

## LAND COVER CHANGES IN FOOTHILL AND MOUNTAIN LANDSCAPES OF THE LVIV OBLAST (UKRAINIAN CARPATHIANS)

*Anatoliy Smaliychuk*

*Abstract:* This paper analyzes land cover changes at a small scale with respect to the environmental and socio-economic characteristics in five model municipalities. The data used included 1:50,000 Soviet topographic maps (1976–1989), recent fine scale satellite images from the Google Earth, natural geoecosystems data and 1:10,000 cadastral maps which provide land use structure data. The model areas selected for our study are rural and situated in different parts of Ukrainian Carpathians. A common tendency for four of five model areas is an increase in the area with forest or shrubland owing to the abandonment of former agricultural lands. The results of statistical analysis showed that land use type, landform, location within an ecotone and slope inclination have the most significant influence on the occurrence of secondary succession. At the same time, transport infrastructure parameters have no essential influence on recent land cover changes.

*Keywords:* Ukrainian Carpathians, land cover changes, secondary succession, logistic regression, GIS.

### Introduction

Conservation and sustainable use of landscape and biotic diversity are stipulated both in the international (e.g., UNEP 2003) as well as in the national Ukrainian legislation (Verkhovna Rada 2000). A successful implementation of these decisions requires, among other preconditions, accurate geodata about the structure and recent dynamics of the landscape.

Over the two past decades significant socioeconomic transformations have taken place in the Carpathian countries, including Ukraine. Drastic changes have occur-

red particularly in land ownership, land use, and as a consequence, in land cover (e.g., Kuemmerle *et al.* 2006, 2007, 2008, 2009; Ressler *et al.* 2008). This dynamics is caused by political and economic factors, which have a nationwide, and even international, impact. However, it is assumed that the effects of these factors manifest themselves somewhat differently, depending on local natural and socioeconomic conditions. For instance, the Ukrainian Carpathians include low- and medium-mountain areas with different landform types, assemblages of altitudinal bioclimatic belts, and thus with different patterns of natural and cultural geoecosystems (Herenchuk 1968; Holubets *et al.* 1988; Kruhlov *et al.* 2008). Recent land cover changes (LCC) studies in the Ukrainian Carpathians, based on medium-resolution Landsat TM/ETM+ remote sensing data, have revealed some peculiarities and trends in land cover dynamics (Kuemmerle *et al.* 2006, 2007, 2008, 2009).

The goal of this study is to examine how the natural landscape, economic location and land use structure influence the LCC on the local level. To reach this goal it was necessary to create detailed LCC and natural geoecosystem maps. This was accomplished by using five model municipalities with significant contribution of agricultural land, which represent different (low and medium mountains, and foothills) ecoregions of Ukrainian Carpathians and have fine scale remote sensing data available in free access.

To perform a quantitative analysis of the recent LCC, namely the secondary succession, and to model a potential secondary succession a logistic regression model was used.

## Study area

For our study five rural municipalities were selected within the Lviv Oblast (Fig. 1). They are situated in different parts of the Ukrainian Carpathians: 1) foothills – Naguevychi (2,513 ha) and Stara Sil (3,179 ha); 2) low mountains – Yamelnytsya (2,061 ha), Boberka (6,797 ha; and 3) middle mountains – Yasenysya (4,314 ha). The climatic conditions within the model areas change from warm and moderately warm to cool and very cool. The elevation varies from 301 m (Naguevychi) to 1102 m a.s.l. (Yasenysya). The natural vegetation of Precarpathians (foothills) is represented by broadleaved forests with a domination of pedunculate oak (*Quercus robur*) and European beech (*Fagus sylvatica*), often mixed with hornbeam (*Carpinus betulus*) and silver fir (*Abies alba*) on brownish podzolic pseudogleyic and brown mountain soils. Carpathian municipalities were predominately occupied by natural mixed beech–silver fir and beech–Norway spruce (*Picea abies*) forests on brown mountain soils (Kruhlov *et al.* 2008).

