

# Recent Forest Cover Change in Low Mountain Landscapes of Lviv Oblast in the Ukrainian Carpathians

Anatoliy Smaliychuk and Ivan Kruhlov

**Abstract** This chapter analyzes forest cover change (FCC) with respect to the natural landscape structure and proximity to roads and settlements in two municipalities: Stara Sil' and Boberka in the Ukrainian Carpathians. A natural landscape is perceived as a mosaic of natural geoecosystems (GES), whose pattern is defined by landforms, which also reflect distribution of other hydro climatic and biotic components, including the potential natural vegetation (PNV). The forest cover of the 1980s was digitized from topographic maps, while its recent change was manually detected using high-resolution images from the Google Earth. The FCC data were overlaid with the natural GES data for further analysis. Proximity to roads and settlements was included into the analysis as an additional economic parameter. The important intermediate result of the study is a geodataset of natural GES that includes 35 types with attributes on topographic location, average altitude, mean slope, soil, and dominant PNV sub-formation. We distinguished five types of FCC. The total area with the FCC is estimated as 79.4 ha (2.5 %) for Stara Sil' and 715.9 ha (10.5 %) for Boberka. A common trend is the increase of the forested area due to forest succession on former agricultural land.

## 1 Introduction

Conservation and sustainable use of landscape and biotic diversity are stipulated by international (e.g. UNEP 2003) and national legislation (Verkhovna Rada 2009). Successful implementation of these decisions requires, among other

---

An erratum to this chapter is available at [10.1007/978-3-642-12725-0\\_50](https://doi.org/10.1007/978-3-642-12725-0_50)

---

A. Smaliychuk (✉) · I. Kruhlov  
Faculty of Geography, Ivan Franko National University of Lviv,  
Doroshenka St. 41 79000 Lviv, Ukraine  
e-mail: zljukalviv@gmail.com

preconditions, accurate and current geodata about the structure and recent dynamics of the landscapes.

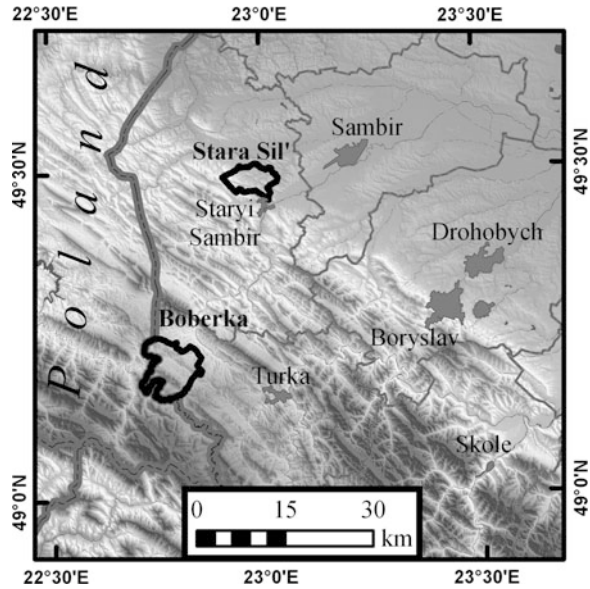
Two past decades have marked significant socioeconomic transformations in the Carpathian countries, including Ukraine. Drastic changes have occurred particularly in land ownership, land use, and as a consequence, in land cover (e.g. Kuemmerle et al. 2006, 2007, 2008, 2009; Ressler et al. 2008). These dynamics are 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 embrace 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 2008; Kruhlov et al. 2008). Recent forest cover change (FCC) studies in the Ukrainian Carpathians, which are based on medium-resolution Landsat TM/ETM+ remote sensing data, reveal some peculiarities and trends in land cover dynamics in the northwestern part (Kuemmerle et al. 2006, 2007, 2008) and in the whole region (Kuemmerle et al. 2009).

The goal of this study is to examine how natural landscape and economic location influence FCC on the local level. We intended to use large-scale maps and fine-resolution forest cover data. To reach this goal, detailed FCC and natural geoecosystem (GES) maps have to be created and the FCC pattern has to be analyzed over the background of the natural GES mosaic. This was accomplished by using two model municipalities located in the flysch low mountains with significant portions of agricultural land.

