Bulletin of the *Transilvania* University of Braşov • Vol. 3 (52) - 2010
Series II: Forestry • Wood Industry • Agricultural Food Engineering

ESTIMATION OF FOREST LAND-COVER CHANGE IN ROMANIA, BETWEEN 1990 AND 2006

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Abstract: *The main goal of this study was to estimate the changes in land cover in the period 1990-2006 in Romania by using Corine Land Cover products, based on satellite images from three different years: 1990, 2000 and 2006. Two major land cover-change types were considered: from forest to other land-cover (i.e. by deforestation) and from different land covers to forest (i.e. by afforestation). Using the CLC model, 5197.4 ha affected by deforestation or afforestation in decade 1990-2000 and 941.3 ha between 2000 and 2006 were identified. The product accuracy has a high influence on detected area affected by land-cover change. Due to the fact that CLC model has a low resolution, the results presented give only a partial picture of land cover change by deforestation and afforestation in Romania.*

Key words: *afforestation, deforestation, Corine Land Cover land-cover change, Romania.*

1. Introduction

The change of land-cover is in many cases associated with the land-use change. In the present international context of addressing climate change, reporting carbon storage in vegetation is an obligation of each country which ratified the Kyoto Protocol. In this matter, the carbon dynamics due to land-use change became an important issue. A first step in quantifying the carbon stored due to land-use change is the inventory of areas affected by this process.

After the falling of communism regime in 1990, Romania has seen a tumultuous dynamics of social and political life, which initially created a favorable context for a potentially intensive land-cover change especially by deforestation.

Using satellite images Romania's land-cover distributions at three different moments (i.e. 1990, 2000 and 2006) are compared, identifying those areas which changed cover type, from forest to other land-cover and form other land-cover to forest.

2. Material and Methods

The products used in this study are Corine Land Cover (CLC), from European Environmental Agency (EEA) and Joint Research Centre of the European Commission (JRC). For Romania, the products were developed in collaboration with the "Danube Delta" National Institute for Research and Development.

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CLC is a digital map of the European environmental landscape. Based on the interpretation of satellite images, CLC provides comparable maps of land-cover for almost all European countries. The standard CLC nomenclature includes 44 land cover classes. These are grouped in a three-level hierarchy. The five main (i.e. level-one) categories are: *i*) artificial surfaces, *ii*) agricultural areas, *iii*) forests and semi-natural areas, *iv*) wetlands, and *v*) water bodies [1].

In order to detect land cover changes, a GIS raster based algorithm extracted from raster CLC1990, CLC2000 and CLC2006, was used. In this matter, two comparisons were made: the changes in CLC2000 towards CLC1990 and in CLC2006 towards CLC2000. The analysis was made using a change detection algorithm. Each pair of analog pixels from the two matrixes were compared and eliminated if similar. Then, using the raster data, polygons were created in order to get the area of each location.

The main characteristics of vector product are:

- the results have the same accuracy and trust as the data used for input;
- the projection system is Stereo 70;
- the thematic accuracy is higher than 85%.

Due to the fact that the final version of CLC 2006 has not been developed, the level of accuracy for this product is questionable. Moreover, the pixel length for the raster used in CLC2000 and CLC2006 comparison is 250 m, while for CLC1990 - CLC2000 comparison is 100 m, thus better results being expected. The minimum mapping area for CLC is 25 ha. Therefore the areas smaller than this limit are not quantified in this study.

Confusions can be made especially in young coniferous forests from hilly area, as they can be easily consideres as broadleaf forests. Also, the "*transitional woodland-shrubs*" category is not very well defined as it could include nurseries, cleared cut forests, abandoned orchards etc., which have different land use [2].

3. Result and Discussions

3.1. Land-Cover Change from Forestland to Other Land-Cover

Deforestation is defined as the change of land cover with depletion of tree crown cover to less than 10 percent. Changes within the forest class (e.g. from closed to open forest) which negatively affect the stand or site and, in particular, lower the production capacity, are termed forest degradation [3].

Detected area of forestland converted to other land-cover between 1990 and 2000, was 2171.5 ha (Table 1), representing approximately 0.035% of Romanian forests. Between 2000 and 2006, detected area affected by deforestation was lower (699.7 ha).

Table 1

Land-cover change (*in hectares*) *by deforestation*

Nr. crt.	**Type of transition**	**1990 to 2000 [ha]**	**2000 to 2006 [ha]**
1	forest to grassland	578.2	0
2	forest to pasture	234.6	0
3	forest to non irrigated arable land	50.9	0
4	forest to mineral extraction sites	1041.5	666.1
5	forest to water bodies	120.1	17.1
6	forest to water courses	124.6	0.0
7	forest to discontinuous urban fabric	21.6	12.7
8	forest to dump sites	0.0	3.8
TOTAL		**2171.5**	**699.7**

Between 1990 and 2000, detected land-cover change from forestland to other land-cover occurred more frequently in South-East of Harghita county, at the border between Covasna and Buzău counties and in South-West of Gorj county (Figure 1). At the country level 74 polygons were identified, where this type of land-cover change occurred. The most common land-cover change was from broad-leaved forests to mineral extraction sites, covering about 1041 ha, most of these areas being located in Gorj county (784.6 ha).

