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Delineation of Response Functions

D2.3.2

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Abstract

Objectives / aims

This deliverable report has been developed during the first phase of the PLUREL project. It deals with the methodological approach to derive response functions based on regression models. The follow up documents related to this report are deliverable D2.3.9/10 describing an application case with improved model quality and presenting the derived results, as well as D4.3.1 focussing on the indicators. This paper delivers a description of working steps for the development of Response Functions in Module 2, work package 2.3.
These functions are meant to quantify the functional relationships between land use changes and impact issues relevant for sustainability in the fields of landscape bound recreation, biodiversity, commuting and traffic, population, housing and household structure, migration, social issues and emissions (deliverables 2.3.3 to 2.3.10).

Methodology

Conceptually the response functions follow the M1 scenarios as well as the land use change modelling including land use change allocation. The results of the response function development will be fed into the iIAT Europe and the Xplorer in M5.

The response functions are sketched as regression functions, which can be used for exante assessments based on the scenario storylines for the PLUREL time slices 2015, 2025 and 2050. The independent variables can be the outcomes of M1 modelling procedures as well as any other relevant influencing variable that is suitable for scenario based projection into the future. The methodology suggested is multiple linear regression, which can be applied at NUTS 3 or 2 level (or NUTS X, which is the spatial scale of the iIAT Europe). Since neither the land use change modelling nor the existing European land use related datasets are available as continuous timelines, full scale timeline analysis is out of the question. Instead the functions can link variables in a “timeless” cross section analysis model, applied for each time slice. The alternative possibility is to link relative changes between two points in time on the independent and the dependent side of the function.

The second crucial issue is the integration of the RUR typology (Steinnocher et al. 2008) as well as other typologies and regional clusters. Membership of any region to a region type or cluster can be interpreted as a non-metric, categorical variable, which can be integrated into the response function. We suggest that either

- · response functions are developed specifically for individual types,
- · type specific adjustment factors are calculated
- · or the types are integrated as dummy variables into the regression.

Results

As a general methodological approach, we suggest three steps:

(1) Identification of target variable. The variable should be easily quantifiable, meaningful in terms of sustainability in the respective thematic field, available for the EU 27 and plausible as a consequence of peri-urban land use processes.

(2) Identification of independent variables. The central variable is land use change, provided by M1, but other (socioeconomic and other) variables can have integrated as well, depending on plausibility, theory based assumptions and availability. The field of independent variables can be structured and reduced in complexity by applying factor analysis.

(3) Establishment of functional relationships by applying regression analysis.

For the deliverables 2.3.9 (agriculture and food) and 2.3.10 (open space, including biodiversity, recreation and soil) the described methodology to derive response functions for landscape related target variables has been applied. The results are described in an article,which was incorporated into this report. Instead of assigning indicators to each of the individual impact issues we looked at landscapes and their ecological, recreational and productive potential in a holistic way by deriving integrated landscape indicators.

The database for our regression model consists of: (1) the European land cover inventory CORINE Land cover, which is available for the years 1990 and 2000, (2) the vector based spatially explicit Eurostat GISCO database as well as (3) the general socioeconomic statistical Eurostat REGIO database. We used CORINE and GISCO to define a set of four dependent variables representing the degree to which a landscape is affected by urbanisation related developments:

(1) Share of natural and semi-natural areas: A set of CORINE classes (agricultural area with high share of semi-natural areas, pastures, meadows and grassland, shrub-land as well as wetlands) are aggregated as particularly valuable areas for biodiversity. They also provide high recreational value. Their relative share is an indicator for a landscape's natural ecological potential (database: CLC).

(2/3) Fragmentation by major road and rail networks as well as settlements: Two fragmentation indicators were calculated using the GISCO database and CLC. Fragmentation is a measure for anthropogenic superimposition of the landscape, especially with regard to habitat size and impacts on genetic mobility of species.
(4) Green Background index: The indicator is derived from the CORILIS dataset, which is a smoothed version of CLC. It represents the presence, e.g. not only the share, but also the spatial structure or permeation, of natural areas in a given region. Therefore it is an aggregate measure for ecologic potential.

The independent variables are the share of urban land as well as population and economic affluence indicators obtained from the Eurostat REGIO database. By applying correlation, factor and regression analysis we could show, that fragmentation can be explained quite well using the independent variables. Therefore the established regression coefficients are suitable for response functions as a part of the ex ante Sustainability Impact Assessment Tool. The Green Background Index can partially be explained, but the biophysical and land cover setup of each particular region has probably a stronger influence than the independent variables taken into account. The share of natural and semi-natural areas can not be explained by our independent variables. Therefore we contribute response functions for landscape fragmentation and green background as meaningful proxies for the impact issues in the deliverables D2.3.9 and D2.3.10.

Popular science description

This report deals with the methodological approach to derive response functions based on regression models. These functions are meant to quantify the functional relationships between land use changes and impact issues relevant for sustainability in the fields of landscape bound recreation, biodiversity, commuting and traffic, population, housing and household structure, migration, social issues and emissions. It is suggested to (1) identify target variables, (2) identify independent variables, and (3) establish functional relationships by applying regression analysis. Specifically this is done by linking changes in the share of natural and semi-natural areas, and the fragmentation by major roads and settlements, to the dynamics of population and economy.

Keywords

Regression analysis, statistical modelling approach, Recreational Function, RUR Typology

Classification of results/outputs:
For the purpose of integrating the results of this deliverable into the PLUREL Explorer dissemination platform as fact sheets and associated documentation please classify the results in relation to spatial scale; DPSIR framework; land use issues; output indicators and knowledge type.

Spatial scale for results: Regional, national, European	Europe
DPSIR framework: Driver, Pressure, State, Impact, Response	Driver/Pressure/State/Impact
Land use issues covered: Housing, Traffic, Agriculture, Natural area, Water, Tourism/recreation	Recreation, biodiversity, commuting and traffic, population, housing and household structure, migration, social issues and emissions
Scenario sensitivity: Are the products/outputs sensitive to Module 1 scenarios?	yes
Output indicators: Socio-economic & environmental external constraints; Land Use structure; RUR Metabolism; ECO-system integrity; Ecosystem Services; Socio-economic assessment Criteria; Decisions	Socio-economic indicators, landscape related indicators
Knowledge type: Narrative storylines; Response functions; GIS-based maps; Tables or charts; Handbooks	Response functions

How many fact sheets will be derived from this deliverable:	**1**

Introduction

For the past decades, urbanisation has brought about substantial changes in European landscapes. The trends apparent at the fringes of Europe's cities and city regions have been discussed under the heading of "urban sprawl", which is characterised by rapid urban growth and the expansion of urban areas of all kinds and densities. The European Environmental Agency (2005) assessed that 8,000 km of open spaces was converted into artificial urban land between 1990 and 2000. A low density urban expansion beyond former city boundaries (Burdack, 2008; Ingersoll, 2006), bringing about an urban landscape with varying urban densities and a high degree of fragmentation, isolation and degradation of the remaining open spaces (Antrop, 2000) is accompanied by far reaching impacts on properties of landscape and environment. But not only the environment is effected by urban sprawl, moreover the society and economy in these areas are changed.