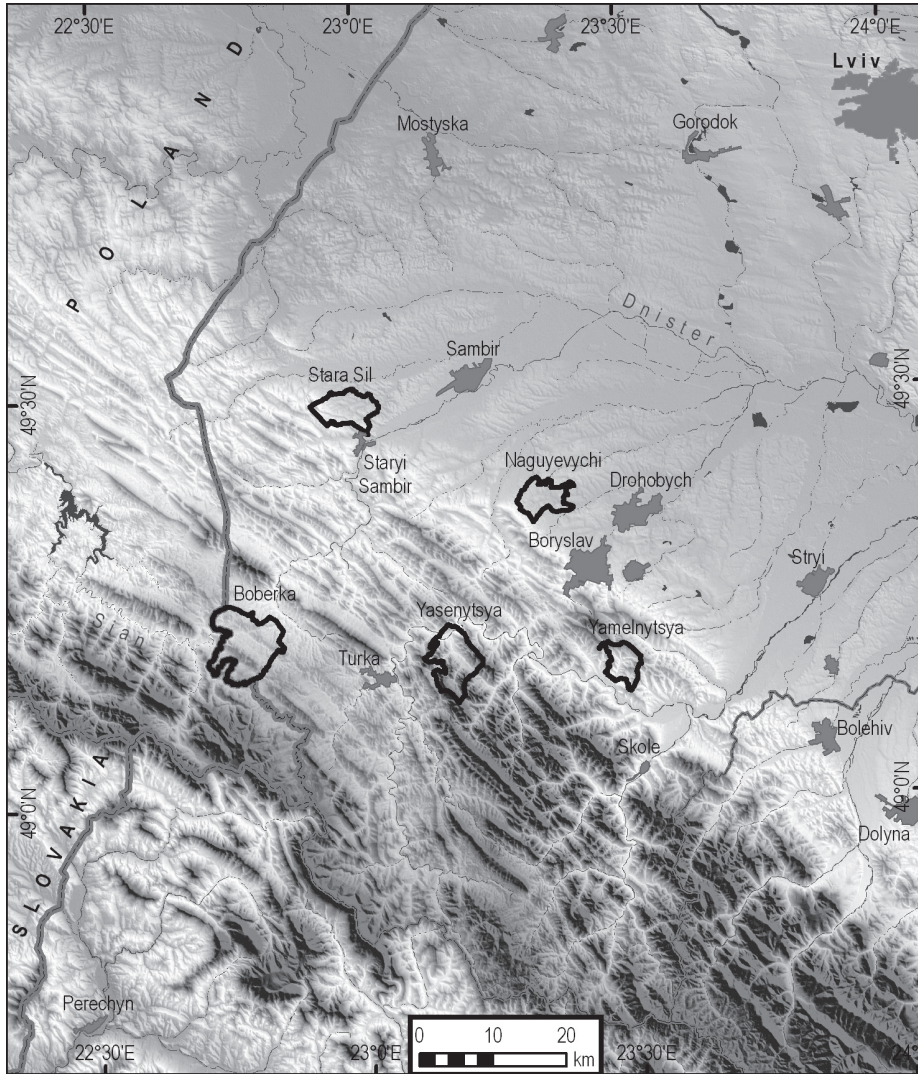


Fig. 1. Location of the study areas

Foothill areas have a long history of agricultural development: their low elevation and gentle slopes enabled wide expansion of grasslands and cultivated fields around villages. Naguevychi and Stara Sil' are located close to the raion (district) administrative towns – at 7 and 9 km respectively. At the end of World War II, large collective farms were created here with the share of arable land of about 50%. They collapsed at the beginning of the twenty-first century, and the agricultural land is now partly abandoned and partly used individually by local people as a household-scale natural economy (Anonymous 2008; Grom 2002).

