Spatial planning indicators – the geoland approach

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1 INTRODUCTION

The Spatial Planning Observatory (OSP), which is part of the Integrated Project **geoland**, funded within the 6th framework program of the EC, will generate products and services based on Earth Observation (EO), geo-spatial and statistical data. The project aims at developing a project portfolio that covers some key issues of spatial planning frameworks and concepts, especially the ESDP (European Spatial Development Perspective) with ESPON (European Spatial Planning Observatory Network, ESPON 2004) as one of the measures for implementing the ESDP, as well as national and regional spatial planning directives and sustainability strategies. The products and services comprise indicators, spatial typologies and scenarios, presented in tabular, graphical and map forms.

Widely used frameworks for indicator development are the Pressure-State-Response framework of the OECD and the DPSIR – Driving Forces-Pressure-State-Impact-Response framework of the EEA. Land cover change as derived by EO-based methods, has been related to the DPSIR as a "pressure indicator", which characterises the depletion of natural resources. At the same time, the status of land cover (that characterizes the intensity of land use) and of the depletion of natural resources can be regarded as indicators for state and impact. Both frameworks do not explicitly include the aspect of land potential, which may be expressed as land attractiveness for people or as the degree of (potential) biodiversity. Land potential, however, can be considered a loop factor in the DPSIR framework in the sense that it is on the one hand impacted (to a variable degree) by driving forces/pressure/state factors, and on the other hand constitutes a driving force by itself by attracting people or companies to certain places where landscapes attractiveness is high. The indicators conceived on the basis of user requirements take this effect into account.

In this paper a selection of indicators on European, national/transnational and subnational level will be presented. These indicators relate to the DPSIR framework and include in addition aspects of land potential. They characterize driving forces and pressure related to demographic developments and their manifestation in land consumption per capita and settlement structures. State of and impact on the environment is represented by land cover/use patterns, agricultural intensity, and availability of recreational areas. These indicators form the basis for spatial typologies and scenarios to be developed in the course of the **geoland** project.

Besides these aspects on the supply side of the products and services there is the question of how users actually digest and utilise the provided information for spatial planning decisions or other purposes, such as reporting obligations. The EO based products and services constitute not only information from another than conventional data source, but also in some respects a new type of information, i.e. spatially explicit information. This offers not only additional application potentials, but also bears the necessity to adapt to their utilisation. In addition, the information provided is directly linked to concepts such as the DPSIR and sustainable development, and thus has to be evaluated and used in this context.

2 DATA AND TEST SITES

The indicators were developed in cooperation with an end user consortium comprising European, national and sub-national organisations. At the European level representatives of the ESPON projects, DG Regio, Metrex and Eurocities gave input to the OSP. The Austrian Institute for Regional Studies and Spatial Planning and the Austrian Federal Environment Agency represent the users on the national/transnational level. At the sub-national level the State of Vorarlberg supported the developments.

In the first phase of the project 14 indicators have been defined, seven for the European level, three for the national/transnational and 4 for the sub-national level (see table 1). These are subdivided into four product groups, including two for the European level, and one for both the national/transnational and subnational level. All indicators at European level are based on aggregated CORINE land cover (CLC) data and statistical information. The national indicators are built on full resolution CLC data, regional indicators on refined land cover data of CLC type.

CORINE Land Cover is a compilation of national land cover inventories, which are integrated into a seamless land cover map of Europe. The resulting European database is based on a standard methodology and nomenclature (EEA, 1999a). At European level the data base is available in a 100m grid format, representing the first two levels of the three level nomenclature. Currently an update (CLC 2000) of the first data base (CLC 1990) is being produced by the national teams of the participating countries, which should be available by spring 2005.

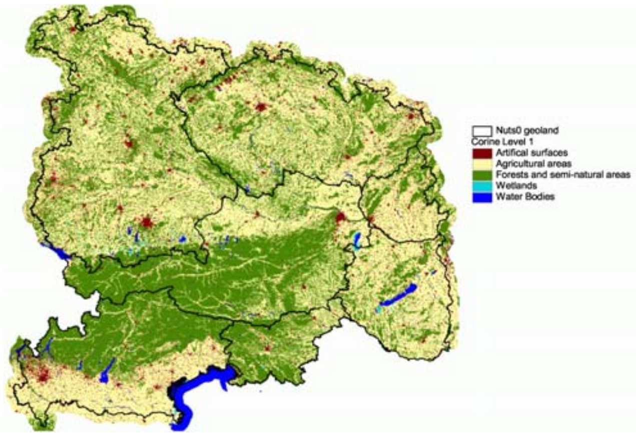

Fig.1: European test site a) MERIS satellite data mosaic b) CORINE land cover level 1

