

# Index-based Decomposition and Econometric Analysis of Driving Forces of Biodiversity Change

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by

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## **Abstract**

The main purpose of our study is to provide an integrated assessment of land-use patterns that have been induced in the Czech Republic since 1990. We applied several approaches that enable us to investigate the impacts of driving forces on the state of ecosystems and biodiversity. The biodiversity change is measured by the Mean Species Abundance index, which comes from the family of approaches based on ecosystem intactness. Integrated assessment of biodiversity and land use changes based on Corine Land Cover data (CLC 1990, 2000, 2006) combines several methodological approaches including GIS, welfare and decomposition analysis.

**Keyword:** Biodiversity, Land Cover, Welfare Analysis, Decomposition Analysis, Laspeyres Index

**JEL classification:** C51, C43, Q24

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## **Introduction**

The Czech Republic is an example of newly transformed economy in Central and Eastern Europe, where the transition process culminated with joining the European Union in 2004. The transition process started in 1990 and brought economic differentiation among regions and concentration of economic activities in large cities (e.g. Prague, Brno or Pilsen). The territorial differentiation has subsequently led to increased migration and labour mobility. Migration flows have strengthened urban sprawl and suburbanisation especially around big cities.

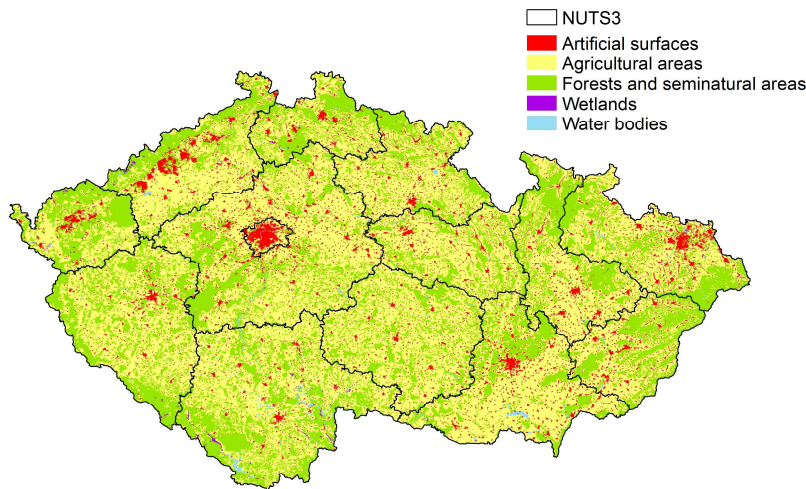
Social driving forces, economic transformation, suburbanisation, migration and recent construction of linear infrastructures have inevitably contributed to unfavourable land use trends. Arable land area has been continuously declining and has been replaced by artificial and built-up areas or other transformed areas (transport infrastructure). The construction of transport structures leads to fragmentation of the landscape and threatens the existence of many species. On the other hand, land use trends are more favourable in remote areas, which are not so economically attractive.

The overall objective of our study is to provide an integrated assessment of land-use patterns that have been induced in the Czech Republic since 1990. We applied several approaches that enable us to investigate the impacts of driving forces on the state of ecosystems and biodiversity. The biodiversity change is measured by the Mean Species Abundance index, which comes from the family of approaches based on ecosystem intactness. Integrated assessment of biodiversity and land use changes based on Corine Land Cover data (CLC 1990, 2000, 2006) combines several methodological approaches including GIS, welfare, decomposition and econometric analysis. Regionally differentiated MSA indicator, according to NUTS 4 regions, was analysed using an index-based decomposition (additive method linked to Laspeyres index) in order to assess the effects of driving forces such as change in economic scale and its regional structure.

