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Scenarios of land use change in Europe based on socio-economic and demographic driving factors

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1 ABSTRACT

In this paper we will present scenarios of land use change on European scale that were developed in the course of geoland, an Integrated Project funded within the 6th framework program of the EC. The Spatial Planning Observatory, which is part of geoland, will generate products and services based on EO data, geo-spatial and statistical data, fulfilling the demand of spatial planning as provided by European, national and regional regulations and policies. The products and services comprise indicators, spatial typologies as well as models and scenarios, which are presented in tabular, graphical and map forms.

Scenarios of land use change provide alternative views of future landscapes, depending on the underlying assumptions of the scenarios and the modelling approaches applied. The aim is not to forecast future development, but to reveal impacts of economy, society and current spatial patterns on future spatial development and to show different pathways of spatial development. Our scenarios focus on the development of artificial surfaces such as residential areas based on statistical Eurostat data and CORINE Land Cover data in a selected European test region. For modelling future landscape scenarios past development patterns were analysed and interrelations between land use, economic and demographic data were derived. The methodology of multiple linear regressions was applied to learn more about the relationship between settlement development and several explanatory variables which have been identified as driving factors for settlement growth (or decline) such as demographic development, economic structures and changes, etc. The resulting linear regression equation statistically explains past land use changes and can be applied for estimating future land use change scenarios. A common scenario approach is the extrapolation of current trends into the future (business as usual, trend-scenario) assuming that no change of current policies and driving factors occurs. Additionally, we will present scenarios that result out of alternative assumptions on population development using population projections from Eurostat (baseline variant, high and low population variant, no migrations variant, high fertility variant, younger and older age profile population variant).

Traditional scenarios mainly focus on either land use or statistical data as input. The specific approach in our scenarios is that statistical, not land use related data such as demographic and socio-economic development are considered as driving forces for land use change. Thus, the interdependency between society and landscape is incorporated into the scenario calculations. In this paper we will explain our approach in detail and present different scenarios of land use change at the European NUTS 3 level derived from regression analysis demonstrating the interdependency between demographic and land use development.

2 INTRODUCTION

The land use change scenarios presented in this paper were developed in the course of the Integrated Project geoland, funded within the 6th framework program of the EC. The Observatory Spatial Planning (OSP) is part of geoland and aims to introduce innovative Earth Observation (EO) derived land cover/land use products into spatial planning procedures and methods. The land cover/land use data are combined with socio-economic information and integrated in GIS procedures and models (for details see www.gmes-geoland.info). The OSP-consortium comprises users and political representatives as well as research organisations and companies. The European policy framework is considered in the project by referring to the European Spatial Development Perspective (ESDP) and to findings from the European Spatial Planning Observatory Network (ESPON).

Within geoland the team of the Austrian Research Centers, division systems research, was engaged in developing spatial typologies, indicators, land use transformation models and scenarios on European scale. European spatial indicators developed from our team within geoland were already presented at the CORP 2006 (Steinnocher et al. 2006). These previous works already revealed patterns and dynamics of land use change in Europe. Thus based on these findings, we aimed to derive potential future transformation patterns for residential and industrial land use on European scale. These scenarios will be presented in this paper.

We chose the scenario technique, because on the one hand it is crucial for planners and politicians to get a picture of a plausible future world, in order to develop strategies and measures for or against certain development paths. On the other hand it is not possible to predict future development in its whole complexity. Thus, the technique of scenario planning is a good device for exploring different possible futures, for facilitating the understanding of complex relationships and for creating an awareness of different possibilities. Scenario construction appears to be an "all-rounder" in the field of complex problem solving (Wiek et al. 2006). Different scenario typologies exist. However, several typologies reflect the view that futures studies explore possible, probable and/or preferable futures (e.g. Amara 1981, see figure 1), which means a differentiation into the questions What will happen?, What can happen? and How can a specific target be reached? (Börjeson et al. 2006).

