

## TRENDS IN THE DEVELOPMENT OF FORESTED AREAS OF BULGARIA FROM 1990 TO 2012 ESTABLISHED BY THE RESULTS OF THE PROJECT „CORINE LAND COVER”

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### Abstract

The main objectives of the EU project „CORINE Land Cover” are creation of a unified European land cover map through interpretation of satellite images and preparation of a digital database of land cover and the changes in it. The results are used for assessment of land cover and its state and policy formulation on protection of the environment, planning and management of agriculture, forestry, transportation, etc. at European and national level. The databases created in different stages of the project “CORINE Land Cover” – Bulgaria are analysed, some of the most typical changes in the forest territories of Bulgaria concerning the forested areas during the period 1990–2012 are identified, and from there the trends in their development are found.

**Key words:** satellite images, deforestation, afforestation, change detection, CLC classes, CLC changes.

### Forests in the World, in Europe and Bulgaria

Today, one third of the Earth’s land surface, or a total of 34 million km<sup>2</sup> is covered by forests. Half of the planet’s forests are located in Russia, Brazil, Canada, the US and Congo. Most forested are some small countries like Suriname (95 %) and Gabon (84 %). Worldwide afforested areas begin to decrease dramatically over the past 150 years. A major cause of deforestation is the need for agricultural lands.

According to a study of the World Wildlife Fund (World Wide Fund for Nature – WWF) in the future the rate of deforesta-

tion in the world will fall, but if we do not initiate anything, 230 million hectares of forests will be extinct until 2050 (Galhidi 2011). Only a balance between the processes of deforestation and afforestation may change these trends.

Over 40 % (1.77 million km<sup>2</sup>) of the land territory of the EU is covered by forests and almost 20 % (over 14 million ha) of forest habitats are included in the „Nature 2000” network. Unlike in many other parts of the world forest cover in the EU increases by 0.4 % per year. (Anonymous 2015).

Forests in Bulgaria provide about 85 % of the water flow in the country or around 3.6 billion m<sup>3</sup> of clear drinking water. They

have a significant role in reducing greenhouse gas emissions into the atmosphere, accumulating carbon in the biomass and actually absorbing carbon dioxide. In this connection, the adaptation of forests to climate change is one of the most important objectives of forest policy.

Priceless are forests for soil protection, water and climate, and protection from natural disasters. By parameters of forest fire risk Bulgaria is usually associated to the traditionally dangerous regarding fires Mediterranean region. For the last 15 years in the forest territories of the country an annual average of about 500 fires are registered, affecting on average 11,000 ha of these territories. Direct damage is estimated an average of 13 million leva per year.

Lands and forests within the forest territories of Bulgaria store:

- over 80 % of the protected species of plants;
- over 60 % of the threatened by extinction animal species;
- over 60 % of the types of habitats of priority for conservation;
- eight of the twelve landscape complexes defined in the National Strategy for the Conservation of Biodiversity as unique and representative for the Bulgarian biodiversity;
- populations of 43 globally threatened species.

In order to protect this diversity 3 national parks, 10 nature parks, 55 reserves and 35 maintained reserves have been separated on the territory of the country (Anonymous 2006).

What changes have occurred in the forested areas of the forest territories of Bulgaria for the period 1990–2012, covering the former four stages of the project „CORINE Land Cover”? According to

the methodology of the project (Bossard et al. 2000) forests and open areas in the forest territories are fully integrated in Class 3 – „Forests and semi-natural areas” as its subclasses (Anonymous 1994). This analysis tracks the evolution of these 6 CLC classes (level 3) (Anonymous 2011):

- 3.1.1. – „Broad leaved forest”;
- 3.1.2. – „Coniferous forest”;
- 3.1.3. – „Mixed forest”;
- 3.2.2. – „Moors and heathlands”;
- 3.2.4. – „Transitional woodland scrub”;
- 3.3.4. – „Burnt areas”.

#### **Extraction of Summarized Data by Periods for the Studied Land Cover Classes and Analysis of the Results Results from the project „Corine Land Cover 1990”**

In Table 1 the data are summarized from the output database CLC1990 for the studied 6 classes, indicating the number of polygons and their total area, as well as their percentage representation for the entire mapped territory.