### **1. Land Use Trends**

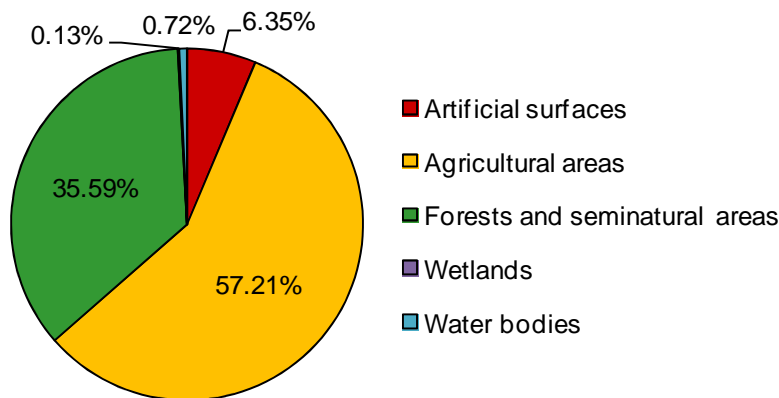
The area of the Czech Republic is rather small, less than 79 thous. km<sup>2</sup>, and is characterised by different climatic conditions and corresponding variety of land-use categories. Landscape coverage of the Czech territory may be documented using European land-monitoring data of the Corine land cover inventory (CLC), which was collected in 1990, 2000, and recently in 2006. The geographical distribution of main land-cover types, based on the Corine 2006 data, is depicted in Figure 1.

Figure 1 - Main land-cover categories in the Czech Republic, based on the Corine land cover 2006 inventory



According to the Corine data for 2006, agricultural land accounts for 57.2% of the territory, built-up areas cover around 6.4%. In total, more than 63% of the area is covered by land-use categories that do not promote biodiversity. Land use categories more favourable for biodiversity (forests, wetlands) cover one-third of the territory (35.7%) (Figure 2).

Figure 2 - Share of land-cover types in the Czech Republic, based on the Corine land cover 2006 inventory



## 2. Methodology Used

### 2.1 Measuring biodiversity changes

The biodiversity change is measured by the Mean Species Abundance index, which comes from the family of approaches based on ecosystem intactness. MSA, developed for the global biodiversity model GLOBIO, is calculated as the remaining mean species abundance of the original species compared to their abundance in a pristine state, which is supposed not to be disturbed by anthropogenic activities (Alkemade et al., 2009).

MSA indicator measures a percentage distance from a natural level of biodiversity for given land-cover. Primary vegetation with minimal disturbance, where flora and fauna species abundance are near pristine, exhibit MSA values equal to 1, built-up areas have MSA values of about 0.05.

For the analysis of biodiversity change in the Czech Republic, we used an impact-type measure of MSA, which is based on Corine land-cover flows (LCF). Data for MSALCF was obtained from the land-cover flow matrix, which stems from Corine land-cover reports for the Czech Republic for periods 1990-2000 and 2000-2006.

$MSA_{LCF}$  in the period  $t$  is then given as:

$$MSA_{LCF} = \frac{\sum_i \sum_j (MSA_i - MSA_j) \times A_{LCF_{ij}}}{\sum_i A_{LCF_i}}$$

where  $A_{LCF_{ij}}$  denotes area of land-cover flow (in hectares) from land-cover category  $j$  into category  $i$  during given time period.  $MSA_j$  denotes MSA index of land cover class  $j$  in the period  $t-1$  and  $i$  marks the class in the period  $t$ . The  $MSA_{LCF}$  indicator weights total changes of land cover in a given time period and is therefore based on normalization by area changed in a given period.

$MSA_{LCF}$  is a weighted average of total  $MSA_{LCF}$  changes from one land-use type to other, where the weight is the area of particular land-cover flow (in hectares). It is therefore based on normalization by area changed in a given time period.

## 2.2 Welfare measures of land-cover change

Welfare analysis (Freeman, 1993) of land-cover change in the 2000-2006 period for the Czech territory was based on the concept of total economic value. The corresponding welfare change comprises of 15 types of ecosystem services – provisioning, regulating and cultural. The economic values for these ecosystem services were adopted from the COPI (the Cost of Policy Inaction) database and adjusted for 2011 prices (Braat, ten Brink, 2008).

The total value of land-cover change of a given land-use type were calculated as follows (Troy, Wilson, 2006):

$$V(ES_{ij}) = \sum_i \sum_j (V(ES_{ki}) - V(ES_{kj})) \times A_{LCF_{ij}}$$

where  $A_{LCF_{ij}}$  is the area of land-use change (in ha) from land-cover type  $j$  into type  $i$  during the given period.  $V(ES_{kj})$  is per hectare annual value of ecosystem service  $k$  for land-use type  $j$  in the period  $t-1$  and  $V(ES_{ki})$  is per hectare annual value of ecosystem service  $k$  for land-cover type  $i$  in the period  $t$ .

The measure represents the total annual value associated with ecosystem service change that occurred during given time period (1990-2000; 2000-2006 respectively).

