Monitoring of forests structure in North and West of Ukraine in connection with problems of ecology and estimation of carbon cycle using multispectral space images

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Abstract - The forests in investigated regions occupy the significant areas in limits of Pre-Carpathians, Carpathians and Ukrainian Polesje. Last years in connection with Chernobyl accident and significant cuttings down of forests in Carpathians region and in some other areas of Ukraine the ecological problems became more essential. For the control of an environment it is necessary to carry out forests monitoring, that most effectively can be carried out on the basis of satellites images. For research realization the multispectral images from Landsat-7\ETM, SPOT XI, TERRA/MODIS, NOAA/AVHRR, ENVISAT/MERIS were used. The work is carried out in the frames of BEAR projects of ESA, with focus on thematic "Forest changes and global carbon monitoring". As a result of the carried out researches the images with different spatial and spectral resolution were classified and compared. Areas occupied by coniferous, deciduous and mixed forests were specified within the limits of investigated regions.

Keywords: monitoring of forests, multispectral images.

1. INTRODUCTION

The forests of North and West Side of Ukraine occupy the significant areas in limits of Pre-Carpathians, Carpathians and Ukrainian Polesje. Alongside with primary forests the significant areas are engaged by planting forests since 1945. The forests in research regions are intensively exploited for timber, while playing the important role in ecological condition (localisation of pollution, preservation of water and carbon cycle etc.) and influence on climatic changes at regional and global levels. Last years in connection with Chernobyl accident and significant cuttings down of forests in Carpathians region and in some other areas of Ukraine the ecological problems became more essential.

For realization of the control of an environment it is necessary to carry out monitoring of forests, that most effectively can be carried out on the basis of using of modern satellites images.

The work is carried out in the frames of BEAR initiative of ESA, which aims are supporting the formation of research networks between Europe, Russia and Ukraine, as well as promoting the use of data from Earth Observation satellites from ESA, Russia and Ukraine together. The our research focus on monitoring of forests state of investigated region according the following thematic of the GMES initiative of ESA and the European Commission - "Forest changes and global carbon monitoring".

The classification of space images is in a basis of our study of forest vegetation. The different classes of vegetation are created on the basis of the given ground data on tests - sites within the research area. For research realization the images with different spatial and spectral resolution from Landsat-7\ETM, SPOT XI, TERRA/MODIS, NOAA/AVHRR, ENVISAT/MERIS etc. were used. The paper describes the preliminary results of comparison of classification to check how accurate coarse resolution images estimation and especially MERIS reduced resolution data (RR) for land use and land cover (first of all deciduous and coniferous forests) mapping and monitoring. The comparison have been done for results of images classification both within 2 separate test polygons and for whole North and West Ukraine. First test polygon is situated in Ukrainian Polesje, within Chernobyl exclusion zone and the second one in Ukrainian Carpathian, within Carpathian national natural park (South of Ivano-Frankovsk oblast). Thus, this is one of the case studies to find bridge between coarse / medium resolution images data (especially MERIS) and Landsat/SPOT data that can be used for vegetation monitoring at regional and global scales.

2 DATA SOURCES AND METHODS

The reduced resolution image ENVISAT/MERIS level1b (1.2 x 1.2 km^2) recorded on April 16, 2004 have been used. MERIS (RR) image was sponsored by ESA in the frames of BEAR initiative. Specification of the spectral bands are given in Website (Meris User Guide). MERIS data were converted to ERDAS Imagine format using programs BEAM and ENVI. The image covers the whole territory of investigation and areas far from the boundaries of research regions. Therefore, after the geometric correction the MERIS data were cut for territory of North and West Ukraine within coordinates 22^o 20' and 31^o 00' E and 47^o 45' and 56^o30'N. Thus, the west and north limits of the investigated territory are in fact boundaries of Ukraine.

The following satellite images were used for comparison with MERIS data:

- The NOAA/AVHRR imagery (resolution 1.1 x 1.1 km^2), acquired on 15 April 2004, well-known sensor, 5 spectral band. The AVHRR data have similar to MERIS (RR) data resolution but significantly less number of spectral band in zones VIS and NIR but have thermal-infrared bands. The AVHRR data as MERIS have been cut for the area of investigation.
- The images of TERRA/MODIS with medium resolution 250 m for bands 1 and 2 (600 – 900 nm), and 500 m for bands 3 to 7 (400-2100 nm) were used. Images recorded on April 15, 2004 and covered whole territory of research. For MODIS image with 250 m resolution the NDVI (Normalized Difference Vegetation Index) has been calculated and was used as addition layer of image for further data classification.

