eagle/content-documentation-of-the-eagle-concept/manual/introduction-to-the-eagle-concept/referencemanual-all-pages, and Arnold 2016 modified)

The INSPIRE Directive (Infrastructure for Spatial Information in Europe) and the EAGLE concept (EIONET Action Group on Land monitoring in Europe) of the European Commission and the European Environment Agency (EEA) were established in order to link both levels, i.e. the European and the national, and to homogenize the data and the understanding of nomenclature (cp. https://land.copernicus.eu/eagle/pan-european-implementation-of-CLCplus).

3. Zooming in concrete data

In order to understand the challenges of a pan-European land monitoring system with small-scale resolution, it is important to take a closer look at the existing data collection methods. Therefore, the CLC database and the LUCAS methodology will be further investigated. Both survey methods have strong and weak points, which will be discussed in this section of the report.

CORINE Land Cover (CLC)

The CORINE Land Cover data is the most comprehensive data set for land cover/use questions. The CORINE data is derived from satellites (Landsat-5, Landsat-7, SPOT-4/5, IRS P6 LISS III, RapidEye, Sentinel-2, Landsat-8), covering a spatial resolution of 10-30 m (cp.

Sleszynski et al. 2020). So far, five editions of the database are available, including the years 1990, 2000, 2006, 2012 and 2018.

The open access data from CORINE is provided as raster data, with a Minimum Mapping Unit (MMU) of 25 ha for areal objects and 100 m width for linear objects. The smaller areas are not identified.

CORINE Data come along with a series of challenges that limit the use for Alpine and/or cross-border spatial planning:

- Availability on a fine spatial scale: The already mentioned thresholds for mapping units and width limits detailed interpretations. The spatial resolution results in inaccuracies when mapping land cover change. Thus, changes in areal phenomena are only mapped when they show a minimum of 5 ha and linear phenomena are only mapped when they show a boundary displacement from minimum 100 m.
- Data quality management: The data quality control is hosted by EIONET National Reference Centres Land Cover, National Teams and the EEA. With a thematic accuracy of about 85%, the data quality is typical for remote sensing in general but raises questions for planning procedures.

One can conclude that “the CLC database has been designed as a basis for the creation of medium-scale (1:100,000) maps of land cover, particularly useful for the interregional comparisons” (Sleszynski et al. 2020: 4).

Copernicus High Resolution Layers (HRL)

The Copernicus High Resolution Layers are closely interlinked with CLC data. The HRLs are produced from Copernicus satellite imagery through a combination of automatic processing and interactive rule based classification. HRL provide Pan-European information (EEA 39) on specific land cover characteristics. The HRL are available for five themes (related to the main themes from CLC):

- level of sealed soil (imperviousness)
- tree cover density and forest type
- grasslands
- wetness and water
- small woody features

All products aim to provide time series and fine scale information. The table (Fig. 4) provides an overview of the available data features for each product. It is important to differentiate between status and change information. As land take is a process of time, change data are much more important that status information.

Type of product	Name of product	Available reference years or periods	Pixel size	Projection
Status layers	IMD – Imperviousness degree	2006, 2009, 2012, 2015, 2018	10m & 100m (2018) 20m & 100m (2006,2009,2012,2015)	National projections and LAEA (for pan-European mosaics)
	IBU - Impervious Built-up	2018	10m (IBU), 100m (SBU)	National projections and LAEA (for pan-European mosaics)
Change layers	IMC Imperviousness change	2006-2009, 2006-2012, 2009-2012, 2012-2015, 2015-2018	20m & 100m	National projections and LAEA (for pan-European mosaics)
	IMCC Imperviousness change classified	2006-2009, 2006-2012, 2009-2012, 2012-2015, 2015-2018	20m	National projections and LAEA (for pan-European mosaics)

Fig. 4 Features of the available HRL data (source: https://land.copernicus.eu/pan-european/high-resolution-layers/imperviousness)

It is important to note that HRL data are provided in raster format. This means that linking them with institutional information, like statistical units or regional affiliation, demands data processing that is not trivial. But even without this step, cartographic representations can be provided in way that is illustrated in Fig. 5 as an example.

