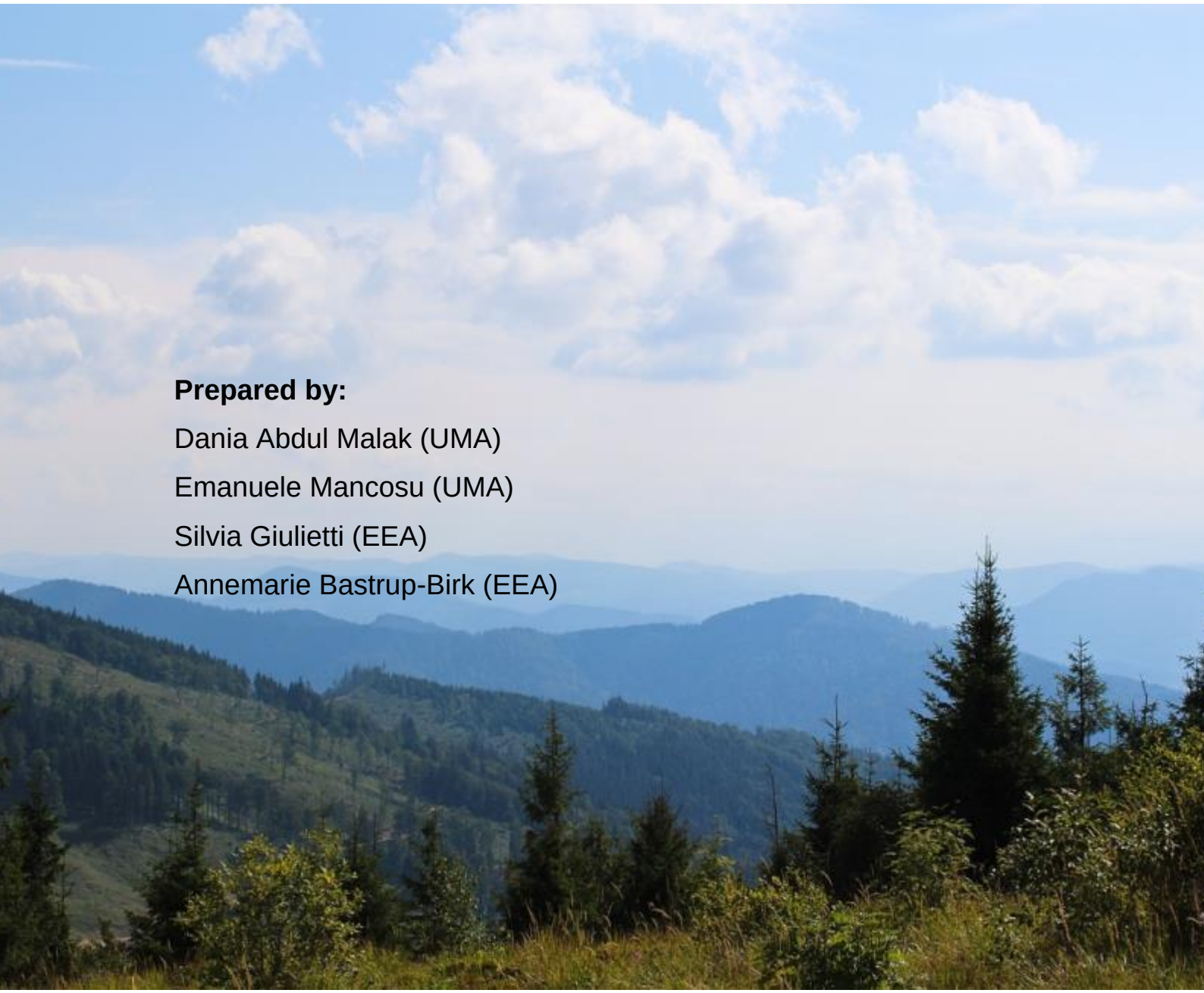
# Forest indicators to support regional policy and management in the Carpathian region



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**Draft version 1.0** **Date: 19.09.2016**

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# 1 CONTEXT

The European Environment Agency signed a partnership agreement with the Carpathian Convention Secretariat in July 2014 which includes a common work plan on topics of mutual interests and for cooperation activities in the field of environmental observation and information that is being implemented by the European Topic Centre on Spatial Information and Analysis (ETC/SIA) in 2014 and was continued in 2015 and 2016 by ETC/ULS represented in both ETCs by the same partner, the University of Malaga (UMA).

In particular, this is a report prepared by the European Topic Centre on Urban, Land, and Soil Systems (ETC/ULS) to inform on the intermediate results of 2016 activities to support the achievement of the EEA's contribution to the progressive realization of an inventory of virgin and high natural forest of the Carpathian Convention. ETC ULS is part of the Eionet and provides additional technical expertise to the European Environment Agency (EEA) in the achievement of its multiannual objectives mainly by supporting and informing policy development and implementation in the area of urban, land use and soil by means of data, information/indicators and assessments.

# 2 INTRODUCTION

Among its activities, since 2014 ETC/ULS has been providing support to the activities of the Carpathian Convention as regional cooperating partner of the EEA. The activities developed during the previous years focused on providing background information to support sustainable management within the Carpathian forest ecosystems through the realization of an inventory including:

- the identification of the most relevant datasets, and
- the potentials and limitations of their use to develop specific regional indicators

Previous ETC/ULS activities produced a report assessing the multi-sourced regional input datasets available that could be used for this purpose (2014), followed by the development of a questionnaire and an assessment of the local and national datasets available for the countries within the Carpathian Environment Outlook (KEO) and the possibility to access these data for their inclusion in the developments of the forest specific indicators.

