Bulgarian Academy of Sciences. Space Research and Technology Institute.
Aerospace Research in Bulgaria. 27, 2015, Sofia

# LAND-USE/LAND-COVER CHANGE OF BISTRISHKO BRANISHTE BIOSPHERE RESERVE USING SENTINEL-2 SIMULATED DATA

***Lachezar Filchev***

*Space Research and Technology Institute – Bulgarian Academy of Sciences*
*e-mail: lachezarhf@space.bas.bg*

***Abstract***

*The aim of this study is the evaluation of changes in land-use/land-cover on the territory of Bistrishko Branishte biosphere reserve (UNESCO, MAB), Vitosha; with the use of simulated Sentinel-2 data. For this purpose the CHRIS/PROBA image acquired on 22 June 2012, and on 28 September 2012 are geometrically and atmospheric corrected and co-registered. The topographic normalization is applied to the second image due to shadows cast on the slopes of the Valley of the river Bistrica. In order to simulate the Sentinel-2 bands, the spectral channels of the CHRIS/PROBA are spectraly resampled to spectral width of the Sentinel-2 bands. The spatial resampling of the Sentinel-2 bands is done using a Landsat 7 ETM + panhromatic band (15 m). On the classification of land-use/land-cover an accuracy assessment and cross-validation is made by using ground-based data. The results show that between 60 ha and 72 ha of coniferous plants were devastated by a forest fire in 2012. the results obtained demonstrate the ability of the Sentinel-2 mission to detect sudden changes in land-use/land-cover caused by forest fires.*

## 1. Introduction

In recent decades the Land-Use and Land-Cover (LU/LC) change detection is used as one of the main tools to detect changes of Earth surface. With the advancement of preparation of *Sentinel-2* mission within the COPERNICUS Programme the LU/LC will become even more important tool to get insight of the changes that take place in Europe (Copernicus – observing the world, 2014). The protected forests in Europe are 39 million ha (nearly 19 %) (FOREST EUROPE, 2011) and *Bistrishko Branishte* biosphere reserve is part of them. Its protected area was designated to preserve a high-value Norway spruce (*Picea abies L.*) forests.

Present study aims at revealing LU/LC change of *Bistrishko Branishte* biosphere reserve using simulated *Sentinel-2* high-resolution satellite data. The time frame of the study is June – September 2012. During this period a significant change in the biosphere reserve's LU/LC took place due to a wildfire (Filchev and Dimitrov, 2013; Filchev *et al*. 2014).

### *1.1. Study area*

The *Bistrishko Branishte* biosphere reserve was included in the UNESCO Man And Biosphere (MAB) Programme in 1977. It is located in the upper *Bistrica* river basin in the *Vitosha* Mountain between 1430 and 2282 m a.s.l. The designated protected area is 1061.6 ha (Georgiev, 1995), and according to official statistics 52 % of the reserve is occupied by forests, while the rest is covered with sub-alpine meadows, rocks, and rock screes. The dominant tree species is Norway spruce (*Picea abies L.*), represented by 7 forms and varieties. By 2010 > 27 % (~300 ha) of the reserve's territory was devastated by a tornado which occurred on 22 May 2001 (Gikov and Pironkova, 2005) and the successive European spruce bark beetle (*Ips typographus*) infestation (Filchev, 2012; Filchev *et al*. 2013; Panayotov *et al*., 2011; Panayotov and Georgiev, 2012). Following a wildfire in 2012 part of the dead tree stands (i.e. between 0.60 $km^2$ and 0.72 $km^2$) were burned (Filchev, 2012; Filchev *et al*. 2013, Filchev and Dimitrov, 2013; Gikov and Dimitrov, 2013; Panayotov and Georgiev, 2012; EUFODOS Newsletter, 2013).

## 2. Materials and methods

### *2.1. Data*

The data used in this study consists of: 1) raster data: two Landsat 7 ETM+ and two CHRIS/PROBA Mode 1 images, a subset from ASTER GDEM V. 2; 2) vector data: a boundary (shape-file) of the *Bistrishko Branishte* biosphere reserve. Software used: BEAM VISAT (Brockmann Consult & ESA under GNU license), ArcGIS/ArcInfo 9.2 (ESRI Inc. under Academic License), ENVI 4.7 (Exelis ITT VIS under Academic License). The methodology of this study is presented on a flowchart (Fig. 1).

