

**DYNAMICS AND STABILITY OF LAND USE:
ANALYSIS ON THE BASIS OF THE NATURAL
LANDSCAPE AND THE CORINE LAND COVER
DATA (CASE STUDY REGION OF BRATISLAVA)**

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Introduction

- **The rate and extent of LC changes directly involve organization of cultural landscape and the environment. Analysis of long-term development and land use changes is based on various sources.**
- **Historical maps and statistical records** are reliable obligatory data for the long-term LU/LC change assessment (Bastian 1991, Bičík et al. 1996, Lipský 1995, Boltžiar 2005, Demek et al. 2009, Olah 2003, Ot'ahel' et al. 1993, Van Eetvelde a Antrop, 2009).

Remote sensing and specially CORINE land cover (CLC) data (CLC90), 2000 (CLC2000) and 2006 (CLC2006) offer new possibilities for the correct LU/LC change assessment in the regional (Ot'ahel' et al. 2004, Kuemmerle et al. 2006) national (Feranec et al. 2005, 2006) and international context (Feranec et al. 2007, 2010, Haines-Young, R., Weber, J.-L. 2006, Willems et al. 2005)

The aim - to present the long-term development of cultural landscape in the context of relative stability (persistency) of forest land use and simultaneously to point to the dynamics and character of landscape changes pursuing natural conditions and the CLC data for periods of 1990 and 2006 in the region of Bratislava.

Data and methods

Identification of representative landscape states (conditions):

- the natural (reconstructed) condition of landscape – **hypothetical land cover** - exist free of human impact and land use – *the relatively homogeneous bioclimatic, georelief and soil/substrate areas in condition close to the original forest landscape or to potential natural vegetation –homogeneous their functioning and potential land use*
- natural landscape is identified by the method of geocological analysis and mapping (Mazúr et al. 1977, Ot'ahel' 2000, Minár et al. 2001), or by mapping of potential natural vegetation (Mikyška et al. 1968, Michalko et al. 1986)

- **the human conditions of landscape – land cover in 1990, 2000, 2006 (CLC90, CLC2000, CLC2006)** – integrate natural conditions and human impact – **physical state of real landscape**
- **CORINE land cover method Heymann et al. (1994), Bossard et al. (2000), Feranec and Ot'ahel' (2001) applicated by the computer aided visual interpretation**
- The quoted data layers or information associated with the CLC Slovakia Project are available on the website of the Slovak Environmental Agency <http://www.sazp.sk/corine>
- **Computer processing - software ArcGIS 9.2 of ESRI - for spatial statistical analysis and visualisation and cartographic representation**

The data layers - in vector polygon format were converted into the raster data model, where the smallest addressable spatial unit was represented by the square with a side approx. 200 m (precisely 200,233 m) long

Analysis of relative stability (persistency) of forest land use

Data and processing:

Data (map) of natural landscape types at scale 1:100 000

CLC90, CLC2000, CLC2006 data layers at scale 1:100 000

By overlay of natural landscape as a referential layer and the CLC90, CLC2000 a CLC2006 land cover data layers intersection (concordance) of reconstructed forest areas with those which are often secondary in terms of wood species (broad-leaved, coniferous and mixed) but spatially relatively unchanged were analyzed. Delimited areas represent relative stability (persistency) of forest land use

Analysis of landscape changes

Dynamics of landscape changes was analysed by the CLC 1990-2000 a CLC 2000-2006 data layers and expressed by **number and area of LC changes** by their relation to natural landscape (Van Eetvelde, Antrop 2009)

Types (character) of landscape changes were assessed on the basis of LC changes by the methodological approach (Feranec et al. 2002) **respecting basic social and economic processes**

U- urbanization (suburbanization) – (expansion of urban fabric and artificial surfaces, urban sprawl)

I - intensification of agriculture (intensive use of agricultural land) – (changes of forest, pastures into arable land and permanent crops or changes of arable land into permanent crops or complex cultivation pattern)

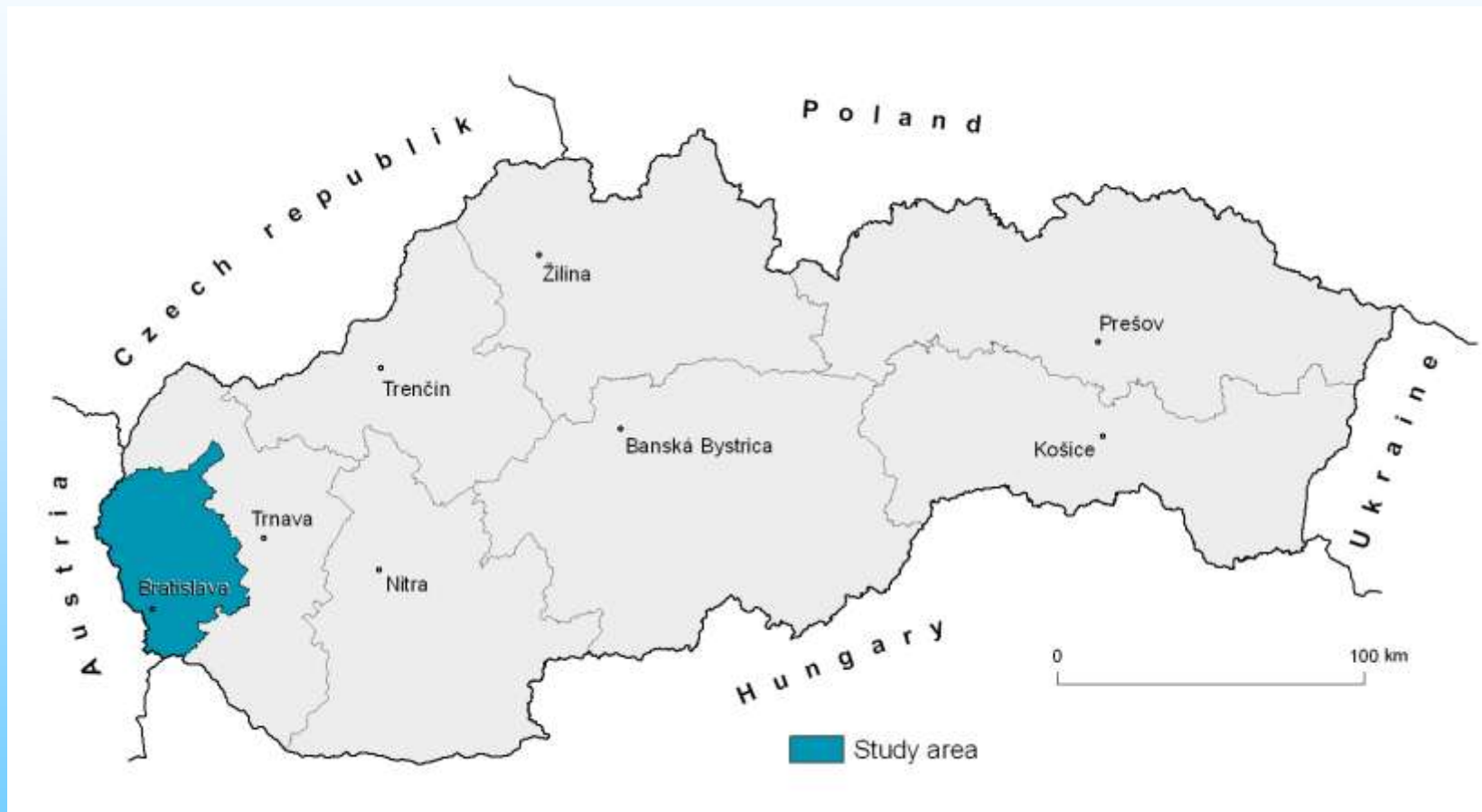
E - extensification of agriculture (extensive use of agricultural land) – (changes of permanent crops into arable land and pastures or changes of arable land into pastures)