Political programmes and strategies have to undergo an ex-ante sustainability impact assessment, which also addresses the impacts of urban and peri-urban developments on socioeconomic and environmental conditions. Within the 6th EU Research Framework (FP6) modelling approaches and tools are developed which depict the functional relationships of socioeconomic drivers, land use pressures and impacts following the DPSIR approach (EEA 2002) and thus establish a link between global drivers and regional impacts at the NUTS 2 or 3 level. The work at hand draws on previous working steps undertaken in FP6: In a scenario approach based on the IPCC SRES (IPCC, 2001) storylines, economic and demographic trends have been quantified by probabilistic modelling (Boitier et al., 2008; Ravetz et al., 2008; Scherbov and Mamolo, 2008). The modelling outputs on land use, economic and demographic changes due to four different scenario storylines for the time period 2008 – 2050 at national level (NUTS 0) provided the starting point for the modelling of Response Functions (RF) for European regions.

RF are the core modelling tool approximating true behaviour between influencing drivers and pressures on the various spatial components of land uses within rural-urban-regions and their functional relationships along strings of impacts. RF provide intermediary results as basis for computing sustainability indicators within the Sustainability Impact Assessment. RF of the various sectoral modelling teams need to have a coherent output results to get operated in the common project framework – they need to be oriented to the further users, such as WP 2.4 (quantifying RF in the context of land use scenarios) and M4 (SIA). RF need to be validated on the case study level.

In this deliverable we present our understanding of and our perspectives on the work in WP 2.3 in general. Chapter one comprises a discussion of the conceptual basis for the development of response functions. Chapter two contains suggestions for individual working steps and methodology for the development of response functions, including our own. Chapter three consists of a paper we put together as a conference contribution, showing the potential reach, quality and utility of response functions.

Response Functions in WP 2.3 refer to the following impact issues as described in the DoW:

2.2.3: Population and Household Structure
2.3.4: Social Issues
2.3.5: Housing and Infrastructure
2.3.6: Economic development and Working Places
2.3.7: Traffic and Commuting
2.3.8: Energy Consumption and Emissions
2.3.9: Food and Agriculture
2.3.10: Open Space

The methodological steps described in this report can be applied by other working groups in WP 2.3, although response functions can alternatively be based on more qualitative, deductive model based or heuristic methods or a combination of different approaches.

Response Functions: general considerations

The M2 response functions conceptually follow the land use change modelling process, which includes a quantitative land use change component and an allocation component. The question of representation of land use change and sustainability impacts is addressed in Deliverable Report 2.3.1.

For 2.3.9 and 10, we currently work on response functions for the indices: agricultural output and naturality of landscape (percentage of natural areas). The response functions and their meaning are further described in Deliverable 2.3.9/10. In our understanding they will be **multiple regression models** that depict the expected state of the depending variables at a certain time in the future. **They do not depict the timeline of the studied value (for example landscape diversity, as a proxy for biodiversity) itself, but its dependence on the independent variables, which will be made available for the time slices 2013, 2025 and 2050. The reason that we do not understand response functions as timelines is, that the most important input, Land Use Change, is not made available as a timeline, but as discrete values for three points in time.** Again: The social, economic and ecologic impacts are modelled as variables depending on the land use change outputs derived in the last step plus other plausible variables, which can be forecast for the three time slices depending on the scenarios.

For work on response functions the following considerations are to be made:

→ Should the function be static or dynamic? The question refers less to the model type (multiple regression) than to the variables being computed: Do you test for the influence of relative changes (delta degree of urbanisation from, say, 1990 to 2000) on relative changes (delta diversity in the same time), or absolute numbers at a certain point of time (influence of the share of urbanised land on diversity in the year 1990). Both possibilities can lead to the required result. In our case both are tried and compared regarding their explanatory strength (R^2)

→ Apart from the land use change results a set of indicators for real world phenomena, which are suspected to have an influence, should be identified. If the field is large, factor analysis can help to reduce its complexity. In the case of 2.3.9 and 10, average farm size is such a (socioeconomic) indicator.

→ Do the RUR types respond differently to the influence of independent variables? The influence of different types of regions on land use change was already mentioned in step 1. But quite possibly, in different region types, land use change brings about different impacts. Two steps can help to determine this relation: Again variance analysis can be used, this time in order to test the RUR typology's influence on the final impacts, or more precisely, the individual residues left by the regression model. Another way of testing is to build a regression model for each RUR type and check if the R^2 are higher than the general one.

The outcome is ideally a regression function that serves as response function. The integration of the RUR typology can take place in three ways: development of a function for each type, delineation of a RUR type specific factor to adjust the dependent variable of the function, or the integration of the RUR type as a non-metric variable using multiple regression with dummy variables.

Version 1: A function for each RUR type

RUR type 1: $y = a_{type1} \times SU_{2025} + b_{type1} \times SI + c_{type1} \times DI_{2025} + k$

RUR type 2: $y = a_{type2} \times SU_{2025} + b_{type2} \times SI + c_{type2} \times DI_{2025} + k$

With:
y = output variable, example diversity
SU = share of urban land cover at a certain time slice
SI = static indicator, for example biophysical characteristics like soil type
DI = dynamic indicator, for example farm size, at a certain time slice
a = regression coefficient for SU, different for each RUR type
b = regression coefficient for SI, dito
c = regression coefficient for DI, dito

Version 2: Integration of the RUR type as a coefficient

$$y = RTF \times (a \times SU_{2025} + b \times SI + c \times DI_{2025} + k)$$

With: RTF = RUR Type Factor

However, biophysical and socioeconomic indicators may not necessarily be regarded as influencing factors. They could also be used to depict a regions "responsiveness", "sensitivity" or "vulnerability" to certain developments. If the issue, as in our example, is biodiversity, and the response function delivers a change in landscape diversity as a proxy, regions could further be differentiated with regard to the sensitivity of their ecosystems. The simplest way would be to look at Natura 2000 areas: A loss of landscape diversity might be considered more damaging there, than in an area which has not met the attention of institutionalised environmentalism. Of course this implies that Natura 2000 areas are more sensitive than others – a view that neglects that an area's protection status is a mere legal, not an ecologic category. Other data sources are available. Possible examples of "vulnerability" checks could be:

- Regional percentage of low income groups, which need open green spaces nearby for their recreation and health (attached to deliverable 2.3.9, Accessibility of Open Space)
- Existing soil erosion risk, understood as vulnerability to soil sealing and landscape fragmentation
- Percentage of urban population as a sensitivity index to air pollution

Those sensitivity figures could be integrated into the response functions as a factor that further specifies the impacts (possibly the end use could have the choice to switch them on and off).