### *2.2. Sentinel-2 simulation procedure*

Prior to simulation of *Sentinel-2* from CHRIS/PROBA a higher Spatial Resolution (SR) image was required to resample the original CHRIS/PROBA bands to the *Sentinel-2*'s SR. The *Sentinel-2* sensor will acquire its images in three SR modes, i.e. 10 m, 20 m, and 60 m (Fletcher, 2012). For this purpose two Landsat 7 ETM+ images, acquired on closer dates to CHRIS/PROBA acquisitions – i.e. before and after the wildfire, were selected from USGS LP DAAC online archive, (Table 1). The dates were selected to be as close as possible due to seasonal changes which effects on vegetation in the high-mountainous area. The image values of panchromatic band № 8 (15 m SR) of Landsat 7 ETM+, were converted from digital numbers (DN) to reflectance using the build in correction parameters in the metadata files (.MTL). Atmospheric correction was applied using the QUick Atmospheric Correction (QUAC) algorithm in ENVI (ENVI Atmospheric Correction Module, 2009).

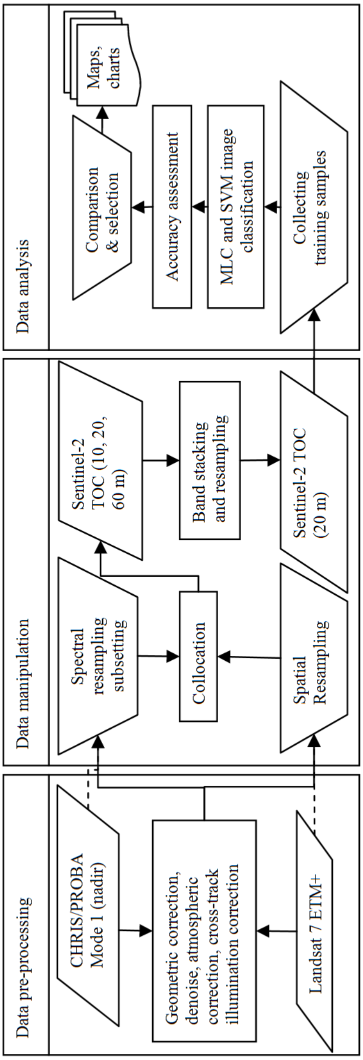


*Fig. 1. Workflow of the study*

*Table 1. Dates of acquisition and ID of the Landsat 7 ETM+ and CHRIS/PROBA images used for simulation of the Sentinel-2 images*

| Landsat 7 ETM+ \| Image ID(date) | CHRIS/PROBA Mode 1 \| Image ID(date) |
|---|---|
| LE71840302012181ASN00 (29 June 2012) (PAN) | CHRIS_HQ_120622_E48E_41 (22 June 2012) |
| LE71840302012245ASN00 (1 September 2012) (PAN) | CHRIS_HQ_120928_EA88_41 (28 September 2012) |

The first CHRIS/PROBA Mode 1 (CHRIS_HQ_120622_E48E_41_c) image used for *Sentinel-2* simulation was acquired on 22 June 2012, i.e. before the wildfire in the reserve. In present study it is used only the nadir image from the five image stack. The second post-fire CHRIS/PROBA Mode 1 image used in the analysis (CHRIS_HQ_120928_EA88_41) was acquired in nadir on 28 September 2012. Both images were spectrally resampled in ENVI 4.7 (Academic license) using the following band information, Table 2 (Law and Nichol, 2004; Drusch *et al*. 2012). The CHRIS/PROBA spectral coverage is not as wide as the one of *Sentinel-2*. Thus, only those *Sentinel-2* bands which correspond to the CHRIS/PROBA's bands in Mode 1 were simulated.

*Table 2. Spectral characteristics of Sentinel-2 simulated bands. After Law and Nichol, (2004) and Drusch et al. (2012) with modifications*

| *Sentinel-2'* bands | Central wavelength λ (nm) | FWHM* (nm) |
|---|---|---|
| 1 | 443 | 20 |
| 2 | 490 | 65 |
| 3 | 560 | 35 |
| 4 | 665 | 30 |
| 5 | 705 | 15 |
| 6 | 740 | 15 |
| 7 | 783 | 20 |
| 8 | 842 | 115 |
| 8b | 865 | 20 |
| 9 | 945 | 20 |

*Full width at half maximum (FWHM)