Based on the outcomes of previous reports, the possibilities and limitations were indicated and a set of three region-wide indicators were agreed between EEA, the Carpathian Convention Secretariat and ETC/ULS as high priority to be developed for 2016. These indicators are the main focus of this report:

1. *forest naturalness,*
2. *forest connectivity and fragmentation,*
3. *temporal change in forest cover in the region 2000-2012 (based on the temporal data flow of Corine Land Cover)*

# 3 PAST ACTIVITIES AND 2016 ACTION

In 2014, the University of Malaga (UMA), as a partner within the ETC/SIA, provided an extended analysis supporting the identification of available harmonized Carpathian-wide information, datasets and indicators on the multifunctional role of forests and forest resources as basis to realize the agreed activities.

As a first step, the boundaries of the working area were set using a 50 km buffer around the limits identified in the Carpathian Environment Outlook (KEO) (Figure 1). Furthermore, an exhaustive list of useful Regional, European and Global datasets was explored and their relevance for the work was analysed.

The outcomes of this work were presented in the 4th COP Meeting to the Carpathian Convention that took place in Mikulov, Czech Republic on the 23-26 September 2014.

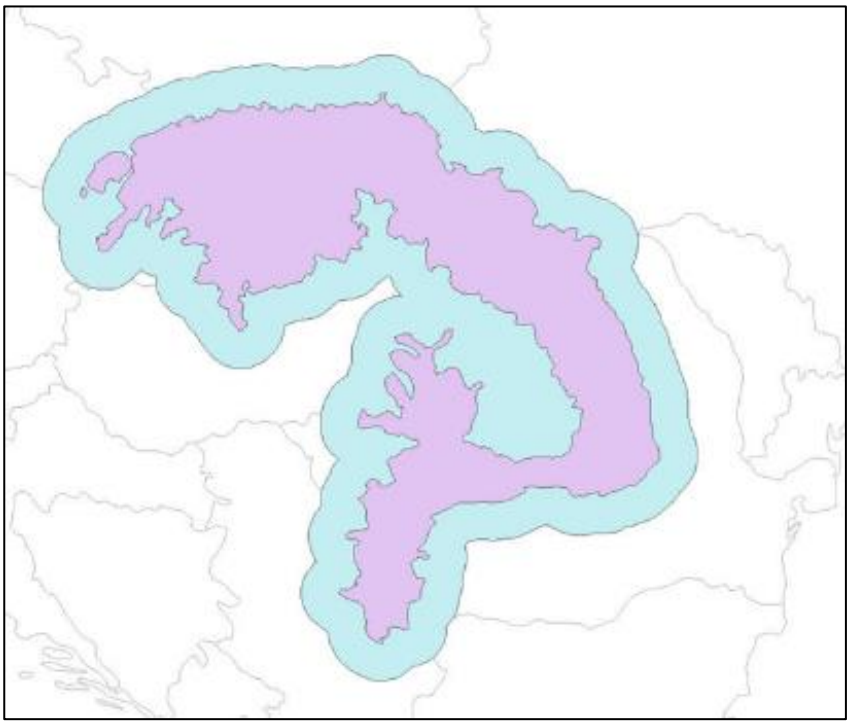


*Figure 1 - 50 km buffer (blue) around KEO limits of the Carpathian Mountains (violet) (ETC/SIA, 2014).*

In order to improve the data collection and integration with additional regional data of relevance, UMA developed a questionnaire to be shared with the partners of the Carpathian Convention as a second step of the 2014 outcomes. This process made possible the acquisition of an overview on data availability at local and national levels within each of the Carpathian countries within the Convention.

Based on the received information from member States, a teleconference between EEA, the Secretariat, UMA, and the CCFPs took place in February 2015. It aimed at identifying the possibilities and limitation of accessing the data listed in the questionnaires. The teleconference served to understand the complexity of accessing available data within MSs, which was crucial for planning the 2016 common activities between EEA, the CCS, and the ETC-ULS.

The aim of the 2016 activity was to produce three harmonised forest related indicators covering the whole region within the KEO boundaries, namely:

- *Forest naturalness,*
- *Forest connectivity and fragmentation, and*
- *Temporal change in forest cover (based on the data flow of Corine Land Cover).*

The major limitations identified during their calculation are on one hand, the lack of data for Ukraine in most of the European products and datasets available, producing gaps in the spatial extent of the results (for the part of the KEO that belongs to Ukraine).