The two municipalities, Stara Sil' and Boberka, belong to Lviv Oblast (Fig. 1). Stara Sil' has an area of 3,208 ha, population of 2,119 inhabitants (The State Statistics Committee of Ukraine 2002), and is located at the edge of the Carpathians, where the Marginal Beskydy low-mountain meso-ecoregion borders with the upland of Upper Dniester Fore-Carpathians (Kruhlov 2008; Kruhlov et al. 2008). The elevation varies from 304 to 651 m. The natural vegetation is represented by broadleaved forests with 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 (Kruhlov et al. 2008). Boberka has an area of 6,819 ha, a population of 1,654 inhabitants (The State Statistics Committee of Ukraine 2002), and belongs to the Sian-Stryi Verkhovyna meso-ecoregion of elevated low mountains (Kruhlov 2008) with the elevation range from 536 to 826 m occupied by natural mixed beech–silver fir and beech–Norway spruce (*Picea abies*) forests on brown mountain soils (Kruhlov et al. 2008).

Both areas have a long history of agricultural development: low elevation and gentle slopes afforded vast expansion of grasslands and cultivated fields around the villages. Stara Sil' is proximate to the raion (district) administrative town Saryi Sambir at 7 km. It was a major regional centre of salt production until the end of the Nineteenth century. At the end of the World War II, a fairly large collective farm was created here with the share of arable land of about 50 %. It collapsed in

**Fig. 1** Location of the study areas, Stara Sil' and Boberka, in the Lviv Oblast of the Ukrainian Carpathians



2000, and agricultural land is now partly abandoned and partly used individually by local people as a household-scale natural economy (Anonymous 2008). The local population was partly resettled from here after the World War II. The area is known for the preserved ethnical architecture, clothes, and customs. 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 (Maryskevych and Niewiadomski 2005).

## 2 Materials and Methods

In this study, a natural landscape is interpreted as a natural morphogenic geosystem: a geospatial model of an area, in which landform elements (georelief) determine differentiation of local hydro climatic and natural (potential) biotic features (Kruhlov 2006), namely potential natural vegetation (PNV) (e.g. Tüxen 1956). Thus, the landforms determine the spatial pattern of the GES. The FCC pattern is analyzed over the background of the natural GES mosaic, thus providing insight about the importance of natural factors for forest cover dynamics. Proximity to roads and settlements was also chosen as an important economic factor of FCC (e.g. Kuemmerle et al. 2009). A geographic information system (GIS) was used as the main tool of the analysis. The general scheme of the data processing is presented in Fig. 2.

The materials used in the study included:

- topographic maps from the USSR period-1980s at a scale of 1:50,000 and 1950s at a scale of 1:25,000 (only for Stara Sil' ) (Anonymous 2006)
- satellite images (2005–2008) with spatial resolution at about 2.5 m available from Google Earth (earth.google.com),
- Shuttle Radar Topography Mission Digital Elevation Model (SRTM DEM), 3-arc-second (Jarvis et al. 2008),
- cadastral scheme at a scale of 1:50,000 with borders of the model communities (The State Committee of Ukraine on Land Resources 1993),
- literature on climate, soil, and vegetation of the study areas (Herenchuk 1968; Holubets et al. 1988; Kruhlov et al. 2008),
- field material on the interrelations of landforms, soil, and vegetation collected within 72 plots used as additional source for the description of the GES.

All analogue map data were scanned and transformed into a single coordinate system: UTM Zone 34 N. Boundaries of the municipalities were vectorized from rather imprecise cadastral schemes and corrected using high-resolution satellite

