ENHANCEMENT OF HIGH RESOLUTION LAYERS PRODUCED UNDER GMES – LAND MONITORING

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Abstract. The land monitoring data derived from satellite images for the 2006–2012 period provide information on land-cover changes in Romania. Availability and the quality of these data can contribute to new approaches of landscape assessment, for instance, in the context of environmental policies, the diversity of land use (patchiness) and surface as well, can show land dynamics in different regions, having in view that land cover reflects the biophysical state of the real landscape. In this paper, we present the results of the enhancement activity where we put an extra-work load aiming to have a more detailed thematic map that is missing in this country. These enhancements of the High-Resolution Layers (HRLs) products were derived from the service provider's products and in-situ data sets with a lot of manual editing. The products obtained are specifically for local-use and are different from those produced as part of contract obligation to the European Environmental Agency (EEA). HRLs are welcome products as no such recent thematic layers are available in Romania: e.g. a first wetland map of Romania, updated maps of forest and water bodies. This HRLs of 20 × 20 m pixel resolution may be of use in the monitoring of Natura 2000 sites, WFD, modelling projects, spatial planning, etc. The purpose is to show the usual omissions or discrimination of the sites and misclassification of Corine Land Cover classes. The overall area of misidentified land-cover changes in Romania between 2006–2012 was around 1.3% of their total area.

1. INTRODUCTION

High Resolution Layers (HRL) provide information on specific land-cover characteristics, and are complementary to land-cover or land-use mapping, such as in the CORINE land cover (CLC) datasets (Büttner and Kosztra, 2011). Within the Land monitoring service of the Global Monitoring of Environment and Security (GMES) – Initial Operation (GIO) the production of the 5 High Resolution pan-European layers by service providers started in 2011 under the coordination of the EEA. The National Focal Points and National Reference Centres Land Cover in 39 European countries has contributed to implementing GIO Land tasks including verification and enhancement process for the production of the five High Resolution Layers: Imperviousness (degree of imperviousness), Forest areas (tree-cover density and forest type), Agricultural areas (permanent grassland), Wetlands (wetland inventory), and Water bodies (permanent water bodies) (Langanke, 2016). Production of the HRLs of Romania was granted to the Danube Delta National Institute for Research & Development as National Reference Centre for Land Cover in Romania. General overview of data quality was done by intersecting the best in-situ data, e.g. LPIS data, city maps, versus HRL. Look-and-feel verification was done by visual inspection of the areas with potential classification errors. The verification was done in selected strata by comparing the HRL with the existing reference data in order to derive one of the five qualitative classes (excellent, good, acceptable, insufficient, very poor). Qualitative verification was done by strata. The 5 HRLs were checked for omission and commission errors. The risk of bias in

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direct area estimation from classified images is particularly strong if the targeted classes occupy a small proportion of the geographic area (Gallego *et al.*, 2016). For example: beaches and bare soil erroneously mapped as imperviousness; young wheat fields and young tree plantations erroneously mapped as permanent grassland; and permanent water bodies missing due to shadow effects in mountainous areas. Riparian areas appear heavily diminished compared to their potential extent, with figures varying regionally. Major losses can be attributed in the first place to historical agricultural land take, followed by extension of urban land use (Weissteiner *et al.*, 2016). We present a land-cover change detection methodology in the framework of the GMES. The generated data of high resolution layers cover 39 European countries with a total area of about 5 million square kilometers, scale 1:100,000. This makes use of the revised data layer and the Landsat ETM satellite images from 2012 for generation of the CLC 2016 data layer. The observed changes data layer is generated by the overlay of the HRLs data layers, from different years, with the change area of minimum 5 ha. This approach may overestimate and underestimate identified land-cover changes in some specific situations described in the paper. The results can be widely used in land management, nature conservation and water management.

2. MATERIALS AND METHODS

A high-resolution dataset of five high resolution layers (HRL) of 5 main land cover types: 1) The high-resolution **imperviousness** dataset representing all artificially sealed areas produced using automatic derivation based on calibrated normalized difference vegetation index (NDVI) 5; 2) The **tree cover density** and **canopy type**; 3) Permanent grassland; 4) Wetlands and 5) permanent water bodies. The maps were produced by the service providers using the semi-automatic image classification of the year 2012, 20m × 20m pixel resolution and in national projection system, Pulkovo 1942(58) / Stereo70, EPSG 3844.