The image was subsequently corrected for topography using Minnaert topography correction algorithm implemented in SAGA GIS (Verrelst *et al*. 2010). The so-formed bands were spectrally subset from the *Sentinel-2* simulated image (inheriting from CHRIS/PROBA the 30 m SR) in order to provide an input for simulation of 10, 20, and 60 m SR *Sentinel-2* bands. The spectral subsets are: 1) 2, 3, 4, and 8 bands (10 m SR); 2) 5, 6, 7, and 9 (natively the 8b *Sentinel-2* band) band (20 m SR); 3) 1 and 10 band (60 m SR) (Law and Nichol, 2004). Then the high resolution (15 m SR) panchromatic Landsat 7 ETM+ bands were degraded to 20 m SR. The next step in the simulation approach was collocating the Landsat 7 ETM+ spatially degraded panchromatic band to 20 m SR with the spectral subsets from *Sentinel-2* simulated images before and after the wildfire, using BEAM-VISAT 'Collocate' procedure. Three Top Of Canopy (TOC) (atmospherically corrected) *Sentinel-2* simulated images at three different SR (10 m, 20 m, and 60 m) were simulated for both dates. Finally, before image classification the simulated *Sentinel-2* bands were all stacked and spatially resampled to 20 m SR using Cubic Convolution (CC) algorithm.

### *2.3. Image classifications*

On the stacked high-resolution (20 m SR) *Sentinel-2* TOC simulated image a supervised Maximum Likelihood Classification (MLC) and Support Vector Machines (SVM) image classifications were performed. The accuracy of the classification outputs were assessed after using a stratified random sampling (seed proportionally – 10 % to the class weigh). Finally, the areas estimated after the best performing classification algorithm were compared to each other.

### 3. Results and Discussions

The false colour composites of *Sentinel-2* TOC simulated images (20 m SR) from both dates are presented on (Fig. 2).

The major challenge in performing an image classification on the *Sentinel-2* simulated images was the difference in illumination conditions of two CHRIS/PROBA scenes due to the seasonal changes (Fig. 2). Those difference were persistent even after performing a topographic correction on the images which later on imposed on adding to the LU/LC classification scheme an additional LU/LC class 'Shadows'. The quality of the second image was additionally deteriorated due to an airplane trail, which crossed just above the burnt area. The classification scheme for LU/LC classification is based on expert knowledge for the distinctive LU/LC classes on both images. The spectrally discriminated classes in present study are: 1) for first-date *Sentinel-2* simulated image: 'Urban area', 'Rock screes', 'Grassland', 'Bushes', 'Broadleaf forest', 'Coniferous forest', and 'Unclassified'. The latter LU/LC class is practically void because no probability threshold was applied to either MLC or SVM and images were completely classified. This was done intentionally in order to assess whether the *Sentinel-2* spectral bands are providing enough information to discriminate between those classes; 2) for the second-date *Sentinel-2* simulated image some additional classes were introduced due to different image spatial coverage and the wildfire occurred in the nature reserve: 'Water bodies', 'Fire scar', and 'Shadows'. The results from the LU/LC classifications differed significantly in their accuracies and barely reached 80 % accuracy. The worst performing LU/LC classification outputs were discarded in the subsequent analysis. On (Fig. 3) are presented the most accurate results for *Sentinel-2* image classification. The visual comparison, between 22 June 2012 and 28 September 2012 image classification results, bring some interesting insights to the seasonal changes and the changes in LU/LC caused by the wildfire in July 2012. Firstly, the 'Shadows' class is introduced in the LU/LC classification due to the high extent of shadows casted on the slopes of Bistrica river valley. The presence of this class is explained with the changed solar zenith angle due to the autumn season. The applied atmospheric and topographic corrections gave little visible effect which also reflected the introduction of the new 'Shadows' class. The thematic accuracy of classification of the 'Fire scar' class was also lessened due to the fact that the fire scar falls almost completely in the 'Shadow' class, see Fig. 2d and Fig. 3, image 2. Another complication was the presence of an airplane trail, which trespasses exactly over the burned up area as well as the atmospheric haze which was abnormal for this day, Fig. 2c. Furthermore, the extension of the 'Rock screes' class in expense of 'Bushes' and 'Grassland' classes are due to the seasonal changes of insulation and the drying out grass from mountain meadows which either uncover the rock screes in some places or become spectrally similar with the rocks.