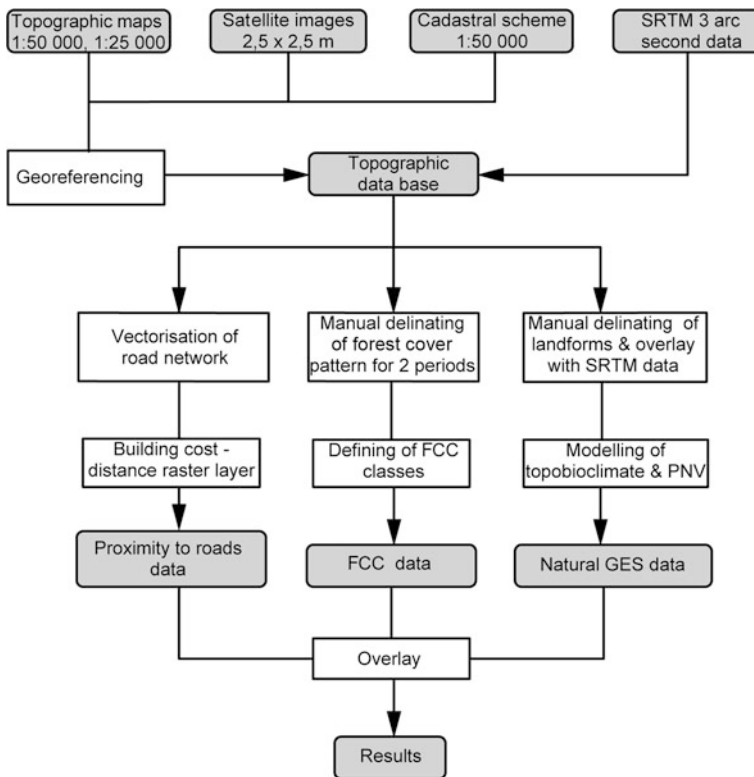


Fig. 2 Study workflow and data processing

images and large-scale topographic maps, as the boundaries mostly run along visible landscape features (roads, watersheds, streams, or forestry blocks).

The landforms were manually delineated from scanned 1:50,000 topographic maps and characterized by average slope, aspect, and mean elevation (representing altitudinal elevation belts) using statistical overlays with SRTM 3-arc-second data. Since large-scale vegetation and soil data are not available, the PNV and the soil were established as a function of morphometry, surface drainage and elevation within the landforms using information from the literature and the field observations. The forest cover pattern of the 1980s was digitized from the topographic maps, while its recent changes were manually detected using high-resolution images available in Google Earth to detect forest or non-forest (agriculture) transformations. Then, the FCC data were overlaid with the natural GES data for further analysis.

The road network and boundaries of settlements were vectorized from the satellite images. Proximity to roads (including paved, forested, and field roads) and settlements were included into the analysis as a proxy variable describing the economic accessibility, since it is assumed that the FCC may occur more intensively in more remote areas (Kuemmerle et al. 2009). We calculated also a cost-distance surface from the roads and settlement edges using slope gradients reclassified and assigned as cost values from 1 to 4.

### 3 Results

The important intermediate result of the study is a geodataset of natural GES that includes 35 types with attributes on topographic location, average altitude, mean slope gradients, type of bioclimatic altitudinal belts, soil, and dominant PNV sub-formation (according to Kruhlov et al. 2008; Table 1, Fig. 3).

We distinguished five types of FCC. Four of them can be aggregated in a group with secondary succession changes at the areas, which were formerly extensively used by agriculture. These types included areas where grassland was replaced by deciduous forest, mixed forest, coniferous forest, or shrubland. The fifth type of forest cover changes shows the areas where former forest or shrubland had been replaced by grassland. The last FCC type is the result of logging.

The total area with FCC for Stara Sil' is estimated at 79.4 ha (2.5 % of overall area), while for Boberka, 715.9 ha (10.5 %). In Stara Sil' replacement of grassland with broadleaves forest dominates. However, in Boberka, the occurrence of coniferous forest is more frequent (Table 2, Fig. 4).

Average elevations were calculated for each FCC type using the SRTM DEM. There were significant differences between the two study areas (Fig. 5): whereas in Boberka mean elevation of the whole municipality and the area with FCC were the same (644 m a.s.l.), in Stara Sil' these values were equal to 379 and 415 m a.s.l. respectively. Slope classes were also calculated from the SRTM DEM and overlaid with the FCC areas (Fig. 6).

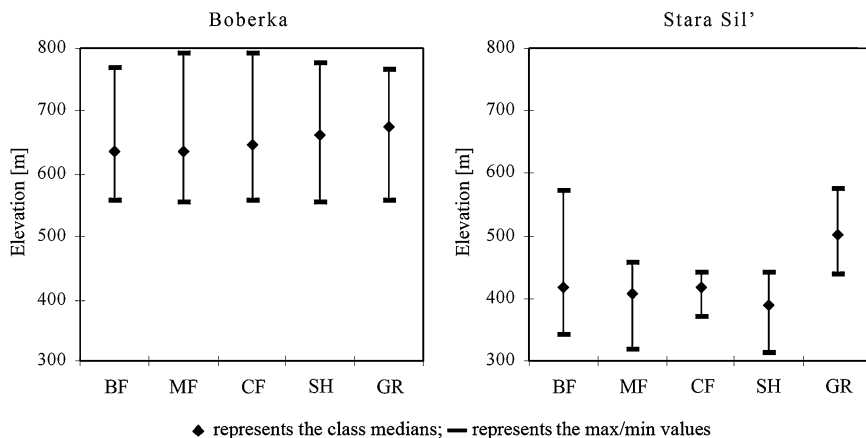
Table 1 Natural GES types in Stara sil' and Boberka