The verification of the data was made by the national team. The verification method (György Büttner, 2012) of the high-resolution data consists of three parts: (I) General overview of data quality, (II) Checking “error prone” locations in each HRL by means of look-and-feel control and (III) Applying an additional, statistically-based quantitative verification by using randomly selected samples to estimate commission and omission errors.

Verification was made on the intermediate products at full resolution (20m x 20m, in national projection).

In-situ data include the topographic map of Romania, scale 1:25,000 (Resource Locator: http://geoportal.ancpi.ro/geoportal/catalog/search/search.), Land Cover TOPRO5, scale 1:5,000, Object class "CATEREN", of polygon type includes agricultural and non-agricultural land, water bodies, and forest, vineyard, pasture, etc. (Resource Locator: http://geoportal.ancpi.ro/ geoportal/catalog/search/search.), Ortho-photo plans of Romania in 2006, (Resource Locator: http://mmediu.ro/new/?page_id=1175), Forest Inventory, Up-dated forest database, (Resource Locator: http://geoportal.ancpi.ro/geoportal/catalog/search/search.page), National grassland inventories, scale 1:50,000, Grassland-type map covering 650,000 ha (Resource Locator: http://ddni.ro/nardus/),DEM, (Resource Locator: http://geoportal.ancpi.ro/geoportal/catalog/ search/search.page), Hydrographical Map of Romania, scale 1:50,000, The Digital Map of rivers and catchment river basins (ID between 1 and 6 for permanent courses), including also natural and anthropic lakes in Romania (Resource Locator: http://www.inhga.ro/) City maps, (Resource Locator: http://geoportal.ancpi.ro/geoportal/catalog/search/search.page), LUCAS database and photos, (Resource Locator: http://www.insse.ro/cms/), Agricultural statistics (LPIS), (Resource Locator: http://geoportal.ancpi.ro/geoportal/catalog/search/search.page) National land-cover inventories,

(Resource Locator: http://www.ddni.ro/index.php?page_id=404&siteSection=5&sectionTitle=International%20Projects).

For the enhancement task, the data content was improved on the basis of the findings of the verification task. All enhancements were done for the full resolution datasets (20 m x 20 m, in national projection). In-situ data were used to support the enhancement process. The methodology of enhancement was semi-automatic with lots of manual editing. Enhancement was done for all HRLs, excepting the grassland layer, as verification conclusion drive to an overall insufficient classification.

The verification methods used to guide the enhancement were: general overview of data quality, look-and-feel analysis and statistical verification. The methodology of enhancement was Semi-automatic with lots of manual editing. For the removal of commission errors, all-country omission errors have been checked.

3. RESULTS

3.1. Enhancement of Water bodies HRL

Regarding commission errors, **w**e have found 6,978 ha of Black Sea water classified as water bodies (ALL ROMANIAN Black Sea shore); 307 situations of building areas (greenhouses, industrial, urban areas) classified as water body; 32 commission errors for lakes in mining areas; 24,417 ha of temporary water-logged areas from the 2006 flood events, while for omission errors we found 89 from 307 omissions for high-altitude lakes (all lakes from the Făgăraş and Retezat mountains, Fig. 1) 33 from 1,300 omissions for small lowland lakes < 25 ha and > 0.16 ha; 8 from 280 omissions for lakes in mining areas; 11 from 280 omissions for lakes in recreation areas; 43 from 1,600 omissions for fishponds.