Version 3: Dummy variables

$$y = a \times SU_{2025} + b \times SI + c \times DI_{2025} + d \times RUR1 + e \times RUR2 + \ldots + k$$

With:
a = regression coefficient for SU
b = regression coefficient for SI
c = regression coefficient for DI
d, e, ... = regression coefficient for each RUR type
RUR1, RUR2, ... = RUR types as non-metric 1/0 dummy variables

Methodological steps

Aims and requirements of RF

- RF are the core modelling tool approximating true behaviour between influencing drivers and pressures on the various spatial components of land uses within rural-urban-regions and their functional relationships along strings of impacts.
- RF provide intermediary results as basis for computing sustainability indicators within the Sustainability Impact Assessment
- RF of the various sectoral modelling teams need to have a coherent output results to get operated in the common project framework – they need to be oriented to the further users, such as WP 2.4 (quantifying RF in the context of land use scenarios) and M4 (SIA)
- RF need to be validated on the case study level

Step 1: Spatial functions with relevance for urban-rural-relationships – Selection of dependent target figures

Each working team should choose relevant spatial functions, which suitably represent urban-rural-relationship incorporating social, economic and ecologic aspects.

The basis for the selection process should be the influence of the target figures on urban-rural-relationships. Influencing target figures, which are less regional em-bedded because demand and supply can be easily imported or exported on a na-tional, European or even global scale e.g. most parts of agriculture, tourism, water supply or energy won't play a role when it comes to urban-rural-relationships. In contrast target figures like water treatment, soil function or local recreation/open space are much more bound into regional relationships.

Accordingly dependent variables need to be adapted regarding possible levels of output (see figure 1) – variables representing changing pattern of structures (e.g. households), activities (e.g. recreation), use of land and resources (spatial recreation potential), non-commodity impacts (recreation functions)

Example Recreation Function

Landscape functions distinguish between economical production functions (i.e. agriculture, extraction of water and mineral materials), ecological regulation functions (i.e. cycle of matter, filtering, buffering, soil function, ground and surface water, micro climate, biodiversity) and social habitat functions (i.e. landscape identity, recreation)

The concept of landscape functions serves as the basis for identifying the target figures. Among other we focus here on the aspect of recreation function of landscape. Recreation functions can be expressed by spatial figures (level 3) as well as quality representing non commodity impacts (level 4). These are determined by infrastructure/accessibility, aesthetics/usability of the countryside as well as ecological quality.

Step 2: Modelling of generalised functional relationships

Following the definition of dependent output variables, the second step will ap-proach simple and generalised functional relationships between dependent (land use/ non commodity impacts) and independent variables – social, economical, ecological drivers as well as physical characteristics of the surface.

At this point it would not imply consideration of more precise sub-regional differentiation (proceed in step 3) and regional differentiations of a RUR-typology (proceed in step 4).

Definition of input variables

By applying of various statistical procedures such as factor analysis, regression analysis, variance analysis or cluster analysis on existing statistical data, it should be possible to identify the important independent variables as well as revealing their influence on dependent variables.

Appropriate variables need to meet certain requirements, such as: quality assess-ment for predication of a second (dependent) variable; an error-reduced measurement (avoiding of mutual interdependencies of variables) and a setup for a data-reduced processing (bundling of various variables; exclusion of variables without any influence)

Another question regarding the selection of point is the availability of data.

Relevance of quantitative data

RF modelling will rely on the existence of quantitative statistical timeline datasets to be analysed with statistical procedures

Sources of data-input are among others European and national statistical depart-ments: time series of statistical data, scenarios of social, economic and ecologic drivers of module M1 as well as regional data from the case study stakeholders

Relevance of qualitative data

- Alongside quantitative statistical data, qualitative information and expertise on causal relationships between two variables will be necessarily comprised in the modelling work, especially where appropriate data is not available
- Therefore primary and secondary literature, external field work contributing to the evidence of general functional relationships is necessary
- Further sources of information should be expert panels, Delphi- and regional forecasting processes
- To get used within the modelling of the RF qualitative formulated relationships need to be quantified by heuristic approximation or fuzzy-logic measures

Statistical procedures

- Regression analysis aims at representation of the relationship between a dependent and one or more independent variables.
- Under the condition that the necessary data will be available (which is doubtable) we also consider factor and cluster analysis to be useful components in our set of methods. Factor analysis aims at reduction of influencing variables by bundling of numerous variable characteristics to so-called factors. Measurement of the most influencing compartments (factors) by principal component analysis.
- Cluster analysis aims at grouping of various characteristics of a variable, providing approximate functions for each group

Example Recreation Functions

- As figures defining recreational functions (by defining the three meta figures) we identified following independent figures (with source)

  (a) land use, in number of suitability (CORINE land cover, topographical maps)
  (b) type of landscape, in number of suitability (CORINE land cover, topographical maps)
  (c) areas of environmental protection, in qkm (environmental, statistical agencies)
  (d) transportation infrastructure density, in km/qkm (statistical agencies, Eurostat)
  (e) level of recreational equipment, (in km/qkm bicycle lanes (tourism offices))

- The figures (b) to (e) represent regional characteristics regarding recreation function – regional framework. They measure the degree of how a particular region reacts on certain land use changes.

- So the only true variable at hand representing regional changes, because of its influence by drivers/pressures (over level 1 – structures and level 2 – activities) is here (a) land use respectively land use change. Therefore data input regarding the future development of land use depends on results of modelling teams of 2.3.5 (housing), 2.3.6 (economic development) and 2.3.7 (transportation).

- Whereas areas of environmental protection, transportation infrastructure density as well as level of recreational equipment could be expressed in absolute figures, type of landscape as well as land use need to be "translated" into numbers of suitability (BASTIAN 1993 provides an approach using a measurement for recreation of the land use type (combination of land use and landscape type).

- The various independent figures need to be weighted according to their influence. The first assumption is that they all having the same influence. During the construction process of the RF, it is most likely to adjust weighting of each independent figure to improve their ability of approximation of the real functional relationships.

- Approximation of the influencing factors on recreation function:

$$f(x) = \sum (wxa) + (wxb) + (wxc) + (wxd) + (wxe)$$

- Approximation of the influencing factors on recreation function with changing land use:

$$f(x) = \sum (\Delta wxa) + (wxb) + (wxc) + (wxd) + (wxe)$$

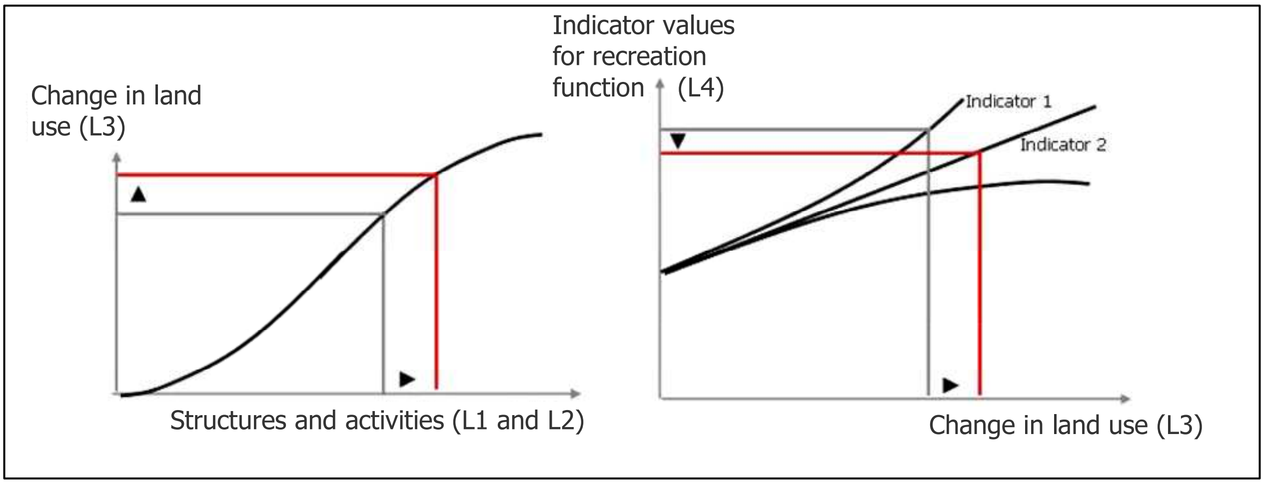

Fig. 1: link between land use change and response functions

Step 3: RF Differentiation regarding RUR sub-regions

At this stage further complexity of mutual land and resource use relationships be-tween urban, peri-urban and rural sub-regions as well as their effects on public goods are intro-duced. Approaching a RUR-delineation appears useful to differentiate between urban and rural areas and their particular production and consumption situation (sink and source) of commodities and public goods before involving the peri-urban zone.

It can be assumed that the various urban, peri-urban and rural sub-regions will respond differently on certain degrees of land-use change because of their different framing characteristics. Most likely particular developments are going to show even contrary directions. Another aspect related to the introduction of a sub-regional delineation is the measurement of further figures representing particular sub-regions.

These differences need to be represented by the RF, so that there is a distinct RF for each RUR sub-region. The aim is to introduce a prototype-like RUR-region representing those functional relationships.

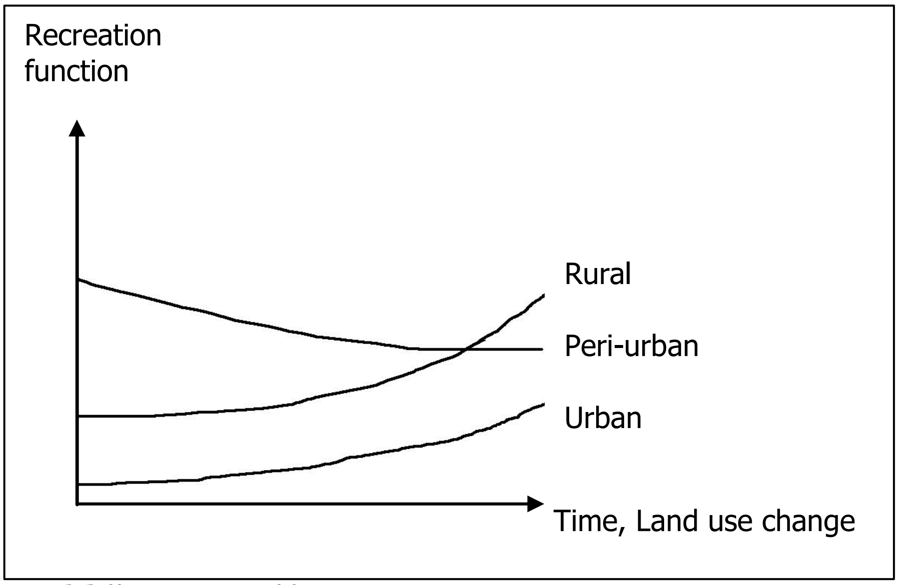

Fig. 2: Spatial differentiation of functions

Example Recreation Functions

Regarding recreation functions the type of landscape and accessibility plays a less crucial role in urban areas as it does in peri-urban and rural areas, whereas parks are most important for urban recreation.

For the future development the particular sub-regions will show even contrary directions: With a continuing suburbanisation process focussing on peri-urban areas the recreation potential there is under pressure. Accordingly the demand from urban areas satisfied in peri-urban areas need to shift (to rural and urban areas, where decreasing settlement densities will allow increasing recreation potential).

Step 4: RF Differentiation regarding several RUR typologies

- Based on the RF of the RUR prototype a further differentiation consisting of several RUR typologies is the last step including RUR typical demand and supply structures and elasticity.

- Essential requirement therefore is a delineation of useful RUR typologies by WP 2.1

- Adjustment of the RF for the particular contexts of the different RUR typologies

- A further delineation of RUR typologies could be applied to respond to the presence of dominating sectors and actors, such as in global city regions (i.e. large commuting areas, service industry), tourism regions (i.e. large recreational areas) or agricultural regions with dominance of primary production

3. Recent Output of the Work on Response Functions

The following paper, which was submitted as a contribution to the Special Issue of the Journal Environment and Planning B following the Impact Assessment of Land Use Change (IALUC) conference in Berlin in June of 2008, originated from our work on PLUREL response functions. It can be taken as an example of a complete derivation process of response functions

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Urbanisation and Landscape related Indicators: Response Functions for Impact Assessment in the EU27 at NUTS 3 Level

Abstract

The objective of this article is to present a procedure for the quantification of functional relation-ships between urbanisation and ecologically relevant impacts on landscapes at NUTS 3 level for the EU 27. The relationships are depicted as regression functions based on empirical data which serve as Response Functions (RF). The dispersed expansion of urban areas during the last three decades often labelled as 'urban sprawl' had profound impacts on natural habitats, water balance, soil and recreational quality, mainly by fragmentation and land consumption. Based on a literature survey and the analysis of the CORINE Land Cover (CLC), the EUROSTAT Regio database and the EU-ROSTAT GISCO database we derived the following indicators for landscape fragmentation and the related ecological potential, to be applied for the assessment of landscapes at NUTS 3 level: fragmentation by major road and rail networks in km per km2, share of non-interrupted low traffic areas of the total area in %, the mean Green Background Index (GBI) and the share and change of natural and semi-natural areas of the total area in %. These indicators served as dependent variables in the regression analysis, which was performed as a static cross section. A set of land cover related and socioeconomic indicators for urbanisation were chosen as independent variables: Share and development of urban and agricultural land cover, population density, GDP per capita as well as development of population, GDP and GDP per capita. Correlation and factor analysis were applied to select the relevant independent variables. The resulting regression functions proved to be suitable for quantifying anthropogenic landscape fragmentation as a result of urbanisation. The mean GBI and the share of natural and semi-natural areas have substantially higher residues in the model. The application of a settlement morphological typology proved useful for improving the model results. How-ever a number of limitations in data availability, methodology and regional differentiation remain which restrict the reach of the regression models and prevent the inclusion of dynamic components into the model function.