GES types	Area, ha		Topographic location	Bioclimatic belt	Soil	PNV type
	Stara Sil'	Boberka				
A1a	152.2	–	Alluvial floodplains and terraces	Warm, moderately warm	Luvisol haplic	<i>Alneta glutinosae</i>
A1b	–	536.9		Moderately cool, cool	Fluvisol umbric and Leptosol umbric	<i>Alneta incanae</i>
A2a	110.1	–	V-shape alluvial valleys, gullies	Warm, moderately warm	Luvisol haplic	<i>Alneta glutinosae</i>
A2b	1.5	418.0		Moderately cool, cool	Fluvisol umbric and Leptosol umbric	<i>Alneta incanae</i>
A3a	29.1	–	Ravines	Warm, moderately warm	–	<i>Fraxineto-Querceta</i>
A3b	–	85.9		Moderately cool, cool	–	<i>Fraxineto-Fageta</i>
B1a	291.5	–	Watershed surfaces and gentle slopes (0 – 6°)	Warm	Albeluvisol stagnic	<i>Carpineto-Querceta</i>
B1b	233.7	–		Moderately warm		<i>Abiето-Querceta</i>
B1c	0.9	976.7		Moderately cool, cool	Cambisol dystric	<i>Fageto-Abieta</i>
B2a	139.7	–	Watershed surfaces (>6°)	Warm, moderately warm	Albeluvisol stagnic	<i>Fageto-Querceta</i>
B2b	14.5	585.7		Moderately cool, cool	Cambisol dystric	<i>Abiето-Fageta</i>
C1a	15.8	–	Flat surfaces (0 – 2°)	Warm, moderately warm	Albeluvisol stagnic	<i>Fraxineto-Querceta</i>
C1b	–	9.4		Moderately cool, cool	Cambisol dystric	<i>Fraxineto-Fageta</i>
C2a	134.2	–	Concave gentle slopes (3 – 5°)	Warm, moderately warm	Albeluvisol stagnic	<i>Fraxineto-Querceta</i>
C2b	–	290.8		Moderately cool, cool	Cambisol dystric	<i>Fraxineto-Fageta</i>

(continued)

Table 1 (continued)

GES types	Area, ha		Topographic location	Bioclimatic belt	Soil	PNV type
	Stara Sil'	Boberka				
C3a	170.0	–	Concave moderate slopes (6 – 12°)	Warm, moderately warm	Albeluvisol stagnic	<i>Fraxineto-Querceta</i>
C3b	5.0	538.2		Moderately cool, cool	Cambisol dystric	<i>Fraxineto-Fageta</i>
C4c	9.8	59.8	Concave moderate-to-steep slopes (13 – 20°)	Moderately cool, cool	Cambisol dystric	<i>Fageto-Abieta</i>
C5c	–	13.3	Concave steep slopes (>20°)	Moderately cool, cool	Cambisol dystric	<i>Fageto-Abieta</i>
D1a	77.5	–	Flat surfaces (0 – 2°)	Warm	Albeluvisol stagnic	<i>Carpineto-Querceta</i>
D1b	3.0	–		Moderately warm		<i>Abieto-Querceta</i>
D1c	–	39.2		Moderately cool, cool	Cambisol dystric	<i>Fageto-Abieta</i>
D2a	596.4	–	Straight and convex gentle slopes (3 – 5°)	Warm	Albeluvisol stagnic	<i>Carpineto-Querceta</i>
D2b	267.7	–		Moderately warm		<i>Abieto-Querceta</i>
D2c	–	920.0		Moderately cool, cool	Cambisol dystric	<i>Fageto-Abieta</i>
D3a	834.1	–	Straight and convex moderate slopes (6 – 12°)	Warm, moderately warm	Albeluvisol stagnic	<i>Fageto-Querceta</i>
D3b	71.6	1,989.8		Moderately cool, cool	Cambisol dystric	<i>Abieto-Fageta</i>
D4b	51.4	343.8	Straight and convex moderate-to-steep (13 – 20°)	Moderately cool, cool	Cambisol dystric	<i>Abieto-Fageta</i>
D5b	–	15.2	Straight and convex steep slopes (>20°)	Moderately cool, cool	Cambisol dystric	<i>Abieto-Fageta</i>