### 2.3 Decomposition analysis of driving effect on biodiversity

Regionally differentiated MSA indicator, according to NUTS 3 regions, was analysed using an index-based decomposition in order to assess the effects of driving forces such as change in economic scale and its regional structure (Ang, Zhang, 2000; Ang, 2004; Ang, Huang, Mua, 2009).

The changes in  $MSA_{LCF}$  index during the transition period have been decomposed into 3 factors:

$$\Delta_t MSA_{LCF,i} = \Delta_t \frac{MSA_i}{Y_i} + \Delta_t \frac{Y_j}{Y} + \Delta_t Y$$

where  $i$  denotes NUTS 3 region and  $t$  denotes time (1990-2000 and 2000-2006 periods in this case).  $\Delta_t MSA_i$  denotes the MSA change in the NUTS 3 region  $i$ .  $Y_i$  is the change in gross domestic product in the sector  $i$ .  $Y$  is sum of GDP across the NUTS 3 regions.

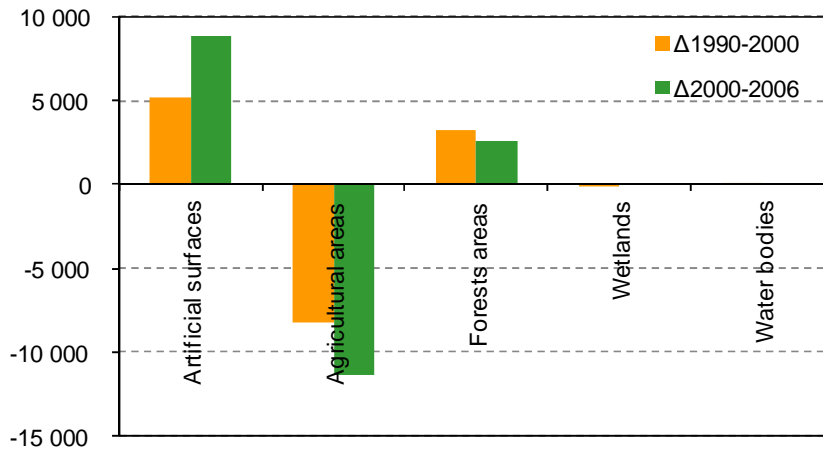
Thus, the first term ( $\Delta_t MSA_i / Y_i$ ) captures the effect of the change in the MSA intensity (wilderness intensity effect), the second term ( $\Delta_t Y_j / Y$ ) captures the effect of the change in the regional composition of economic activity (composition effect) and the third term ( $\Delta_t Y$ ) measures the effect of economic growth (scale effect).

### 3. Net Land-cover Changes

Using CLC vector data about the land-cover 1990-2000 and 2000-2006 changes, we analysed land-use changes for the Czech Republic in the 1990-2006 period. Since 1990, land-cover has changed by 662,000 ha, i.e. 9% of the Czech territory. During the first period, 1990-2000, the land-cover changed by 505,000 ha (6.8% of the total area), the second period, 2000-2006, exhibited land-cover change on 157,000 ha (2.1% of the total area). Annual land-cover change slowed from 0.62% in 1990-2000 to 0.35% in 2000-2006.

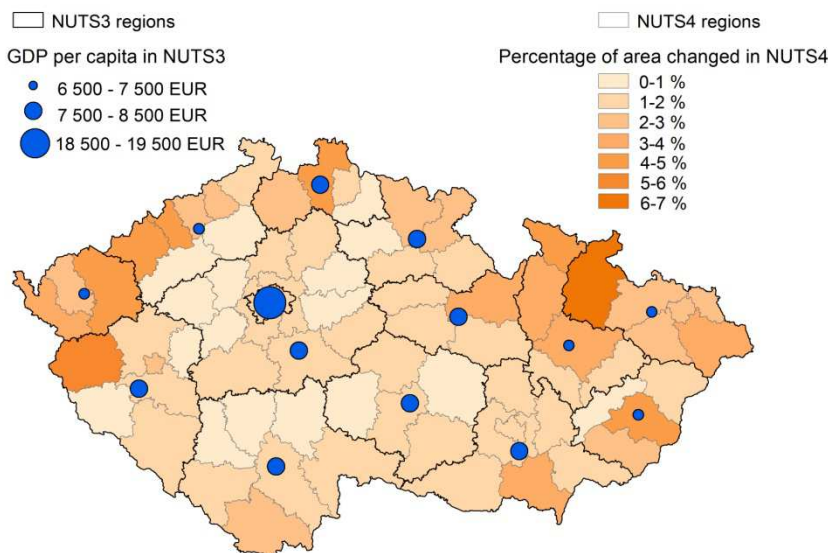
Net land-cover changes for the main land-use categories are demonstrated in Figure 3. The change in agricultural area represents the largest land-cover change measured in absolute terms in both periods. Following the downward trend of 1990-2000, arable land, permanent crops and pastures decreased by 11,400 ha during 2000-2006. Built-up area increased by 5,100 ha in the 1990-2000 period and 8,800 ha in 2000-2006. Total forest area increased by 3,200 ha in the first period and by 2,500 ha in the latter period.