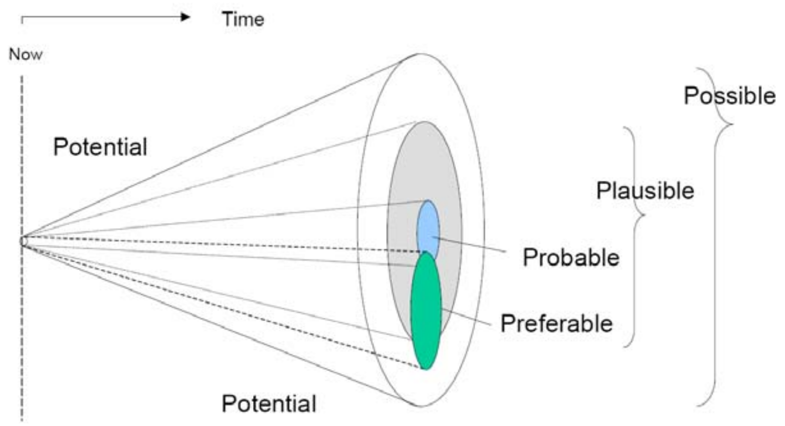


Figure 1: The "futures cone"

Source: Voros 2005 adapted from Hancock and Bezold 1994

Another frequently used approach is to distinguish scenarios between extrapolation scenarios, expert judgement, inclusive approaches and imaginative approaches (Kuhlman et al. 2006): Extrapolating scenarios are based on the extrapolation of existing trends, expert judgement draws on the knowledge of experts about driving forces and most likely developments, inclusive approach means that a set of future scenarios is developed in the hope of also capturing the "real" future (applied e.g. by the Intergovernmental Panel on Climate Change (IPCC 2001)) and the last one, the imaginative approach, asks people to image things which might happen in the future (applied e.g. by PRELUDE project implemented by the European Environment Agency).

The scenarios developed in the geoland project do not aim to exactly forecast what will happen, but to provide alternative views of the future based on major driving forces. We start with an extrapolating scenario and develop further a set of future images of European land use patterns. Our scenarios of land use change visualise images of potential future landscapes, depending on the underlying assumptions of the scenarios and the modelling approaches applied. The aim is not to forecast future development, but to reveal impacts of economy, society and current spatial patterns on future spatial development and to show different pathways of spatial development.

3 DATA AND TEST SITE

For spatial analyses and scenario modelling a test site of approximately 390.000 km2 has been chosen, which comprises Austria in its centre and covers the surrounding countries 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 urban and rural areas. Besides Austria, it comprises the Czech Republic and Slovenia and also parts of Germany, Slovakia, Hungary and Italy are included. Figure 2 shows extent and location of the geoland test site within Europe.

Figure 2: Land use patterns of the geoland test site
Source: land cover data: CORINE land cover level 1 (2000)

We aimed to derive land use scenarios with the help of statistical data and current land use patterns. CORINE land cover (CLC) data on level 2 delivered basic spatial data for analysing land use patterns and calculating land use changes. CLC data provide an essential basis for spatial analyses on European scale, because they are derived from satellite imagery and ancillary data sources on a standard methodology and are classified by a common nomenclature (EEA, 1999). Thus, CLC databases are a valuable source of harmonized data on land cover patterns and changes. Since 2005 CLC data are available not only for one single date, namely the year 1990, but also for 2000. At the same time, the first data base (CLC 1990) was revised and corrected, in order to allow comparing, analysing and evaluating the land cover dynamics between these two dates.

Statistical data from the Statistical Office of the European Communities (Eurostat) were the second essential source for our spatial statistical analysis. Eurostat collects data from the statistical offices of the member states and delivers harmonised data on national and regional (NUTS 2, some NUTS 3) scale. Eurostat offers a range of national and regional datasets covering different areas of European statistics such as demographic statistics, economic accounts and environmental statistics. For our analyses we extracted demographic and socio-economic data form the regional statistics database of Eurostat.