**Fig. 3** Fragment of the 1:50,000 map of geocoecosystems: **a** Boberka, **b** Stara Sil' (explanations to geocoecosystems types in Table 1)

**Table 2** Distribution of forest cover change types within study communities. Replacement of grassland with deciduous forest (*GR-DF*); mixed forest (*GR-MF*); coniferous forest (*GR-CF*); shrubland (*GR-SH*). Replacement of forest/shrubland with grassland (*F/Sh-GR*)

Types of forest cover change	GR-DF ha/ %	GR-MF ha/ %	GR-CF ha/ %	GR-SH ha/ %	F/Sh-GR ha/ %
Stara Sil'	32.4/40.8	19.1/24.0	19/23.9	6.1/7.7	2.8/3.5
Boberka	210.5/29.4	163.2/22.8	229.1/32.0	76.6/10.7	36.5/5.1

The FCC data were overlaid with the natural GES data to analyze the dependence of the change on the PNV types (Fig. 7). In Stara Sil', the majority of FCC could be found in *Fageto-Querceta* (over 50 %) and *Abieto-Querceta* (about 10 %) PNV types. However, in Boberka, FCC mainly occurred in the GES with *Abieto-Fageta* (over 40 %), *Alneta incanae* and *Fageto-Abieta* (about 10 % each) PNV types.

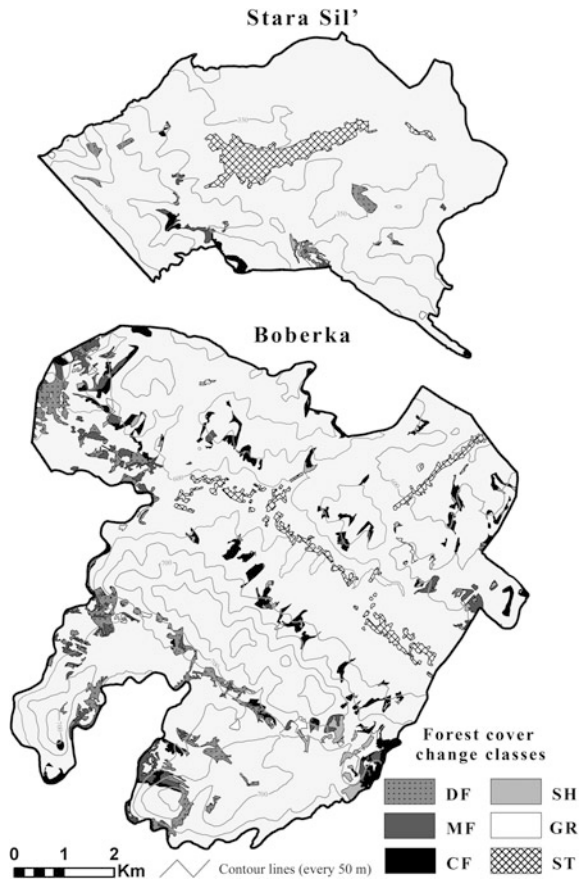
Proximity to roads and settlement edges was calculated and results were aggregated into seven classes for further interpretation. These data were also overlaid with the FCC data (Fig. 8). Proximity to roads and settlements is worse in Boberka due to its cul-de-sac location.

## 4 Discussion

Farmland abandonment and natural reforestation are the main traits of the land cover change in the Ukrainian Carpathians (Kuemmerle et al. 2007, 2008, 2009). Our study reveals the same situation in both of the municipalities. There are some differences in FCC distribution in the two municipalities, which is mainly caused by the variety of GES and PNV types, which is higher in Stara Sil'.