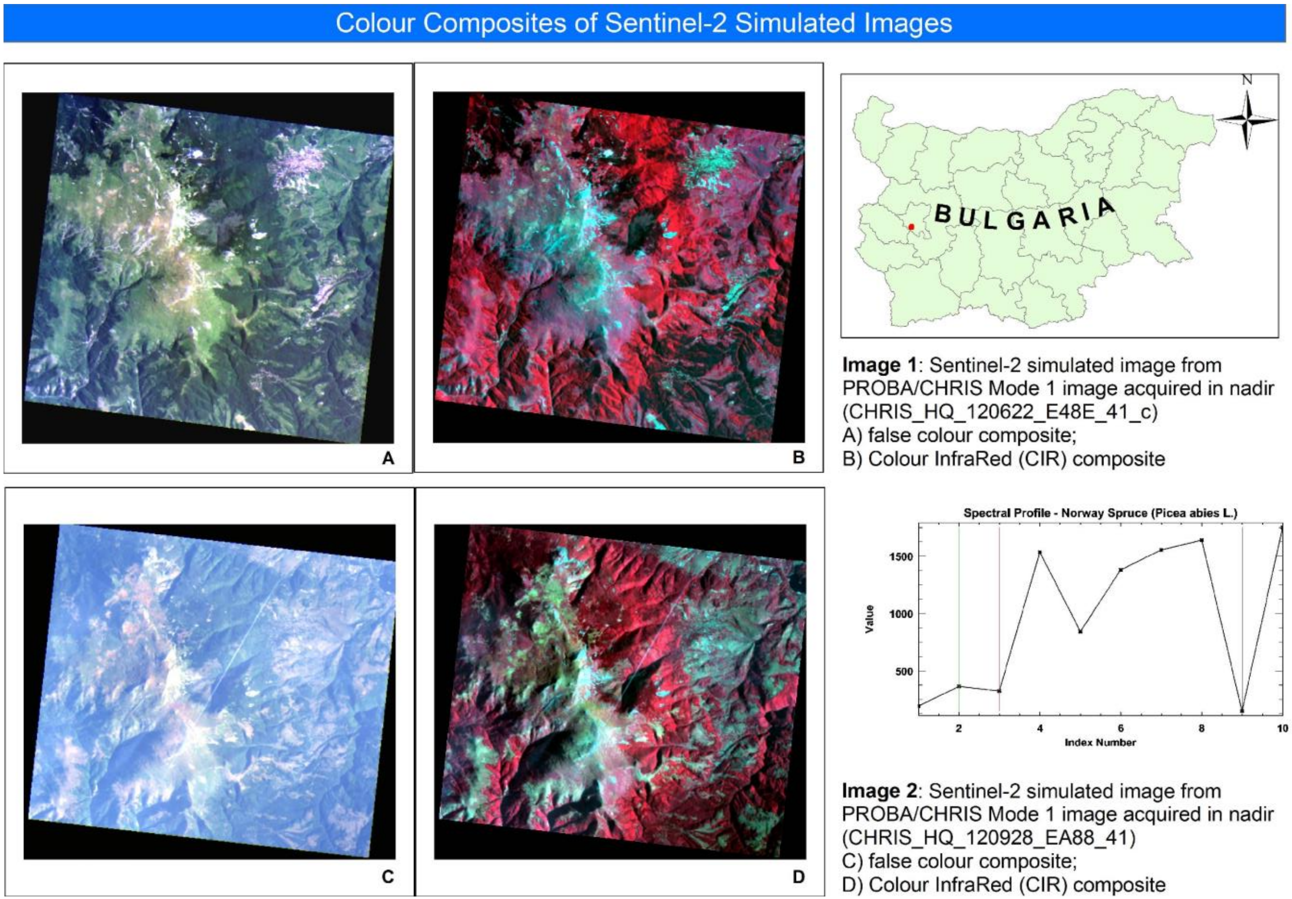


*Fig. 2. Colour composites of Sentinel-2 TOC simulated images (20 m SR). A) and B) false-colour composites of Sentinel-2 TOC (22 June 2012); C) and D) false-colour composites of Sentinel-2 TOC (28 September 2012)*