F – forestation – (expansion of forest areas by planting or natural succession)

D – deforestation – (changes of forest by logging into transitional woodland and scrubs or into agricultural land or urbanized areas)

O other changes – (expansion of water bodies or mining areas).

Location of study area



Study area

Situated in the western part of Slovakia - includes 8 districts (Bratislava I, II, III, IV, V, Malacky, Pezinok and Senec) with total area of 2,053 km² or 4.2% of the national territory.

The total population of the region is 622,706 (as of 1.1.2010) or 11.5% of the national total. By population density (303 inhabitants per km²) - the highest in the country.

Three orographic units differentiate the relief: two lowlands, the Záhorská and Podunajská are separated by the mountain landscape of the Little Carpathians

Capital Bratislava, the administrative and economic centre of Slovakia, is situated on the Danube River and on the contact of the Little Carpathians with the Podunajská Lowland.

Natural conditions are specified in the classification scheme (Tab. 1) and in the map of natural landscape (Fig. 1).

Tab. 1 NATURAL LANDSCAPE - BRATISLAVA REGION

1 INTRA-MOUNTAIN LOWLAND LANDSCAPE

11 Accumulation plain landscape with porous ground waters

111 *Fluvial to aeolian-fluvial plains*

1111 Holocene flood plains with floodplain forests on Fluvisols to Mollic Fluvisols

1112 Pleistocene flood plains covered by prevailing carbonate (aeolian) sediments with xero-thermophilous oak forests on Chernozems