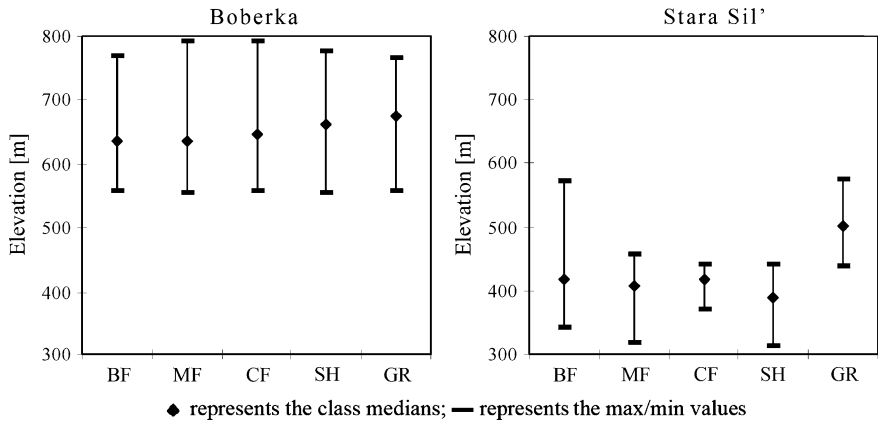
**Fig. 4** Forest cover change. Replacement of former land cover types with deciduous forest (*DF*); mixed forest (*MF*); coniferous forest (*CF*); shrubland (*SH*); grassland (*GR*); settlements (*ST*)



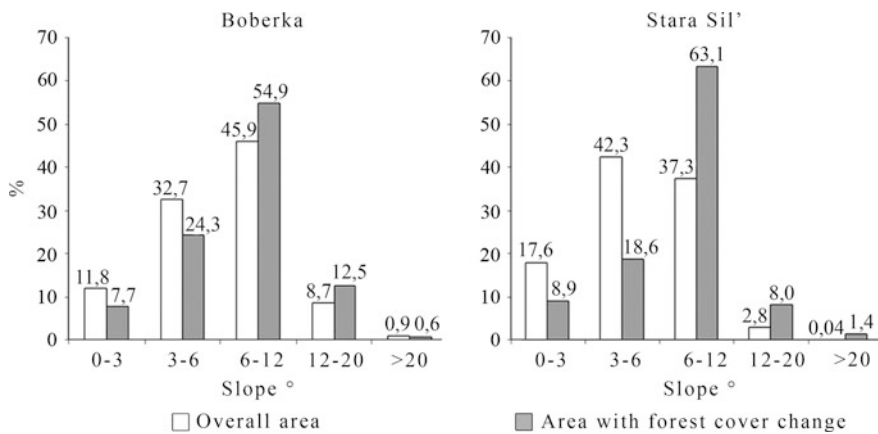
In Stara Sil', which is located at the border of mountains and plains, FCC (predominantly Type 5: replacement of forest by grassland) occurred more on mountain ridges with higher elevations than on the plains with lower elevation, which corresponds well with the results of previous studies (Kuemmerle et al. 2007).

FCC more often occurs on moderate and steep slopes than on gentle ones, because gentle slopes (up to 6°) are predominantly occupied by nonforest-land cover types. The moderate slopes (6–12°) are primarily impacted by FCC: forest succession on former grassland is most explicitly manifested here. This particular case differs from previous studies on FCC in the Ukrainian Carpathians, which revealed that FCC more often occurs on gentle slopes and valley bottoms that are predominately used in agriculture (Kuemmerle et al. 2008).

Our study also shows that FCC occurs with more or less the same intensity in all GES/PNV types. Absence of FCC in the GES with *Carpineto-Querceta* (Stara Sil') can be explained by a very insignificant portion of actual forest cover: these