Boberka can be described as a really remote location: at the impermeable European Union border with a distance of 26 km to the raion town of Turka. The local population was partly resettled from here after World War II. The traditional economies were forestry and agriculture, and in some places the land is still traditionally cultivated on artificially terraced slopes. The municipality is included into the Nadsianskyi Regional Landscape Park, a part of the East Carpathian Biosphere Reserve, and is considered attractive for the development of ecotourism and traditional agriculture (Maryshevych and Niewiadomski 2005).

Yamelnytsya and Yasenytsya due to a significant contribution of moderate-to-steep and steep slopes ( $>12^\circ$ ) have more a larger forest cover. Both municipalities do not have a good transport connection with the raion administrative towns – Skole and Turka respectively. In 1999 part of the Yamelnytsya's territory was included in the Skole National Nature Park. Over the last 30 years Yamelnytsya has also demonstrated the highest depopulation index among the five selected communities – 11,7 % per year (SSCU, 2002).

## Materials and methods

Satellite images with the spatial resolution of about 2.5 m available from Google Earth™ were used for the present land cover mapping. The land cover of the Soviet period was manually delineated using topographic maps at a scale 1: 50,000. Field data collected during own summer campaigns in 2007–2011 was used for accuracy assessment of the present LC. To perform further analysis data on the LCC was overlaid with data about natural geoecosystems, including a potential natural vegetation (Smaliychuk 2011) and socio-economic data. It is assumed that transport infrastructure parameters are crucial for agriculture production in mountain regions and that is why they were included in our investigation. Transport accessibility and marginality, both measured in conditional meters, were calculated as a cost-distance surface from the settlements and roads using terrain slope value as a cost surface. The first parameter reflects the conditional distance from settlements and any kind of road – forest, field or paved, but marginality – shows the distance from settlement and

only paved roads. The road network and boundaries of settlements were vectorized from the satellite images. Cadastral maps at a scale of 1:10,000 (LDLCI, 1995) were used to investigate the relation between land use structure and the recent LCC.

To execute a quantitative analysis of the recent LCC, namely the secondary succession, and to model a potential secondary succession we used a logistic regression. It could be expressed in a form:

$$P = 1 / (1 - e^{-z}) \quad [1]$$

where, P – probability of the event (in our case LCC) which ranges from 0 to 1; e – the base of the natural logarithm and approximately equal to 2,72; z – linear combination of the factors ( $x_1-x_8$ ):

$$z = b_0 + b_1 x_1 + b_2 x_2 + \dots + b_8 x_8 \quad [2]$$

In the statistic analysis were included 8 factors: elevation, slope, aspect, landform, location in an ecotone (200m width), transport accessibility and marginality, land use structure. The values of these factors were aggregated in several groups and thereby expressed in a nominal scale. Inside and outside the areas with the secondary succession LCC an equal number of regular located points were generated in GIS. Then, about 2500 points were overlaid with 8 selected for further analysis parameters. The general scheme of the data processing is presented in Fig 2.