112 *Undulated fluvial to aeolian-fluvial plains*

1121 Low terraces and cones with elm floodplain forests to oak-hornbeam forests on Cambisols

1122 Fluvial-eolian terraces to neogene plains with oak-hornbeam to oak-pine forests on Cambisols

1123 Dunes with pine forests on Regosols

12 Erosion-accumulation hilly landscape with capillary ground waters

121 *Loess erosion-accumulation landscape*

1211 Loess tables with warm oak forests on Chernozems

1212 Loess hilly lands with oak to oak-hornbeam forests on Chernozems, Haplic Luvisols and Luvisols

122 Polygenetic hilly lands with oak to oak-hornbeam forests on Cambisols

2 MOUNTAINOUS LANDSCAPE

21 Basin, furrow, and valley erosion-accumulation landscape with capillary and porous ground waters

211 *Warm basins with oak to oak-hornbeam forests*

2113 Subberglands and intramontane furrows with oak-hornbeam forests on Cambisols

212 *Moderately warm basins with oak-hornbeam forests*

2133 Subberglands and intramontane furrows with oak forests on Cambisols

22 Mountainous erosion-denudation landscape with fissured-layered to fissured-karstic ground waters

221 *Promontories to plateaux*

2211 Warm to moderately warm promontories and plateaux with oak-hornbeam forests on Cambisols to Rendzinas

222 *Uplands to highlands*

2221 Warm to moderately warm uplands to highlands with oak-hornbeam forests on Cambisols to Rendzinas

2222 Moderately cold uplands to highlands with beech to spruce forests on Cambisols to Rendzinas

NATURAL LANDSCAPE TYPES

1 LOWLAND LANDSCAPE

11 Accumulation plain landscape

111 Fluvial to aeolian-fluvial plains

1111 Holocene flood plains

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122 Polygenetic hilly land

2 MOUNTAINOUS LANDSCAPE

21 Basin and furrow erosion-accumulation landscape

211 Warm basins

2113 Subberglands and intramontane furrows

212 Moderately warm basins

2133 Subberglands and intramontane furrows

22 Mountainous erosion-denudation landscape

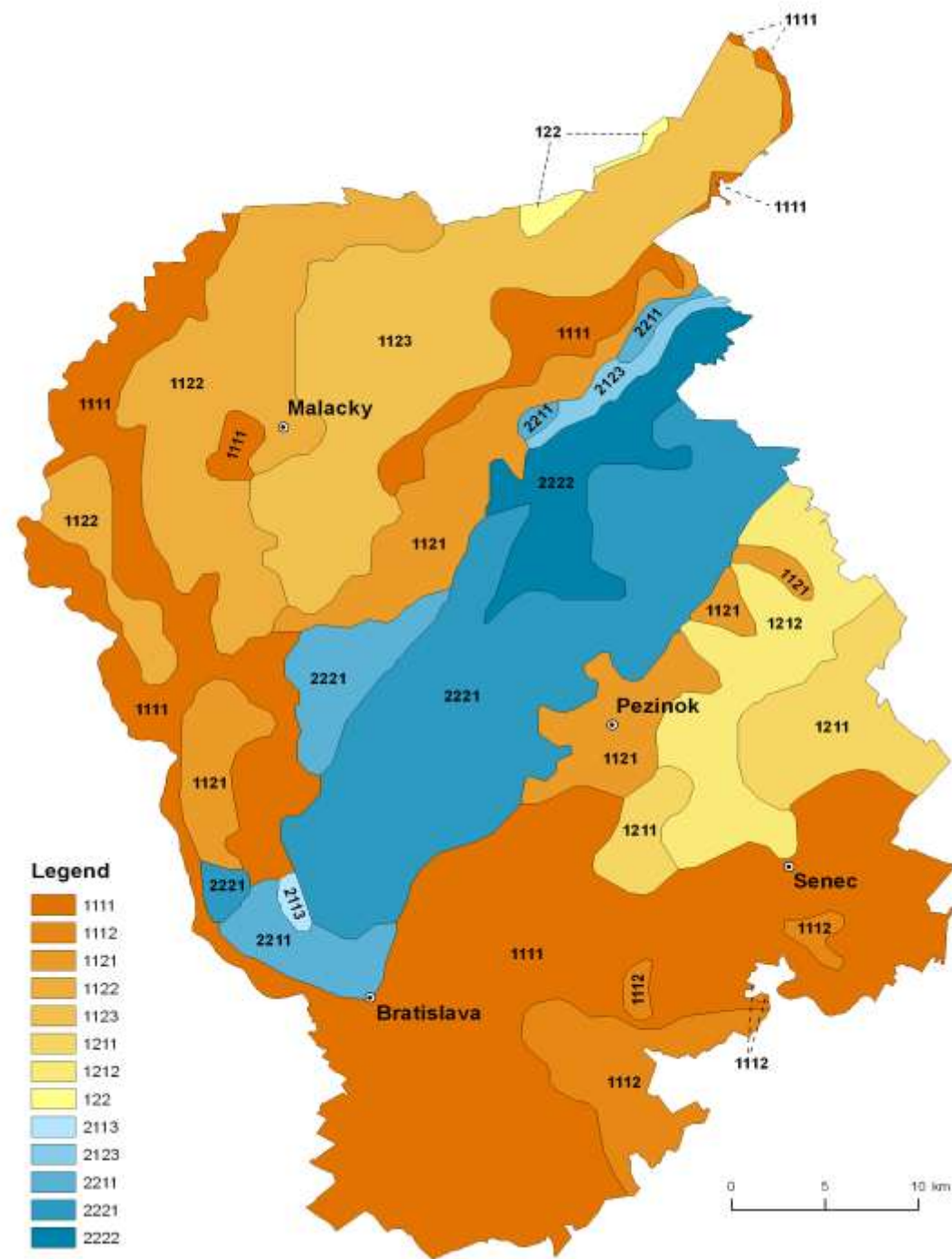
221 Promontories to plateaux

2211 Warm to moderately warm promontories

222 Uplands to highlands

2221 Warm to moderately warm uplands to highlands

2222 Moderately cold uplands to highlands



LAND COVER 1990

1 ARTIFICIAL SURFACES

- 111 Continuous urban fabric
- 112 Discontinuous urban fabric
- 121 Industrial and commercial units
- 122 Road and rail networks and associated land
- 124 Airports
- 131 Mineral extraction sites
- 132 Dump sites
- 133 Construction sites
- 141 Green urban areas
- 142 Sport and leisure facilities

2 AGRICULTURAL AREAS

- 211 Non-irrigated arable land
- 221 Vineyards
- 222 Fruit trees and berry plantations
- 231 Pastures
- 242 Complex cultivation pattern
- 243 Agriculture land with areas of natural vegetation

3 FOREST AND SEMI-NATURAL AREAS

- 311 Broad-leaved forests
- 312 Coniferous forests
- 313 Mixed forests
- 321 Natural grasslands
- 324 Transitional woodland/shrubs
- 334 Burnt areas