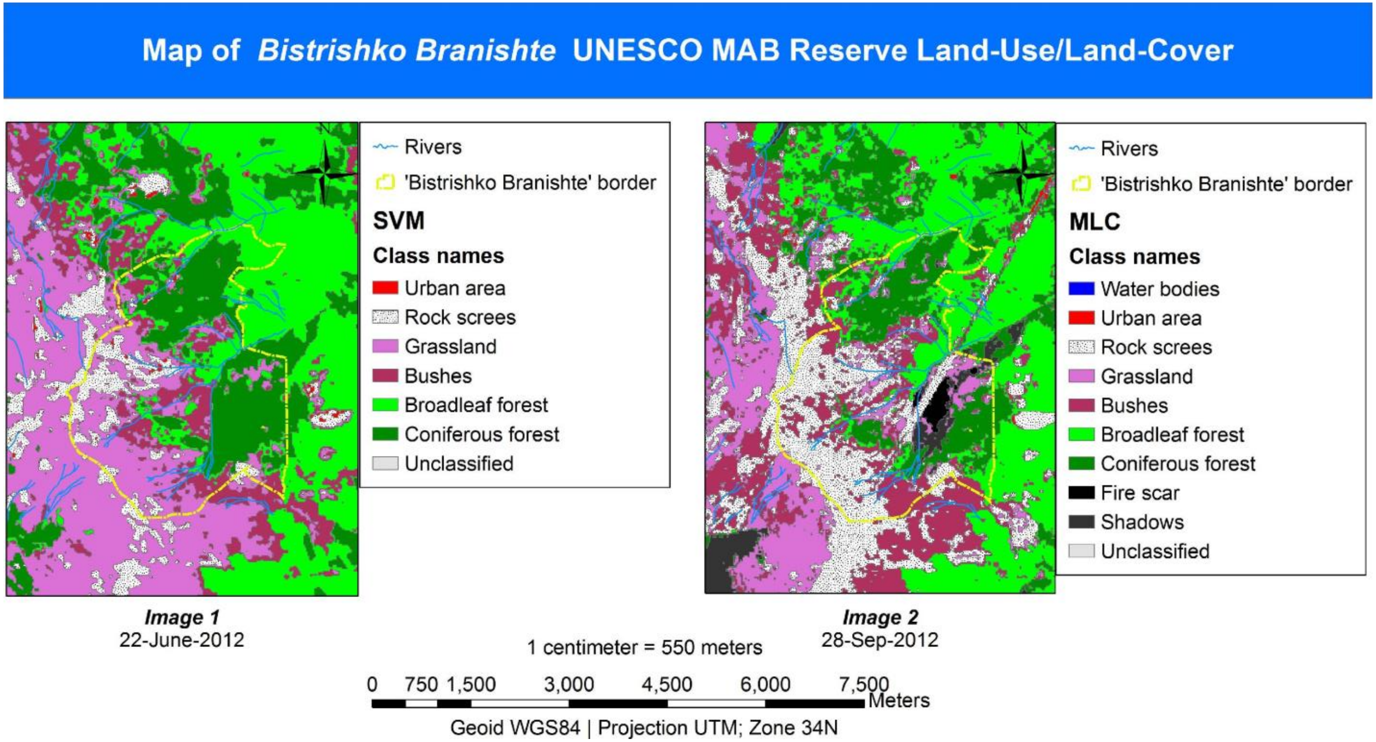


*Fig. 3. LU/LC maps of Bistrishko Branishte UNESCO MAB reserve, prepared from the Sentinel-2 TOC simulated images*

*Table 3. Accuracy assessment of SVM LU/LC classification performed on Sentinel-2 TOC simulated image (22 June 2012) (in percentage)*

| LU/LC Class | Rock screes | Broadleaf forest | Grassland | Coniferous forest | Urban area | Bushes | Total |
|---|---|---|---|---|---|---|---|
| Rock screes | 45.61 | 0 | 1.91 | 0 | 36.11 | 0 | 8.08 |
| Broadleaf | 0 | 98.31 | 1.27 | 22.22 | 0 | 5.88 | 28.65 |
| Grassland | 10.53 | 0 | 79.62 | 0 | 0 | 23.53 | 25.96 |
| Coniferous | 5.26 | 0 | 0 | 77.78 | 0 | 0 | 20.77 |
| Urban area | 38.6 | 1.69 | 0.64 | 0 | 63.89 | 0 | 9.23 |
| Bushes | 0 | 0 | 16.56 | 0 | 0 | 70.59 | 7.31 |
| Total | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

*Table 4. Accuracy assessment (omission and commission) of SVM LU/LC classification performed on Sentinel-2 TOC simulated image (22 June 2012) (cont.)*

| LU/LC class | Commission (Percent) | Omission (Percent) | Commission (Pixels) | Omission (Pixels) | Prod. Acc. (Percent) | User Acc. (Percent) | Prod. Acc. (Pixels) |
|---|---|---|---|---|---|---|---|
| Rock screes | 38.1 | 54.39 | 16/42 | 31/57 | 45.61 | 61.9 | 26/57 |
| Broadleaf forest | 22.15 | 1.69 | 33/149 | 2/118 | 98.31 | 77.85 | 116/118 |
| Grassland | 7.41 | 20.38 | 10/135 | 32/157 | 79.62 | 92.59 | 125/157 |
| Coniferous forest | 2.78 | 22.22 | 3/108 | 30/135 | 77.78 | 97.22 | 105/135 |
| Urban area | 52.08 | 36.11 | 25/48 | 13/36 | 63.89 | 47.92 | 23/36 |
| Bushes | 68.42 | 29.41 | 26/38 | 5/17 | 70.59 | 31.58 | 12/17 |