The statistical data at European level are derived from the REGIO database, Eurostat's harmonised regional statistical database. REGIO is a domain of the General Statistics of the New Cronos database. It contains 14 different collections, such as agriculture, demographic statistics, economic accounts, education statistics, environment statistics, community labour force survey (annual average and second quarter), migration statistics, science and technology (research and development, patents), structural business statistics, health statistics, tourism statistics, transport and energy statistics and unemployment. These data are available at NUTS3 level which is used as spatial reference on the European scale. National and sub-national analysis refers to districts and communes (NUTS5) and applies data from national statistical offices.

Three test sites have been defined for the production of indicator products for demonstration. For the European level an area of approximately 420.000 km^2 located in central Europe has been chosen, covering several nations including new EU member states. The test site represents a wide range of heterogeneous geographic landscapes including Alpine areas, costal zones as well as flat terrain with metropolitan and rural areas. It comprises the Czech Republic, Austria, Slovenia and parts of Germany, Slovakia, Hungary and Italy. Figure 1 gives an overview of the European test site.

The test site for the national indicators covers the area of Austria, the sub-national test site covers the area of Vorarlberg. In the course of the project these test sites will be extended by the transnational test sites of Linz – Budweis and Vienna – Bratislava. Additional sites comprise three of the MOLAND areas, namely the Northern Ireland, the Algarve and the Dresden-Prague corridor (EEA 2002).

European indicator set (NUTS3)
1.1 Proportion of artificial surfaces
1.2 Population density within urbanised areas
1.3 Access to nearby public open areas
1.4 Recreational areas within citizen reach
1.5 Agricultural intensity
1.6 Landscape diversity
1.7 Proportion of protected areas
National indicator set (districts)
2.1 Percentage of built up area of permanently habitable area
2.2 Land cover dispersion
2.3 Agricultural land use intensity
Sub-national indicator set (communes)
3.1 Percentage of built up area of permanently habitable area
3.2 Usability/attractiveness of remaining permanently habitable area
3.3 Degree of urban sprawl
3.4 Land cover dispersion

Table 1: List of indicators

3 INDICATOR DERIVATION AND BOTTLENECKS

The European indicator set comprises four indicators, which refer to the urban sprawl and to the urban and urban-rural attractiveness of land in terms of outdoor activities and three indicators referring to rural/environmental issues. The national and the sub-national indicator sets comprise three and four indicators respectively referring to urban/rural/environmental issues.

The methodology for deriving these indicators is based on GIS functions, especially intersections of EO data with other geo-spatial data and statistical information. Thus the technology for producing these indicators is entirely state of the art, but data quality and homogeneity can be regarded as a bottleneck. At European level, currently only aggregated CLC data with 100 m ground resolution is available, which is quite a rough data base for localised analyses, even though the results are subsequently aggregated to NUTS3 units or maps of the scale 1:1 Mio. In addition, statistical data may not be homogeneous over large European areas, and the NUTS3 regions themselves constitute a very uneven reference basis in terms of size and administrative basis in different European countries. Although full resolution CLC data (polygon representation on level 3) is available at national level, this might still be not sufficient for localised analyses, due to the minimum mapping unit of 25ha. Especially landscape diversity is known to be underestimated when derived from CLC data. In addition, CLC data heavily underestimate land cover classes that frequently occur in small patches, especially built up areas, which are not captured at all in many small communities.

At the sub-national level constraints exist mainly with regards to the costs of regularly updated land cover data. Potential users often argue that there is no need to acquire satellite imagery, since the regions are covered by aerial photography every 5 to 7 years. Thus in many regions, there might be a lack of willingness to pay for (additional) space-based EO data. Aerial photography, on the other hand, is costly to analyse, although costs are decreasing with the new automated techniques available today. In addition, image acquisition every 5 to 7 years might not be frequent enough for applications related to environmental reporting obligations.