Figure 3 - Net land-cover changes 1990-2000 and 2000-2006 in the Czech Republic (in hectares)



The regional structure of land-cover changes is measured for two region categories of Nomenclature of Units for Territorial Statistics (NUTS) established by Eurostat: 14 regions on NUTS3 level and 77 NUTS4 local administrative units. Analysis of regional trends reveals that significant land-cover changes occurred in the regions with low economic performance, where we can see continued conversion from arable land to pastures. This pattern is depicted in Figure 4, where the economic performance in terms of the average annual GDP per capita is compared to the relative land-cover change in 2000-2006.

Figure 1 - Relative changes of land-cover according NUTS 4 regions and the average gross domestic product per capita in NUTS 3 regions in 2000-2006



#### 4. Analysis of Biodiversity Change

Out of numerous indicators measuring pressures and impacts on ecosystem services and biodiversity, the Mean Species Abundance (MSA) index, which had been developed under the Economics of Ecosystems and Biodiversity initiative, was selected as the most

appropriate indicator representing aggregate biodiversity change for the Czech Republic. MSA is based on the biodiversity intactness approach, when natural areas with high levels of biodiversity are valued close to 1 and the value of artificial areas is set to close to 0 (Alkemade et al., 2009).

Figure 2 - Average MSA change in NUTS 4 regions in 1990-2000

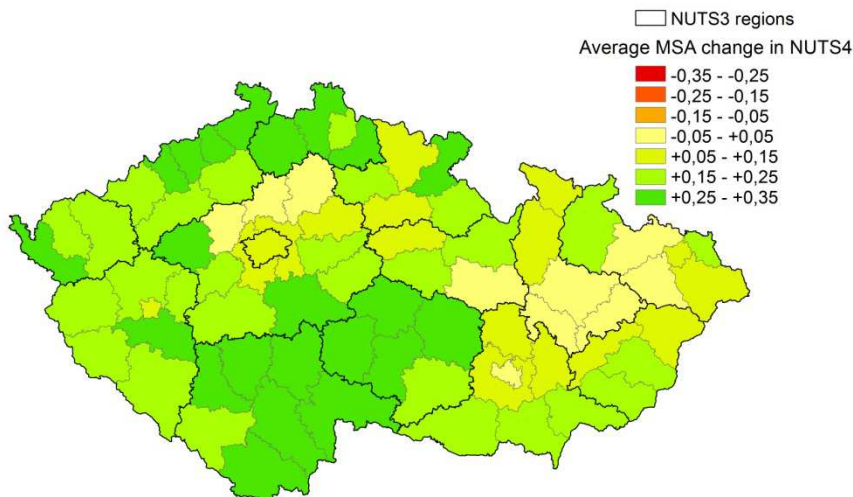
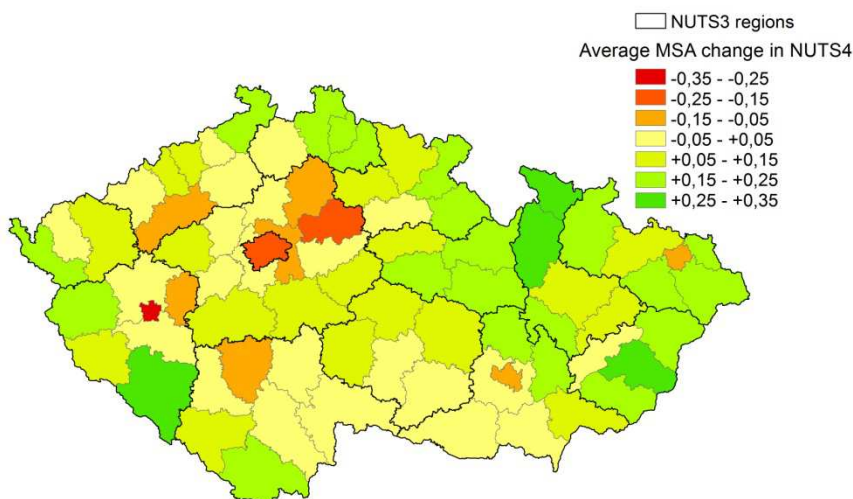