Basically, Eurostat is a valuable data base for European wide analyses down to NUTS 2 or – for some indicators – even NUTS 3 level. However, data are not available on a finer scale. Availability of historic data is also limited, particularly for the new member states, where most statistical series start only in the mid 1990s. Although Eurostat data base offers a wide range of present and historic statistical data, forecast data are scarce. Future projections of indicators only exist for population development on national scale or on European scale, which is too coarse for scenarios on NUTS 3-level. Recently, 3 population variants (baseline, low population, high population) are also available on NUTS 2-level.

The following CLC and Eurostat data were selected and incorporated into further statistical analysis:

CLC data 1990 and 2000

- share of major land cover types per NUTS 3 area
- ratio of different land cover types

Eurostat regional statistics data

- demographic data
  - population
  - population density
  - change of population / population density
- socio-economic data
  - employees (different sectors) and changes
  - purchasing power parity and changes

4 METHODOLOGY

Our scenarios focus on the development of artificial surfaces such as residential (CLC class 11) and industrial areas (CLC class 12). As traditional scenarios mainly focus on either land use change or statistical data as input data, our specific approach is to combine statistical Eurostat data and CORINE Land Cover data on European scale. Statistical, non-land use data such as demographic and socio-economic development are considered as driving forces for land use change. Thus, the interdependency between society and landscape provide the base for the scenario calculations.

For modelling future landscape scenarios past development patterns were analysed and interrelations between land use, economic and demographic data were derived. First, the availability of statistical data was proved. We required data on NUTS 3-level for the EU25 member states and for 2 different dates, namely 1990 and 2000, analogue to the CLC-data. Although statistical data from Eurostat are enlarged and improved continuously, data are not available in the same completeness and time range for the entire EU. We used CLC data from 1990 and 2000, but partly we had to combine them with statistical data from 1995 and 2000 due to lacking availability of data from 1990 (e.g. data on purchasing power parity). Changing NUTS-codes over time also caused additional efforts. A problem in terms of resolution resulted from the different sizes of NUTS 3 areas in different countries. NUTS 3-regions of the Czech Republic can almost be compared to NUTS 2-regions in Germany, which shows extraordinary small NUTS 3-units. Thus, in the EU-project SENSOR a NUTS X classification was developed primarily based on the NUTS 3-regions, but changing the German NUTS 3-regions into NUTS 2 (Verweij et al. 2006). We applied another approach and adapted the German NUTS 3-units to the spatial planning regions of Germany as will be discussed later.

After a first data research and data collection the correlations between different variables were explored in order to get an overview about the relationships between the variables. This led to a preliminary selection of relevant variables for the regression. Generally, the purpose of a multiple regression is to learn more about the relationship between several explanatory variables and a dependent predicted variable. In our case, changes of residential and industrial areas were to be explained by statistical and land cover variables. As explanatory variables socio-economic data (employees, purchasing power parity), demographic data (population, population density) and land cover data were used. To avoid multicollinearity, it had to be proved if two or more independent variables correlated as to exclude variables with high autocorrelation. Then a stepwise regression was calculated in which the predictor variables were added or removed iteratively so that at the end the most explanatory non-autocorrelating variables remained. The result of this statistical procedure was a linear regression equation which explained past land use changes in the selected European test region and which was applied for estimating future landscape transformation scenarios. The statistical procedure was carried out by using the statistical software SPSS.

Every regression refers to basic underlying assumptions. The calculations of future scenarios were based on two approaches: First, the approach of extrapolating scenarios was applied. It was assumed that statistically significant relationships observed in historic settlement patterns and dynamics are also valid for future development. Thus, in this scenario historic trends were extrapolated from current state into the future (trend scenario). Second, expert judgments and assumptions on global trends were considered in the scenarios. Current expectations regarding demographic developments on European level were used for developing different scenarios.

5 FIRST REGRESSION RESULTS AND LESSONS LEARNED

In a first step, a common scenario approach was applied, namely the extrapolation of current trends into the future (business as usual, trend-scenario). In this case statistical relationships between the variables explained by linear regression are extrapolated into the future for estimating future landscape transformation scenarios. It is assumed that past land use changes will continue and no change of current policies and driving factors occurs.