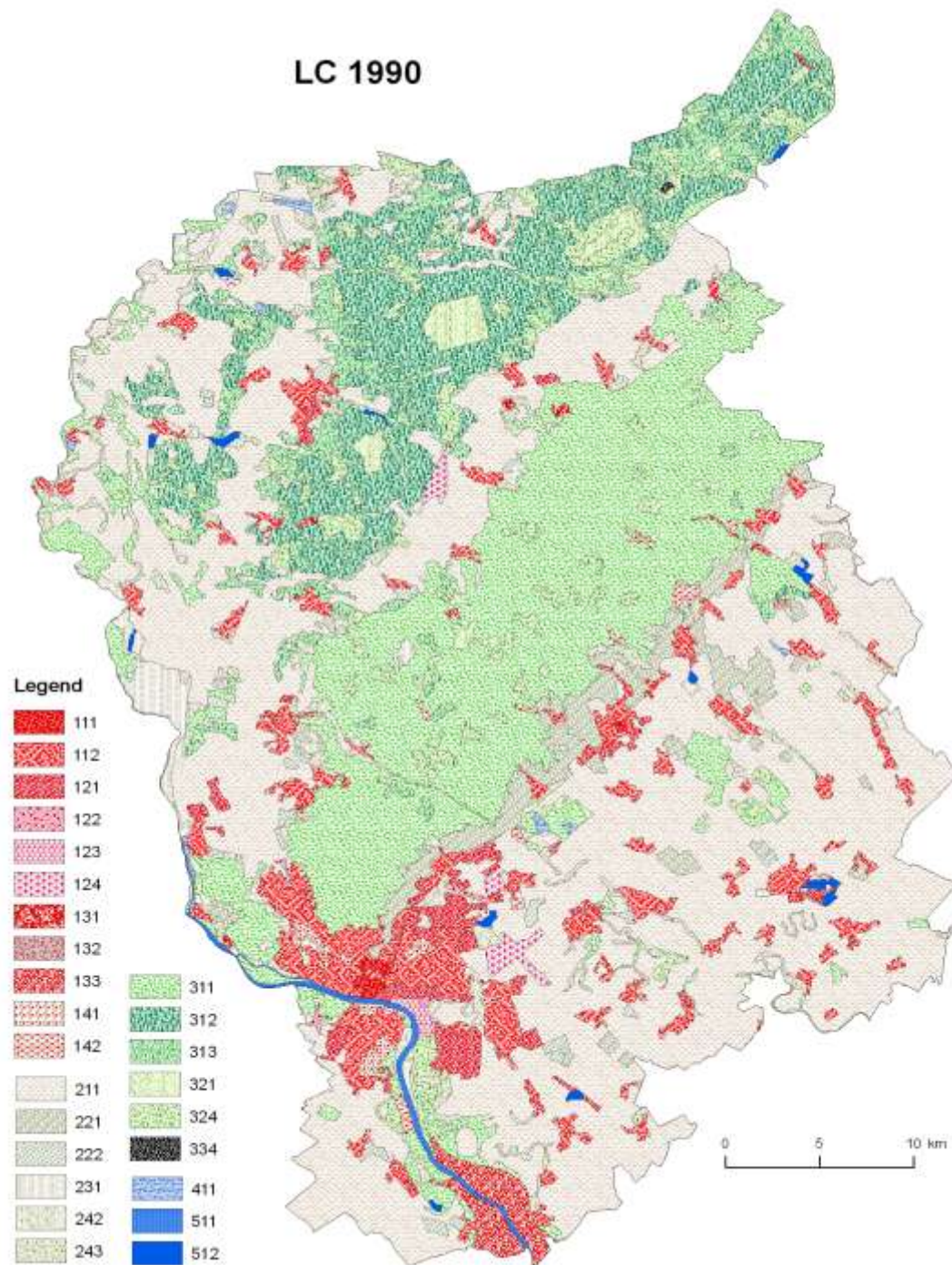
4 WETLANDS

- 411 Inland marshes

5 WATER BODIES

- 511 Water courses
- 512 Water bodies

LC 1990



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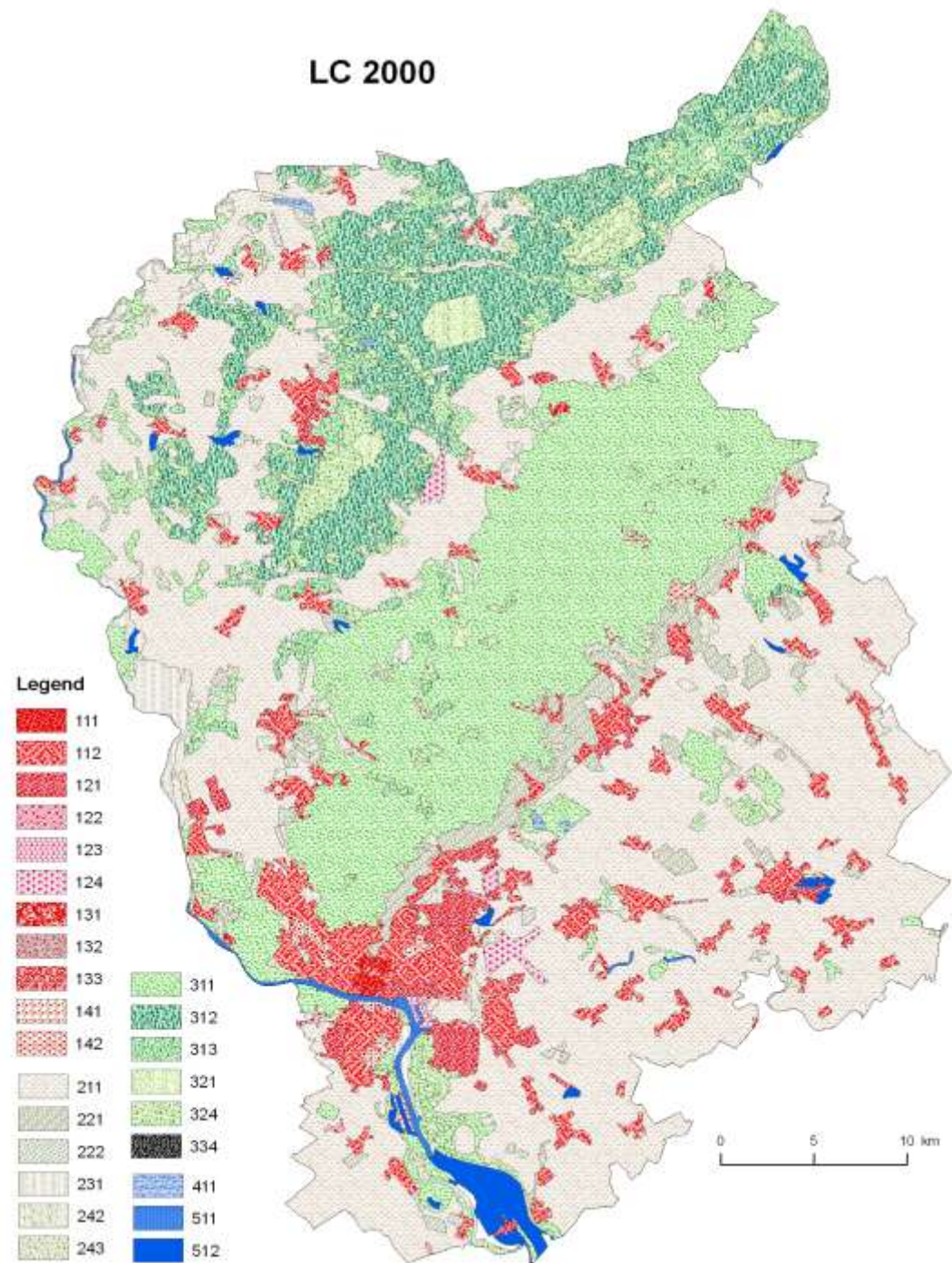
4 WETLANDS