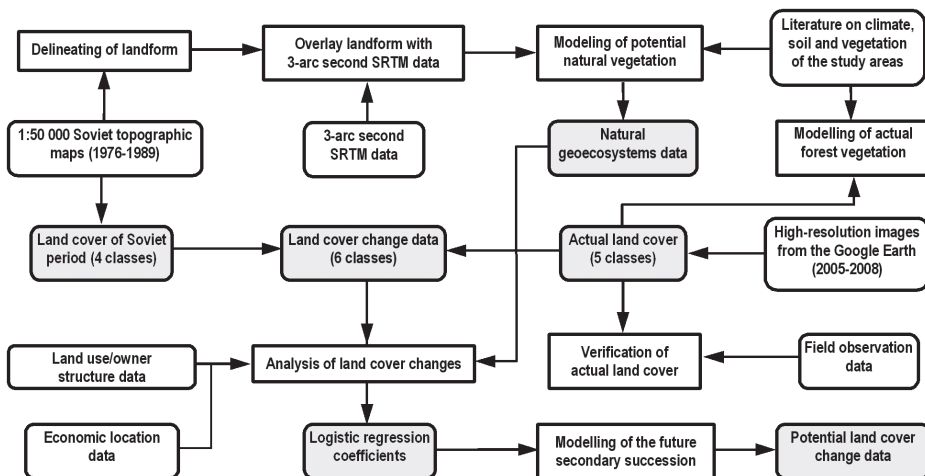


Fig. 2. Workflow of data processing

## Results

Five classes of the recent LC were interpreted on satellite images: coniferous forest, deciduous forest, succession area (shrubland or/and coppice), grassland and settlement. Verification showed that the accuracy of present LC mapping is 75-82 %. This result was influenced by the time difference between the date when the satellite images were taken (2005-2008) and the time, when the majority of field data was collected (summer 2011).

For the two forest classes interpreted from satellite images plant communities were distinguished using the information from regional literature and own field data. The present forest cover is rather different from the potential natural one because of a higher abundance of coniferous communities, e.g. with Norway spruce presence in low mountain Boberka. In foothill municipalities – Naguevychi and Stara Sil – forest communities with pedunculate oak domination were changed by mixed forests with silver fir.

The three land cover classes that were used in further analysis – forest, succession area and grassland – allowed distinguishing six types of the LCC. Three of them can be aggregated in a group with secondary succession changes. In these areas, which had formerly been extensively used by agriculture, land cover has been replaced by shrubs and young forest. The other three types of LCC result from human disturbance. In Stara Sil and Boberka replacement of grassland with forest dominates, but in Yasenytsya the occurrence of forest on the place of shrubland is estimated as more than 30% of the overall LCC. In Yamelnytsya these two types of the LCC are almost equal and they comprise more than 60% of the LCC (Tab. 1).

The total area with LCC is: for Naguevychi and Stara Sil c. 57.6 ha (2.3 % of overall area of municipality) and 133.8 ha (4.2 %) respectively. However, in the other municipalities the LCC area reaches higher values: Yamelnytsya – 581 ha (28.2 %), Boberka – 718.8 ha (10.6%) and Yasenytsya – 622.9 ha (14.4 %). In the foothill model municipalities (Naguevychi and Stara Sil) the LCC is not as significant as in the mountain model areas (the other three). Not only forest disturbance but also secondary succession has happened more often in mountain, especially low-mountain, areas. The reason is that low-mountain areas have less suitable natural condition for agricultural production than foothill ones, and that is why secondary succession here is more widespread.

A common tendency in four of five model areas, except Naguevychi, is an increase in the area with forest or shrubland owing to the degradation of former agricultural lands (Photo 1). These results are similar to the findings of LCC research performed on a medium scale in the Ukrainian Carpathians using Landsat TM/ETM+ data (Kuemmerle *et al.*, 2008).

Table 1. Distribution of land cover change types [%]

| Municipalities<br>(study period) | Types of land cover changes |                                   |                             |                                     |                                |                       |
|----------------------------------|-----------------------------|-----------------------------------|-----------------------------|-------------------------------------|--------------------------------|-----------------------|
|                                  | Secondary succession        |                                   |                             | Forest disturbance                  |                                |                       |
|                                  | Grassland<br>– forest       | Grassland –<br>succession<br>area | Succession<br>area – forest | Succession<br>area – gras-<br>sland | Forest –<br>succession<br>area | Forest –<br>grassland |
| Nahuevychi<br>(1989–2005)        | 8.6                         | 1.3                               | –                           | –                                   | 69.6                           | 20.5                  |
| Stara Sil<br>(1989–2005)         | 50.1                        | 10.0                              | 14.1                        | –                                   | 23.6                           | 2.2                   |
| Yamelnytsya<br>(1976–2006)       | 31.4                        | 16.2                              | 31.5                        | 0.3                                 | 15.7                           | 4.9                   |
| Boberka<br>(1983–2008)           | 82.1                        | 8.6                               | 0.5                         | –                                   | 4.0                            | 4.8                   |
| Yasenysya<br>(1976–2005)         | 10.4                        | 24.8                              | 35.5                        | 0.2                                 | 26.2                           | 2.9                   |

a.



b.



c.



d.