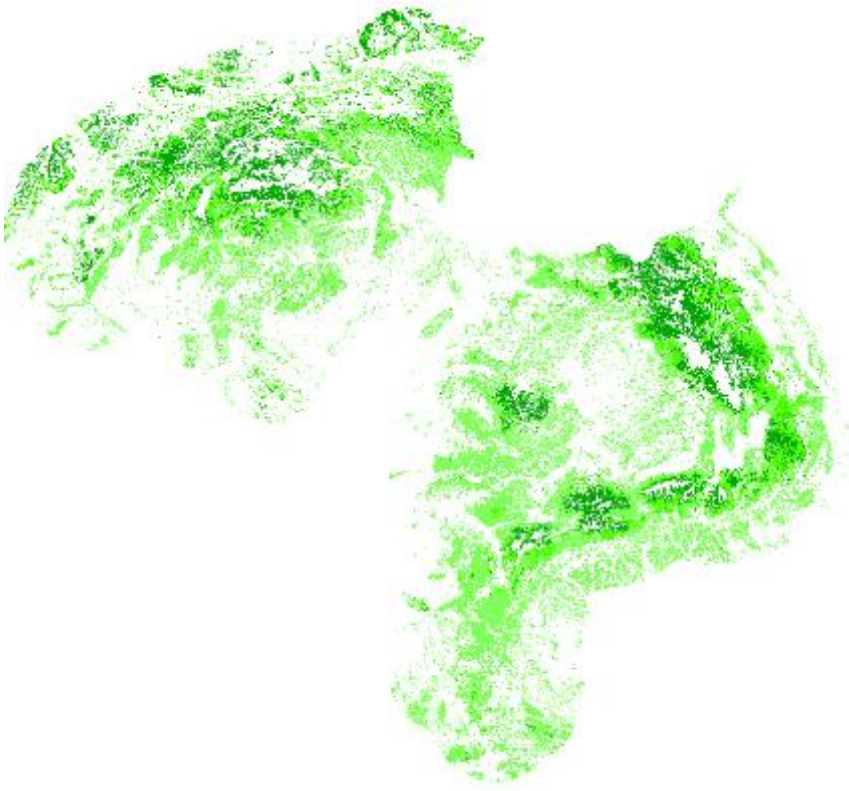


*Figure 2 - CLC 2012 layer in KEO Carpathian Area showing the gap of data in the case of Ukraine*

On the other hand, the second gap is the very limited of access so far to local validated datasets for the region, except the access to few data - generated from small scale previous projects in the region and some thesis outcomes of a small area – that were collected by the UMA team. This fact is limiting the results so far as Ukraine is not included in some Copernicus products (e.g. HRL, CLC), and neither in the indicators previously calculated (e.g. Naturalness, Fragmentation). To overcome these gaps of harmonised information on forest coverage data for specific areas within the KEO boundaries, like Ukraine, and to make possible the development of regional indicators, the exploration of the use of different possible sources started this year.

This report is focused mainly on illustrating the procedures done by the ETC-ULS to fill these gaps and to provide harmonised region wide forest indicators. In the Results section of this report, some outcomes of the indicators developed so far are illustrated and the accuracies reached in the results discussed.

# 4 RESULTS

## 4.1 CONNECTIVITY AND FRAGMENTATION OF CARPATHIAN FORESTS

The indicator on the morphological structure of forests detects and describes the geometry and the connectivity of forest ecosystems. This indicator, developed and based on the methodology of the European study *Forest landscape in Europe: Pattern, Fragmentation, and connectivity* (Estreguil et al., 2012), was calculated for the Carpathian forest included within the KEO buffer boundaries (EEA, 2010) using the GUIDOS toolbox modelling tool (Vogt, 2013).

The tool was run with the PALSAR forest coverage (2015) at a 100 m resolution as input data. Statistics about the quantity of core, edge, islet and linear forest in the KEO were extracted and analysed by MS and by level of forest protection policy (e.g. Natura 2000, EEA) within the KEO boundaries.

The results of this analysis show that the core forests estimated by this model cover a high share (79%) of the total forest of Carpathian Mountains within the KEO boundaries.

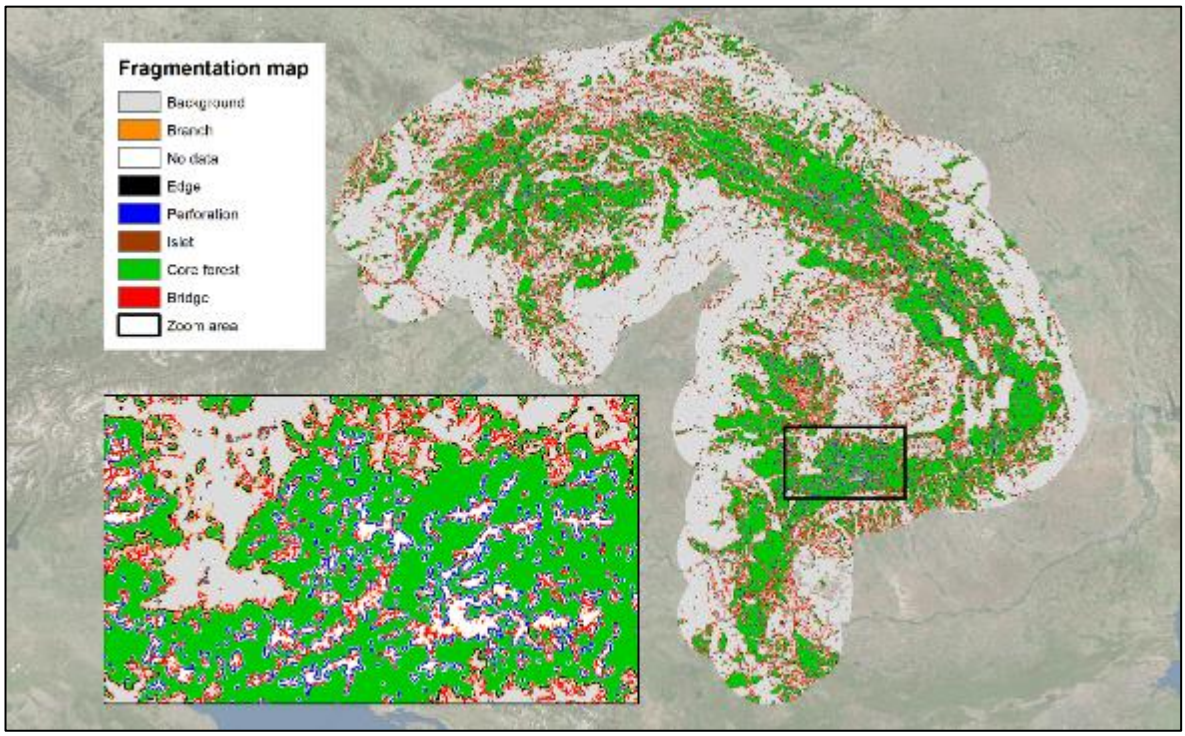



*Figure 3 Fragmentation map of Carpathian forest. The core forest is represented by the green colour (ETC-ULS, 2016).*

The indicator on the morphological structure of forests offers a general harmonised overview of the structure of the Carpathians Mountains. It identifies the level of fragmentation within Carpathian forests with the KEO boundaries and spatially locates area these fragmented forests in the region. The outcomes of this indicator support regional efforts of the management, conservation, and restoration of Carpathian forests. The identification of fragmented forests in the region and the areas with potential risk of fragmentation are deemed essential for the prioritisation of the actions of regional managers and policy makers.