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5 WATER BODIES

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- 512 Water bodies

LC 2000



LAND COVER 2006

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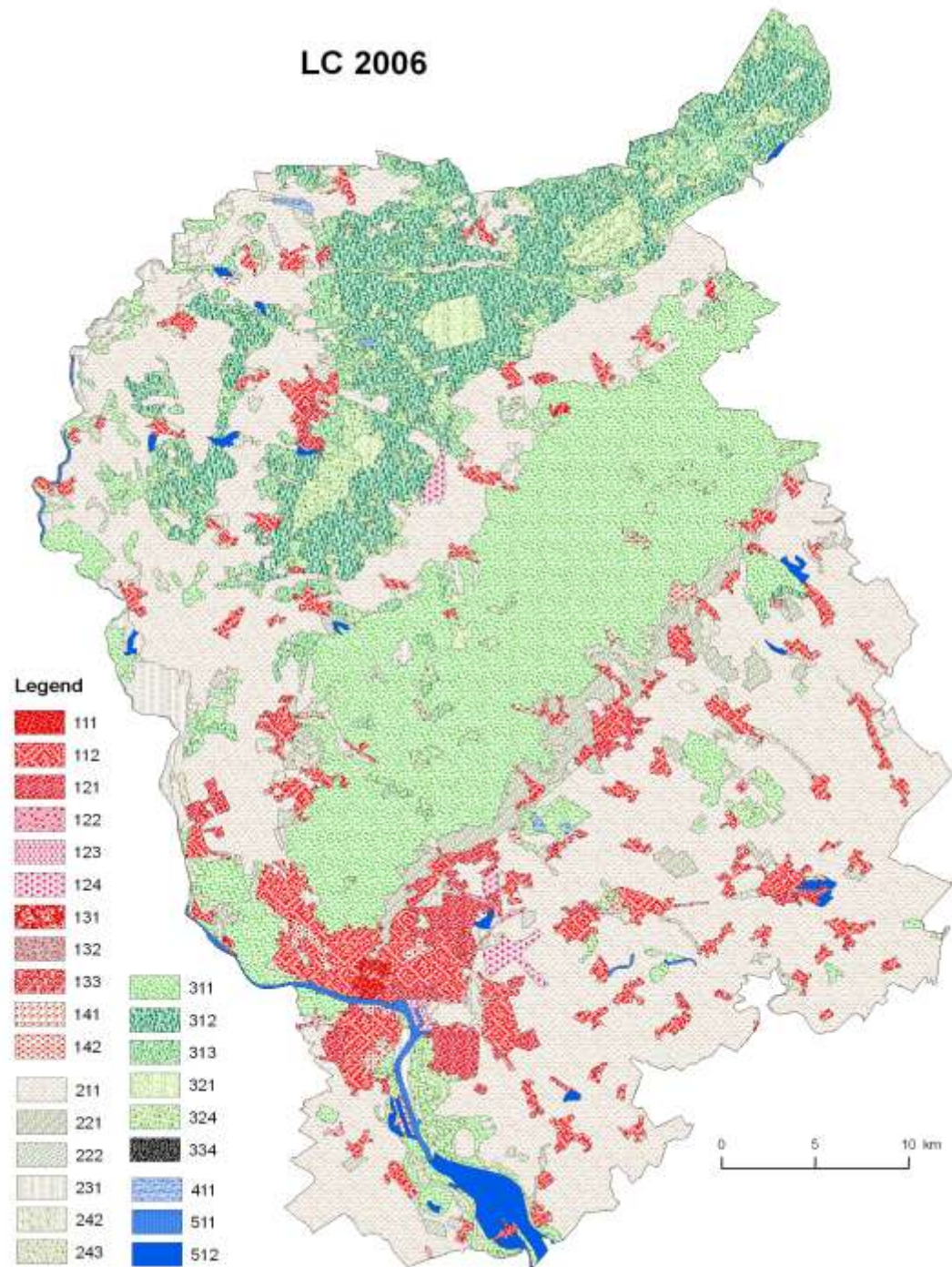
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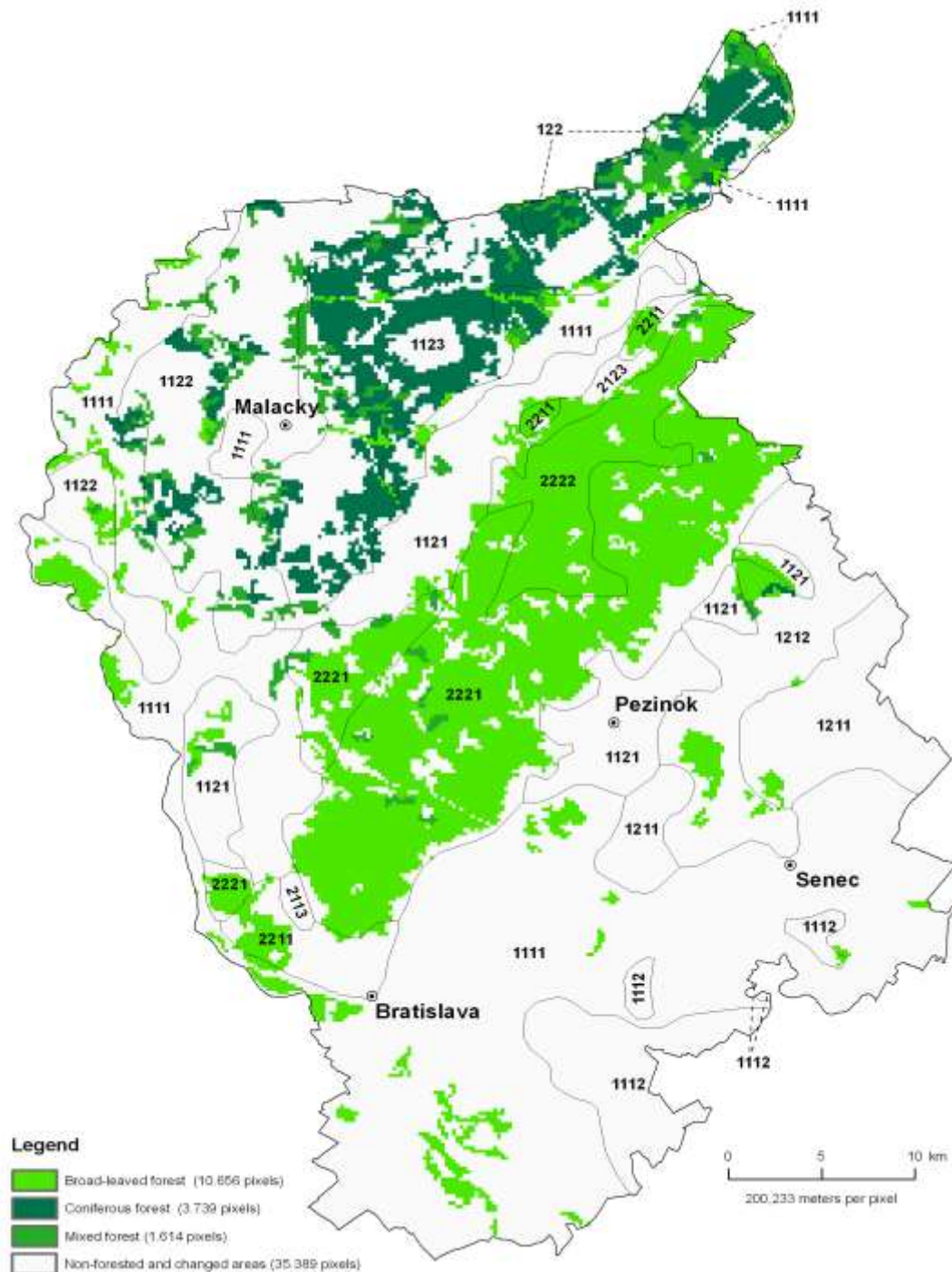
LC 2006