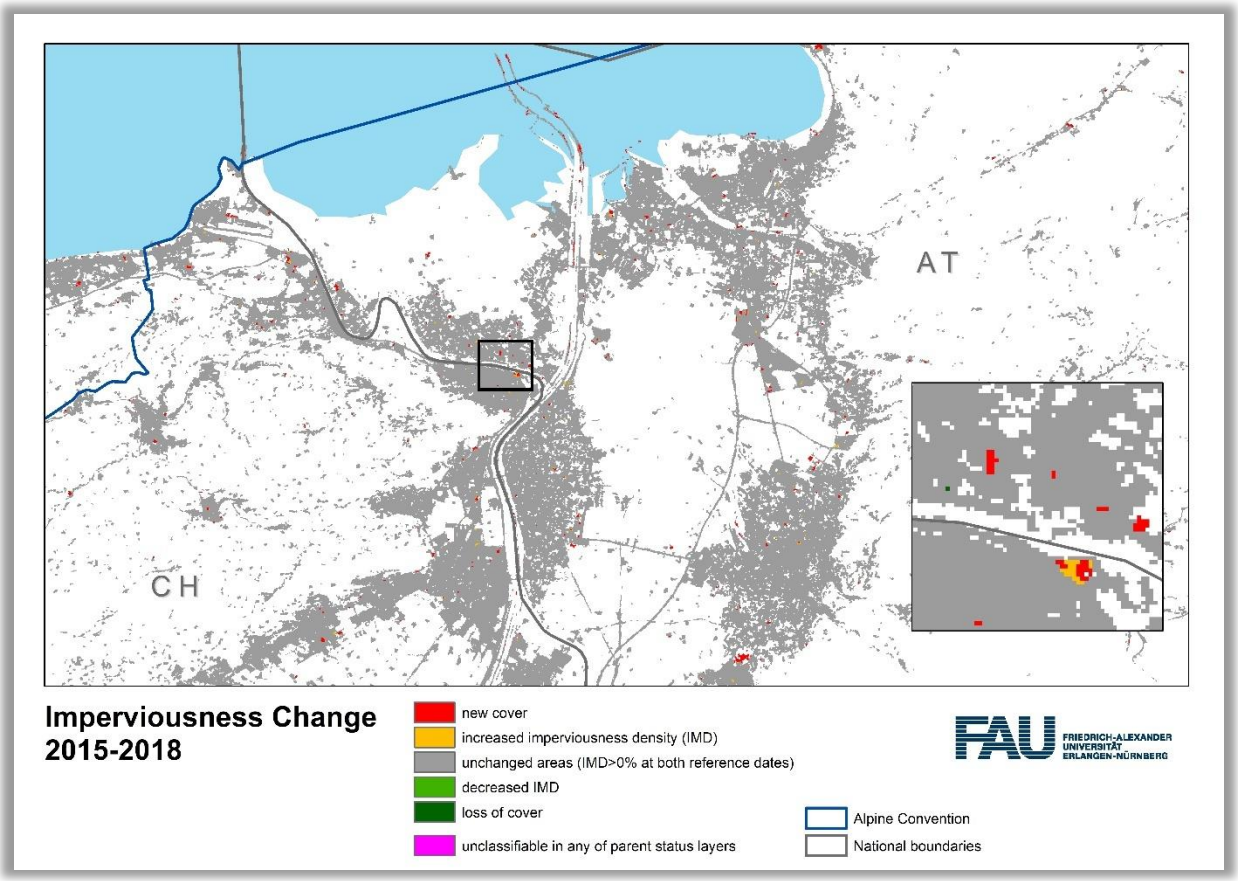

Fig. 5 Cartographic example for imperviousness change data

Land Use and Coverage area Survey (LUCAS)

The LUCAS survey is carried out by EUROSTAT every three years since 2006. This survey is not part of the Aerospace programme of Copernicus but combines orthophoto interpretation with an intensive in situ survey. The data is produced by covering a grid across Europe in the following way:

- First step: 1.1 million points across Europe (2 km square GRID) land cover information (orthophoto interpretation)
- Second step: sample of around 337,000 points: in situ investigation and data collection (parameters: Land cover, Land use, Pictures, etc.)

The focus of LUCAS data is on the state and dynamic of land use, but also additionally on land cover in the European Union.

The limitation of LUCAS with regard to Alpine spatial development is twofold. Firstly, the geographical focus does not comprise Switzerland and Liechtenstein as the coverage is not EEA 39 but EU member state (different from CLC and HRL). Secondly, the grid based approach comes along with limitations in data accuracy. LUCAS data are crucial for the interpretation and reliability of CLC data, but as stand alone data they do not reach the quality as the CLC and HRL data.

Domestic level

Statistical information

Official statistics comprise a series of indicators and topics that are of high relevance for the land take topic. The following three data foci are of particular interest (for a synthetic overview see the conclusion chapter):

- **Agricultural statistics** are of very good quality. They provide fine scale data details of agricultural use and coverage, and many data are harmonised. However, they are limited to only one sector and the relevant territories. The loss of agricultural land can be quantified, but land use dynamics or land take beyond the agricultural sector is beyond the scope.
- **Building statistics:** All countries provide data on building statistics, e.g. number of building permits, number of new houses. However, the indicator definitions are not harmonised and the spatial scales do not correspond. Eurostat only provides data on the national level (NUTS 0).
- **Land use/cover monitoring approaches** are in place in all parts of the Alpine area. Some of them provide very exact information on the land use dynamics, including land take. However, they are not harmonised. The next section illustrates this in more detail with regard to visual approaches. The EU context was introduced earlier.