Photo 1. Secondary succession on abandoned agricultural land (a–c) and after forest clear cutting (d) (photo: author)

The LCC more often occurs on moderate and moderate-to-steep slopes and usually at forest edges or inside the forest (Fig. 3). In general, our results showed that the LCC occurs with more or less the same intensity in all potential natural vegetation types.

Areas with the LCC are not situated far from roads and settlements. But in Boberka and Yasenytsya about 40% of the LCC occurs on the area with a high marginality of location (>4500 conditional meters from settlements and paved road).

In Naguevychi and Yasenytsya, situated in foothills and middle mountains respectively, the LCC more often has taken place in state and communal forest lands. However, in the low mountain municipalities, Yamelnytsya and Boberka, the LCC was observed more often on agricultural land outside the settlements and within communal forest lands – more than 50 and 20 % of the overall LCC.

The results of logistic regression analysis, regression coefficients  $b_1$ - $b_8$  of the equation (2), showed that land use type, landform, location within an ecotone and slope have the most influence on the occurrence of secondary succession (Tab. 2). Hence, the probability of secondary succession is higher within silviculture lands, ecotones and steeper slopes. At the same time, according to our results, on south-facing and well drained slopes the probability of succession is lower. Unexpectedly, the transport infrastructure parameters have an insignificant influence on the LCC. The quality regression parameters indicate a fairly good model: 75.3 % of overall points were correctly classified by the created model.

Tab. 2. Logistic regression coefficients

| Factors                      | Regression coefficients | Standard error | Odds Ratio Exp(b) | 95% confidence limit of Exp(b) |        |
|------------------------------|-------------------------|----------------|-------------------|--------------------------------|--------|
|                              |                         |                |                   | Lower                          | Upper  |
| Elevation                    | 0,211                   | 0,062          | 1,234             | 1,092                          | 1,395  |
| Slope                        | 0,672                   | 0,058          | 1,957             | 1,746                          | 2,194  |
| Aspect                       | -0,531                  | 0,059          | 0,588             | 0,524                          | 0,660  |
| Landform                     | -0,829                  | 0,048          | 0,437             | 0,397                          | 0,480  |
| Transportation accessibility | 0,278                   | 0,039          | 1,320             | 1,223                          | 1,425  |
| Land use/owner type          | 1,997                   | 0,277          | 7,370             | 4,283                          | 12,682 |
| Allocation in an ecotone     | 0,73                    | 0,103          | 2,075             | 1,694                          | 2,541  |

Logistic regression coefficients were used for modelling a potential secondary succession for the next 20-30 years. The results of performed modelling show that the succession potential is much higher in low and middle mountain research areas than in foothill municipalities (Fig. 4).