The highest producer's accuracy features the 'Broadleaf forest' class, while the highest user's accuracy has 'Coniferous forest' and 'Grassland' classes. The 'Urban areas' class is largely misclassified with 'Rock screes' due to the spectral similarity of the materials used in urbanized areas with rocks. The results from for MLC LU/LC classification (after wildfire) are presented on Table 5 and Table 6. The overall accuracy of MLC is 76.98 %, which is well below for routine LU/LC mapping purposes (Kappa 0.7293). It could be inferred, that the highest user's accuracy has the 'Urban areas' class followed by 'Broadleaf forest', and 'Coniferous forest' class. Conversely, the highest producer's accuracy have in descending order 'Broadleaf forest', 'Bushes', 'Coniferous forest', and 'Urban areas' classes. This discrepancy is explained with the differences between ground-truth data and the classification output. Finally, the classification outputs were updated using on-screen digitizing to avoid the airplane trail. The mapped area is found to be close to formerly published estimates of the burnt area (Filchev, 2012; Filchev *et al*. 2013, Filchev and Dimitrov, 2013; Gikov and Dimitrov, 2013; Panayotov and Georgiev, 2012; EUFODOS Newsletter, 2013).

*Table 5. Accuracy assessment of MLC LU/LC classification performed on Sentinel-2 TOC simulated image (28 September 2012) (in percentage)*

| LU/LC Class | Unclassified | Grasslands | Rock screes | Urban areas | Fire scar | Water bodies | Shadows | Bushes | Broadleaf forest | Coniferous forest | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Unclassified | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Grasslands | 0 | 83.51 | 38.16 | 11.86 | 7.69 | 0 | 4.08 | 10.91 | 0 | 0 | 20.42 |
| Rock screes | 62.5 | 1.03 | 56.58 | 8.47 | 0 | 18.18 | 0 | 0 | 0.86 | 0.75 | 9.4 |
| Urban areas | 0 | 4.12 | 0 | 74.58 | 0 | 0 | 0 | 0 | 0 | 0 | 7.78 |
| Fire scar | 0 | 0 | 0 | 0 | 23.08 | 0 | 0 | 0 | 0 | 0 | 0.49 |
| Water bodies | 0 | 0 | 0 | 0 | 0 | 54.55 | 0 | 0 | 0 | 0 | 0.97 |
| Shadows | 25 | 2.06 | 0 | 1.69 | 69.23 | 18.18 | 69.39 | 0 | 0 | 9.02 | 10.05 |
| Bushes | 12.5 | 7.22 | 3.95 | 1.69 | 0 | 9.09 | 0 | 89.09 | 4.31 | 0.75 | 11.02 |
| Broadleaf forest | 0 | 0 | 1.32 | 1.69 | 0 | 0 | 0 | 0 | 92.24 | 8.27 | 19.45 |
| Coniferous forest | 0 | 2.06 | 0 | 0 | 0 | 0 | 26.53 | 0 | 2.59 | 81.2 | 20.42 |
| Total | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

*Table 6. Accuracy assessment of MLC LU/LC classification performed on Sentinel-2 TOC simulated image (28 September 2012) (cont.)*

| Class | Commission (Percent) | Omission (Percent) | Commission (Pixels) | Omission (Pixels) | Prod. Acc. (Percent) | User Acc. (Percent) | Prod. Acc. (Pixels) | User Acc. (Pixels) |
|---|---|---|---|---|---|---|---|---|
| Unclassified | 0 | 100 | 0/0 | 8/8 | 0 | 0 | 0/8 | 0/0 |
| Grasslands | 35.71 | 16.49 | 45/126 | 16/97 | 83.51 | 64.29 | 81/97 | 81/126 |
| Rock screes | 25.86 | 43.42 | 15/58 | 33/76 | 56.58 | 74.14 | 43/76 | 43/58 |
| Urban areas | 8.33 | 25.42 | 4/48 | 15/59 | 74.58 | 91.67 | 44/59 | 44/48 |
| Fire scar | 0 | 76.92 | 0/3 | 10/13 | 23.08 | 100 | 3/13 | 3/3 |
| Water bodies | 0 | 45.45 | 0/6 | 5/11 | 54.55 | 100 | 6/11 | 6/6 |
| Shadows | 45.16 | 30.61 | 28/62 | 15/49 | 69.39 | 54.84 | 34/49 | 34/62 |
| Bushes | 27.94 | 10.91 | 19/68 | 6/55 | 89.09 | 72.06 | 49/55 | 49/68 |
| Broadleaf forest | 10.83 | 7.76 | 13/120 | 9/116 | 92.24 | 89.17 | 107/116 | 107/120 |
| Coniferous forest | 14.29 | 18.8 | 18/126 | 25/133 | 81.2 | 85.71 | 108/133 | 108/126 |

## Conclusions

In conclusion of present study, the following have been found:

The simulated *Sentinel-2* TOC data can serve for mapping and monitoring of coniferous, deciduous forests, and grasslands due to the achieved high-level of producer's and user's thematic accuracies, i.e. between 78 % and 98 %.