The first regression runs revealed that certain variables worsened the R-square results while others were still missing in the regression and thus, were included in the following calculations. Further, the German part of the test site appeared to be a challenge for statistical regressions: first due to the small NUTS 3-regions and second due to the contradicting development of population and settlement area in former Eastern Germany.

The first problem was solved by adapting the German NUTS 3 regions to the spatial planning regions (“Raumordnungsregionen”) of Germany (www.bbr.bund.de).

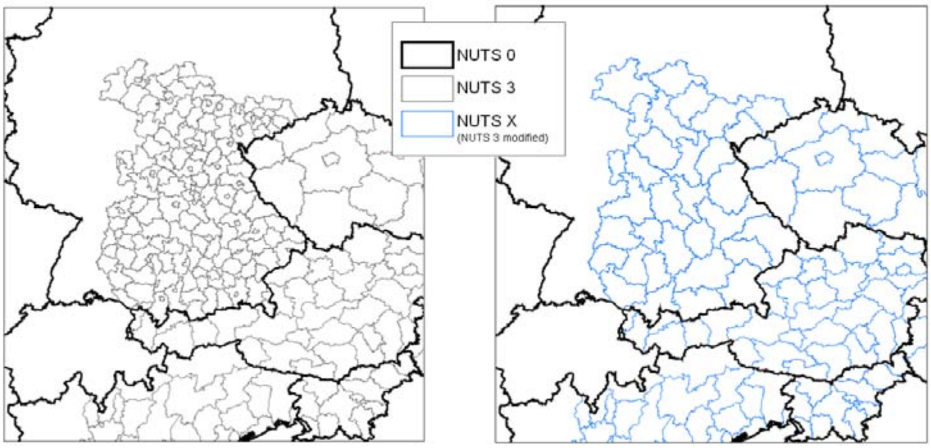


Figure 3: Left: European NUTS 3-regions; right: modified NUTS 3-regions (NUTS X): German spatial planning regions in comparison to other European NUTS 3-regions

The German spatial planning regions show a size between NUTS 2 and 3 – they are aggregated NUTS 3 regions but smaller than NUTS 2. We chose them for two reasons: they are official borders representing functional spatial planning units and they fit better to NUTS 3-regions of the other EU-countries than German NUTS 2 or NUTS 3 regions. The change of borders also meant an adaptation of the data base and a recalculation of the regression.

The second challenge was the contradicting development of population and settlement area in former East Germany and in some cities. Although the population decreased significantly, the settlement area grew between 1990 and 2000 (see figure 4). The reasons for this phenomenon are well-know: after the reunification of West and East Germany many East German regions experienced on the one hand high out migration rates (Heiland 2004) and on the other hand a drastic decline in their birth rate (Lechner 2004). While the population decreased, the settlement area did not shrink, but on the contrary, it was even enlarged. This specific development in East Germany together with suburbanisation trends in some cities caused regression results where change of settlement area negatively correlated to change of population. In other words: the regression said that settlement area grows if population declines. This was a correct statistical conclusion, but for future extrapolations this regression results were not useful.