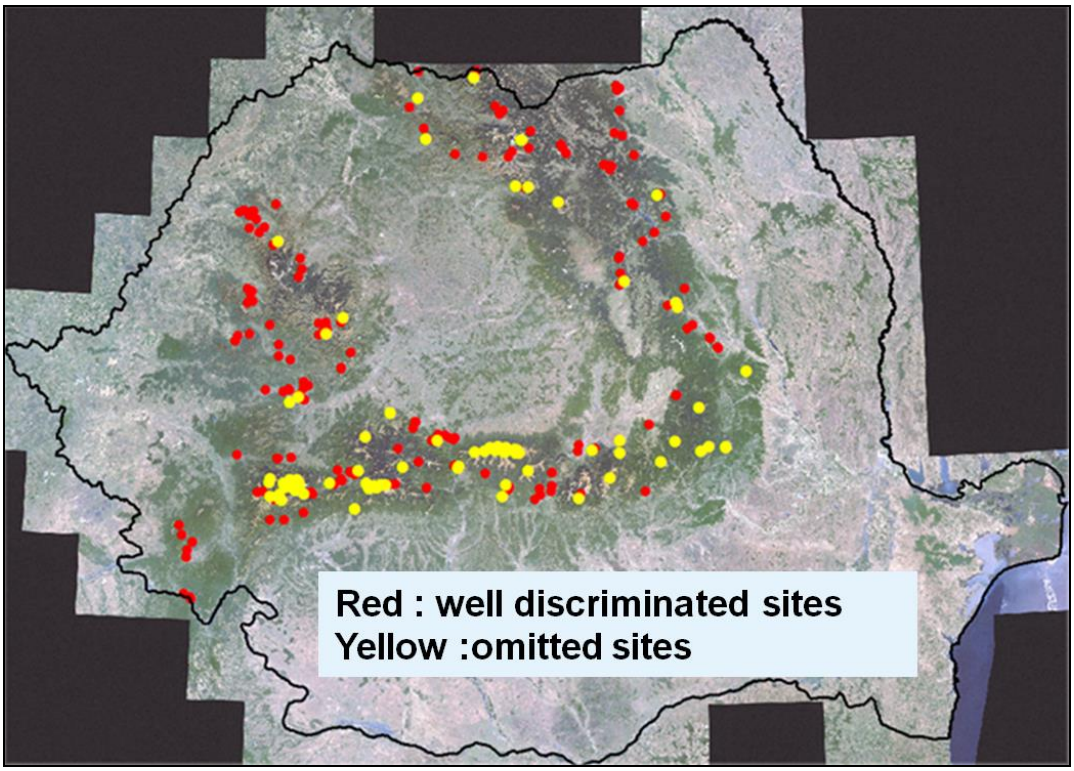

Fig. 1 – Water bodies ommision lake errors.

3.2. Enhancement of Wetlands HRL

In the analyses of commission errors for the enhancement of the wetland layer, we have found 6,631 commission errors for dry areas, such as forest, pastures, agriculture and 813 commission errors for dry areas, such as urban and industrial areas.

Regarding the removal of omission errors (Fig. 2) we found 2,824 omissions for wetlands associated to permanent water bodies and 854 omissions for wetlands with vegetation (macrophyte).