Depending on the illumination conditions, throughout the seasons, the accuracy of specific LU/LC classes such as 'Bushes', 'Rock screes', and 'Urban area' vary significantly, due to the spectral similarity.

The 'fire scar', area estimate by the second *Sentinel-2* TOC simulated image, was not found reliable enough due to the airplane trail which passed through the burnt area.

In summary, in future more studies on *Sentinel-2* capabilities of detection and mapping of forest-fire area estimation are needed.

## 4. Acknowledgements

The CHRIS/PROBA images used in the study were acquired within the ESA Third-Party Mission Category-1 Project No 8072 *Model for Assessment of Coniferous Vegetation Stress Using Multispectral and Hyperspectral Satellite Data*, PI: Dr. Lachezar Filchev. The author is also deeply appreciated to RSAC (UK) for the precise planning of the CHRIS/PROBA acquisitions during the summer campaign of 2012. The ASTER GDEM Ver.2 and Landsat 7 ETM+ satellite data is courtesy United States Geology Survey, Land Processes Distributed Active Archive Center (USGS LP DAAC), ERSDAC, National Aeronautics and Space Administration (NASA), and Ministry of Economy, Trade, and Industry (METI) of Japan. The ENVI (Exelis VIS) and ArcGIS 9.2/ArcInfo Academic licenses are property of SRTI-BAS.

## References

1. Copernicus: observing the world. http://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus [Date accessed 19/1/2015]
2. ENVI atmospheric correction module: QUAC and FLAASH user's guide, Version 4.7, 20AC47DOC, August, 2009 ITT VIS. http://www.exelisvis.com/portals/0/pdfs/envi/Flaash_Module.pdf [Date accessed 19/1/2015]
3. Ivanov, I. and V. Vassilev. Disaster mapping in a Bulgarian biosphere reserve. In: *EUFODOS Newsletter*, November 2013. http://www.eufodos.info/sites/default/files/downloads/EUFODOS_Newsletter13_1113_0.pdf [Date accessed 19/1/2015]
4. Filchev, L. An assessment of European spruce bark beetle infestation using Worldview-2 satellite data. In: Proceedings of European SCGIS conference: "Best practices: Application of GIS technologies for conservation of natural and cultural heritage sites", SRTI-BAS, Sofia, Bulgaria, 2012, 9–16. http://dx.doi.org/10.13140/2.1.3005.2647 [Date accessed 19/1/2015]