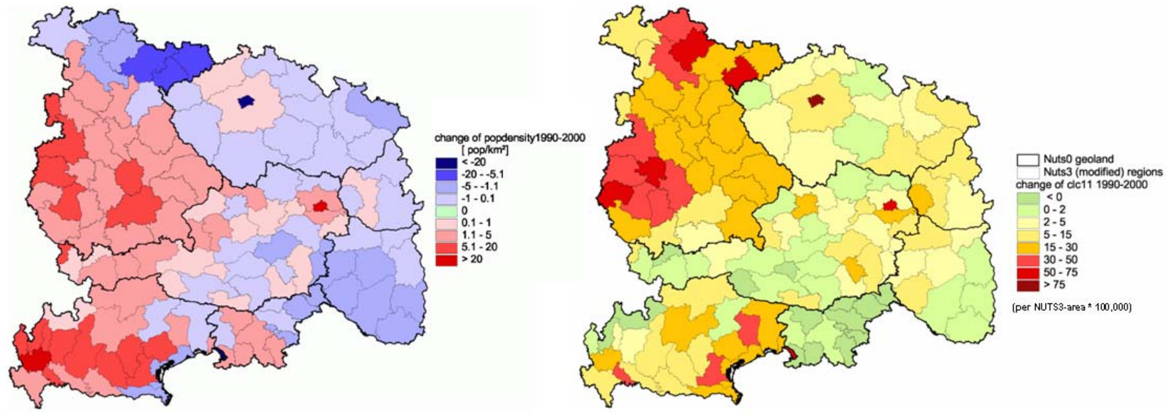


Figure 4: Left: change of population per NUTS 3 (modified) area; right: change of residential area real per NUTS 3 (modified) area

Empirical findings from Austrian studies proved that nowadays the growth of settlement area is not solely caused by growing population numbers but particularly in prosperous and urbanised regions by increasing demand for settlement area per person due to higher living standard and income (Loibl and Tötzer 2003, Tötzer 2006). As the German example illustrated, growth of population and growth of built up area are more and more decoupled. Thus, it was decided to include the demand for settlement area per person into the regression instead of only the number of population. The effect was that even declining population can cause settlement growth due to its higher demand per person. This adaptation appeared to achieve plausible results and was applied for calculating future extrapolations which provided the trend scenario.

6 RESULTS

After this preparatory work the final regression for explaining the development of residential area within the geoland test site was calculated. An R-square of 82% could be achieved. The resulting regression equation delivered the basis for extrapolating historic trends into the future. This trend scenario illustrates the potential future development of residential area under the assumption that historic and current economic and demographic trends will continue linearly (Figure 5, left map). As the aim of our scenarios was not to forecast future development, but to reveal impacts of economy, society and current spatial patterns on future spatial development and to show different pathways of spatial development in Europe based on different demographic and economic trends, scenarios also for extreme forecasts and assumptions on future European trends were calculated. Further scenarios were calculated that result out of alternative assumptions on population development using population projections from Eurostat (baseline variant, high and low population variant, no migrations variant, high fertility variant, younger and older age profile population variant). The right map in figure 5 shows the range of how much the 8 different variants deviate from each other.

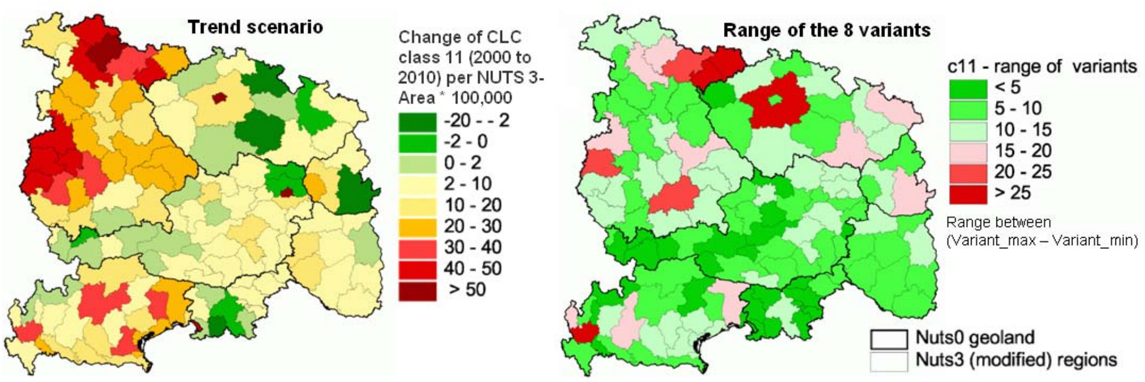


Figure 5: Left: Trend scenario; right: range of the 8 scenario variants

The results were discussed with project partners and practitioners. The following conclusion can be drawn from the scenarios:

As the trend scenario is an extrapolation of current trends from 1990/2000 to 2010, this scenario depicts even extremer land use effects than in the past decade between 1990 and 2000. In particular in the cities Vienna and Prague as well as in former East Germany, in the region around Stuttgart and also in some regions of North Italy the trend scenario shows a continuing growth of residential area. South Germany and North Italy are regions with increasing demand for residential area. In contrast, the district of Nitra in Slovakia and some regions in the Czech Republic, Slovenia, Western Austria and North of Vienna tend to stabilise (or even decrease) their settlement areas. It has to be said that it is very unlikely that settlement area really decreases because even if houses are abandoned vacant buildings often persist. Thus, the statistical extrapolation has to be relativised. However, it can be interpreted that only limited settlement development will take place in these regions.