Beside the constraints stated above the actual challenge of the work is the current lack of experience in building combined indicators linking (highly aggregated) land cover data with aggregated statistical data. But exactly this combination represents the major benefit of these indicators as localised (i.e. geo-referenced) information is offered instead of pure statistical data (EEA 2001). This provides additional information; for instance population density and its evolution can be related to the actually built up area; or access of the population to green and recreational areas can be directly estimated by looking at the local surroundings, instead of using pure statistical aggregated figures indicating only the quantity but not the accessibility of those areas. Consequently, these land cover based indicators express more precisely the living circumstances of people and issues of spatial developments in urban and sub-urban areas.

For the remaining paper we will concentrate on a set of selected indicators, describe their characteristics and method of production, and discuss their benefits and limitations.

3.1 Population density within urbanized areas (European level)

This indicator refers to the actual population density that occurs within built-up areas in contrast to the traditional measure that refers to population per statistical area, such as NUTS3. Assuming that people live in residential areas rather than in the fields or forests the population number of a statistical unit can be assigned to the actual built-up areas within this unit. Calculation of this indicator requires information on land cover – in particular on artificial surface types (CLC class 1 and sub-classes) – and on population statistics as provided by Eurostat on a NUTS3 level.

The indicator can be based either on the entire artificial surface areas or limited to residential areas. The first approach represents the general land consumption per capita, including commercial, industrial and transport related areas etc., while the second approach gives an indication on the density of housing within residential areas.

Representation of the indicators can be based on polygons or a regular grid. For the first approach the land cover layer is intersected with NUTS3 polygons, the proportion of the relevant land cover classes per polygon is calculated and the population data divided by it. This approach gives one value for each NUTS3 polygon. The grid-based approach goes one step further by mapping the calculated density measures on the relevant land cover units leading to a spatially refined density map. This layer is then intersected by regular grid allowing to calculate a density measure for each grid cell. Figure 2 compares both representations of the indicator for the European test site.

3.2 Recreational areas within citizen reach (European level)

This indicator represents the proportion of attractive landscapes (as potential recreational areas) within a specified distance from residential areas. For each "residential cell" the amount of "recreational areas" within its reach is calculated, for instance within a circle of 10 km, to express residential area attractiveness for short one-day or weekend trips.

Recreational areas are defined as green urban areas, forest and semi-natural areas, wetlands and water bodies within a specified distance from residential areas. In order to calculate this indicator raster representation of the land cover map is required (as e.g. provided by the CLC100m grid). First the recreational areas are given one common class code, next the focal sum of this class for a circular neighborhood is calculated for each grid cell. The resulting grid is intersected with the residential areas in order to assign each residential grid cell the number of recreational cells within reach. Summing up these aggregated values for the each NUTS3 polygon and harmonizing the result by dividing by the number of residential cells within the NUTS3 polygon leads to the final indicator. Figure 3a shows the indicator for the European test site.

3.3 Agricultural intensity (European level)

This indicator refers to the percentage of arable land and permanent crops on the potential utilizable area. The potential utilizable area may be taken either as total agricultural area or as agricultural area plus forests and semi-natural areas. In the first case the indicator represents the ratio between intensive and extensive agriculture, as the total agricultural area without arable land and permanent crops leaves meadows and pastures. The latter approach represents the importance of intensive agriculture in terms of agricultural land consumption for the area under investigation.

In order to calculate the indicator the NUTS3 boundaries are intersected with the land cover layer and for each polygon the area of the single land cover types is calculated. The total area of arable land and permanent crops is then divided by the total agricultural area or the total vegetated area respectively. Figure 3b shows the result of the former approach, i.e. the degree of agricultural intensity.

3.4 Degree of urban sprawl (Sub-national level)

All indicators on sub-national level refer to communes (NUTS5) as spatial entity. The calculation of these indicators relies on standard GIS operations such as intersection and spatial statistics. Data sources for indicators on sub-national level are SPOT-based land cover classifications (minimum mapping unit: 0,25ha for artificial surfaces, 1ha for non artificial surfaces) for two dates (1990/2000) as well as national statistics. In contrast to the European indicators this allows for the analysis of changes over time.

The urban sprawl indicator describes the degree to which urban area elements are fragmented. The indicator is calculated by dividing the actual border length of built-up areas by their minimum border length (Forman, 1995). The latter is represented by the perimeter of a circle that has the same surface area as the built-up area. Built-up area comprises residential areas as well as industrial, commercial and transport units. The indicator can be presented in various map versions or as table (see Figure 4).