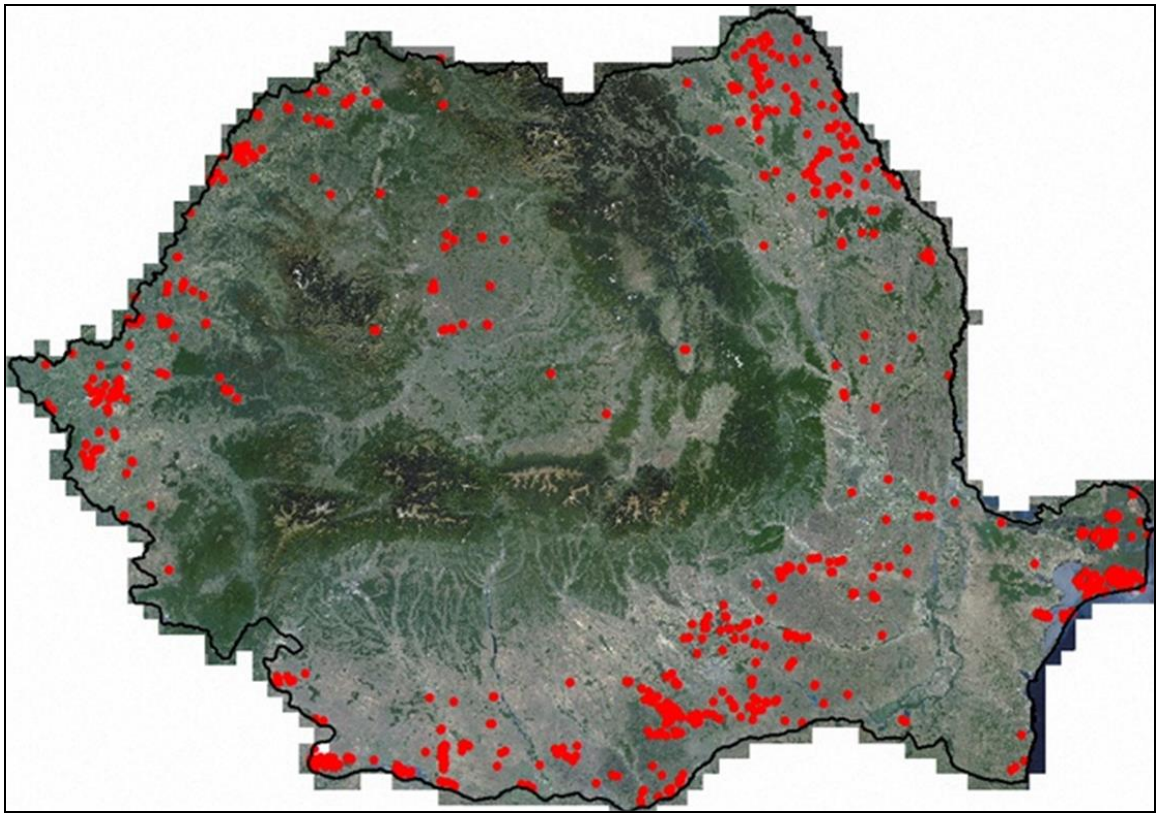

Fig. 2 – Wetlands ommision lake errors.

3.3. Enhancement Imperviousness Density

The results of the enhancement of the imperviousness density layer show that 1,497 commission polygons have been found counting a total area of 3,860 ha (Fig. 3). A description of the commission errors type is presented in Table 1.

Table 1

Misclassification of CLC classes as built up areas

CLC class	No. poly	S(ha)	%poly	%ha
511, 512	324	1,392.76	21.64%	36.08%
122	509	1,417.52	34.00%	36.72%
131, 132, 133	136	559.68	9.08%	14.50%
211	65	57.6	4.34%	1.49%
112, 121, 141, 142	267	215.52	17.84%	5.58%
322, 323, 332, 333	196	217.12	13.09%	5.62%

Regarding the removal of omission errors (Fig. 3), 4,294 omission polygons have been found summing an area of 3,495 ha. A description of the omission errors type is presented in Table 2.

Table 2

CLC classes as built up areas

CLC	No. poly	S(ha)	%poly	%ha
112	3,880	1,680.23	90.36%	48.08%
122 (railway stations)	14	235.49	0.33%	6.74%
122 (major roads)	400	1,578.82	9.32%	45.18%

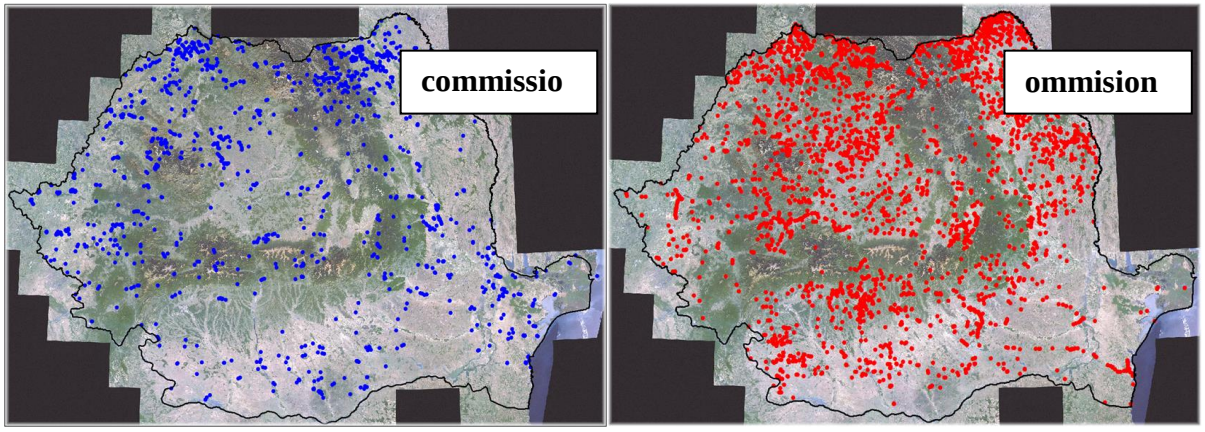

Fig. 3 – Imperviousness Density errors.

3.4. Enhancement forest DENSITY MAP

During enhancement of forest DENSITY MAP, 1,564 commission polygons have been found with an area of 27,145 ha. In the process of removal of omission errors (Fig. 4) 1,855 omission polygons have been found with an area of 4540 ha. Class C254 (meaning no data) has been replaced by real forest digitizing 715,111 ha in total (101 = 454,754 ha, 102 = 260,357 ha).