Stability (persistency) of forest land use in natural landscape types

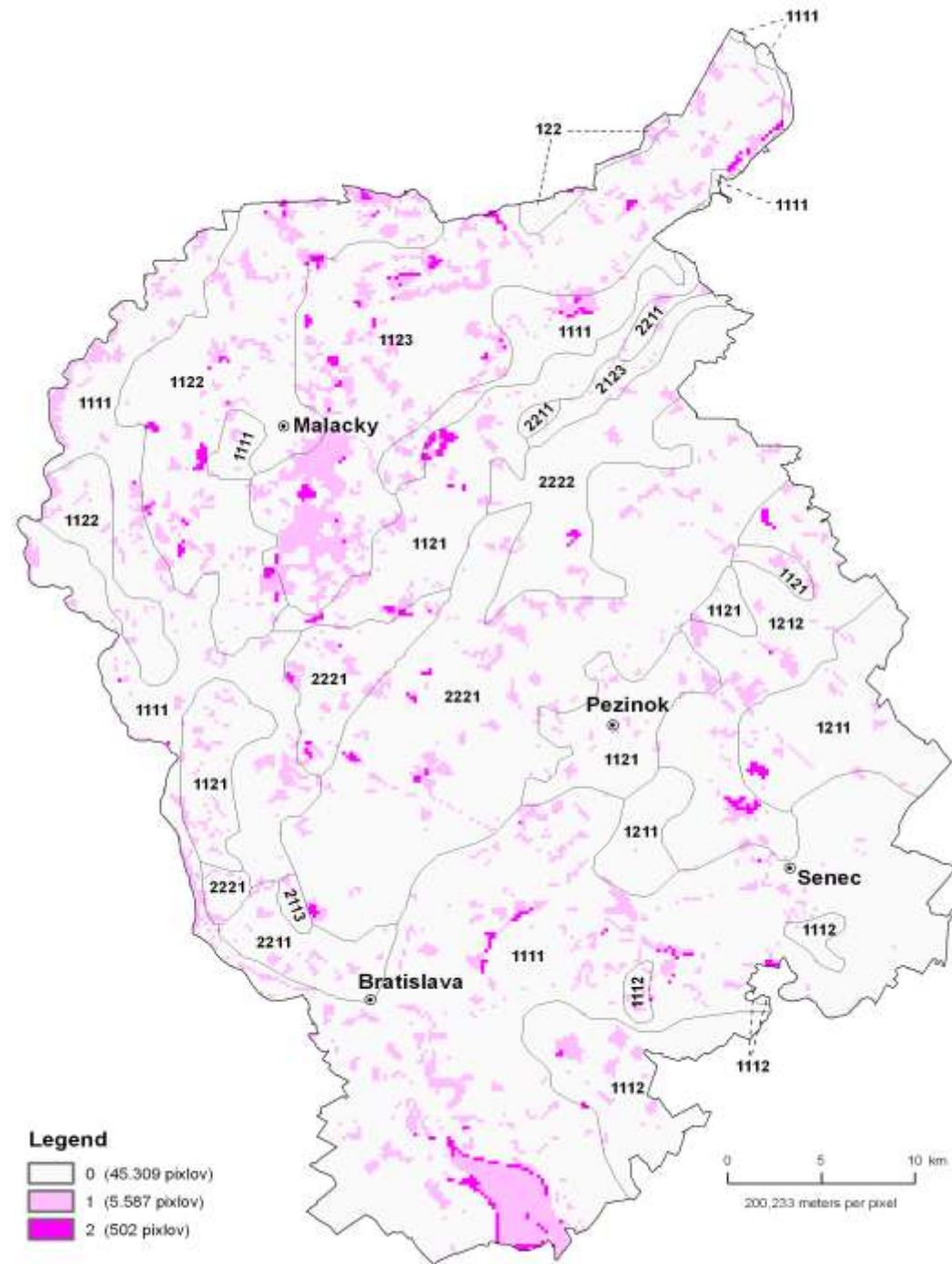
(area of broad-leaved, coniferous, mixed and total forests in %)