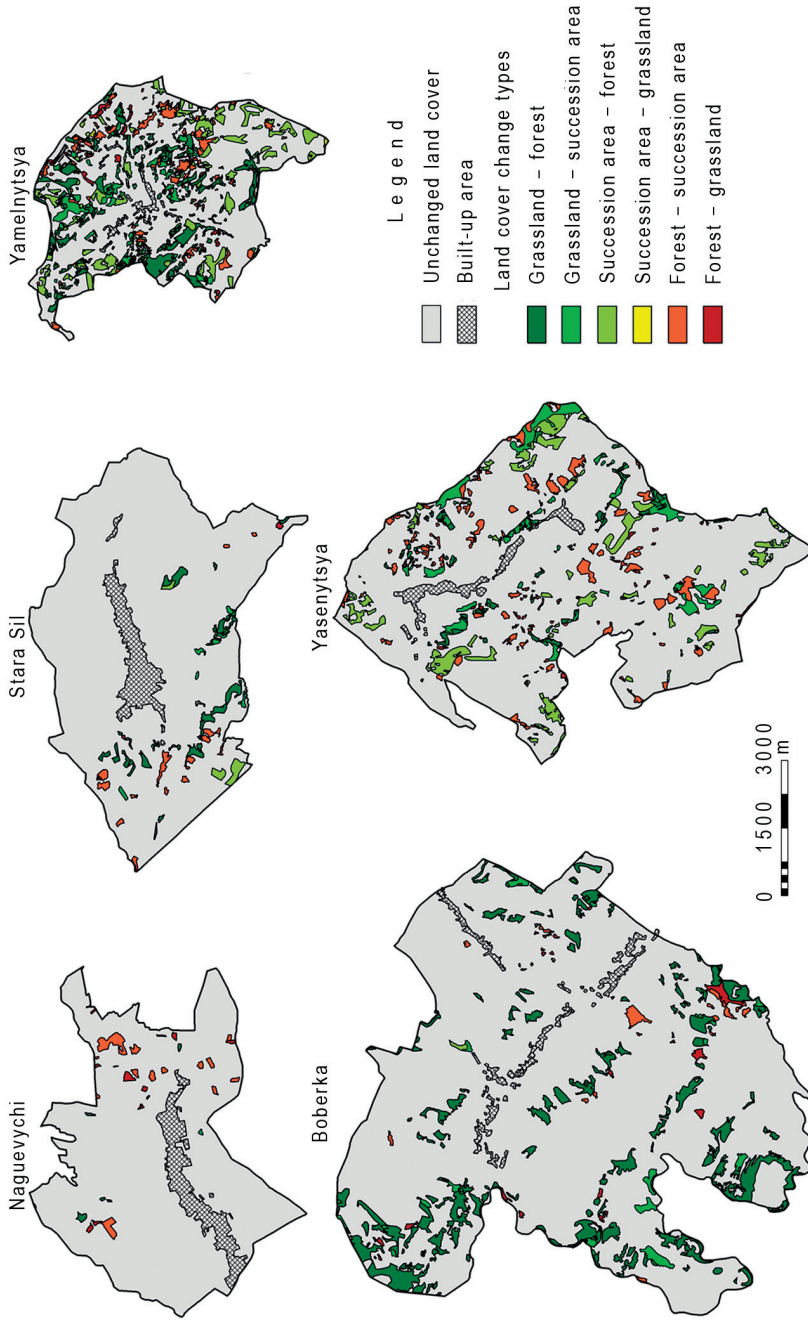


Fig. 3. Land cover change map

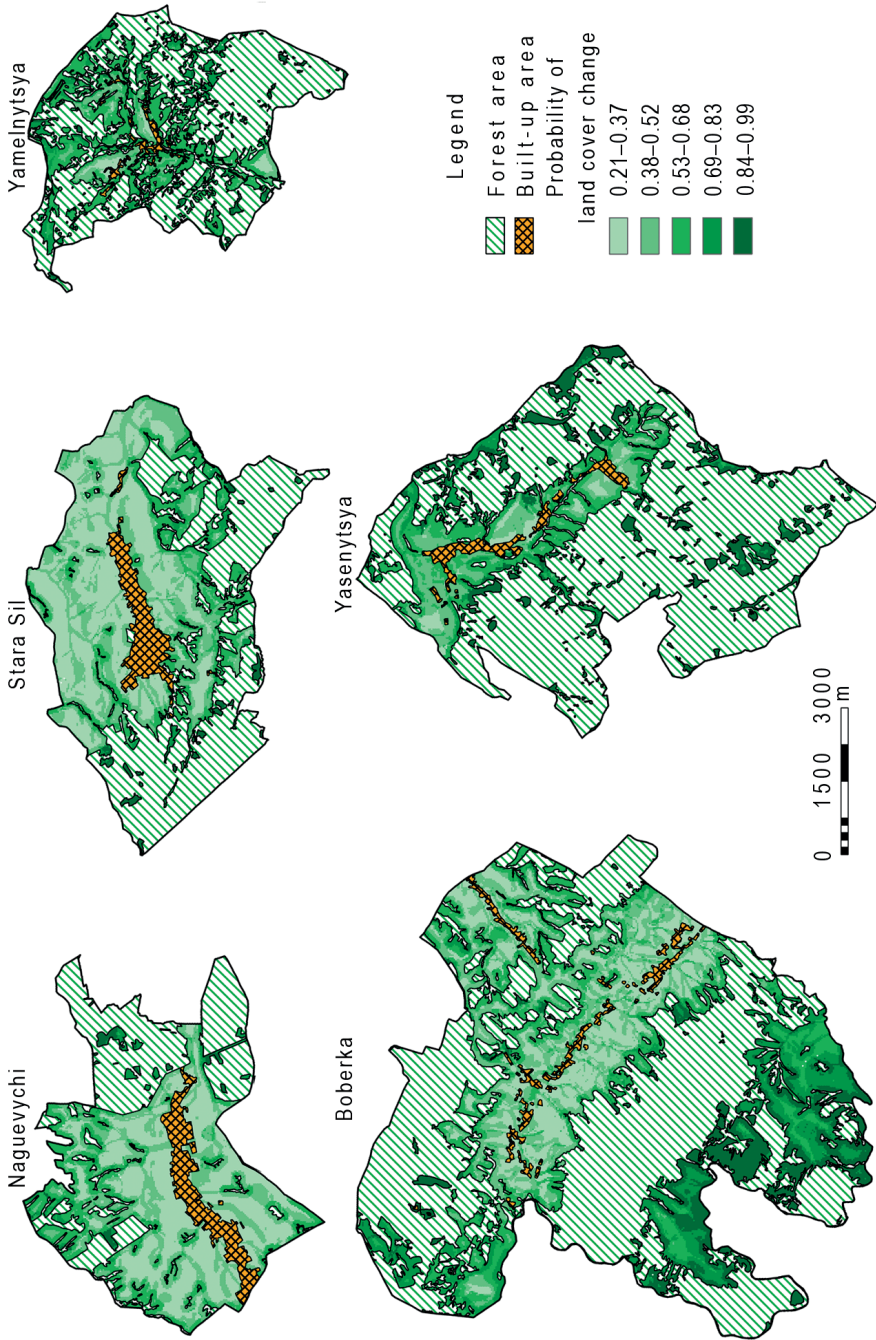


Fig. 4. Potential forest succession in the future 20–30 years

## Conclusions

A common tendency for four of five model areas, except Naguevychi, is an increase of the area with forest or shrubland owing to the degradation of former agricultural lands. During the last decades the increase of forest areas was estimated at 0.08-0.09 % a year for Stara Sil and Yasenytsya. For Boberka and Yamelnytsya it estimated at 0.31 and 0.39 % a year respectively. The results of statistical analysis revealed that land use type, landform, location within an ecotone and slope have the most influence on the occurrence of secondary succession. At the same time, the economic (transport infrastructure) location has not an essential influence on the recent LCC. Also, the findings of this study about present and potential LCC have been already used in our further research concerning designing local ecological corridors.