5. Filchev, L. and P. Dimitrov. Fire scars area estimation using CHRIS-Proba satellite data. In: CD Proceedings of the ESA Living Planet Symposium, 9–13 September, 2013, Edinburgh, United Kingdom (UK), ESA, 2013, SP-722, 163 p.
6. Filchev, L., M. Panayotov, and F. Ling. An assessment of land-use/land-cover change of Bistrishko Branishte biosphere reserve using Landsat data. In: IOP Conference Series: Earth and Environmental Science, 35th International Symposium on Remote Sensing of Environment (ISRSE'35), 22–26 April 2013, Beijing, China, 2014, Vol. 17, Paper ID 012060. http://dx.doi.org/10.1088/1755-1315/17/1/012060 [Date accessed 11-01-2015]
7. Filchev, L., M. Panayotov, and F. Ling. A study of Ips Typhographus pest infestation with the use of multi-angular CHRIS-Proba data. In: CD Proceedings of the ESA Living Planet Symposium, 9–13 September, 2013, Edinburgh, United Kingdom (UK), ESA, 2013, SP-722, 259 p.
8. Fletcher, K. (ed.). Sentinel-2: ESA's optical high resolution mission for GMES operational services. ESA. 2012, SP-1322/2.
9. Drusch, M., U. Del Bello, S. Carlier, O. Colin, V. Fernandez, F. Gascon, B. Hoersch, C. Isola, P. Laberinti, P. Martimort, A. Meygret, F. Spoto, O. Sy, F. Marchese, P. Bargellini. Sentinel-2: ESA's optical high resolution mission for GMES operational services. Remote Sensing of Environment, 120, 2012, 25–36. http://dx.doi.org/10.1016/j.rse.2011.11.026 [Date accessed 11-01-2015]
10. Forest Europe, UNECE and FAO 2011: State of Europe's forests 2011. Status and trends in sustainable forest management in Europe. http://www.foresteurope.org/docs/SoEF/reports/State_of_Europes_Forests_2011_Report_Revised_November_2011.pdf [Date accessed 11-01-2015]
11. Georgiev, G. People's parks and natural reserves in Bulgaria. Prosveta. 1995, 192 p. (In Bulg.)
12. Gikov, A. and Z. Pironkova. (2005). Using geoinformation technologies for assessment of tornado damages in forest areas. In: Proceedings of Scientific Conference with International Participation "Space, Ecology, Safety" (SES' 2005), 10–13 June 2005, Varna, Bulgaria, 269–274. (In Bulg.)
13. Gikov, A., P. Dimitrov. (2013). Application of medium resolution satellite images for assessment of damages caused by the wild fires in Vitosha mountain in 2012. In: Proceedings of 8th Science Conference with International Participation "Space, Ecology, Safety" (SES' 2012), SRTI-BAS, Sofia, 306–315. (URL: http://www.space.bas.bg/SES2012/R-2.pdf) (In Bulg.) [Date accessed 11-01-2015]
14. Law, K. H., J. Nichol. Topographic correction for differential illumination effects on Ikonos satellite imagery. International Society for Photogrammetry and Remote Sensing and Spatial Information Science (ISPRS). 35(3), 2004, 641–646. (URL: http://www.isprs.org/proceedings/XXXV/congress/comm3/papers/347.pdf) [Date accessed 11-01-2015]
15. Panayotov, M., D., Kulakowski, D. S. Laranjeiro, and P. Bebi. Wind disturbances shape old Norway spruce-dominated forest in Bulgaria. Forest Ecology and Management. 262, 2011, 470–481. http://dx.doi.org/10.1016/j.foreco.2011.04.013
16. Panayotov, M. and Georgiev, D. Dynamics in the Ips Typhographus outbreak following the 2001 windthrow in Bistrishko Braniste reserve. Silva Balcanica. 13(1), 2012, 38–48.

17. Sentinel-2 user guides - radiometric resolutions. https://earth.esa.int/web/sentinel/user-guides/sentinel-2-msi/resolutions/radiometric [Date accessed 11-01-2015]
18. Verrelst, J., J. G. P. W., Clevers, and M. E. Schaepman. Merging the Minnaert-k parameter with spectral unmixing to map forest heterogeneity with CHRIS/PROBA data. IEEE Transactions on Geoscience and Remote Sensing, 48(11), 2010, 4014–4022. http://dx.doi.org/10.1109/TGRS.2010.2047400 [Date accessed 11-01-2015]

## ОЦЕНКА НА ПРОМЕНИТЕ В ЗЕМНОТО ПОКРИТИЕ НА БИОСФЕРЕН РЕЗЕРВАТ „БИСТРИШКО БРАНИЩЕ“ С ИЗПОЛЗВАНЕ НА СИМУЛИРАНИ SENTINEL-2 ДАННИ

***Л. Филчев***

**Резюме**

Целта на настоящото изследване е оценяването на промените в земеползването/земното покритие на територията на биосферен резерват „Бистришко бранище“ (ЮНЕСКО, МАВ) в ПП „Витоша“, с използването на спътникови данни от CHRIS/PROBA и симулирани данни от *Sentinel-2*. Заснетите на 22 юни 2012 г. и на 28 септември 2012 г. CHRIS/PROBA изображения, са геометрично и атмосферно коригирани и ко-регистрирани. Топографската нормализация е приложена на второто изображение поради хвърлената сянка върху склоновете на долината на река Бистрица. С цел симулиране на *Sentinel-2* данни спектралните канали на CHRIS/PROBA са спектрално ресамплирани по ширината на спектралните канали на Sentinel-2. Пространственото ресамплиране на съответните канали на *Sentinel-2* е направено с помощта на панхроматичен канал (15 m) от Landsat 7 ETM+. На направената класификация на земеползването/земното покритие е извършена оценка на точността и крос-валидация с помощта на наземни данни. Резултатите показват, че между 60 ha и 72 ha от иглолистна растителност са опустошени от горския пожар през 2012 г. Получените резултати доказват и потвърждават способността на *Sentinel-2* мисията за откриване на промени в земеползването/земното покритие.