Results in the database CLC1990 show that in 1990 the forested areas within the forest territories (deciduous, coniferous and mixed forests) are 3,553,457 ha or 31.6 % of the territory of the country. This exceeds the official data for 1990 – 3,348,032 ha (Bogdanov 2002). The guaranteed total accuracy of the database CLC1990 is 85 %. Under this condition, the difference found of 205,425 ha (5.8 %) is negligible. The main reason for this difference is that according to the methodology of the project open areas smaller than 25 ha within the forest areas are not differentiated as separate polygons of another land cover class. Furthermore, there are self-seeded but not inventoried forest stands.

**Table 1. Land cover classes in the database CLC1990 – Bulgaria.**

| No | CLC code<br>(level 3) | CLC class                   | Number of<br>polygons | Area      |       |
|----|-----------------------|-----------------------------|-----------------------|-----------|-------|
|    |                       |                             |                       | ha        | %     |
| 1  | 3.1.1.                | Broad leaved forest         | 5,369                 | 2,385,150 | 21.21 |
| 2  | 3.1.2.                | Coniferous forest           | 1,946                 | 551,865   | 4.91  |
| 3  | 3.1.3.                | Mixed forest                | 3,765                 | 616,442   | 5.48  |
| 4  | 3.2.2.                | Moors and heathlands        | 100                   | 32,458    | 0.29  |
| 5  | 3.2.4.                | Transitional woodland scrub | 7,787                 | 755,818   | 6.72  |
| 6  | 3.3.4.                | Burnt areas                 | 15                    | 2,361     | 0.02  |

### Changes occurred in the period 1990–2000

Finding the land cover changes in the period 1990–2000 is a necessary step for obtaining the updated database CLC2000. Change detection is a process of comparison and analysis of vector and raster data from the beginning and the end of the period. Taking the wright decisions is determined by the good knowledge of the study area as a natural region, the socio-economic conditions, the seasonal changes in the reflectance of the land cover, and by the knowledge and experience in computer assisted interpretation of multitemporal satellite images.

For the period 1990–2000, 2670 polygons of changes in the land cover of Bulgaria are registered with a total area of 122,579.7 ha, which is 1.10 % of the mapped area. As a total, the changes in the studied 6 land cover classes are 54.2 % of the area of all changes detected for the territory of Bulgaria.

The changes in class 3 – „Forests and semi-natural areas” are associated with two large-scale processes in these areas,

which are described with the following CLC codes (level 3):

- Deforestation – cut down forests: „3.1.1. to 3.2.4.”, „3.1.2. – 3.2.4.” and „3.1.3. – 3.2.4.” and burned areas: „3.1.1 to 3.3.4.”, „3.1.2. – 3.3.4.” and „3.1.3. – 3.3.4.”.

The number of changes reflecting the cut forests is 701 with a total area of 29,859.4 ha, which is 24.25 % of the total area of all changes for the territory of Bulgaria. Burned areas almost do not affect the total forested area – seven in number with a total area of 948.6 ha or 0.01 % of the total area of the changes;

- Afforestation – „3.2.4. – 3.1.1.”, „3.2.4. – 3.1.2.”, „3.2.4. – 3.1.3.” and „3.3.4. – 3.1.1.”.

The number of changes related to self-seeded or planted forests is 965 with a total area of 36,767.9 ha, which amounts to 29.86 % of the total area of all changes for the territory of Bulgaria. The area of restored deciduous forests in burned areas is 206.6 ha, which is 0.001 % of the total area of all the changes.

This is the only stage of the project, within which time span afforestation process dominates the process of deforesta-

tion. Over the period 1990–2000, the forested areas in the forest territories have increased by 6,166.5 ha. The reason is mainly that a change in land cover is registered only if the area of the polygon is over 25 ha. As we will see in the next stages loggings in the forests are mostly with smaller areas and therefore many of them are not included in the database CLCchange1990–2000.