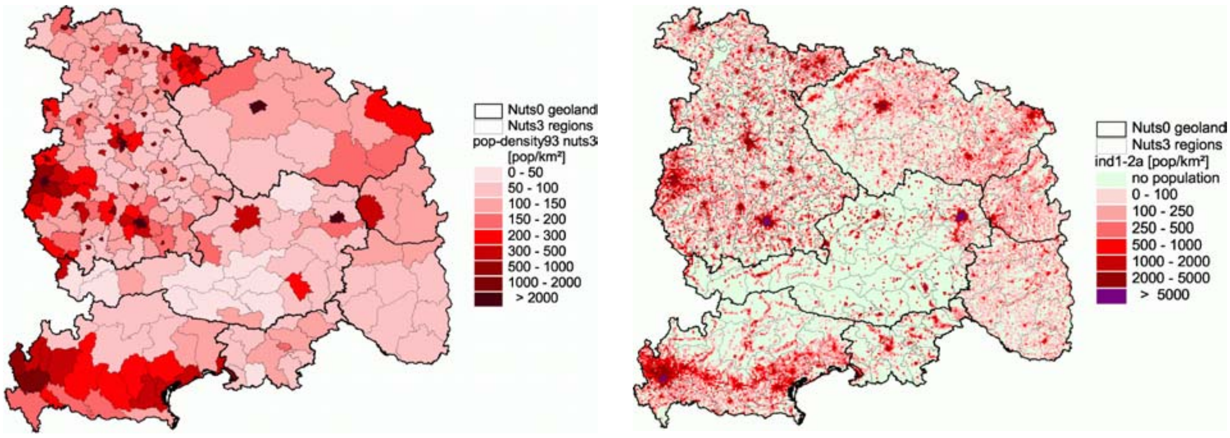

Fig.2: Population density a) polygon representation, b) grid representation

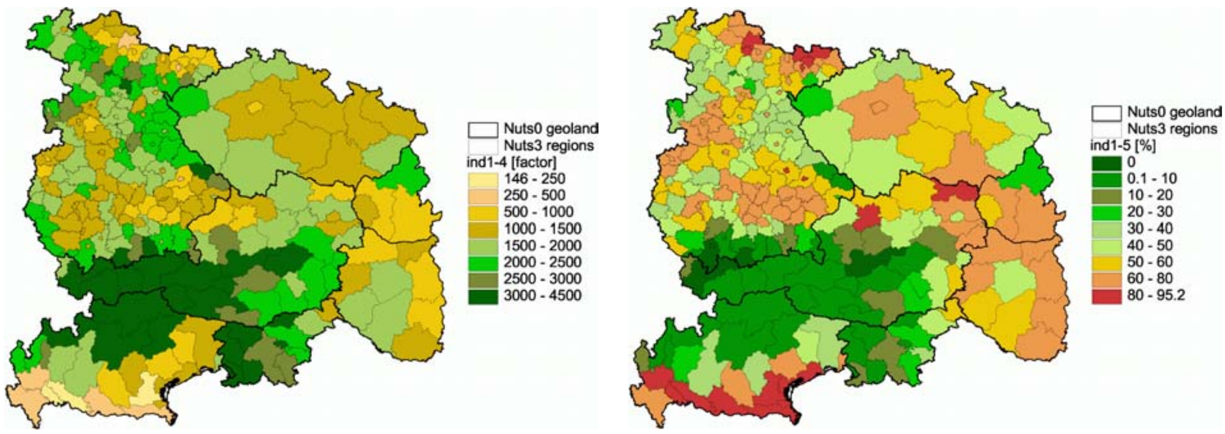

Fig.3: a) recreational areas within citizen reach, b) agricultural intensity

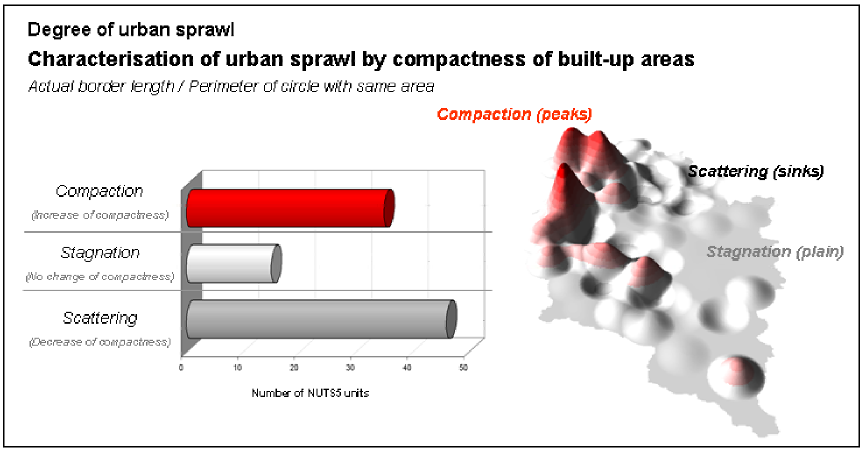

Fig.4: Urban sprawl indicator at sub-national level (Vorarlberg)

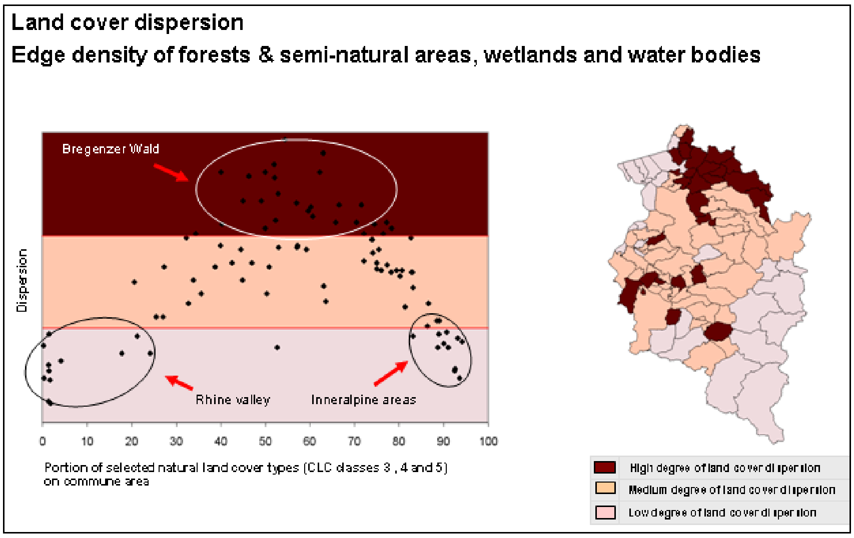

Fig.5: Land cover dispersion at sub-national level (Vorarlberg)

3.5 Land cover dispersion (Sub-national Level)

The dispersion of single or groups of land cover classes provides a measure for the size and distribution of land cover elements and landscape diversity. At this spatial level, the indicator is calculated on detailed land cover data with minimum mapping units of 1 ha or smaller to show variations at a larger scale (1:25.000 to 1:100.000).

Land cover dispersion is indicated by the edge density of selected, non-artificial land cover types, including CLC classes 3 (forests and semi-natural areas), 4 (wetlands) and 5 (water bodies) with their relevant subclasses. The calculation of the edge density is based on the number of boundary pixels between adjacent land cover objects divided by the area under investigation.

The raster approach allows for two levels of aggregation; firstly a continuous surface can be generated by applying a moving window approach, secondly the indicator can be calculated for any irregular spatial entity such as administrative units (see Figure 5). Depending on the approach the result is either a polygon layer or a regular grid where each polygon / grid cell represents the degree of land cover dispersion within its area. The indicator can be either presented as map or as table (only for polygon approach).

4 DISCUSSION

All indicators described above are the results of a first approach and basis for discussion with the users. In the following chapter the outcome of these discussions is presented in terms of problems encountered related to data quality and availablitiy, uncertainty of definitions and potential improvements of the indicators.

4.1 Data sources and quality

One basic source of information is CLC data. At the time of the production of the demonstrators only CLC 1990 data were available for the European test site. Though the production of CLC 2000 land cover maps is nearly finished they will not be available before 2005. This fact limited the presented approach to monotemporal analysis, but analysing the change of indicators over time will be an issue for future work.

In terms of data quality the grid representation of CLC was found not to be sufficient for certain analyses. This is less due to the spatial resolution of 100m – which seems to be appropriate when working on a European scale – but more related to the minimum mapping area of 25ha. In particular for small built-up areas but also for certain agricultural structures the level of spatial detail is too coarse. This has an effect on both the spatial and temporal variability and significance of the indicators. Many land cover changes are not recorded because they are below the minimum mapping unit; likewise, the character and diversity of landscapes – in as much as it is related to smaller landcover objects - is not expressed in the data.