Keywords: response function, landscape impacts, urbanisation, sprawl, impact assessment, regression

1. Introduction

For the past decades, urbanisation has brought about substantial changes in European landscapes. The trends apparent at the fringes of Europe's cities and city regions have been discussed under the heading of "urban sprawl", which is characterised by rapid urban growth and the expansion of urban areas of all kinds and densities. The European Environmental Agency (2005) assessed that 8,000 km of open spaces was converted into artificial urban land between 1990 and 2000. A low density urban expansion beyond former city boundaries (Burdack, 2008; Ingersoll, 2006), bringing about an urban landscape with varying urban densities and a high degree of fragmentation, isolation and degradation of the remaining open spaces (Antrop, 2000) is accompanied by far reaching impacts on properties of landscape and environment. Such properties are landscape structure, biodiversity, soil and water regime as well as on agricultural production. Urban expansion is seen as the major anthropogenic impact on nature (Krogh et al., 2006) responsible for a multitude of cumulative effects (Siedentop, 1999; Theobald et al., 1997), especially in ecologically sensitive areas (EEA, 2006; Faulkner, 2004). This paper addresses the impacts of urban and peri-urban develop-ments on the landscape. The issue is relevant for policy makers on all levels. Programmes and strategies have to undergo an ex-ante sustainability impact assessment, which also addresses the impacts of urban and peri-urban developments on socioeconomic and environmental conditions. Within the 6th EU Research Framework (FP6) modelling approaches and tools are developed which depict the functional relationships of socioeconomic drivers, land use pressures and impacts following the DPSIR approach (EEA 2002) and thus establish a link between global drivers and regional impacts at the NUTS 2 or 3 level. Our work draws on previous working steps undertaken in FP6: In a scenario approach based on the IPCC SRES (IPCC, 2001) storylines, economic and demographic trends have been quantified by probabilistic modelling (Boitier et al., 2008; Ravetz et al., 2008; Scherbov and Mamolo, 2008). The modelling outputs on land use changes due to four different scenario storylines for the time period 2008 – 2050 at national level (NUTS 0) provided the starting point for the modelling of land use changes in urban and rural areas. Land use change, especially urbanisation, is the basis for the quantification of impacts on the environment by deriving Response Functions (RF) for European regions.

In this paper we aim to answer the question whether RF at NUTS 3 level for later application in an ex-ante assessment tool, depicting the functional relationship between urbanisation and ecologically relevant landscape characteristics can be derived using existing European datasets and regression analysis. RF are understood as generic regression functions with dependent and independent variables being represented by quantitative indicators at NUTS 3 level. Independent variables are land cover related and socioeconomic indicators describing urbanisation. Dependent variables are land cover based indicators describing a landscape's ecological potential and the strength of anthropogenic impacts. In order to contribute to efforts in pan-European impact assessment at NUTS 3, general landscape characteristics with relevance for a wide range of ecological issues are taken into focus. The aim is to derive regression models with the best possible explanatory power and thus to provide information on the feasibility of the NUTS 2/3 RF approach for impact assessment of urban and peri-urban developments. The article is structured as follows: Section 2 provides an overview of datasets and methodology used. Section 3 addresses the question how indicators as variables for the regression models can be derived using the existing datasets. In section 4 the results of the statistical analysis are presented. In section 5 the results are discussed. Section 6 provides an outlook on future work.

2 Data and methodology

2.1 Used datasets

The central dataset for our analysis is the satellite based European land cover inventory CORINE land cover (CLC) provided by the EEA (2000). CLC provides information on land cover for the territory of the EU 27 in a 100m x 100m grid distinguishing 44 land cover classes, which are aggregated into built-up, agricultural, forest and semi-natural, wetland, and water areas. Eleven classes are related to urban land use: urban fabric (1.1.1.-1.1.2.), industrial, commercial and transport units (1.2.1.-1.2.4.), mine, dump and construction sites (1.3.1.-1.3.3.) and artificial, non-agricultural vegetated areas (1.4.1.-1.4.2.). The relevant areas for our analysis are urban land (built-up), agricultural land and natural/semi-natural areas. CLC data is currently only available for the years 1990 and 2000, allowing for an analysis of changes over ten years, but inhibiting timeline analysis. In addition to CLC the CORILIS dataset is available for the year 2000. CORILIS is a smoothed version of CLC which based on the moving window method, provides a measure for the proximity of any given point within a grid cell (usually 1x1 km) to a particular land use class. Its purpose is the expression of certain area-specific intensities and potentials of the particular land use (Páramo 2006). A CORILIS dataset focussing on green (non built-up) spaces was used for our analysis. As an additional land cover related data source the European major road and rail network for the year 1997, a spatially explicit vector dataset from EUROSTAT (EUROSTAT GISCO database 1997) was used for the development of landscape indicators. Statistical data on population number, population density and economic development at NUTS3 were provided from the EUROSTAT Regio database. They are available annually, dating back to the beginning of the 1990s, although with considerable data gaps for individual countries. The socioeconomic data is used to depict urbanisation drivers (see table 1).

2.2 Methodological steps

As a first methodological step we derived indicators, which serve as dependent and independent variables in our analysis, from literature and existing datasets. Using GIS software package ArcGIS the spatial datasets on land use were applied to polygons of NUTS 3 administrational borders by intersection and area calculation In our case reclassified raster and vector based CLC data for 1990 and 2000 as well as a vector data for the road and rail network were used. Based on data available for the indicators, hypotheses are derived as a starting point for the statistical analysis. The statistical analysis was performed in SPSS. It aimed at the formulation of RF and is subdivided in three steps. (1) The relationships of independent variables composed of land cover based and non land cover based data, were analysed using correlation and factor analysis with the aim to obtain non-correlated independent variables for the regression analysis. All independent variables were individually correlated using Spearman's rank correlation coefficient. The choice of this correlation measure is based on the consideration that spatially explicit, land use related datasets often display distributions other than the normal distribution, which is the precondition for the calculation of the Pearson correlation coefficient. As a result of the correlation analysis, variables which are not correlated at all (we took .5 as a threshold) were excluded and variables, which show an indication of a relationship to others, are used to derive factors. The method for factor estimation is ordinary least squares, for the same considerations on distribution as above. Next to the derived factors, data rep-resenting probable influences on the dependent variables aside from urbanisation and socioeconomic data were kept separate for a later inclusion into the regression analysis. (2) The derived factors and other relevant variables were then used as regressors for linear regression models with each of the landscape indicators (dependent variables). (3) The settlement morphological typology was integrated into the regression analysis as a set of dummy variables aimed at improving the model results.

3 Indicator based representation of urbanisation and landscape impacts

3.1 Impacts of urbanisation on landscape structures and functions

Caused by expansion of settlement and infrastructure areas sealing of surfaces represents the major impact on soils (Arnold Jr and Gibbons, 2007; Schueler, 1994,) causing several negative effects such as increased stormwater runoff, reduced evapotranspiration (Haase and Nuissl, 2007) along-side with higher above ground temperature and various forms of contamination (Callender and Rice, 2000; Cunningham et al., 2007). It leads to disruption and limitation of soil functions (Doichinova et al., 2006), degradation of fertile soils and the destruction of habitats (Barnes et al. 2001). Due to reduced infiltration rates the increase of impervious surfaces additionally influences the water balance in terms of lower groundwater recharge rates (Volk et al., 2001). The conversion of natural area for urbanisation also affects flora and fauna species. Even though the impacts of urbanisation on biodiversity are not fully understood, there is common sense, that land use change modifies numbers, richness, composition and behaviour of species (Blair, 2004; Marzluff, 2001). Obviously also the intensity and the spatial pattern of the urban area and accordingly the remaining landscape and habitat structure play a major role for the biodiversity (Donnelly and Marzluff, 2006; Theobald et al., 1997). So changes in urban land use and morphology as well as landscape composition and fragmentation accompanied with habitat and connectivity loss accounts as a main anthropogenic pressure. Hence the degree of landscape fragmentation, the remaining amount of an ecologically valuable and sensi-tive area and the dispersion of the urban area ranging from compact to scattered form, mirrored by the spatial pattern of open space, are the relevant landscape characteristics to look at.