Comparing the trend scenario with the others reveals to what degree settlement growth depends on population development and on peoples increasing demand for residential area. Furthermore, it points out which regions are especially sensitive to different population trends. As the right map in figure 5 illustrates, in many regions the different variants assuming high or low population growth do not deviate very much from each other. This originates in a) the low deviation between the different population projections and b) in the fact that population itself is not the only driving force for settlement growth (as already discussed previously). As the right map in figure 5 shows, a significant variance between the scenarios can only be observed in a few regions such as the suburban region of Prague, the East Germany part within the geoland test site and the greater urban regions of Munich, Stuttgart and Milan. The development of settlement area in these regions is particularly sensitive to the different population projections.

The scenarios which are based on a very dynamic population development (Eurostat variants: high population, high fertility and younger age) are very similar. The same similarities can be observed between the scenarios that assume only modest or negative population growth (Eurostat variants: low population, no migrations variant and older age profile). In Figure 6 two scenarios from the 8 variants were selected which most clearly point out the differences. Both maps present the deviation from the trend scenario.

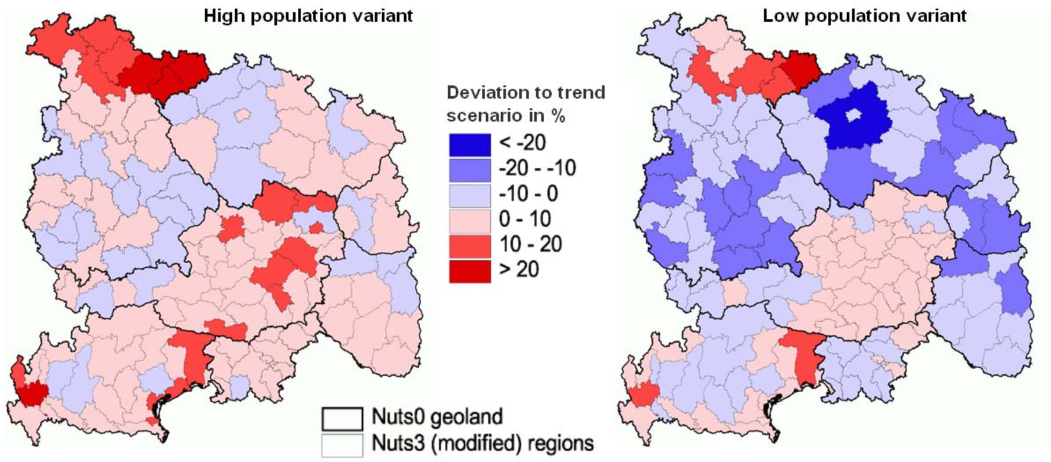


Figure 6: Scenarios with high population (left) and low population (right) forecasts in difference to the trend scenario (in %)