3.5. Enhancement of FOREST TYPE

During the removal of commission errors we found 17,671 ha of dwarf mountain pine shrubs, 322 class, classified as forest, Fig. 5). A total of 2,164 commission polygons have been found with an area of 26,183 ha (817 ha are from the additional intermediate layer). In the process of removal of omission we found 1,919 omission polygons, summing an area of 4,750 ha (19 polygons with 31 ha are from the additional intermediate layer). The class C254 has been replaced by real forest digitizing, 715,111 ha in total (101 = 454,754 ha, 102 = 260,357 ha.

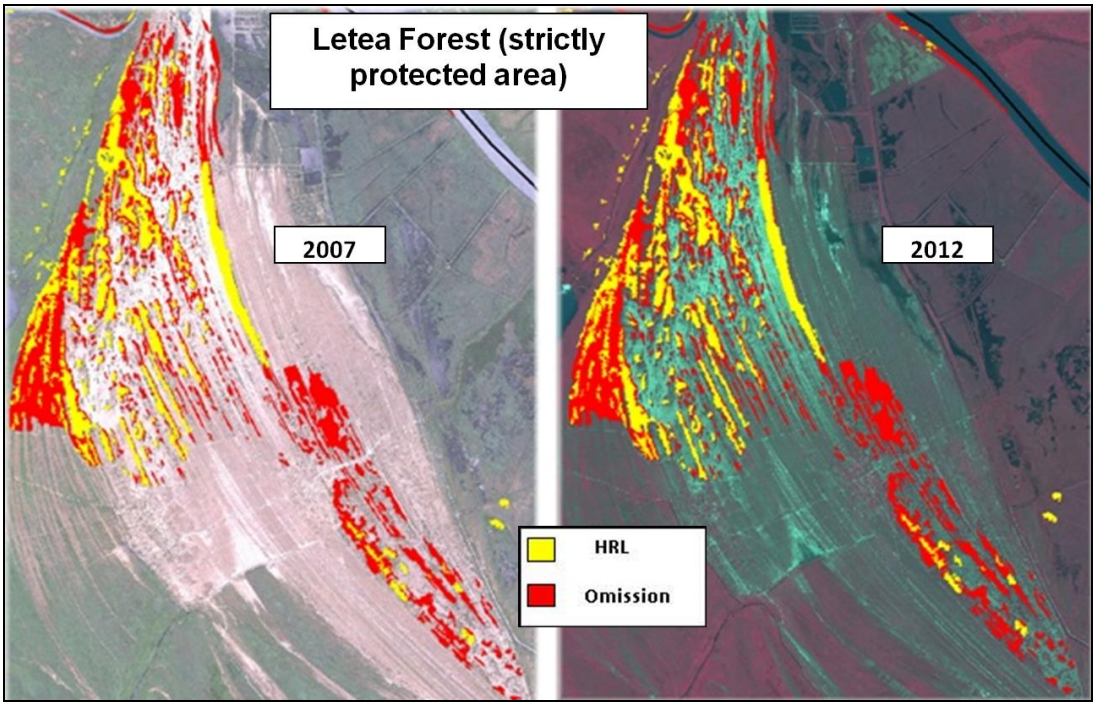

Fig. 4 – Forest density ommision errors.