## References

- Angelstam P., Borešjő-Bronge L., Mikusiński G., Sporrang U. & Wästfelt A., 2003, *Assessing village authenticity with satellite images: a method to identify intact cultural landscapes in Europe*, *Ambio*, 32 (8): 594-604.
- Anonymous, 2008, *Mista i sela Ukrainy. L'vivschyna* [Cities and villages of Ukraine. Lviv region], <http://who-is-who.com.ua/bookmaket/mistalvov2008/7/19/1.html> (9. 10.2008).
- Grom G., 2002, *Naguevychi, Vidrozhennya*, Drohobych.
- Herenchuk K. (ed.), 1968, *Pryroda Ukrayinskykh Karpat* [Nature of the Ukrainian Carpathians], Vydavnytstvo Lvivskoho Universytetu, Lviv (in Ukrainian).
- Holubets M., Honchar M., Komendar V., Kucheryavyi V. & Odynak Y. (ed.), 1988, *Ukrainskiye Karpaty. Priroda* [The Nature of the Ukrainian Carpathians], Naukova Dumka, Kyiv (in Russian).
- Kruhlov I., Mukha B. & Senchyna B., 2008, *Natural geoeosystems*, [in:] Roth M., Nobis R., Stetsuk V. & Kruhlov I. (ed.), *Transformation processes in the Western Ukraine. Concepts for sustainable land use*, Weissensee Verlag, Berlin.
- Kuemmerle T., Chaskovskyy O., Knorn J., Radeloff V.C., Kruhlov I., Keeton W.S., Hostert P., 2009, *Forest cover change and illegal logging in the Ukrainian Carpathians in the transition period from 1988 to 2007*, *Remote Sensing of Environment*, 113: 1194-1207.
- Kuemmerle T., Hostert P., Radeloff V.C., Perzanowski K., Kruhlov I., 2007, *Post-Socialist forest disturbance in the Carpathian border region of Poland, Slovakia, and Ukraine*, *Journal of Applied Ecology*, 17: 1279-1295.
- Kuemmerle T., Hostert P., Radeloff V.C., van der Linden S., Perzanowski K., Kruhlov I., 2008, *Cross-border comparison of post-socialist farmland abandonment in the Carpathians*, *Ecosystem*, 11: 614-628.

- Kuemmerle T., Radeloff V.C., Perzanowski K., Hostert P., 2006, *Cross-border comparison of land cover and landscape pattern in Eastern Europe using a hybrid classification technique*, Remote Sensing of Environment, 103: 449–464.
- Maryskvych O., Niewiadomski Z., 2005, *Regionalnyi landshaftnyi park Nadsyanskyi [Nadsianskyi Regional Landscape Park]*. [www.bieszczady.pl/download/pdf/broszura\\_NRPK\\_v.UA.pdf](http://www.bieszczady.pl/download/pdf/broszura_NRPK_v.UA.pdf). Accessed 27 September 2008 (15.03.2009).
- Ressl R., Endlicher W., Lehmann S., Baruth B., Bosch B. & Rosenthal G., 2008, *Current land use structure of Upper Dnister Basin and recent changes in the model communities*, [in:] Roth M., Nobis R., Stetsuk V. & Kruhlov I. (ed.), *Transformation processes in the Western Ukraine. Concepts for sustainable land use*, Weissensee Verlag, Berlin.
- Smaliychuk A., 2011, *Morfologichna structura landshaftiv nyzkohirya Karpat v mezhah Lvivskoi oblasti [Morphological structure of the low mountain Carpathian landscapes within Lviv Oblast]*. *Fizychna geografiya i geomorfologiya* 62: 61–70 (in Ukrainian).
- LDLCI (Lviv Department of Land Cadastre Institute), 1995, *Proekty rozderzhavlennya i pryvatyzatsii zemel kolektyvnyh agrarnyh pidpryemstv [Cadastral schemes of collective agrarian enterprises]*, the State Committee of Ukraine on Land Resources, Lviv.
- SSCU (The State Statistics Committee of Ukraine), 2002, *Demografichnyi shchorichnyk za 2001 rik [Demographic Yearbook 2001]*, Kyiv (in Ukrainian).
- UNEP, 2003 *Framework Convention on the Protection and Sustainable Development of the Carpathians*, <http://www.carpathianconvention.org/index.html> (19.04. 2009).
- Verkhovna Rada, 2000, *Zakon Ukrainy pro zagalnodержавnu programu formuvannya ekologichnoi merezhi Ukrainy na 2000–2015 [The Law of Ukraine about state program of creation ecological network of Ukraine in 2000–2015]*, Verhovna Rada Ukrainy, Kyiv (In Ukrainian).

Anatoliy Smaliychuk  
Geographical Faculty, Ivan Franko National University of Lviv  
Doroshenka st. 41, 79000 Lviv, Ukraine  
[a.smaliychuk@gmail.com](mailto:a.smaliychuk@gmail.com)