### Results from the project „Corine Land Cover 2000”

In Table 2 the data for the studied 6 land cover classes are summarized, taken from the output CLC2000 database for this second stage of the project. The number of polygons is given, as well as their total area and percentage representation for the mapped territory. As a result, the wooded areas are 3,564,390 ha or 31.97 % of the territory of Bulgaria, which is 166,083 ha (4.6 %) more than that in the data of EFA 2000 – 3,398,307 ha (Bogdanov and Tonchev 2011). Again the difference is negligible, and the main reasons are the same as those for 1990.

### Changes occurred in the period 2000–2006

For this second stage of the project „CORINE Land Cover” some substantial changes have been made in its methodology (Büttner and Kosztra 2007). A change of a land cover / land use class is registered in the database CLCchange2000–2006, when the following geometrical requirements are fulfilled:

- A minimum area of 5 ha of the actual and the technical changes, the same for the aggregated area of „elementary” polygons smaller than 5 ha (incl. the „island” type);
- A minimum polygon width of 100 m, keeping the area restrictions.

The total number of changes identified for the period 2000–2006 is 2,706 with an area of 58,464.6 ha, which is 0.52 % of the mapped territory (Stoimenov 2008). In general the total area of the changes in the studied 6 land cover classes is 83.5 % of the total area of all changes for the entire mapped territory. From the comparison of these data with the similar data from the previous period is seen that when the improved methodology is used, the area of the changes in forest territories compared to the area of all identified changes greatly increases – from

Table 2. Land cover classes in the database CLC2000 – Bulgaria.

| No | CLC code (level 3) | CLC class                   | Number of polygons | Area      |       |
|----|--------------------|-----------------------------|--------------------|-----------|-------|
|    |                    |                             |                    | ha        | %     |
| 1  | 3.1.1.             | Broad leaved forest         | 5,431              | 2,366,779 | 21.05 |
| 2  | 3.1.2.             | Coniferous forest           | 2,018              | 548,265   | 4.88  |
| 3  | 3.1.3.             | Mixed forest                | 4,032              | 649,346   | 5.78  |
| 4  | 3.2.2.             | Moors and heathlands        | 89                 | 32,166    | 0.29  |
| 5  | 3.2.4.             | Transitional woodland scrub | 7,706              | 735,105   | 6.54  |
| 6  | 3.3.4.             | Burnt areas                 | 3                  | 1,265     | 0.01  |

54.2 % to 83.5 %. The two processes in the forest territories that are analyzed in this case have the following dimensions:

- Deforestation – 1,659 changes with a total area of 34,810.2 ha which is 59.5 % of the total area of all changes identified on the territory of Bulgaria. Burned areas in total are 382.6 ha or 0.65 % of the total area of changes;

- Afforestation – in total for the three classes (level 3) – 3.1.1., 3.1.2. and 3.1.3. – 685 changes with a total area of 13,563.5 ha or 23.19 % of the area of all changes identified on the territory of Bulgaria.

In contrast to the period 1990–2000 in which the process of afforestation dominates, in the period 2000–2006 the process of deforestation is already dominant. In general, as a result of the two processes forested areas in the forest territories have decreased by 21,629.3 ha.

Figure 1 shows an example of the process of deforestation. This is part of the

numerous cuttings east of Lukovit (their total area within the Basic Working Unit is 1,752 ha). Similar examples can be found often near settlements – illegal cutting of firewood.

Figure 2 is an example of recovery of deciduous forests.

### Results from the project „Corine Land Cover 2006”

The results obtained for the studied 6 types of land cover are summarized in Table 3. They show that forested areas are 3,541,847 ha or 31.61 % of the mapped territory. According to the EFA in 2006 the forested area is 3,691,858 ha (Bogdanov and Tonchev 2011). While the results in the databases CLC1990 and CLC2000 indicated that forested areas were more than those in the official data, in 2006 according to the data of EFA these areas are with 150,011 ha (4.2 %) larger than these in the CLC2006