The analysis of the condition of Carpathian forests within protected areas (N2000, EEA) versus unprotected areas proved that the conservation measures within the Carpathian region are leading to a higher percentage of core forests. More precisely, around 10% higher core forests are identified within N2000 areas when compared to the % of core forests within the whole Carpathian forests.

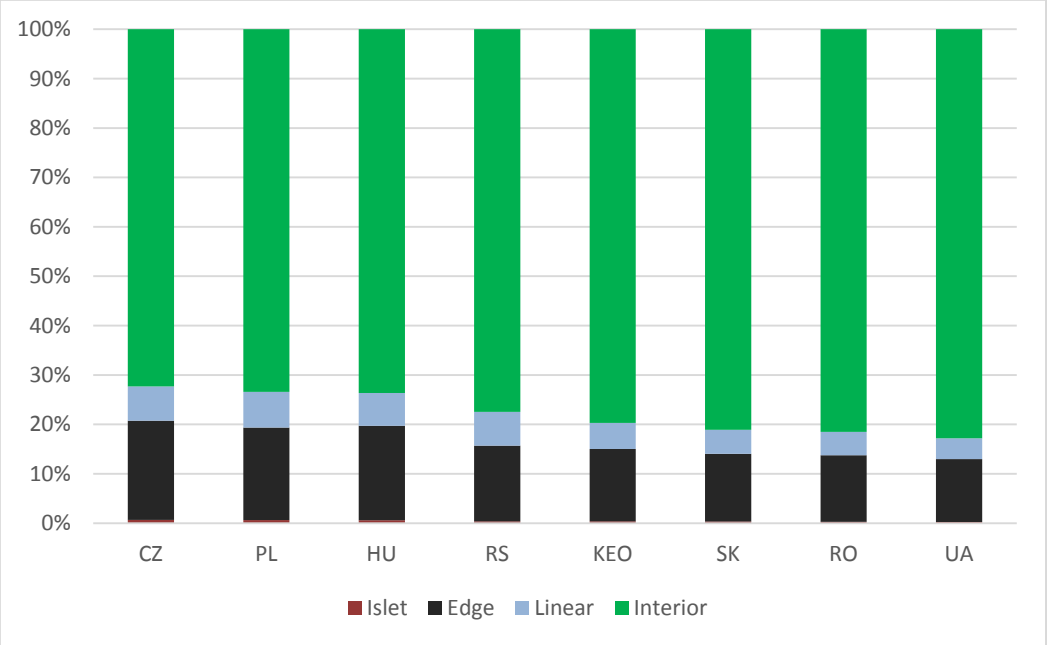



*Figure 4 National and Carpathians (KEO) profiles of forest morphological shape.*

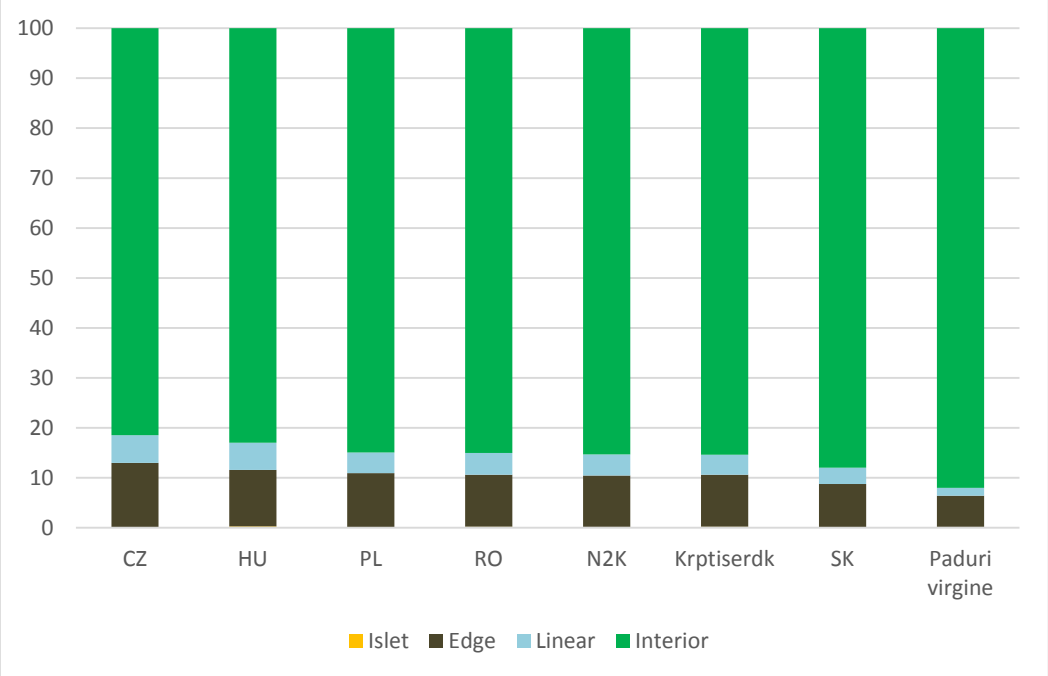



*Figure 5 Protected areas (N2K) and by country (CZ, HU, PL, and RO) and virgin forest (Paduri virgine and Krptiserdk) profiles of forest morphological shape in 2015.*

## 4.2 NATURALNESS

The naturalness index is calculated for the entire Carpathian region using the biogeographical region maps and the linkages between dominant forest species types under each biogeographical region (Barbati et al. 2013).
The Naturalness Index ($N_i$) (table 2) identifies the relation between the high percentage of natural forest species presence and the percentage of forest coverage. More precisely, this indicator could be used as a proxy for the identification of the level of natural forest species available in a forest ecosystem.