| Natural landscape | Non-forested areas | Broad-leaved forest | Coniferous forest | Mixed forest | Forest areas total | Total |
|-------------------|--------------------|---------------------|-------------------|--------------|--------------------|--------|
| 1111 | 90,77 | 6,75 | 1,47 | 1,01 | 9,23 | 100,00 |
| 1112 | 99,65 | 0,35 | 0,00 | 0,00 | 0,35 | 100,00 |
| 1121 | 90,58 | 6,15 | 1,04 | 2,23 | 9,42 | 100,00 |
| 1122 | 79,09 | 1,85 | 9,83 | 9,23 | 20,91 | 100,00 |
| 1123 | 41,58 | 2,93 | 45,20 | 10,30 | 58,42 | 100,00 |
| 1211 | 98,22 | 1,78 | 0,00 | 0,00 | 1,78 | 100,00 |
| 1212 | 88,67 | 10,38 | 0,65 | 0,30 | 11,33 | 100,00 |
| 122 | 17,65 | 0,00 | 54,12 | 28,24 | 82,35 | 100,00 |
| 2113 | 98,98 | 1,02 | 0,00 | 0,00 | 1,02 | 100,00 |
| 2123 | 53,12 | 44,44 | 0,00 | 2,44 | 46,88 | 100,00 |
| 2211 | 50,67 | 45,98 | 0,00 | 3,35 | 49,33 | 100,00 |
| 2221 | 21,01 | 77,88 | 0,00 | 1,11 | 78,99 | 100,00 |
| 2222 | 6,78 | 92,43 | 0,00 | 0,79 | 93,22 | 100,00 |



Number and area of land cover changes in natural landscape types in 1990-2006 (in %)

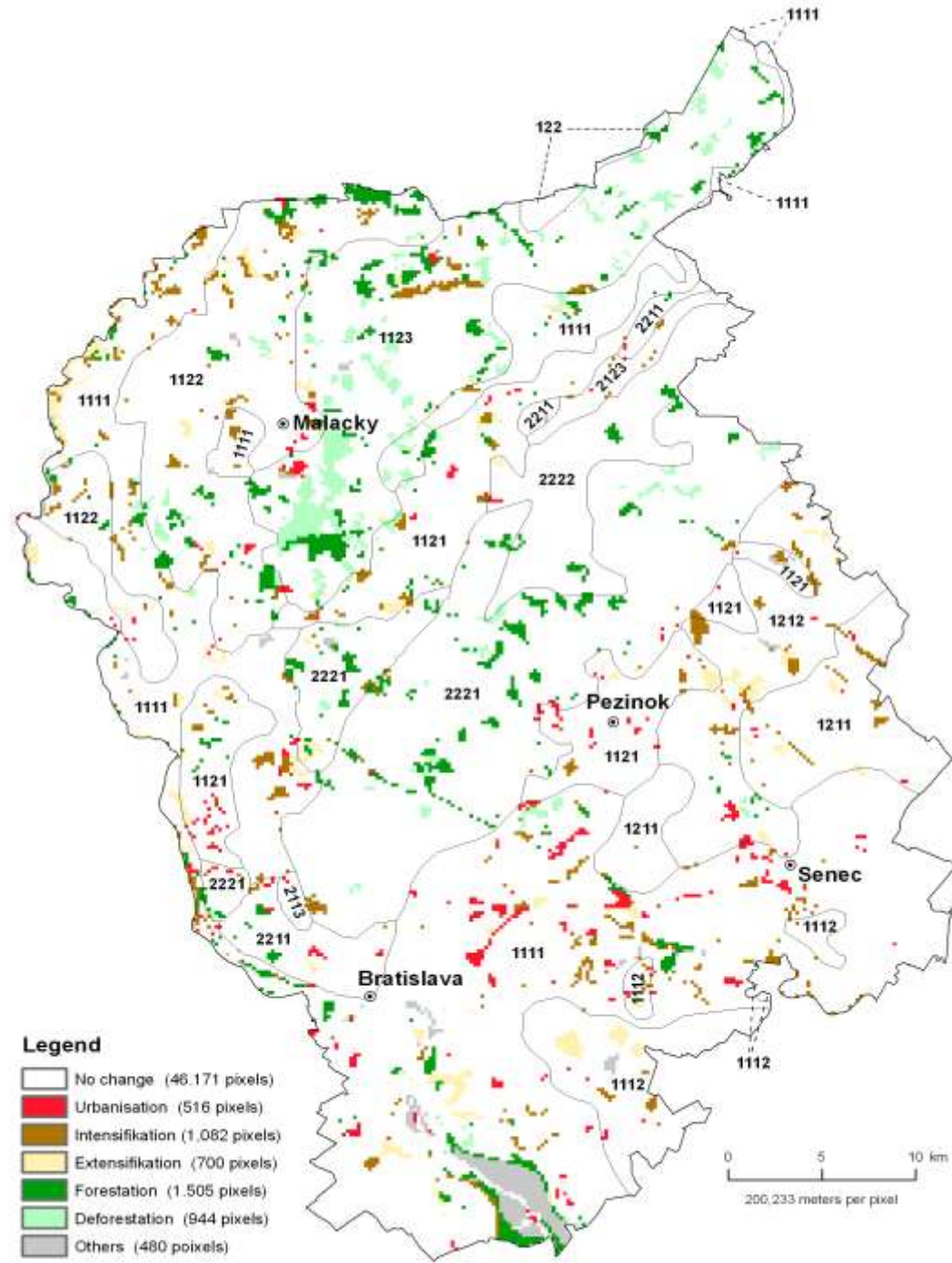
| Natural landscape | Areas without change | Areas with 1 change | Areas with 2 changes | Total |
|-------------------|----------------------|---------------------|----------------------|--------|
| 1111 | 87,40 | 11,71 | 0,89 | 100,00 |
| 1112 | 91,88 | 7,89 | 0,23 | 100,00 |
| 1121 | 90,37 | 8,46 | 1,17 | 100,00 |
| 1122 | 86,34 | 12,19 | 1,47 | 100,00 |
| 1123 | 77,41 | 20,83 | 1,76 | 100,00 |
| 1211 | 96,10 | 3,15 | 0,75 | 100,00 |
| 1212 | 89,47 | 9,24 | 1,29 | 100,00 |
| 122 | 85,80 | 13,02 | 1,18 | 100,00 |
| 2113 | 91,00 | 9,00 | 0,00 | 100,00 |
| 2123 | 95,21 | 4,79 | 0,00 | 100,00 |
| 2211 | 88,14 | 10,98 | 0,88 | 100,00 |
| 2221 | 93,07 | 6,53 | 0,40 | 100,00 |
| 2222 | 95,78 | 3,74 | 0,48 | 100,00 |