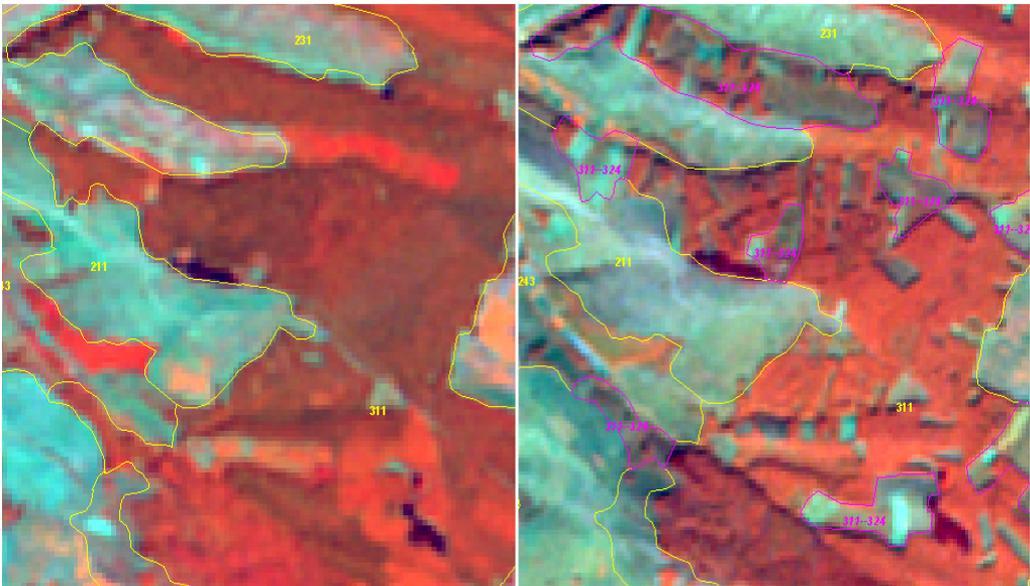


Fig. 1. Cut deciduous forests – change „3.1.1.-3.2.4.”

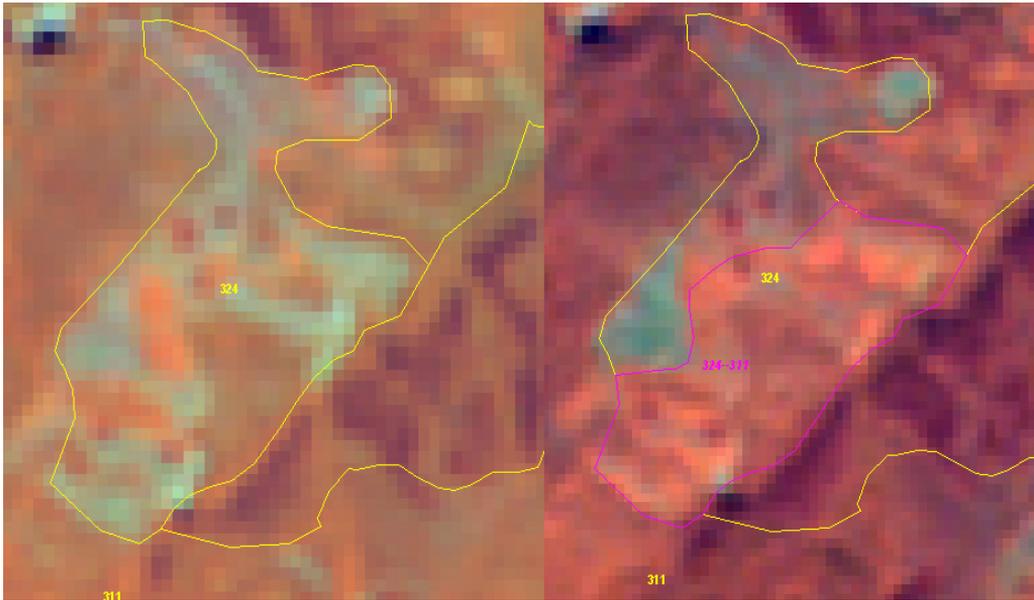


Fig. 2. Recovered deciduous forests – change „3.2.4.-3.1.1.”

database. The reasons are from one side the changed methodology of the project and the mapping of all changes with an area of over 5 ha, and on the other – the domination of the process of deforestation over this of afforestation as a result of the numerous illegal cuttings identified by computer interpretation and analysis of multitemporal satellite images.