3.2 Derivation of landscape indicators

Indicator 1: Share of natural and semi-natural areas

The CLC nomenclature allows for an aggregation of land cover classes, which are considered to be ecologically valuable and sensitive since they provide favourable conditions for habitats. These natural and semi-natural areas consist of agricultural area with high share of semi-natural areas, pastures, meadows and grassland, shrub-land as well as wetlands (CLC classes 243 and 321 to 423). Their share serves as representative indicator of the regional state of environment especially the provision of habitats for the survival of species. Weber et al. (2008) state that "Agro-systems with pastures and/or mosaics of parcels, forests and other semi-natural or natural dry land, wetlands and water bodies are land cover types a priori favourable to nature". The use of natural and semi-natural CLC classes for measurements of the biodiversity potential is in line with assessments of the utility of CLC for environmental observation purposes (BMU, 2004).

Indicator 2: Fragmentation by major road and rail networks

Another commonly used indicator in the ecological assessment of landscapes is the degree of fragmentation (ESPON 2006, EEA 2001). In contrast to the share of natural area it provides a measure for the spatial structure of the land cover fabric. Fragmentation can be interpreted as separation of grown ecological cohesion between spatially divided areas of landscape (Haber 1993) or mainly linear landscape structures with barrier, emission and collision effects (Grau 1998). Fragmentation as a landscape characteristic represents a limiting factor to the realisation of the ecological potential of a landscape (Weber et al. 2008). The ecological potential is strongly influenced by the size of habitats without physical network infrastructures, most notably roads and rail, since they impose both a barrier to mobility and an increased level of disturbance by light, sound and pollution (Seiler 2001). Alongside with linear structures also area settlement structures account for fragmentation effects (Siedentop 1999). In general the functional capability of open spaces is negatively influenced by fragmentation (Trombulak & Frissel 2000, Seiler 2001). Beyond proven effects on biodiversity (Jaeger et al., 2001), the influence on recreational issues through detraction of landscape image, barrier effects and disturbance of nature-based recreational activities are seen as important (Schrijnen 2000, Dosch 2002, Antrop 2004). Urbanisation goes along with an expansion of traffic networks. A relationship between urbanisation and the density of traffic networks can be assumed. As a first fragmentation indicator we therefore calculated the density of major road and rail networks in km per km .

Indicator 3: Share of non-interrupted low traffic areas

In order to represent fragmentation both by linear infrastructures and settlement areas a measure for the cohesion of the remaining open spaces had to be found. In order to characterize a whole land-scape in terms of availability of non-fragmented areas, the most efficient way is to measure the share of such areas. Therefore we chose and calculated the share of non-interrupted low traffic areas at NUTS 3 level. In order to define such areas a size threshold has to be defined. At the local level 10 km² is recommended as size threshold for non-interrupted low traffic areas (Siedentop et al., 2003), while at the NUTS 3 level 100 km² is understood as a meaningful threshold (Lassen, 1990). There-fore indicator 3 measures the share of areas, which are not interrupted by settlement areas, major roads or major railway lines and at least 100 km² in size.

Indicator 4: Mean Green Background Index (GBI)

A possibility to combine structural aspects with shares of different land cover classes is to make use of the CORILIS dataset. Its purpose is the expression of certain area-specific intensities and potentials of the particular land use (Páramo, 2006). When applied for artificial surface it can be used as an indicator for the dispersal of settlement. In the context of ecosystem appraisal the methodology is used to give an account of the dominance of green CLC classes (pastures & mixed farmland, forests and transitional woodland shrub, natural grassland, heathland, sclerophylous vegetation, open space with little or no vegetation and water bodies) in a grid cell. The resulting indicator is labelled "Green Background Index" (GBI) and is assigned to each grid cell as a count between 0 and 100. At NUTS X level the mean value of all grid cells in each region was calculated. Since both the mere share of the respective land cover classes and their spatial patterns have an influence on the indicator value, it can be understood as an aggregate measure for the 'presence' of land cover classes favourable to natural and semi-natural ecosystems.

3.3 Derivation of indicators for urbanisation and settlement morphology

Measuring urbanisation

Urban sprawl is characterised by a great diversity of land use types (residential, commercial, infra-structural) and densities and functions (Aring, 1999; Brake et al. 2001). Hence there is not one single type of urban land cover in the CLC nomenclature that could be identified as the most relevant one. Instead the whole area of urban land covers as defined in 2.1 is understood as the land cover based expression of urbanisation. The share of urban area is the central indicator for urbanisation in our analysis. In addition to urban land, the share of agricultural area is a potential influencing variable, at least for the GBI and the share of natural and semi-natural areas. It is therefore integrated into the analysis.

Furthermore socioeconomic and demographic variables are expected to shape the spatial patterns of urbanisation and thus its impact on landscapes. A more dispersed and infrastructure intensive form of urbanisation is expected in more affluent regions. Therefore GDP, GDP per capita, and population density are integrated as additional independent variables. In order to include developments over time also the relative change of total GDP as well as GDP per capita between 1995 and 2000 and relative change of population from 1990 to 2000 are included.

The rural-urban typology

Within the FP6 IP PLUREL a Rural-Urban Region (RUR) typology, for NUTS 3 regions was developed based on the morphology of their settlement areas (Steinnocher et al. 2008). The database for this typology is CLC, combined with a GIS point layer depicting the centres of cities with more than 10.000 inhabitants (EUROSTAT GISCO database) as well as data from Urban Audit. The typology distinguishes the types 'monocentric very large', 'monocentric large', 'monocentric medium', 'urban polycentric', dispersed polycentric' and 'rural'. NUTS 3 regions belonging to one functional urban area were clustered and assigned the same RUR type. Since urban morphology, especially the difference between monocentric and polycentric or dispersed developments has a substantial influence on the landscape structures and potentials discussed in 3.2, it can be assumed that a NUTS 3 region's assignment to one of the named region types alters the occurrence of the landscape indicators. Therefore the set of RUR types can be understood as an ordinal variable, which has the potential to specify and improve the regression models once they are derived.