Figure 3 - Average MSA change in NUTS 4 regions in 2000-2006



Measuring the change in biodiversity since 1990, the average value of MSA computed for the whole territory of the Czech Republic has increased during 1990-2000 by 0.213 and by 0.128 in 2000-2006. This indicates a slight increase in biological diversity. However, this trend slows down because of urban sprawl acceleration, which is driven by construction in the past decade (Figure 5 and Figure 6). Corresponding changes in NUTS4 regions are depicted in Figure 5 and Figure 6.

Nevertheless, there are apparent regional differences in the biodiversity change. In particular, this pattern is evident in the second period (2000-2006), when MSA changes in some NUTS 4 regions are negative. The negative unfavourable trend of biodiversity is mainly evident in the regions with high level of economic performance, especially in Prague and its surroundings – the Stredocesky Region.

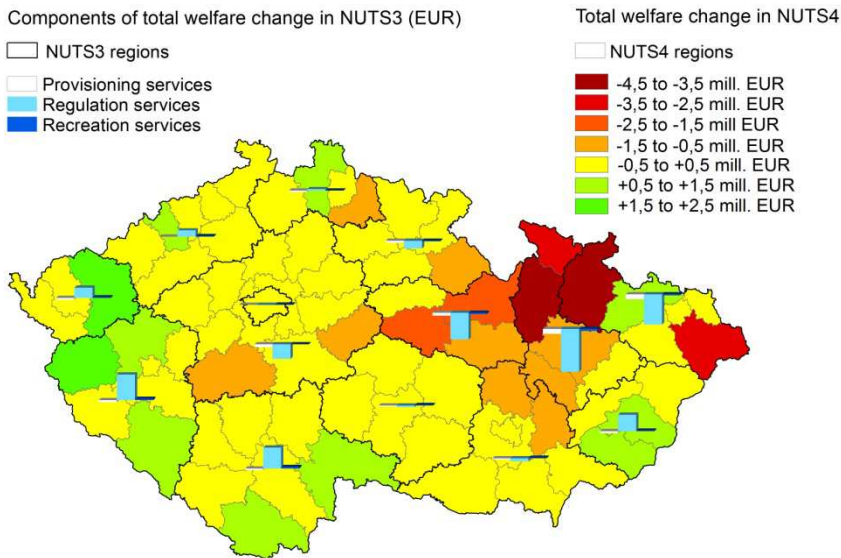
### 5. Welfare Change Analysis

Surprisingly, a completely different picture is shown by a welfare analysis that we calculated for land-cover change in the 2000-2006 period. Into the corresponding welfare changes we incorporated value changes of 15 types of ecosystem services (provisioning, regulating and cultural). Contrary to the increase of the average MSA value by 0.128 associated with the Czech Republic as a whole, there is a welfare loss of almost 13 mil EUR in the 2000-2006 change.

In the 2000-2006 period the urban sprawl affected mainly land-cover types with low biodiversity potential, such as artificial surfaces and agricultural areas. These changes were overweighted by changes in arable land into pastures, more heterogeneous agricultural areas, agro-forestry areas and other semi-natural areas which are associated with much higher level of biodiversity and as such yield higher changes in MSA value; however these changes play only a small role in the total welfare change.

Figure 7 illustrates the regional disparities in the total welfare change according to the NUTS 4 regions. This picture is accompanied by welfare change subdivided into provisioning, regulation and recreation services. The major part of the welfare changes, which was computed for NUTS 3 regions during 2000-2006, is attributed to the changes in regulating services.