### Changes occurred in the period 2006–2012

For the period of 6 years (2006–2012) 2,484 changes have been detected in the land cover of Bulgaria with a total area of 49,375.6 ha, which is 0.44 % of the mapped territory (Stoimenov 2014). More than half of them are in class „Forests and semi-natural areas”. They are mostly related with the two analysed

Table 3. Land cover classes in the database CLC2006 – Bulgaria.

| No | CLC code (level 3) | CLC class                   | Number of polygons | Area      |       |
|----|--------------------|-----------------------------|--------------------|-----------|-------|
|    |                    |                             |                    | ha        | %     |
| 1  | 3.1.1.             | Broad leaved forest         | 5,673              | 2,342,393 | 20.90 |
| 2  | 3.1.2.             | Coniferous forest           | 1,955              | 546,247   | 4.88  |
| 3  | 3.1.3.             | Mixed forest                | 4,117              | 653,207   | 5.83  |
| 4  | 3.2.2.             | Moors and heathlands        | 82                 | 26,620    | 0.24  |
| 5  | 3.2.4.             | Transitional woodland scrub | 7,986              | 730,756   | 6.52  |
| 6  | 3.3.4.             | Burnt areas                 | 2                  | 409       | 0.00  |

**Table 4. Changes in the 6 CLC classes (level 3) of the class „Forests and semi-natural areas” for the period 2006–2012.**

| Afforestation  |              |                 | Deforestation  |            |                |
|----------------|--------------|-----------------|----------------|------------|----------------|
| Type of change | Number       | Area, ha        | Type of change | Number     | Area, ha       |
| 3.1.1.-3.2.4.  | 1,067        | 14,317.2        | 3.2.4.-3.1.1.  | 183        | 4,312.7        |
| 3.1.2.-3.2.4.  | 138          | 3,726.7         | 3.2.4.-3.1.2.  | 1          | 7.6            |
| 3.1.3.-3.2.4.  | 136          | 2,444.3         | 3.2.4.-3.1.3.  | -          | -              |
| 3.1.1.-3.3.4.  | 2            | 15.0            | 3.3.4.-3.1.1.  | -          | -              |
| 3.1.2.-3.3.4.  | 4            | 68.9            | 3.3.4.-3.1.2.  | -          | -              |
| 3.1.3.-3.3.4.  | -            | -               | 3.3.4.-3.1.3.  | -          | -              |
| <b>TOTAL:</b>  | <b>1,347</b> | <b>20,572.1</b> | <b>TOTAL:</b>  | <b>184</b> | <b>4,320.3</b> |

processes on these areas. The process of deforestation encompasses 1,347 changes with a total area of 20,752.1 ha, which is 41.01 % of the total area of all the detected changes for the period. The scope of the afforestation process is considerably smaller – 183 changes with a total area of 4,320.3 ha, which is only 8.75 % of the area of all registered changes for the period. The process of deforestation dominates. As a result of the two processes the forested areas in the forest territories have decreased by 16,251.8 ha.

### Results from the project „Corine Land Cover 2012”

According to the annual report of the Executive Forest Agency (Anonymous 2013), at the end of 2012 the forest territories have a total area of 4,163,415 ha. The forested area is 3,795,338 ha, which is 91.15 % of the total area of the forest territories and 34.19 % of the territory of Bulgaria. The results from the „CORINE Land Cover 2012” project for the studied 6 types of land cover are summarized in Table 5. Forested areas are 3,531,711 ha or 31.42 % of the mapped territory. This area is with 263,596 ha smaller than it is according to

**Table 5. Land cover classes in the database CLC2012 – Bulgaria.**

| No | CLC code (level 3) | CLC class                   | Number of polygons | Area      |       |
|----|--------------------|-----------------------------|--------------------|-----------|-------|
|    |                    |                             |                    | ha        | %     |
| 1  | 3.1.1.             | Broad leaved forest         | 5,697              | 2,337,881 | 20.80 |
| 2  | 3.1.2.             | Coniferous forest           | 1,932              | 542,772   | 4.83  |
| 3  | 3.1.3.             | Mixed forest                | 4,112              | 651,058   | 5.79  |
| 4  | 3.2.2.             | Moors and heathlands        | 82                 | 26,738    | 0.24  |
| 5  | 3.2.4.             | Transitional woodland scrub | 8,079              | 741,423   | 6.60  |
| 6  | 3.3.4.             | Burnt areas                 | 3                  | 441       | 0.00  |

the data of the EFA for 2012. The difference is negligible again, and the main reasons are the same as those already mentioned for the previous stages of the Project.