*Table 1 Calculation of Naturalness index.*

| | |
|---|---|
| $N_i = DA/TF$ | ***DA:*** *% dominant assemblages of species per biogeographical region (based on Barbati et al. 2011, table 3)*<br>***TF:*** *% of total forest cover (PALSAR, 2015)* |

In the Carpathian Mountains, on the one hand, the forest Naturalness index ensures the identification of areas in the Carpathian forests that present a high percentage of potential natural species in relation to the forest tree density. Based on the indicators outcomes, the areas with the highest values of naturalness are located in the Czech Republic, Poland and Romania which show a higher percentage than the one registered in areas under a protection plan, namely Natura 2000.
On the other hand, the results obtained in the case of the virgin forest delineated in the Paduri virgine (Figure 7) are especially interesting as they register values of Naturalness almost twice as high as the values recorded in the Romanian Forests. This result is a proof to the high obtained correlation between the Naturalness indicator and the virgin forest.

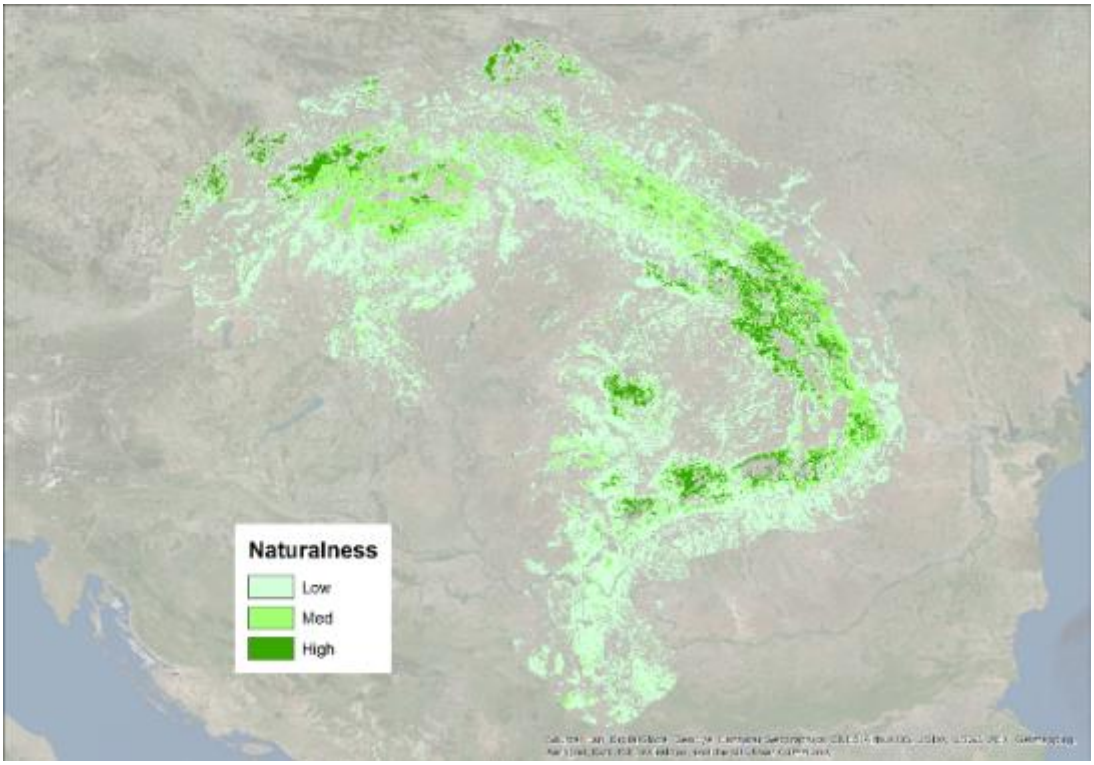



*Figure 6 Naturalness index represented by 3 classes: low, med, and high.*

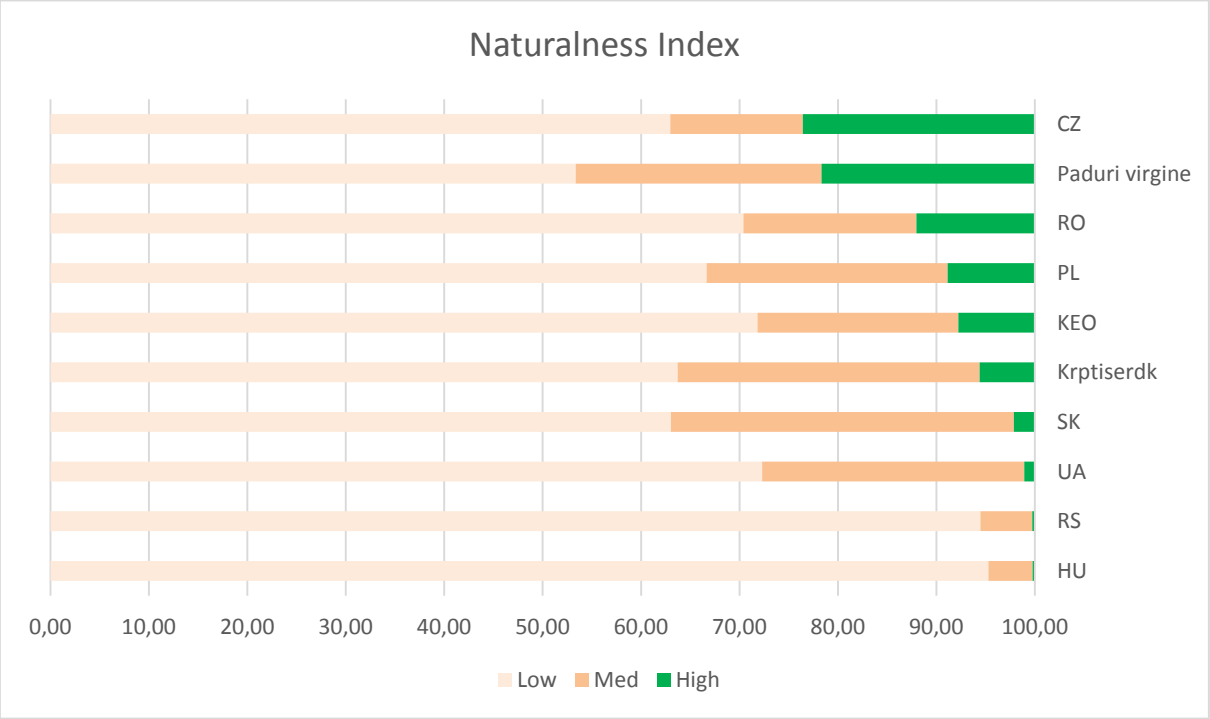



*Figure 7 Naturalness index disaggregate by country and by virgin forest area database (Paduri and Krptiserdk).*

The Naturalness indicator presents a harmonised distribution along the Carpathian Mountains. The resulting map (Figure 8) highlights clusters of high values (hot Spots) and clusters of low values (cold spots). In this map, large hotspots areas show the spatial continuity of the naturalness of forests in specific areas of the Carpathian forests, mainly in its core, whereas more "fragmented" natural forests are located mainly on the edges of the forest mixed with forest species that are not considered of high naturalness in the KEO forest region.