Statistical data were acquired from the REGIO data base available at Eurostat. Besides the complex structure of this data base – requiring interactive data retrieval in order to produce a GIS compatible attributed polygon layers – problems occurred when searching for historic data. Linking land cover with statistical data requires more or less identical acquisition times of both data types. As the reference year for CLC is 1990 statistical data from that time are needed. Unfortunately statistical data from the New Member States are not available before the mid 1990s.

Another difficulty arises from the varying sizes of the NUTS3 areas in different countries. While in the new Member States the size of NUTS3 areas averages out to about 5.000 km^2, in Germany they come down to 1.000 km^2 in rural areas and to 100 km^2 for urban areas. The smallest NUTS3 area of the European test site has a size of less than 36 km^2, the largest a size of more than 11.000 km^2. Comparison of statistical data is somewhat hampered by these disparities but the introduction of land cover data and the referencing of land cover based indicators to a common European grid can help to improve the situation.

4.2 Indicators

Looking at *population density in urbanized areas* we face the problem of lack of land cover detail. As this indicator builds upon the amount of urban area that is partially underestimated due to mapping constraints – as discussed above –, population density can be overestimated. This effect appears e.g. in the North of Austria where many settlements are dispersed and thus fall under the minimum mapping unit of 25ha. As the population is actually distributed over a larger area but only mapped to central villages, the density within these villages will be overestimated while the surrounding land stays "empty".

Deriving the density from population per residential area shows how densely people live in cities, while also indicating the structure of the residential area. This can also be demonstrated by the reciprocal of the density that yields land consumption per capita; high land consumption indicating single family housing, low land consumption indicating apartment buildings. However, having only one type of residential land cover – on level 2 of the CLC nomenclature no differentiations are made on urban densities – only one density value can be calculated per administrative unit not allowing any differentiation of urban structures. In case of two or more residential land cover types, the population distribution can be weighted according to the residential structures, leading to different density values within one administrative unit.

If the calculation of the population density is based on artificial surfaces in general – including industrial, commercial and transport areas in addition to residential areas – the indicator relates not only to housing issues but also to economic activities of the population. Suggestions were made to introduce GDP as a socio-economic parameter and relate it to the land consumption.

The indicator on *Recreational areas within citizen reach* turned out to be an interesting representation of landscape features. As it takes local patterns into account we again face the problem of spatial detail in the land cover representation. The distance applied is to be seen as a proxy variable but does not represent the actual effort to reach recreational areas. Discussions with the users lead to the conclusion that this indicator should not be limited to residential areas but could be improved by introducing population numbers. Applying population density per residential area allows calculating the amount of recreational area available per capita, thus refining the significance of the indicator.

Agricultural intensity represents the ratio between intensive agriculture and extensive agriculture or vegetation cover in general. Problems occur if the absolute amount of agricultural area is small and dominated by one of the parameters. This occurs for example in the urban NUTS3 areas in Germany (Stadtkreise), where the few agricultural areas are mainly intensively used and therefore the indicator shows a high agricultural intensity (higher than in most rural areas, where at least a certain amount of agricultural land is used extensively). A solution to this problem could be the introduction of absolute numbers as thresholds – i.e. as long as only a minor amount of the area is agriculturally used the indicator is set to a "no significant agriculture" status.

Still under discussion is the question whether this land cover information could be linked with agricultural statistics. As agricultural intensity is only partially described by land consumption the introduction of agricultural production might improve the significance of the indicator. However it is not yet clear how these data sets can be combined in a meaningful way.

The sub-national indicator *Degree of urban sprawl* resulted in a characterisation of urban sprawl by the compactness of built-up areas. Applied to the test-site of Vorarlberg this led to a separation into regions which are affected by increase, stagnation or decrease of compactness of the built-up areas (see fig. 4). Areas with an increase of compactness are found in the Rhine valley and in the most southern part of Vorarlberg (Montafon). In the Rhine valley with it's high population density the existing settlement areas are getting densified and settlement dispersion is avoided by legal spatial planning instruments (Grünzonenplan) of the State Government of Vorarlberg. In the Montafon the compaction is induced by the tourism in this Alpine region. Scattering settlements can be found in the Bregenzer Wald and in the Klostertal areas. Especially the Bregenzer Wald region is one of the most attractive single housing areas in Vorarlberg due to the neighbourhood to the Rhine valley and the landscape attractiveness.