Trends in the Development of Forested Areas Within the Forest Territories of Bulgaria from 1990 to 2012

The processes of deforestation and afforestation in the forest territories for the periods 1990–2000, 2000–2006, 2006–2012 and totally for the entire period 1990–2012 are summarized in Table 6. The number of polygons is shown

within the three types of forests according to the CLC nomenclature, as well as their area and percentage share in the total mapped territory. The ratio between the areas covered by the two processes can be seen in Fig. 3. The period in which the afforestation process dominates the process of deforestation is 1990–2000. In the period 2000–2006, forest destruction is in the largest scale. Figure 4 presents the balance of forested areas in the forest territories by periods. Out of the three forest classes only the class „confi-

**Table 6. Deforestation and afforestation in forested areas within the forest territories from 1990 to 2012.**

| Period                                | Deforestation                                 |        |          |       | Afforestation   |        |          |       | Balance for the period, ha |
|---------------------------------------|---|--------|----------|-------|-----------------|--------|----------|-------|----------------------------|
|                                       | Change  | Number | Area     |       | Change          | Number | Area     |       |                            |
|                                       |   |        | ha       | %     |                 |        | ha       | %     |                            |
| 1990–2000                             | 3.1.1. – 3.2.4.                               | 530    | 20,935.6 | 70.11 | 3.2.4. – 3.1.1. | 745    | 28,117.9 | 76.47 | +7,182.3                   |
|                                       | 3.1.2. – 3.2.4.                               | 77     | 5,288.0  | 17.71 | 3.2.4.–3.1.2.   | 42     | 1,212.7  | 3.30  | -4,075.3                   |
|                                       | 3.1.3. – 3.2.4.                               | 94     | 3,635.8  | 12.18 | 3.2.4.–3.1.3.   | 178    | 7,437.3  | 20.23 | +3,801.5                   |
|                                       | <b>Balance for the period 1990–2000</b>       |        |          |       |                 |        |          |       |                            |
| 2000–2006                             | 3.1.1. – 3.2.4.                               | 1,273  | 22,006.2 | 64.93 | 3.2.4.–3.1.1.   | 613    | 11,393.2 | 84.60 | -10,613.0                  |
|                                       | 3.1.2. – 3.2.4.                               | 236    | 7,414.3  | 21.88 | 3.2.4.–3.1.2.   | 25     | 514.4    | 3.82  | -6,899.9                   |
|                                       | 3.1.3. – 3.2.4.                               | 149    | 4,471.9  | 13.19 | 3.2.4.–3.1.3.   | 47     | 1,558.8  | 11.58 | -2,913.1                   |
|                                       | <b>Balance for the period 2000–2006</b>       |        |          |       |                 |        |          |       |                            |
| 2006–2012                             | 3.1.1. – 3.2.4.                               | 1,067  | 14,317.2 | 69.88 | 3.2.4.–3.1.1.   | 183    | 4,312.7  | 99.83 | -10,004.5                  |
|                                       | 3.1.2. – 3.2.4.                               | 138    | 3,726.7  | 18.19 | 3.2.4.–3.1.2.   | 1      | 7.6      | 0.17  | -3,719.1                   |
|                                       | 3.1.3. – 3.2.4.                               | 136    | 2,444.3  | 11.93 | 3.2.4.–3.1.3.   | 0      | 0        | 0     | -2,444.3                   |
|                                       | <b>Balance for the period 2006–2012</b>       |        |          |       |                 |        |          |       |                            |
| <b>Total for the period 1990–2012</b> | 3.1.1. – 3.2.4.                               | 2,870  | 57,259.0 | 67.98 | 3.2.4.–3.1.1.   | 1,541  | 43,823.8 | 80.33 | -13,435.2                  |
|                                       | 3.1.2. – 3.2.4.                               | 451    | 16,429.0 | 19.49 | 3.2.4.–3.1.2.   | 68     | 1,734.7  | 3.18  | -14,694.3                  |
|                                       | 3.1.3. – 3.2.4.                               | 379    | 10,552.0 | 12.53 | 3.2.4.–3.1.3.   | 225    | 8,996.1  | 16.49 | -1,555.9                   |
|                                       | <b>Total balance for the period 1990–2012</b> |        |          |       |                 |        |          |       |                            |