The transition from forest to grassland occurred more often in initially mixed forest (302.7 ha). After 2000, about 97% of the changes in land-cover were from forest to mineral extraction sites.

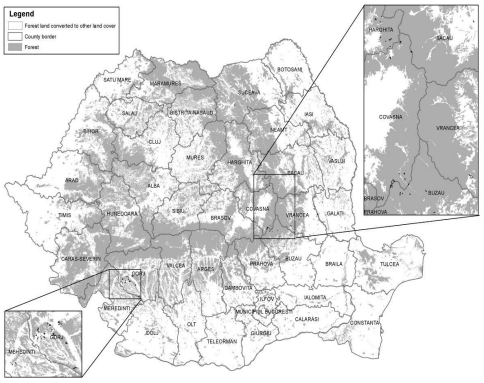

Fig. 1. *Forestland converted to other land-cover, between 1990 and 2000*

The main factors that caused land-cover change from forest to other land-covers are illegal logging and hazards (i.e. wind falls, insect attacks etc.). One of the most important reasons for illegal logging was the implementation of land restitution, that made possible ownership overlapping due to the several steps application process. By 2010, three land restitution laws were applied: *i*) Law 18/1991, *ii*) Law 1/2000 and *iii*) Law 247/2005. The main feature of this succession of laws was the increase of the restituted land area by ownership type. The high number of owners with small forestland properties, combined with the uncertainty of maintaining these forestlands increased the pressure on the forest, some of them being clear cut. Whilst in 1990 all forests belonged to the state, in 2008 more than 45% of the forests were in non-state hands [4].

In most of the cases the forestlands affected by clear cut did not changed their land use. This is because of the small size of such affected areas, which allowed natural regeneration, often with pioneer species.

The precision of the model (minimum mapping area of 25 ha) led to an underestimation of the total detected area affected by this type of land-cover change, as small areas were not considered.

3.2. Land-Cover Change from Other Land-Cover to Forest

The changes in land-cover from other cover types to forest are possible by afforestation or reforestation.

The afforestation is the conversion from other land-uses into forest, or the increase of the canopy covers to above the 10% threshold [3], and can be achieved through either plantations or natural regeneration.

Table 2

Land-cover change area (*in hectares*) *by afforestation*

Nr. crt.	Type of transition	1990 to 2000 [ha]	2000 to 2006 [ha]
1	grassland to forest	1302.8	113.0
2	pasture to forest	1432.2	0.2
3	forest to non irrigated arable land	264.2	0
4	other land-cover to forest	26.7	128.4
TOTAL		3025.9	241.6

Reforestation is the re-establishment of forest formations after a temporary condition with less than 10% canopy cover due to human-induced or natural perturbations [3]. Due to the fact that by reforestation the land use is not changed, this process was not taken into account for this study.

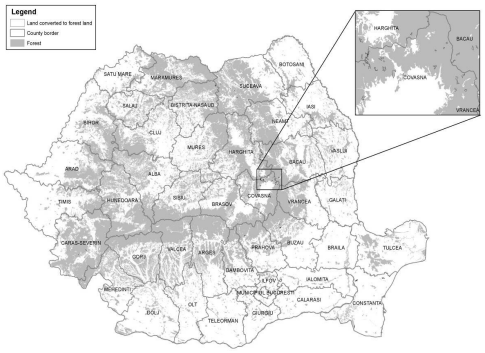

Fig. 2. *Land converted to forest land, between 1990 and 2000*

Between 1990 and 2000 more afforested areas than those affected by deforestation were detected (Table 2). Grasslands and pastures converted to forestland was the most common type of transition (90%). Most of the detected areas are located at the border of Covasna, Harghita and Bacău counties (Figure 2).

In Romania, the extent of plantations was directly influenced by the existing financial sources. After 1990 the main source of funding for afforestation works was the "Land Reclamation Fund". After 2000 the Measure 3.5 of SAPARD Program (Special Accession Program for Agriculture and Rural Development) financially supported the afforestation, along with other sources made available by central and local authorities.

Besides planting, this type of land-cover change to forest was supported by natural regeneration of tree species especially in the pastures of mountain area.

4. Conclusion

Land-cover change occurred in Romania very often on small areas in connection with the small average size of forest properties. Most of these areas could not be quantified in our model, leading to underestimations. The lower land cover-change area between 2000 and 2006 resulting from the model could be attributed to multiple causes: the shorter period of time (i.e. 6 years instead of 10), the lower accuracy of the data used (i.e. 250 m per pixel) compared to CLC1990-2000 (i.e. 100 m per pixel) or the lower rate of land cover change in this period.

Considering the minimum mapping area and the size of the pixels, the precision provided by CLC to quantify a certain type of transition is not high enough to catch all locations affected by land cover change. Therefore, the results presented in this paper give only a partial overview of land cover change by deforestation and afforestation in Romania.

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