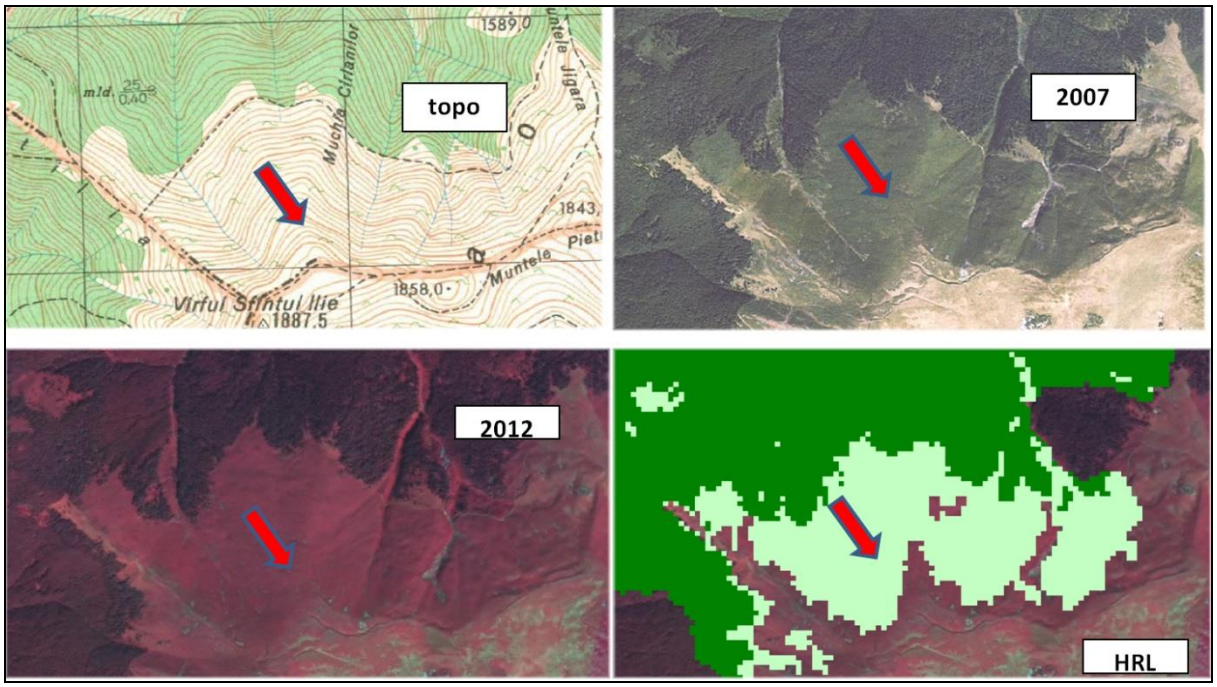

Fig. 5 – Forest commission errors.

4. CONCLUSIONS

Production of five high-resolution layers as artificial surfaces, forest areas, agricultural areas, wetlands and water bodies at pixel level and validated at 1 ha grid cell are of high interest for Romania since such integrated layers are not yet available for the country from other sources. Therefore, we have paid a special attention to and effort for enhancement of Copernicus HRLs in view of using them in potential future projects, e.g.: better delineation of Natura 2000 sites, grassland inventory, etc.

The most remarkable omissions/discriminations identified in Romania were observed in arable land (complex cultivation pattern), forests and wetland classes.

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BIBLIOGRAPHY

Büttner, G., Kosztra, B. (2007), *CLC2006 Technical Guidelines (with 6 annexes)*, EEA, Technical Report **17**/2007, http://www.eea.europa.eu/publications/technical_report_2007_17 Technical Guidelines (general overview on change mapping).

Büttner G., Kosztra, B. (2011), *Manual of CORINE Land Cover changes*, European Environment Agency, 154 p.

Büttner, G. (2012), *Guidelines for verification and enhancement of high-resolution layers produced under GMES initial operations (GIO)*, Land monitoring 2011 – 2013, EEA.

Büttner, G., Soukup, T., Kosztra, B. (2012), *Addendum to CLC2006 Technical Guidelines* – Final Draft – 14.08.2014 V2.

Gallego, J., Sannier, Ch., Pennec, Al., Dufourmont, H. (2016), *Validation of Copernicus Land Monitoring Services and Area Estimation*, Seventh International Conference on Agricultural Statistics, Rome.

Langanke, T. (2016), *GIO land (GMES/Copernicus initial operations land) High Resolution Layers (HRLs) – summary of product specifications*, GIO land team at the EEA, GMES/Copernicus Initial Operations Land Monitoring 2011–2013.

Pataki, R. (2008), *A macro program for generating CLC2006 from CLC2000* and Pataki, R. (2008), A macro program for generating CLC2006 from CLC2000 and CLC-Changes Description of a free Arc/Info programme to produce the new stock layer from the old stack layer and the change layer.

Weissteiner, Christof J., Martin Ickerott, Hannes Ott, Markus Probeck, Gernot Ramminger, Nicola Clerici 3, Hans Dufourmont 4 and Ana Maria Ribeiro de Sousa (2016), Europe's Green Arteries – A Continental Dataset of Riparian Zones, Remote Sens. 2016, 8, 925; doi:10.3390/rs8110925, pp. 1–27.

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