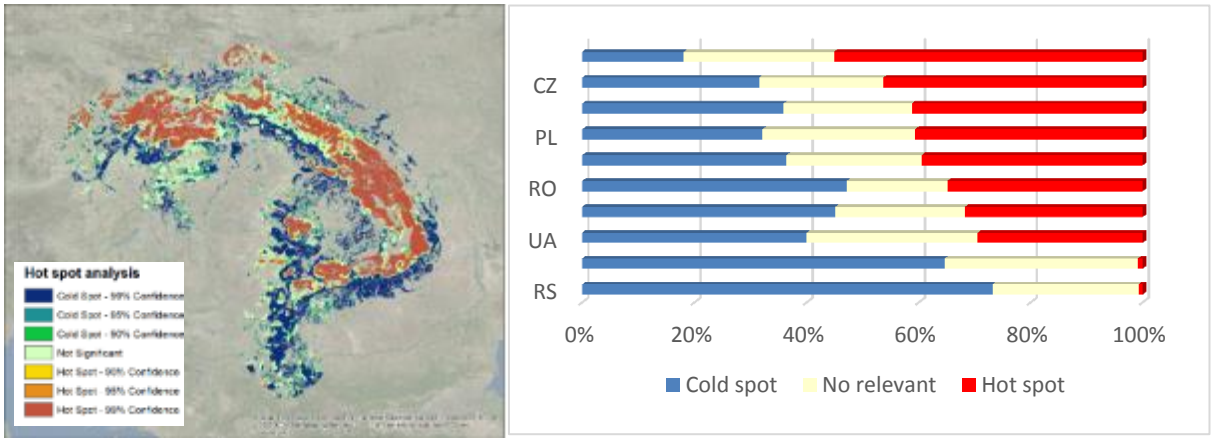



*Figure 8 Hot spot analysis of the Naturalness indicator. Stats by country and by Virgin forest delineation.*

This statistical analysis provides an overview of the hot spot distribution among the Member States, parties of the Carpathian Convention and also by Virgin forest delineation (Figure 8). As stated above, the Czech Republic, Poland, and Romania in addition to Slovakia registered the highest concentrations of these forests, compared to the ones registered as a mean of the overall KEO region. Additionally, in the case of both delineations of virgin forests (local analysis) a very high percentage of Hot spot clusters were registered.

## 4.3 LAND USE LAND COVER CHANGE

The land use land cover flow analysis of the Corine Land Cover (CLC) layers of the years 2000- 2006 and 2012 were applied to the KEO region (covered by the CLC product). The results extracted from this analysis and discussed briefly here focus on the spatial changes or the temporal dynamics in woodland and forests in the Carpathian region between the periods 2000-2006 and 2006-2012.

As shown in figures 9 and 10 respectively, **forest consumption**, being the forest transformed to other uses, is less than 2% during both time periods (Table2). From the total forest area of the year 2000 in the Carpathians, 1,45% was consumed in 2006; and from the total forest area of the year 2006, around 1,6% of the forest extent was consumed in 2012.

On the other hand, **forest formation**, being the forest that has been generated during these periods, Based on the total forest area of the year 2000, 1.64% of new forest was generated in 2006; and from the total forest area of 2006, 1,75% of forest was generated in 2012 (Table 2).