Table 1: Initial independent variables on NUTS 3 level

Indicator	Unit	Meaning and relevance
Indicators for independent variable economic development		
GDP per capita in purchas-ing power parities in 2000	€	Degree of economic affluence measured per person
Relative change of total GDP from 1995 to 2000	%	Development of overall economic strength
Relative change of GDP per capita from1995 to 2000	%	Development of affluence
Indicators for independent variable demographic development		
Population density in 2000	Inhabitants per square kilometre	Concentration of population in a region as an approximation for land use pressures
Population change from 1990 to 2000	%	Development of population size as a driver
Area and land use		
Total area of NUTS 3 re-gion	Square kilometres	Size as a relevant framing condition for the calculation of the dependent variables
Share of urban area	%	Measure for the degree of urbanisation
Share of agricultural area	%	Measure for the extent of agricultural land use
Annual change of urban area 1990 and 2000	%	Dynamics of urban land use
Annual change of agricul-tural area between 1990 and 2000	%	Dynamics of agricultural land use

3.4 Indicator overview and hypotheses

Table 1 shows the independent variables derived in this section as well as their meaning and relevance. The list includes both land use related and non land use related variables for the reasons discussed above. It also contains both static and dynamic variables. As described above, the data base is insufficient for full timeline. However, since the relative changes of some independent variables can be drawn from the data, it is useful to include them. In terms of land cover related indicators this means that relative changes of urban and agricultural land are available on the side of independent variables, with relative change of natural and semi-natural areas being available as a de-pendent variable. Rela-tive changes here are understood as proportional changes of the relative share of the re-spective land cover per year throughout the time span 1990 - 2000. Also the relative changes of GDP and population are included. They can be treated as independent vari-ables for the relative change in natural and semi-natural areas, but also for the static landscape indicators, following the assumption that a region that has been in decline for some time may have other landscape features than a region which has been growing in the same period.

Since most indicators are calculated relative to the NUTS 3 regions' total area in km this parameter probably has a substantial influence on the landscape indicators, especially since one indicator (non-interrupted areas) operates with an absolute size threshold. Instead of area weighting the whole variable set, total area is included as an additional variable. Its importance in comparison to other variables is expected to be noticeable, but not dominant.

Based on the considerations made, following hypothesises are subject of analysis:

(i) Urbanisation is positively correlated with GDP per capita.

(ii) All static independent variables show a negative (in the case of fragmentation positive) correlation to the static landscape indicators and later on will perform well as regressors in a cross section analysis.

(iii) Economic and demographic dynamism influence static landscape indicators, because growth and decline bring about different spatial patterns.

(iv) The relative change of urban area and the relative change of agricultural area show a negative relationship, since agricultural land is consumed by urbanisation.

(v) The growth of population, GDP and urban area account negatively for the development of natural and semi-natural areas.

(vi) Indicators for anthropogenic impacts (fragmentation, non-interrupted areas) show better correlation and regression results to the independent variables than indicators for the remaining natural potential (GBI, natural and semi-natural areas) due to dependence on additional factors, such as natural bio-physical conditions.

(vii) The introduction of typologies, representing regional characteristics, e.g. urban morphology and topology, can contribute to the variance explaination of the regression model.

4. Statistical analysis: correlation, factors and regression

4.1 Correlations of independent variables and factor analysis

Table 2 shows the Spearman rank correlation coefficients of the independent variables with each other, including total area. The coefficients indicate a strong inverse relationship between total area and population density as well as the share of urban area and a weak positive relationship between total area and the change of agricultural area. Population density is, apart from the correlation mentioned above, positively correlated to GDP per capita and share of urban area and negatively correlated to the change of agricultural area. The two measures for GDP growth are mainly correlated to one another. Share of urban area is, apart from the correlations mentioned already, negatively correlated to the change of agricultural area. The variables population development, Share of agricultural area and annual change of agricultural area display no correlation to other independent variables. In consequence to these findings, all correlated variables (population density 2000, change of total GDP, GDP per capita, change of GDP per capita and share of urban area 2000) were used for a factor analysis. Table 3 shows the factor loads of the resulting factors after a rotation. The two emerging factors can clearly be identified as 'degree of urbanisation' (factor 1) and 'economic dynamism' (factor 1).

Table 2: Correlations between independent variables (Spearman rho and F-value / confi-dence)

	Annual change of share of agricultural area 1990-2000 in %	Annual change of share of urban area 1990-2000 in %	Share of agricultural area 2000 in %	Share of urban area 2000 in %	Change of GDP per capita 1995-2000 in %	GDP per capita 2000 in €	GDP growth 1995-2000 in %	Population density 2000 in persons/ sqkm	Population develop-ment 1990-2000 in %	Total area in sqkm
Total area in sqkm	.584 .000	-.061 .053	.041 .154	-.710 .000	.175 .000	-.349 .000	.381 .000	-.727 .000	-.172 .000	1.000 .
Population develop-ment 1990-2000 in %	-.127 .000	.237 .000	.207 .000	.113 .000	-.101 .002	.202 .000	-.062 .056	.024 .490	1.000 .	
Population density 2000 in persons/ sqkm	-.634 .000	-.017 .618	-.150 .000	.911 .000	-.001 .984	.529 .000	-.076 .017	1.000 .		
GDP growth 1995-2000 in %	.261 .000	.036 .257	.031 .290	-.161 .000	.604 .000	-.099 .001	1.000 .			
GDP per capita 2000 in €	-.496 .000	.132 .000	-.131 .000	.425 .000	.073 .014	1.000 .				
Change of GDP per capita 1995-2000 in %	.034 .302	.170 .000	-.050 .094	-.079 .008	1.000 .					
Share of urban area 2000 in %	-.604 .000	-.186 .000	.008 .778	1.000 .						
Share of agricultural area 2000 in %	.095 .002	.129 .000	1.000 .							
Annual change of share of urban area 1990-2000 in %	-.392 .000	1.000 .								
Annual change of share of agricultural area 1990-2000 in %	1.000 .									

Table 3: Outcome of the factor analysis

	1	2
Population density 2000	.925	.042
GDP per capita 2000	.518	.083
Change of total GDP 1995-2000	.056	.610
Change of GDP per capita 1995-2000	.069	1.000
Share of artificial surface 2000	.891	.037

Table 4: Correlations of extracted independent variables and landscape indicators (Spearman rho and level of confidence)

	Fragmentation by major road and rail networks	Share of uninterrupted low traffic areas	Average Green Background Index	Share of natural and semi-natural areas	Change of Share of natural and semi-natural areas 1990-2000
Total area	-.789 .000	.743 .000	.313 .000	.467 .000	-.054 .085
Population change 1990-2000	.148 .000	-.172 .000	.003 .935	-.182 .000	.044 .183
Share of agricultural area 2000	-.009 .744	-.057 .048	-.429 .000	-.292 .000	.017 .583
Annual Change of share of urban area 1990-2000	-.049 .111	.034 .285	.092 .003	.062 .045	-.018 .556
Annual Change of share of agricultural area 1990-2000	-.648 .000	.623 .000	.278 .000	.353 .000	-.016 .603
Factor 1 (urban concentration)	.856 .000	-852 .000	-.484 .000	-.452 .000	.005 .198
Factor 2 (economic growth)	-.119 .000	.078 .000	.100 .000	.055 .002	.010 .187

4.2 First regression models

In advance to the first regression analysis the correlation coefficients of all independent variables (factors and variables not included into the factorisation) with the landscape indicators were calculated. Table 4 shows the results with all correlation coefficients larger than 0.4 being highlighted. Two criteria were relevant for the choice of variables for the regression models: Plausibility and correlation with the landscape indicators. For the two fragmentation indicators these are the degree of urbanisation (factor 1) and total area. For the GBI and the share of natural and semi-natural areas the share of agricultural land was included additionally. Change of the share of natural and semi-natural areas was dropped as a dependent variable at this point, since it was correlated to none of the proposed independent variables. The results of the regression analysis can be seen in table 5: A good model reach was achieved for the indicators fragmentation by road and rail networks and share of non-interrupted low traffic areas. The regression model for the mean GBI performs less well, while the R achieved for the share of natural and semi-natural areas is very low.