Regional monitoring systems

On the domestic level, a series of innovative and helpful monitoring systems are in place. As mentioned before, they are often based on CLC data and complemented with further information. Some of them have very broad focus (ALKIS in Germany), other concentrate on land use (Tiris in Tyrol/AT) and the most specialised tool for land take might be the Italian tool, explicitly monitoring land consumption. They have all their strengths and are certainly helpful for domestic purposes, including the delivery of important information for regional and local planning procedures. Nevertheless, they share an important limitation, namely the focus on a given territory that does not allow covering neighbouring areas. Fig. 6 illustrates this for the case of the Austrian-Italian border at the Brenner pass. As a result, domestic monitoring systems provide interesting background information for planners ‘on the other’ side, but they do not provide cross-border or transnational information.

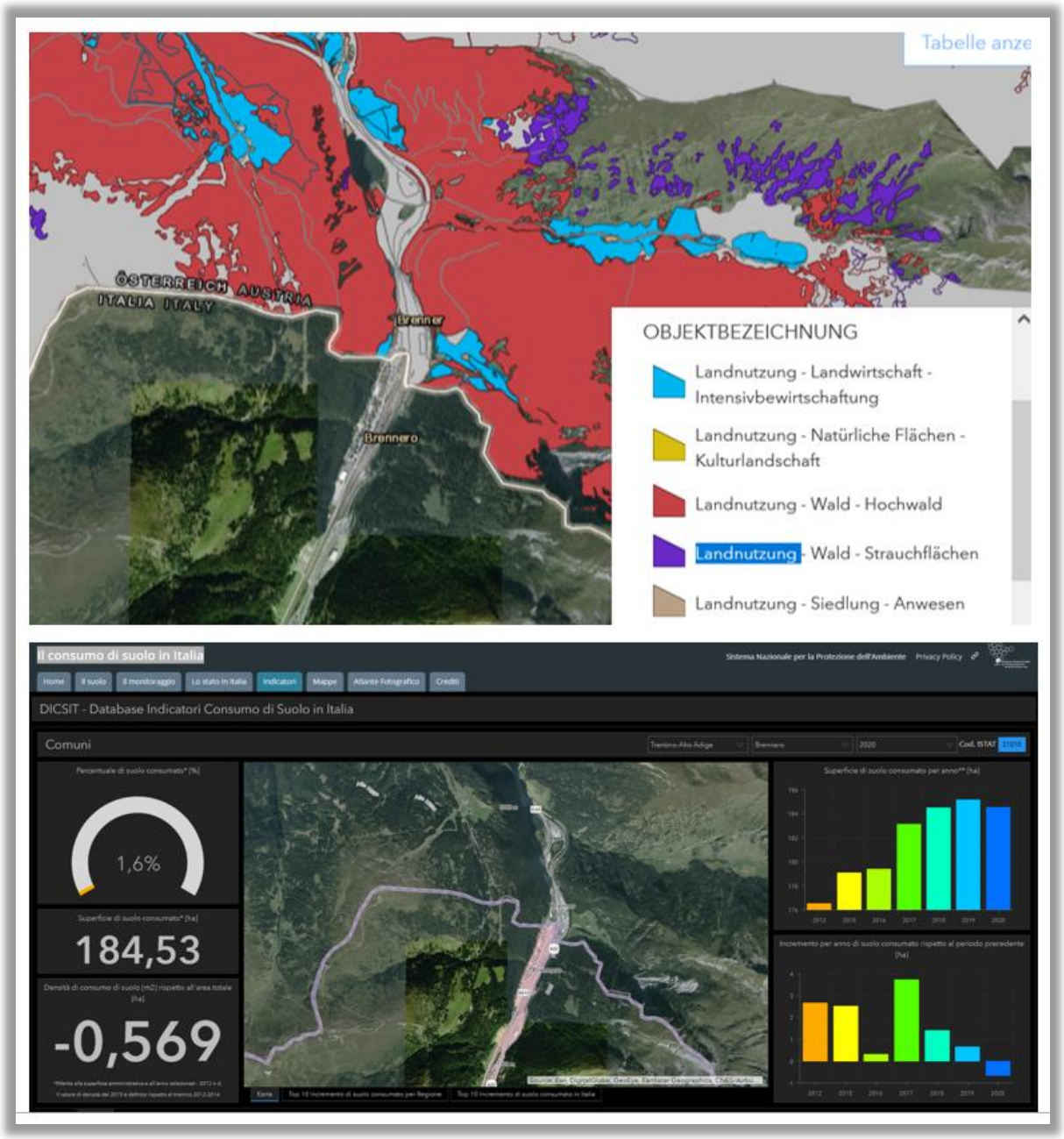

Fig. 6 Screenshots of two domestic monitoring systems, both for the Brenner pass at the Austrian-Italian border. Top: Tiris Tyol (source: https://data-tiris.opendata.arcgis.com/datasets/72b154f150904d9482df893161222403/explore?location=47.008426%2C11.490991%2C13.38&style=OBJEKTBEZEICHNUNG). Bottom: Italian Database on Soil Consumption (source: https://webgis.arpa.piemonte.it/secure_apps/consumo_suolo_agportal/?entry=4)

4. Conclusion

Fig. 7 provides a synthetic overview of this paper. The green background colour shows those parts where a fine scale and harmonised data availability is given in principle, even if other shortcomings have to be considered.

	AT	CH	DE	FR	IT	LI	MC	SI	EU
COPERNICUS (CLC/CLC+, HRL, BioPhysPar)	++ Fully hormonized, time series often possible ++ HRL for imperviousness and natural elements -- no information on land use -- land cover information for settlements only for large cities (Urban Atlas)								
LUCAS		(Areal-statistik, etc.)	++ good categorization, time series -- CH not included, grid based aproach			(Areal-statistik, etc.)			
Agriculture statistics	++ Good data quality -- too selective thematic focus								
Building statistics	-- Problems of harmonization / availibilty								[NUTS0]
Land use/ cover monitoring	Lisa	Areal-statistik	Alkis	Portail de l'artificia-lisation des sol	Arpa	Areal-statistik	...	*CLC data for area statistics*	[CLC, HRL, Lucas]

Fig. 7 Land take knowledge on domestic level (own illustration)

For the time being, we can conclude that there is no tool in place that would provide a comprehensive monitoring basis with regard to land take. This is true for Alpine spatial development in general and in particular for cross-border spatial planning:

- The domestic monitoring approaches that are in place are certainly helpful, but they are limited to institutional borders and perimeters.