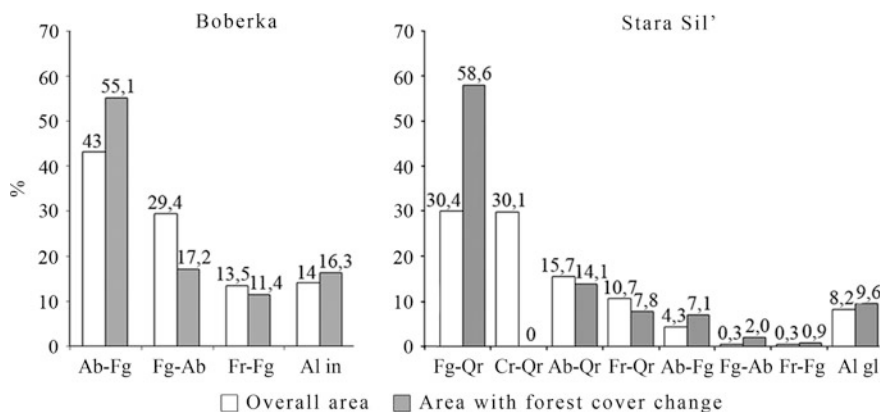
**Fig. 5** Distribution of elevation for each forest cover change class. Replacement of former land cover types with deciduous forest (*DF*); mixed forest (*MF*); coniferous forest (*CF*); shrubland (*SH*); grassland (*GR*)



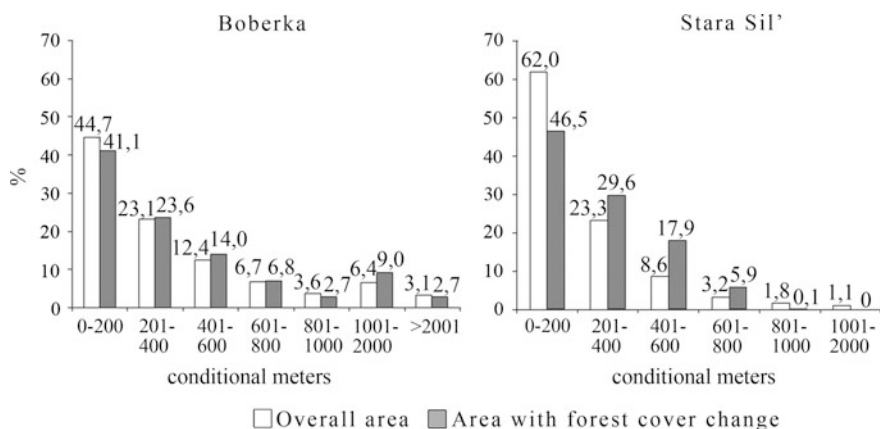
**Fig. 6** Distribution of forest cover change areas according to slope classes

are predominantly gentle watershed surfaces occupied by permanent grassland and agricultural fields.

There is no significant difference in the proximity of the FCC patches to roads and settlements in the two municipalities, and this differs from the study results of Kuemmerle et al. (2009), which showed that FCC more often occurred on remote and nonaccessible places. FCC often occurs on the areas remote from settlements (but not from roads), at forest edges, or inside the forest. In Boberka, FCC patches are concentrated at the abandoned places, where villages existed before World War II: the shrub encroachment on grasslands and arable land had started here in the middle of the Twentieth century (e.g. Angelstam et al. 2003).



**Fig. 7** Distribution of forest cover change areas according to PNV types. *Fg-Qr* *Fageto-Querceta*; *Cr-Qr* *Carpineto-Querceta*; *Ab-Qr* *Abieto-Querceta*; *Fr-Qr* *Fraxineto-Querceta*; *Ab-Fg* *Abieto-Fageta*; *Fg-Ab* *Fageto-Abieta*; *Fr-Fg* *Fraxineto-Fageta*; *Al in* *Alneta glutinosae*; *Al in* *Alneta incanae*



**Fig. 8** Distribution of forest cover change according to proximity to roads and settlements

There is an increase of deciduous forest areas in Stara Sil', while coniferous forest expanded in Boberka. This can be partly explained by the differences in elevations and climatic conditions: the cooler climate in Boberka better supports regeneration of coniferous species. However, field checks showed that the dominant species of the regenerating patches is Norway spruce: this finding does not agree with the PNV types of the sites, and it has a distinct cultural origin. It could be explained by self-seeding of spruce from the adjacent areas of spruce plantations. Also, this can lead to the instability and future dieback of these spontaneous secondary spruce stands due to unsuitable site conditions.

## 5 Conclusions

The low mountain landscapes in Lviv Oblast experienced an increase of forested area because of the abandonment of agricultural lands. During the last decades the annual increase of forest areas was estimated at 0.14 and 0.35 % for Stara Sil' and Boberka, respectively. In most cases FCC correlates with the GES pattern and proximity to field and forest roads and settlement edges. In addition, FCC more often occurs on moderate slopes (in two municipalities) and higher elevation (in Stara Sil'). Higher reforestation rates in Boberka are most likely caused by the remote economic location of the municipality.