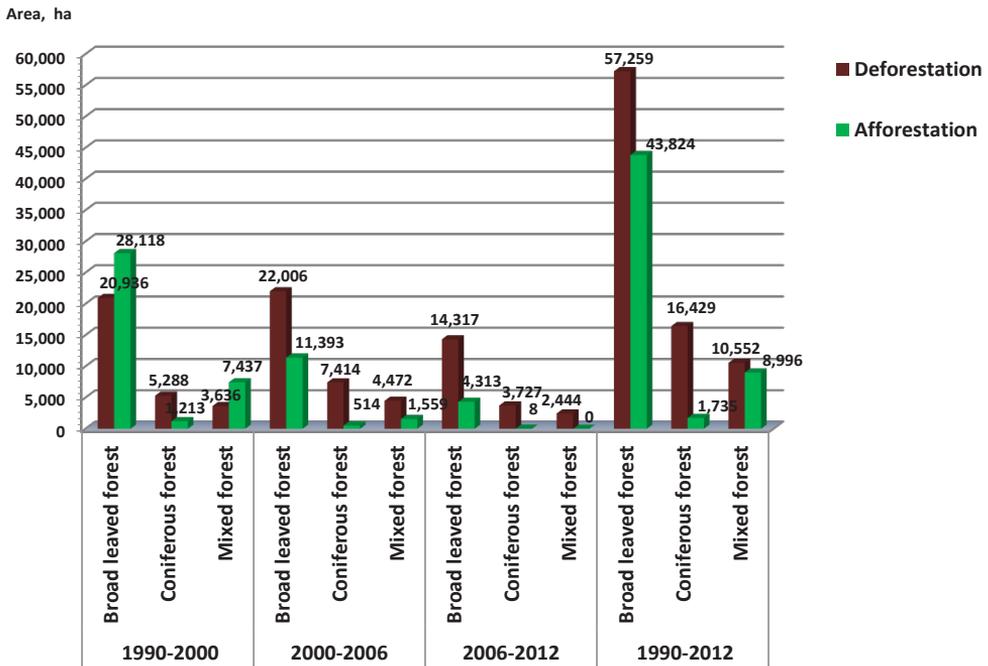


Fig. 3. Processes of deforestation and afforestation in the forest territories from 1990 to 2012.

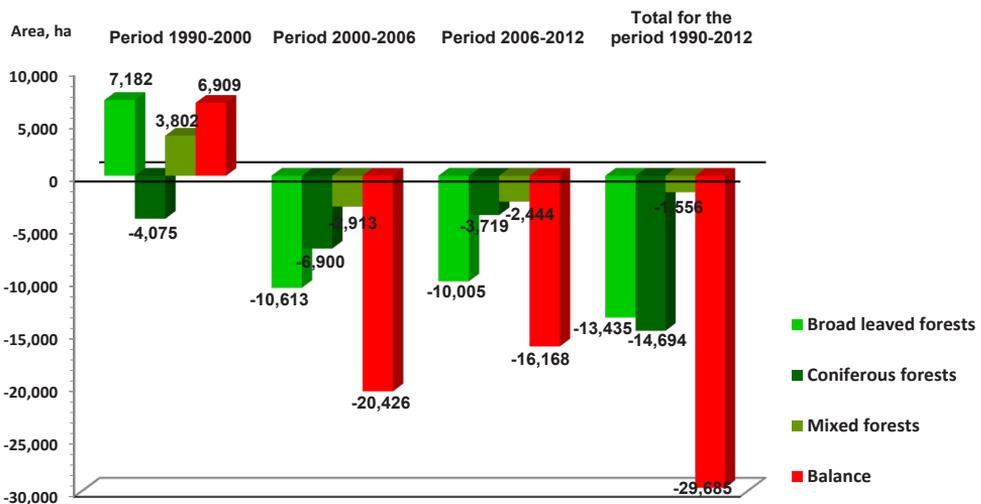
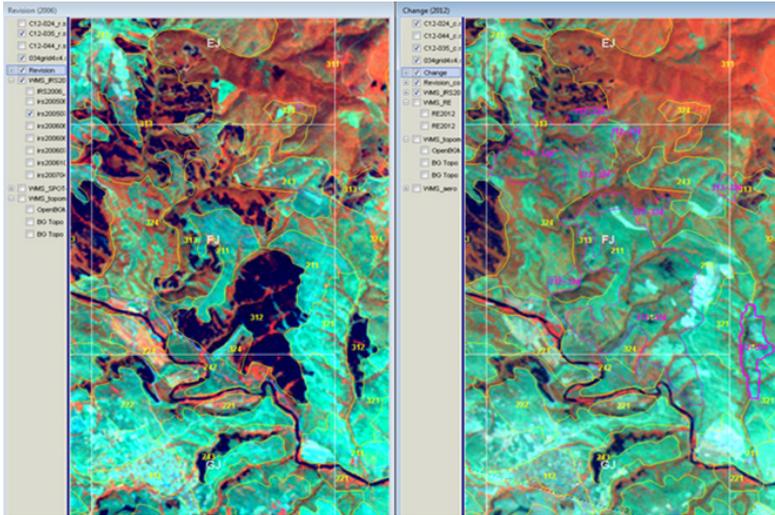