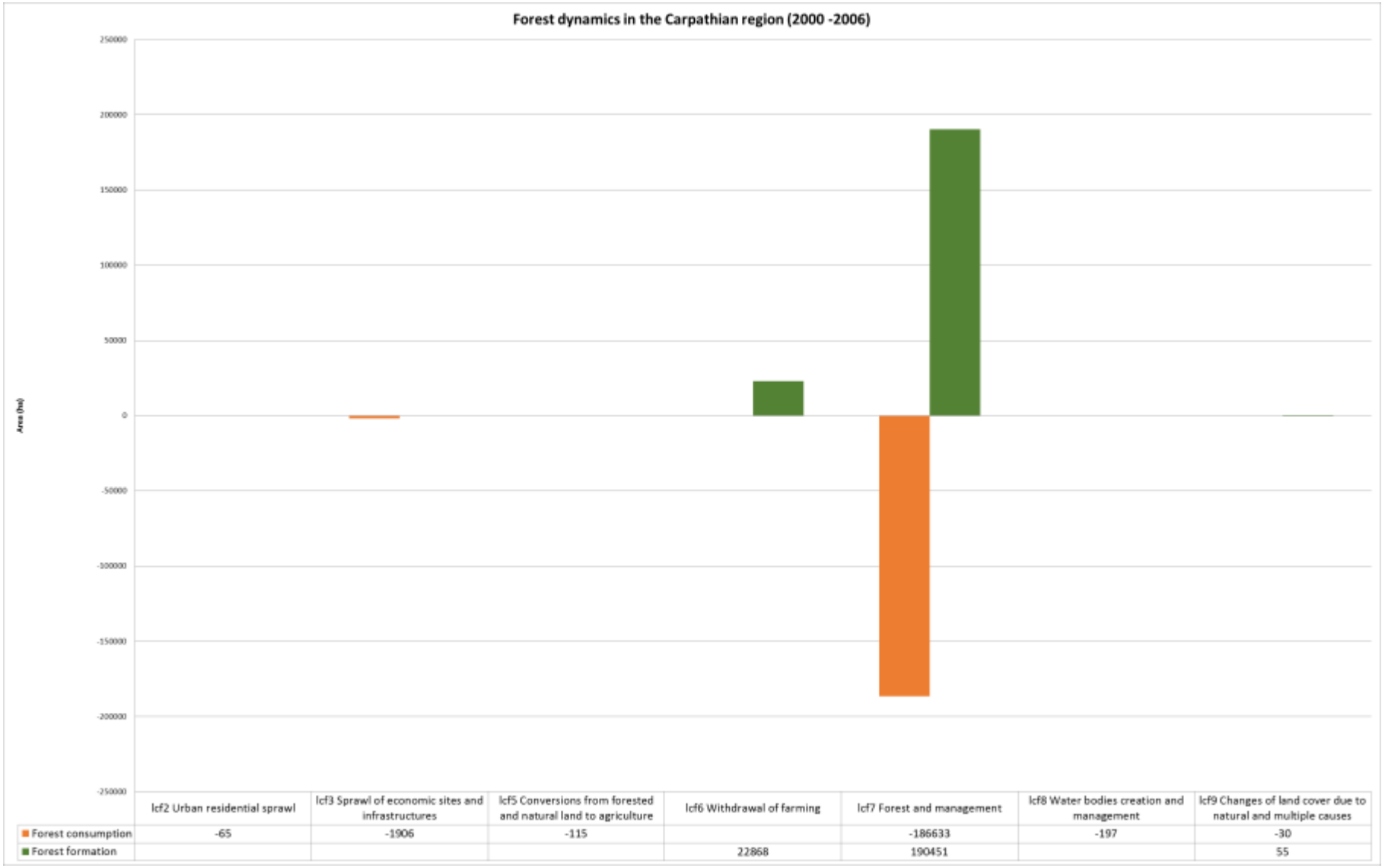
These ranges of forest consumption and forest formation calculated show that the forest formation in both periods of time in the Carpathian region is higher than the forest consumption implying that forest ecosystem is expanding in the region.

The turnover rate of the forest during these periods, being the forest consumption and the forest formation in each period, are around 3 and 3.3% respectively for the years 2000-2006 and 2006-2012. The net change in the total forest area is lower than 0.2 % in both time periods (2000-2006 and 2006 -2012).

*Table 2 Forest dynamics calculated as % change between 2000-2006 & 2006-2012*

| Woodland and forest | % between 2000-2006 | % between 2006-2012 |
|---|---|---|
| **Consumption** | 1,45 | 1,57 |
| **Formation** | 1,64 | 1,75 |
| **turnover (consumption + formation)** | 3,09 | 3,33 |
| **Net change (formation - consumption)** | 0,19 | 0,18 |

In terms of area, the most important land flow contributing to the temporal forest dynamics is forest management between 2000 and 2006 (Figure 9) and between 2006 and 2009 (Figure 10). Though to a much lower extent, urban residential sprawl is considered part of the contributor to forest consumption that has normally irreversible effects on forests.




| | lcf2 Urban residential sprawl | lcf3 Sprawl of economic sites and infrastructures | lcf5 Conversions from forested and natural land to agriculture | lcf6 Withdrawal of farming | lcf7 Forest and management | lcf8 Water bodies creation and management | lcf9 Changes of land cover due to natural and multiple causes |
|---|---|---|---|---|---|---|---|
| Forest consumption | -65 | -1906 | -115 | | -186633 | -197 | -30 |
| Forest formation | | | | 22868 | 190451 | | 55 |

*Figure 9 Corine land cover flows affecting the forest areas from 2000 to 2006 (Corine Land Cover, EEA 2016).*