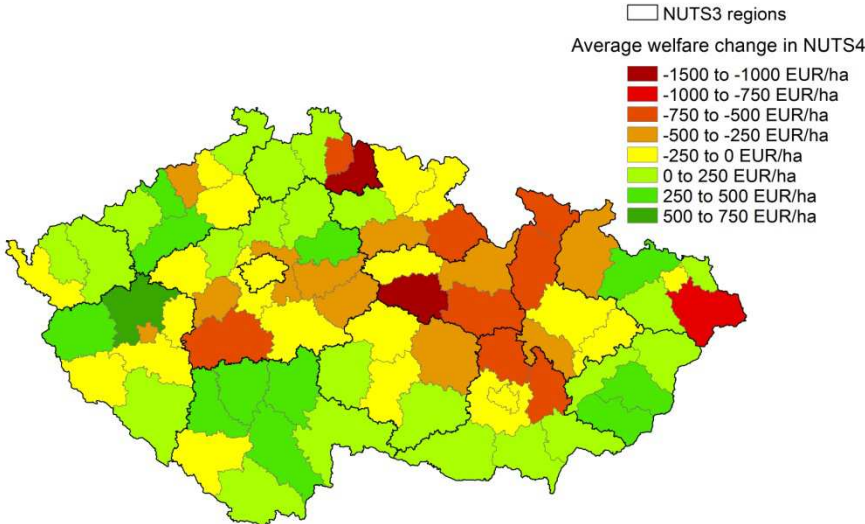
Figure 4 - Total welfare change according to NUTS 4 regions and components of total welfare change in NUTS 3 regions in 2000-2006, values in 2011 prices





The average welfare change in NUTS 4 regions ranges from -1,238 to 700 EUR per ha (Figure 8). These values represent welfare change per hectare of area changed and may be directly related to MSA values in Figure 5 and Figure 6.

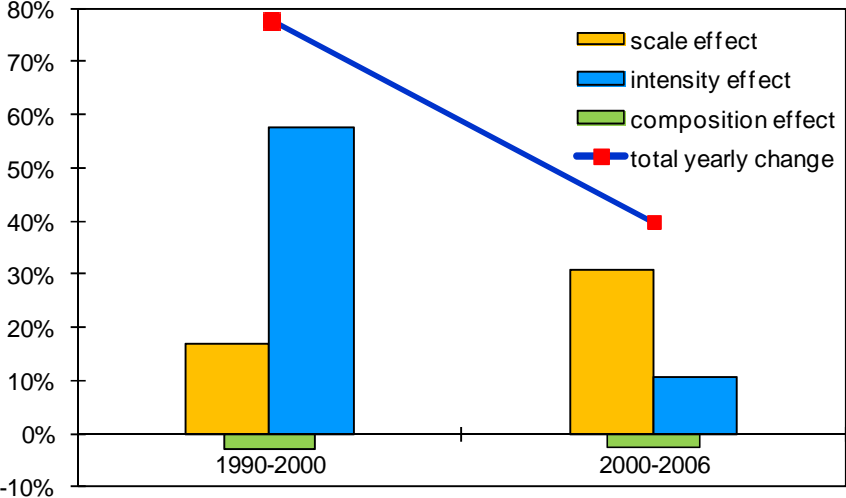
Figure 5 - Average welfare change according to NUTS 4 regions in 2000-2006, values in 2011 prices



### 6. Index-based Decomposition of Driving Forces

Decomposition analysis of the driving forces of the biodiversity change, measured by MSA, was carried out for the period 1990-2000 and 2000-2006. The decomposition was performed additively. The MSA change was decomposed into 3 factors – wilderness intensity, composition and scale effect (see Figure 9).

Figure 6 - Three factor decomposition of MSA change in 1990-2000 and 2000-2006



The results show an increase of MSA in the Czech Republic by 78% during the first decade since 1990 and by 40% in 2000-2006. Scale and wilderness intensity effects contribute positively to the MSA change, and composition effect has a slight negative contribution in both periods. The most important factor of the MSA change in 1990-2000 is the wilderness intensity effect. This effect measures how the change in the ratio of the MSA level over GDP in particular NUTS 3 regions contributes to the overall MSA level.

## 7. Conclusions

Our results show that land-use changes have significant effect on the welfare. The patterns of land-use changes as well as its driving forces sharply diverge in the long run, which was proved in the case of the Czech Republic but holds as well in European context. This has to be considered when designing land-use policies. Carbon sequestration policies and renewable energy policies may be especially associated with large scale and long-run land-use changes where the estimation of welfare effects changes should be taken into account.

The transition economies such as the Czech Republic deserve a detailed analysis of patterns and driving forces that induce land-cover changes during the transformation phase because of unevenly spatially distributed suburbanization, landscape fragmentation and unfavourable land-use trends. Regional and spatially oriented analysis of land-use trends is particularly important. An emphasis should be also placed on the welfare analysis of biodiversity changes and corresponding ecosystem services.

## Acknowledgment

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