Types of landscape changes in natural landscape types in 1990-2006

(area of urbanization, intensification and extensification of agriculture, forestation, deforestation and other changes in %)

| Natural landscape | Without change | Urbanisation | Intensification | Extensification | Forestation | Deforestation | Other change | Total |
|-------------------|----------------|--------------|-----------------|-----------------|-------------|---------------|--------------|--------|
| 1111 | 88,85 | 1,67 | 2,75 | 1,72 | 2,03 | 0,62 | 2,36 | 100,00 |
| 1112 | 92,11 | 0,63 | 1,61 | 4,84 | 0,00 | 0,00 | 0,81 | 100,00 |
| 1121 | 91,72 | 1,56 | 2,63 | 1,98 | 1,40 | 0,49 | 0,21 | 100,00 |
| 1122 | 89,06 | 0,64 | 2,78 | 1,43 | 4,57 | 1,11 | 0,40 | 100,00 |
| 1123 | 81,36 | 0,43 | 1,44 | 0,37 | 6,19 | 9,98 | 0,24 | 100,00 |
| 1211 | 96,32 | 0,40 | 2,26 | 0,97 | 0,04 | 0,00 | 0,00 | 100,00 |
| 1212 | 90,72 | 1,06 | 4,20 | 2,95 | 0,45 | 0,30 | 0,30 | 100,00 |
| 122 | 91,12 | 0,00 | 0,00 | 0,00 | 3,55 | 5,33 | 0,00 | 100,00 |
| 2113 | 97,00 | 2,00 | 1,00 | 0,00 | 0,00 | 0,00 | 0,00 | 100,00 |
| 2123 | 95,48 | 0,53 | 3,46 | 0,53 | 0,00 | 0,00 | 0,00 | 100,00 |
| 2211 | 90,47 | 1,14 | 0,93 | 1,45 | 4,92 | 0,52 | 0,57 | 100,00 |
| 2221 | 93,74 | 0,29 | 0,50 | 0,04 | 4,07 | 1,36 | 0,00 | 100,00 |
| 2222 | 96,58 | 0,27 | 0,00 | 0,32 | 2,67 | 0,16 | 0,00 | 100,00 |



Conclusions

Stability (persistency) of land use confirmed the relationship between permanently forested area and natural types, properties of which predetermine their use: relief limits (inclination), unsuitable soil-substrate conditions

In **moderately cold uplands to highlands** with prevailing beech forests - **93.2% of forest areas remained unchanged**

In **warm to moderately warm uplands** with oak-hornbeam forests - **78.0%**

In **dune landscape** of the Záhorská Lowland with predominantly the pine or oak-pine forest - **58.4%**

Dynamics of landscape changes was expressed by **number and area of LC changes** by their relation to natural landscape:

The greatest number of changes was identified in the dune landscape with pine and oak-pine forests production capacity of which is exploited in forest management: **One change** was identified in **20.8%** and **two changes** in **1.76 %** of the area of this landscape type

Conclusions

Types of landscape changes:

- urbanization (urban sprawl)** was relatively the greatest in the type of **subbergland (2%)** – Area of this change was associated with the living style and economic possibilities of the capital's inhabitants - in the construction of a satellite settlement near Záhorská Bystrica . The greatest increase of urbanization was observed in the most adequate relief conditions in the type of the Holocene floodplains (1.67%).
- intensification of agriculture** is manifested the most markedly on **loess hilly land** with **4.20%** of area; on **fluvial terraces (2.78%)**, but also on the Holocene floodplains (2.75%) by increase of the complex cultivation pattern of new owners or leasers of farmland (for instance in the area Modra)
- extensification of agriculture** - the greatest share was identified in the **Pleistocene floodplains (4.84 %)** and **loess hilly land (2.9 %)** with very fertile Chernozems through shrinkage of permanent cultures, orchards and vineyards. Changes were associated with reduced governmental subsidies to agricultural companies at the beginning of the 1990s.
- forestation** - the greatest share was identified in **the dune landscape (6.19 %)** and in **fluvial terraces with blown sands (4.57%)** of the Záhorská Lowland.
- deforestation** - the greatest share was identified in **the dune landscape (9.98%)**. These changes are due to intensive commercial forestry applied in areas of highly productive pine woods paradoxically on Regosols, which are not apt for cultivation of agricultural crops.
- other changes** - were identified, for instance, in association with expansion of water bodies. The greatest was in the area of water works of Gabčíkovo, where in the type of the Holocene floodplains as much as 2.36% of area changed.

Thank you for your attention