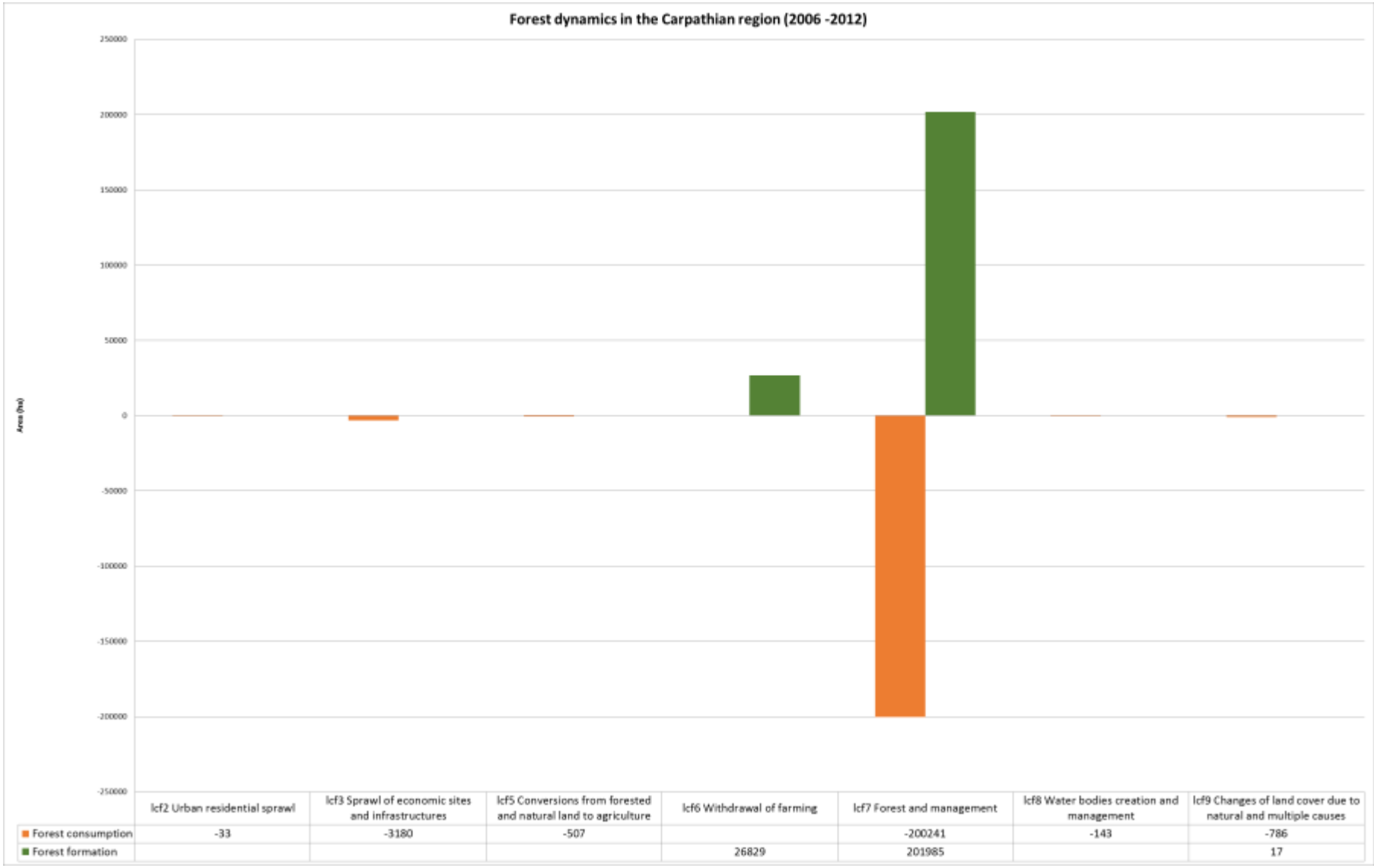



*Figure 10 Corine land cover flows affecting the forest areas from 2006 to 2012 (Corine Land Cover, EEA 2016).*

# 5 RECOMMENDATIONS AND OUTLOOK

Results show that even at a coarse resolution, the regional indicators presented here on the forest morphology and structure and on the naturalness of forest communities in the Carpathian region, are valid information sources to support regional management and policy making. The testing proved that such results are accurate to be used at the level of the Carpathian forests, within N2K areas, and even in the few cases where local data on virgin forests in specific areas of the KEO were accessible.

New satellite images that became available and freely accessible in 2016, namely the Sentinel Images and products of the Copernicus programme, as well as the PALSAR images are valid input data that makes possible filling the gaps in data in specific regions of the KEO that are not normally covered by the thematic European products (namely Ukraine). These data could be used to produce more regional indicators to support forest managers and to steer evidence-based policy making at a Carpathian wide (regional) scale.

The input quality data are always driving the quality of results, and despite the very high resolution forest coverage data derived from different satellite images (PALSAR, Sentinel, and Landsat), the available data about species distribution (Brus et al., 2011) are coming with some estimation errors and with a lower resolution (1 km) that reduces the accuracy of the final results.

Hence, the next steps of this work, the use of local inventories on species distribution with high resolution would be much recommended in order to improve the outcomes and have a better identification of the naturalness of the forest communities in the region, the location of the potential virgin forest areas, as well as the connectivity among Carpathian forests.

In addition, these robust indicators are foreseen as baseline regional harmonised information that needs to be updated regularly to monitor the changes in time. In that sense, the availability of free disposition of Satellite images and products that has been made available in 2016 and is expected to be available regularly (every 6-10 days in the case of Sentinel) will enable a precise monitoring of Carpathian forests.

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