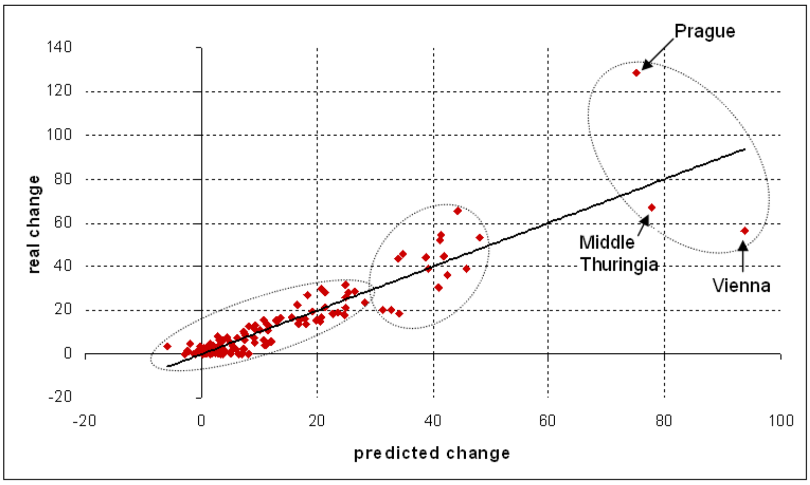
A visual comparison of the two maps already reveals that the East German part of the geoland test site as well as the Milan and Udine regions show high positive deviations from the trend scenario regardless of the different variants. Even in the scenario based on Eurostat´s low population assumption residential area will increase more than in the trend scenario. This originates in the fact that in the Eurostat prognoses population growth is assumed to be higher in the future than it was in the past. Thus, an extrapolation of historic population trends is lower than even the low-population-variant of Eurostat. As population is included into calculations through its demand for residential area, a lower population extrapolation leads in the following to an underestimation of settlement growth.

Low population forecasts mainly stunt the development of residential area in Bavaria, Stuttgart, Tuebingen and in the regions of the New Member States which lie within the geoland test site. For most parts of Austria a higher population growth is forecasted than the trend would predict. The high population scenario shows positive effects in the North and South of Lower Austria, in North Styria, in the region Linz-Wels and in South Carinthia.

7 QUALITY ASSESSMENT

The trend scenario was validated by “control runs” calculating the development of residential areas for the past period 1990-2000 and comparing it with the actually observed development. Graph 1 shows for each NUTS 3 region the real changes of residential area (y-axis) in comparison to the predicted changes extrapolated from linear regression (x-axis). This quantitative comparison of the scenario results on NUTS 3 level allows an indication on the quality of the extrapolation.

As the R-square of the regression is very high (82.3%), most of the dots are very close to the straight line that represents the linear relationship between the real and predicted changes. Particularly in those NUTS 3-regions where the changes from 1990 to 2000 are rather small, the predictions from the regression fit very well. Deviations can primarily be observed for higher values.



Graph 1: Comparison of real and predicted change of residential area (each dot represents a NUTS 3-region)

There are three groups of dots. The first one is the largest group comprising NUTS 3 regions with a decrease or only low increase of residential area between 1990 and 2000. This group fits best with the calculated values from the regression. The second group shows a higher growth of settlement area than the first one and is already more scattered than the first one. The third group contains three outliers which clearly stand out from the others. They represent regions with very high predicted settlement growth: Vienna, Prague and Middle Thuringia. While in Prague the real growth was much higher than predicted by the regression, in Middle Thuringia and Vienna settlement growth was overestimated. Hence, two cities show highest deviations between predicted and really observed settlement growth: the highest positive deviation can be found in the Vienna region and the highest negative deviation in Prague.

Figure 7 integrates the information of Graph 1 in its spatial context. The visualisation in a map allows additional interpreting if regions with high or low deviations from observed growth patterns are spatially related. Regions in blue colour are overestimated by the regression, which means that the real settlement development was lower than the predicted. On the other side of the colour scale, regions displayed in a red colour show that the regression underestimated the regions´ real dynamic settlement growth.