4.3 Differentiation of regression models using a rural urban typology

As the final analysis step the RUR types as ordinal variables were included into each regression function as a set of dummy variables. Table 6 shows the changes of the R adjusted when the RUR typology is integrated. For each landscape indicator a moderate but noticeable improvement of the model can be observed.

Table 5: Regression results

Landscape Indicator	R^2 adjusted	Beta coefficient surface area and significance	Beta coefficient urban concentration factor and significance	Beta coefficient Share of agricultural area and significance
Fragmentation by road and rail	.717	-.201 .000	.748 .000	-
Share of uninterrupted low traffic areas	.682	.219 .000	-.716 .000	-
Average Green Background Index	.537	.003 .912	-.678 .000	-.635 .000
Share of natural and semi-natural areas	.275	.059 .053	-.415 .000	-.482 .000

Table 6: Model improvement by RUR typology

	Fragmentation by major road and rail networks	Share of non-interrupted low traffic areas	Mean GBI	Share of natural and semi-natural areas
R^2 adjusted without RUR typology	.717	.682	.537	.275
R^2 adjusted with RUR typology	.723	.719	.549	.280

5 Discussion

5.1 Interpretation of results

Correlations of independent variables and factors

The hypothesis formulated for the behaviour of the independent variables towards each other could partly be confirmed: Regarding the static cross section, urban land use could clearly be linked to population density and GDP, however a clear trade off between urban and agricultural land at NUTS 3 level is missing. Regarding the dynamic component, expressed in relative changes, almost none of our initial assumptions are supported by the statistical findings: Change of urban area is negatively correlated to the change of agricultural area, but very weakly. Thus the assumption that at the NUTS 3 level of measurement cities grow at the expense of agricultural areas can only vaguely be confirmed. Changes of urban area do not display any correlation with economic growth (change of GDP) or demographic changes. The change of agricultural area is noticeably negatively correlated to population density and (static) share of urban area. The immediate conclusion would be that in more urbanised areas more agricultural land is consumed, but by other land cover classes than urban, since there is no correlation to the change of urban area.

Based on these findings, five indicators for independent variables were chosen for a factor analysis. It contains three static and two dynamic indicators. Included are all independent variables showing correlation to other variables, given they can plausibly be linked to urbanisation. The change of share of agricultural area was excluded from the factor analysis although it is correlated to the share of urban area, since the reason for this relationship remained unclear and it can not plausibly be linked to the urbanisation process. The result of the factor analysis confirms the common notion of urbanised areas as economic growth poles with high value services and job provision, as shown by the inclusion of GDP per capita into the factor. However the degree of urbanisation is not linked to economic dynamics.

Regression analysis

The result of the correlation analysis between independent and dependent variables is in line with the results of the initial correlation and factor analysis: The change of the share of natural and semi-natural areas as the only dynamic dependent variable can not be explained by any independent variable since there is no correlation. The dynamic independent variables population change, change of urban area as well as the economic dynamism factor have no correlation to any of the dependent variables, including the dynamic one. Therefore all dynamic components were dropped and only static variables were integrated into the regression analysis. Again the change of agricultural area displays a correlation to the landscape indicators depicting anthropogenic fragmentation. However this can not be interpreted as a functional link or causal relationship, especially not with the change of agricultural as an independent variable. The more likely explanation is that a general expansion of agricultural area in more thinly populated areas took place over the period of observation. An in depth analysis should clarify whether this is a phenomenon that is specifically to be observed in certain parts of Europe. The static share of agricultural area shows very little correlation to most dependent variables except the GBI. However for plausibility considerations it was included into the regression modelling for the GBI and the share of natural and semi-natural areas.

The results of the first regression models confirm the hypotheses made with the exception of the modelling of dynamic change. Anthropogenic fragmentation of the landscape can clearly be linked to the degree of urbanisation as the strongest influencing force. In the regression models for the mean GBI and the share of natural and semi-natural areas, share of agricultural area shows a high regression coefficient, while the otherwise strong variable total area diminishes. This points at a hitherto undetected relationship between total area and total area.

The regression modelling contributes to the understanding of relationship between land use change and corresponding quantitative and structural responses of the landscape on the European level. It provides an efficient path to bridge the gap between quantitative land use change drivers and pres-sures and structural impacts on the landscape. The integration of a regionalising typology has shown improved regression modelling results.

5.2 Limitations

Although the overall result is satisfactory, both the relationships of dynamic changes and landscape indicators describing the potential of the remaining natural areas could not be explained. Limitations of methodology and dataset are assumed. For considerations of distribution the correlation analyses was limited to Spearman rank correlation coefficient. The additional use of Pearson correlation coefficient can contribute to a better detection of relationships, although with uncertain reliability. Moreover non-linear regression models and geographical weightening could deliver improved regression models. The lack of timeline analysis and timeline regression represents the most notable methodological problem.

Dataset limitations result due to temporal and spatial resolution and scale: CLC data is only avail-able for 1990 and 2000. Moreover the actual observation and accession dates of CLC for the two points in time vary from country to country, so that the actual time span covered can be as little as five years. This lead to a very limited coverage of the actual land use changes taking place. The minimum size of measurement for CLC is 25 ha, with changes being detected only if they exceed five ha. Land use changes, especially settlement growth at the urban fringes rather take place within the fine grain of land use. So, most of the process labelled 'urban sprawl' possibly remains undetected by CLC (Zasada et al. 2007). This is a very likely explanation for the absence of meaningful modelling results for changes over time.

Since urbanisation processes and the corresponding impacts are highly dependent from regional circumstances the application of typologies of regional differentiation are necessary, which is con-firmed by the the application of a settlement morphological typology. Nevertheless integration of further typologies reflecting the bio-physical setups or planning and governance regimes assumingly improve regression modelling results.

6 Outlook

The RF derived and presented in this paper are to be used for a integrated Impact Assessment Tool (iIAT) in FP6. In this context they provide an empirically tested quantification of functional relationships between urbanisation and impacts on landscape. Within the further research, restrictions and shortcomings need to be considered, including the harmonisation of administrative units to NUTS X as well as the use of additionally correlation coefficients. Structurally the most far-reaching improvement of variance explanation of the model results are expected by the integration of regional differentiating typology analogical to the RUR-typology.

PLUREL

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