Fig. 4. Balance of wooded areas in the forest territories from 1990 to 2012.



**Fig. 5. Felled coniferous forests – 9 polygons „Change” with a total area of 591 ha.**

erous forests” has a negative balance for all three parts of the 22-year period. This is explained by the market situation and the high demand for large construction timber as well as with the lack of coppice regeneration in these forests and the reduced area of planted conifers. When analyzing these changes, cutting of large massifs of coniferous forests makes impression. Even in polygons, specified as „mixed forests” only coniferous trees are cut down. The examples which may be given are numerous. Figure 5 shows such changes from the project „Corine Land Cover 2012”. In the right window 9 polygons of changes „3.1.2. – 3.2.4.” are delineated (north of Tserovo, District Pazardjik) with a total area of 591 ha.

In deciduous forests deforestation is contributed by illegal logging near settlements carried out in search of firewood, intentional fires, charcoal production etc. For the period 1990–2012, the forested areas in the forest territories of Bulgaria

have decreased by 29,685.4 ha, which is 0.84 % of the total forested area in 1990. This is an alarming trend that after decades can redraw the map of the land cover types of Bulgaria.

It should be noted that a precise and fair comparison between those results and the official statistics of EFA, which is updated annually, is difficult to make. The reason

is that the data for each Forest Range are updated every 10 years, but not simultaneously for all ranges. These data are of varying degrees of actuality for the different forest ranges.

## Conclusions

The results of the computer assisted interpretation and the analysis of multitemporal satellite images within the EU project „CORINE Land Cover” allow an objective monitoring of the changes in the forest territories of Bulgaria. The analysis of these results leads to the following conclusions:

1. On the background of the increase of the total forested area in Europe, in Bulgaria for the 22-year period under consideration the process of deforestation predominates.

2. Although for the period 1990–2000 the balance is positive and afforestation dominates deforestation, under the

changed methodology of the project „CORINE Land Cover” and the identification of a large number of illegal cuttings for the period 2000–2012 the total balance is negative.

3. Out of the three forests classes only this of coniferous forests has a negative balance for all three parts of the 22-year period. This can be explained by the market situation and the high demand for large construction timber as well as with the lack of coppice regeneration in these forests and the reduced area of planted conifers.

4. In deciduous forests deforestation is contributed by:

- illegal logging near settlements carried out in search of firewood;
- intentional fires, since only the bark of deciduous trees is scorched but the quality of wood is not reduced;
- charcoal production, which leads to another harmful environmental effect – evolution of harmful emissions into the air etc.

5. In the afforestation process self-seeding has the largest share. This phenomenon (as it is in most of the European countries) in Bulgaria is most commonly seen over abandoned agricultural areas located close to forests.

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