- European statistics are available on spatial scales that do not provide meaningful insights for spatial planning in concrete terms.
- On the European level, the regular CLC data are of limited use. The data accuracy and fine scale availability does not provide much insight for spatial planning use (Sleszynski et al. 2020: 1).
- The Copernicus HRL data are the most promising data basis. Even if the data treatment is rather demanding at the moment and time series are hardly available, the information on physical soil sealing is rich. However, socio-economic information like land use information is not available in this data set.

The topic is developing rapidly in these years and there is reason for optimism:

- The HRL data will allow longer time series and more change indicators in the future. Moreover, the data handling might become easier.

- The EU ambitions for systematic harmonization and adaptability of data are ongoing. The INSPIRE directive and the EAGLE concept are two important arguments in this context.
- The future CLC+ database will provide a bundle of data which are EAGLE harmonized and available as geometric vector reference layers and also 10 m spatial resolution raster products. The data availability as vector data and the high resolution of raster data will noticeably improve the future data situation.

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ANNEX

Important links:

European level:

- LUCAS – Land use and land cover survey: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=LUCAS_-_Land_use_and_land_cover_survey#The_LUCAS_survey
- Copernicus – Europe's eyes on earth: https://www.copernicus.eu/en
- Copernicus Land monitoring service: https://land.copernicus.eu/
- Copernicus – CORINE Land Cover: https://land.copernicus.eu/pan-european/corine-land-cover
- Copernicus – CLC+: https://land.copernicus.eu/pan-european/clc-plus
- Copernicus – High Resolution Layers (HRL): https://land.copernicus.eu/pan-european/high-resolution-layers
- Copernicus – Biophysical parameters: https://land.copernicus.eu/pan-european/biophysical-parameters
- Copernicus – Urban Atlas: https://land.copernicus.eu/local/urban-atlas
- EAGLE Concept: https://land.copernicus.eu/eagle/content-documentation-of-the-eagle-concept/manual/introduction-to-the-eagle-concept/referencemanual-all-pages

Domestic level:

- LISA (AT): https://www.landinformationsystem.at/#/lisa/overview
- Arealstatistik (CH): https://www.bfs.admin.ch/bfs/de/home/statistiken/raum-umwelt/erhebungen/area.html
- Arealstatistik (LI): https://www.llv.li/files/abi/pdf-llv-abi-arealstatistik-resultate.pdf
- Arpa piemonte (IT): https://webgis.arpa.piemonte.it/geoportale/
- Tiris (AT - Tyrol): https://www.tirol.gv.at/statistik-budget/tiris/
- Portail de l'artificialisation des sols (FR): https://artificialisation.developpement-durable.gouv.fr/