The sub-national indicator *Land cover dispersion*, which from the methodological approach is based on the edge density of forest and semi-natural areas, wetlands and waterbodies also led to a separation of Vorarlberg into specific land cover characterised areas. In the spatial and statistical analysis the Bregenzer Wald comes out as one of the most attractive landscapes due to a high land cover dispersion factor. Further on, the Rhine valley has been classified as region with a lower landcover dispersion value and a small proportion of the selected land cover types on commune level. Also the inneralpine areas have been classified with a low land cover dispersion value (due to the level 1 class aggregation) but with a significant proportion (nearly 100%) of the CLC classes 3,4 and 5 of the administrative areas.

5 RELEVANCE FOR SPATIAL PLANNING

From a technical point of view, the digestion of the provided indicators, i.e. digital maps and statistics, by the information systems of the users does not constitute problems today, as GIS can be regarded as mature and widely introduced technology. The key question is that of application concepts for the provided information. How and for which goals can these indicators support decision makers and spatial planners?

The presented portfolio only constitutes a selection of indicators out of a huge variety of possible products. They were selected as they provide fundamental and policy-relevant spatial information, but the portfolio remains to be under development. Thus the indicators reflect existing spatial planning/policy making guidelines (e.g., sustainability of land use in the sense of the long-term maintenance of the required land use functions and the natural heritage, European spatial cohesion) and analysis frameworks (DPSIR), as they were derived in relation to these. The knowledge of the concepts and spatial planning targets guiding the indicator selection/definition are consequently the basis for their utilisation. The capital questions that are determining their usage by policy makers are:

- What is the direct message of the indicators and what its significance? In practical terms: What do they describe and "does it matter?"
- What are the causal relations between the origins and the consequences of the environmental problems and what is their ranking in terms of leverage and impact? In practical terms: Which policy targets in a given territory are to prioritise and what are the key causal factors to pay the most attention to or what are the most efficient measures to improve things?
- What are the effects of policies? Has the state of the environment improved? Which measures are likely to improve it?

In addition, the provided indicators can be used to raise public awareness on these issues and to strengthen public support for policy measures (EEA 1999b).

The utility of the provided information for spatial planning or the design of spatial policies is directly linked to whether the products/services fulfil the criteria listed above. In that respect the indicators presented in this paper can by no means be considered a comprehensive and stand-alone information basis for spatial planners. They do, however, present spatially explicit answers to crucial questions - from a sustainable development point of view – when dealing with territories, e.g., how intense is human pressure on land, how are the impacts on the landscape from both, a biodiversity point of view and in terms of land attractiveness for recreational purposes, and how are these things developing over time?

Further improvements of the practical usability of the presented portfolio will arise from the derivation of spatial typologies from the indicators, from spatial disaggregations of population distribution via the distribution and character of the built up area and census data, and from urban growth modelling. These measures and developments will strengthen the assessment potential of the products, their relevance for the population distribution at regional down to local scales, and their potential for policy impact assessments.

6 CONCLUSIONS

The described indicators demonstrate the usefulness of EO based information in particular when linked to statistical information. However, improvements are required both in terms of land cover specification and indicator definition. In order to use land cover data efficiently more spatial detail is needed. While the thematic detail of CLC level 2 is generally sufficient – except for residential areas where different density classes would be helpful – the minimum mapping unit of 25ha is much too large for detailed analyses.

Thematic differentiation of built-up areas that goes beyond basic land use classes such as residential, commercial, industrial etc. should not be based on EO data alone, but should rather be derived in conjunction with statistical data. Linking statistical and EO data in general is not a straight forward process, except for some simple exercises such as spatial disaggregation of population numbers. However, even this simple example shows the benefit that can be gained from the disaggregated information. Applying a regular grid instead of polygons for representing socio-economic data might help to overcome the problem of the varying sizes of administrative areas.

Still missing, at least at the European level, is the demonstration of EO as monitoring tool. Comparing the changes in land use with socio-economic developments should yield further interesting results. With the provision of CLC2000 the development of indicators over time will be demonstrated.

Finally the content and the applicability of some indicators will be analysed and adapted or additional indicators will be produced. These final indicators shall then be the basis for typologies and scenarios to be developed in the course of the geoland project.

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