## References

- Angelstam P, Boresjö-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 (2006) Topographicheskie karty 1:50 000. <http://maps.vlasenko.net/soviet-military-topographic-map/map50k>. Accessed 15 November 2007
- Anonymous (2008) Mista i sela Ukrainy. Lvivschyna. <http://who-is-who.com.ua/bookmaket/mistalvov2008/7/19/1.html>. Accessed 9 October 2008
- Herenchuk KI (1968) Pryroda Ukrayinskykh Karpat. Vydavnytstvo Lvivskoho Universytetu, Lviv
- Holubets MA, Honchar MT, Komendar VI, Kucheryavyi VA, Odynek YP (eds) (1988) *Ukrainskiye Karpaty. Priroda, Naukova Dumka*
- Jarvis A, Reuter HI, Nelson A, Guevara E (2008) Hole-filled SRTM for the globe Version 4, available from the CGIAR-CSI SRTM 90 m Database. <http://srtm.csi.cgiar.org>. Accessed 4 March 2009
- Kruhlov I (2006) Landshaft yak geoeosystema. *Visnyk Lvivskoho Univ Ser Geogr* 33:186–193
- Kruhlov I (2008) Delimitatsiya, metryzatsiya ta klasyfikatsiya morfogenykh ekoregioniv Ukrayinskukh Karpat. *Ukr Geogr Zhurnal* 3:59–68
- Kruhlov I, Mukha B, Senchyna B (2008) Natural geoeosystems. In: Roth M, Nobis R, Stetsuk V, Kruhlov I (eds) *Transformation processes in the western Ukraine. Concepts for sustainable land use*, Weissensee Verlag
- Kuemmerle T, Chaskovskyy O, Knorn J, Radeloff VC, Kruhlov I, Keeton WS, Hostert P (2009) Forest covers change and illegal logging in the Ukrainian Carpathians in the transition period from 1988 to 2007. *Remote Sens Environ* 113:1194–1207
- Kuemmerle T, Hostert P, Radeloff VC, Perzanowski K, Kruhlov I (2007) Post-socialist forest disturbance in the Carpathian border region of Poland, Slovakia, and Ukraine. *Ecol Appl* 17:1279–1295
- Kuemmerle T, Hostert P, Radeloff VC, van der Linden S, Perzanowski K, Kruhlov I (2008) Cross-border comparison of post-socialist farmland abandonment in the Carpathians. *Ecosyst* 11:614–628
- Kuemmerle T, Radeloff VC, Perzanowski K, Hostert P (2006) Cross-border comparison of land cover and landscape pattern in Eastern Europe using a hybrid classification technique. *Remote Sens Environ* 103:449–464
- Maryskevych O, Niewiadomski Z (2005) Regionalnyi landshaftnyi park Nadsyanskyi. [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

- Ressl R, Endlicher W, Lehmann S, Baruth B, Bosch B, Rosenthal G (2008) Current land use structure of upper Dniester basin and recent changes in the model communities. In: Roth M, Nobis R, Stetsuk V, Kruhlov I (eds) Transformation processes in the Western Ukraine. Concepts for sustainable land use, Weissensee Verlag
- The State Committee of Ukraine on Land Resources (1993) Skhema zemlekorystuvannya Stararosambirs'kogo i Turkivskoho rayoniv masshtabu 1:50 000. Lvivskyi filial instytutu zemleustroyu, Lviv
- The State Statistics Committee of Ukraine (2002) Demografichniy shchorichnyk za 2001 rik. Kyiv
- Tüxen R (1956) Die heutige potentielle natürliche vegetation als gegenstand der vegetationskartierung. *Angew Pflanzensoz* 13:5–42
- UNEP (2003) Framework Convention on the Protection and Sustainable Development of the Carpathians. <http://www.carpathianconvention.org/index.htm>. Accessed 19 April 2009
- Verkhovna Rada (2009) Zakon Ukrainy pro landshafty (proekt). [http://gska2.rada.gov.ua/pls/zweb\\_n/webproc4\\_1?id=&pf3511=36258](http://gska2.rada.gov.ua/pls/zweb_n/webproc4_1?id=&pf3511=36258). Accessed 27 December 2009