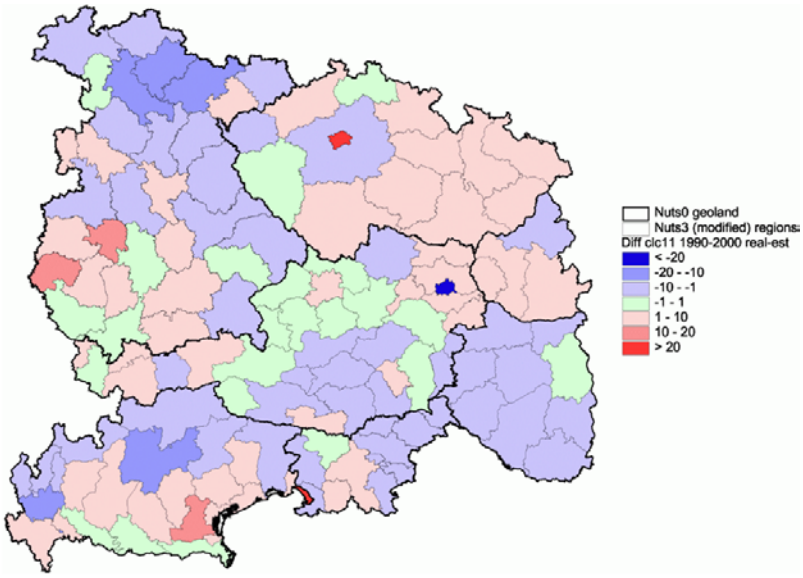


Figure 7: Deviation between predicted and real change of residential area between 1990 and 2000

Figure 7 confirms the previous findings: the Vienna region, where predicted change was much higher than really observed change, is the only one in dark blue colour. This is also the case in the East German part of the geoland test site containing Middle Thuringia. Furthermore, Milan belongs to the regions with the least correspondence between real and predicted growth values. After Vienna, Milan is the region with the second highest overestimation of settlement growth. In the dark red coloured regions – Prague and Trieste at the Italian border to Slovenia – the prediction is much lower than the actually observed growth. However, most of the NUTS 3 regions show a high concordance and only small deviations between real and predicted growth of residential area.

8 CONCLUSION

The scenarios discussed in this paper presented different potential images of future development of residential area based on socio-economic and demographic driving factors. Our approach is based on previous research demonstrating that land use change is driven by human factors such as population and employment development, demand for residential area, GDP and purchasing power. However, integrating statistical, not land use related data combined with current land use patterns posed a specific challenge in the approach applied. For identifying factors determining change of residential area and for exploring the relationship between land use and non-land use factors the methodology of multiple linear regression was used. In order to find the best predictors for land use change, the correlation between the explanatory statistical and land use variables and the dependent variable predicting change of residential area was examined. Regression test runs revealed that population development can not directly be fed into scenario calculations. Only in combination with the continuously rising demand for residential area per person it can reasonably be integrated into statistical regressions. Considering these findings and after adapting the NUTS 3 classification to similar sized regions, regression results could be achieved with a R-square of 82.3%. Thus, for the selected geoland test region a regression equation could be deduced which allows explaining the development of residential area by statistical Eurostat data and CORINE Land Cover data.

The regression delivered the base for extrapolating existing trends into the future. As the aim of the scenarios was to show different pathways of spatial development in Europe, scenarios based on current trends as well as on expert forecasts were calculated. However, European wide forecasts for the demographic or socio-economic development on regional scale are scare. Population projections from Eurostat were the only data available. Limited availability of EU-wide statistical data and of forecasts constrained testing further effects of single variables on scenario results. Thus, the scenarios focused on alternative assumptions on population development using Eurostat´s population projections (baseline variant, high and low population variant, no migrations variant, high fertility variant, younger and older age profile population variant).

The scenarios deliver insights on relationships between demographic, socio-economic and land use variables and on the sensibility of certain regions against varying population projections. Although the scenarios do not include political measures such as changes in planning system (e.g. zoning restrictions) or immigration politics, they can give a hint, where measures would be needed. By constructing images of the future we can learn to identify the major impacts on future development. It is not necessary to know the future as such, but it already helps to realise what differences certain assumptions or projections would make. In our scenarios only a few regions appeared to be particularly sensitive to different population projections, namely Prague, the East Germany part within the geoland test site and the greater urban regions of Munich, Stuttgart and Milan. Even though the scenarios developed allow drawing some interesting conclusions, it has to be noted that the approach is currently limited by data constraints. Further research could be significantly improved by better statistical data and forecasts on European scale.

9 ACKNOWLEDGEMENTS

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