- The multiband SPOT-XI image with resolution 20 m, acquired on July 14, 1998 (1 to 4 spectral bands 500 – 1700 nm) was used. The image covers the territory of test polygon N1 within the Chernobyl Exclusion Zone (Ukrainian Polesje, North of Kiev oblast). The SPOT XI high resolution image data have been used as reference for estimation of accuracy of classification of coarse and medium resolution images within the test polygon.
- The Landsat-7/ETM image (in 7 spectral bands: 1 - 450 - 520 nm (Blue); 2 - 520 -600 nm (Green); 3 - 630 -690 nm (Red); 4 - 760 -900 nm (NIR); 5 - 1550 -1740 nm (SWIR-1); 6 - 10400 - 12500 nm (Thermal); 7 - 2080 - 2350 nm (SWIR-2)), recorded on May 5, 2000. The image overlapping the test polygon N2 in Carpathian region (within Carpatian national natural park (South of Ivano-Frankovsk oblast). The quality of image is good with cloud cover not exceeding 2 %. The image was used as reference data within test polygon similar to SPOT XI image.

The standard Forest Inventory data structured according to forest districts and administrative areas have been used as ground truth data for classification of satellite images. Forest Inventory data include information about tree species composition, age, height origin, site index and relative stocking etc. for relatively homogenous area (Primary Inventory Units). This data in GIS format located within 2 test polygons (N1 and N2) mentioned before were used in this study. Their spatial and attribute data were updated to 1996. The number of Primary Inventory Units within each of the test polygon generally exceeds several hundred units.

The classification of images have been carried out using the modules of ERDAS Imagine program. As a first step, the analysis of spectral brightness was performed for the classification of the images with the purpose to construct maps of vegetative community distribution using ERDAS Imagine software. This study utilised supervised training and classification. The result of the training process was a set of signatures for the selected classes. Spectral characteristics for separate forest vegetation species and different landscapes were analysed using approximately four or five test sites within area for every class. This test sites or AOI (area of interest) were similar for every image.

The minimum-distance decision rule for classification of TERRA/MODIS, NOAA/AVHRR ? ENVISAT/MERIS images was applied in this stage of study, because AOI sometimes cover only 1-2 pixels of images. However, the Maximum Likelihood decision rule have been used for classification of SPOT XI and Landsat-7 images to obtain more accurate reference data for comparison. Reliability of the given high resolution images classification for main classes is usually more then 85 – 95 % according our investigations.

3. RESULTS AND DISCUSSION

3.1. The results of images classification within Chernobyl test polygon.

The forests of the Zone had been planted mainly after 1945, among them the pine woods prevail. After the Chernobyl accident the structure of land use of the Exclusion Zone has changed strongly. The reforestation on the former farmland, the changes in forests structure are marked, the forests are weakened by influence of the radiation, fires, winds, wreckers etc.

For classification of images the objects for training included all selected classes of a vegetative cover, which were chosen on the basis of forests inventory works within the investigated territory. In total about 250 test sites were used (Lyalko, Nilsson, Sakhatsky, McCallum et. al. 2005). Except of forests vegetation species the elements of the landscape occupying significant areas - water surface, industrial plots of Chernobyl NPP, settlements, sandy dams etc. were applied as test sites for class's signature identification.

The results of classification are shown on figure 1. Table A. shows the results of classification in %.

Table A. Results of images classification within Chernobyl test polygon

*Land cover	MERIS (RR) For Area 1758 sq. km %	AVHRR For area 1742 sq. km %	MODIS 500m for area 1697 sq. km %	MODIS 250m For area 1686 sq. km %	SPOT For area 1660 sq. km %
1	15,5	11,0	24,6	27,6	33,5
2	33,6	31,4	30,2	16,3	27,8
3	10,3	11,6	13,1	15,5	10,2
4	35,6	36,1	29,0	32,8	15,7
5	3,8	8,3	2,0	6,0	9,6
6	1,2	1,6	1,1	1,8	2,8
7	0	0	0	0	0,4
Total	100	100	100	100	100
*1 – coniferous forests; 2 – deciduous forests; 3 – mixed forests; 4 – long-fallow land; 5 – built-up areas; 6 – water; 7 - clouds					

The comparison shows that on coarse resolution data the coniferous forests (pine) are better estimated using ENVISAT/MERIS data then AVHRR data within the Chernobyl test polygon. The mixed forests are overestimated by NOAA/AVHRR. However, the forests (coniferous and diciduous) are underestimated and the meadows, long-fallow lands, burned areas and other grasslands are overestimated by the coarse and medium resolution images processing in compare with high resolution SPOT XI classification. The classification of MODIS (500m) shows most satisfactory results for forests estimation.

3.2. Results of classification within Carpathian test polygon

The investigated territory is dominated by heterogeneous coniferous forests with a prevalence of spruce. The pine and diciduous forests (mainly beech and alder) in some sites occupy significant territory.

The classification of the images was carried out as was described in section 2 and 3.1. the Landsat-7 /ETM image (May 05, 2000 have been used as reference similar to SPOT XI image for Chernobyl test polygon.

The figure 2 and table B show the results of minimum-distance classification of images.

The results of classification for Carpathian test polygon show similar relations observed for Chernobyl test polygon.

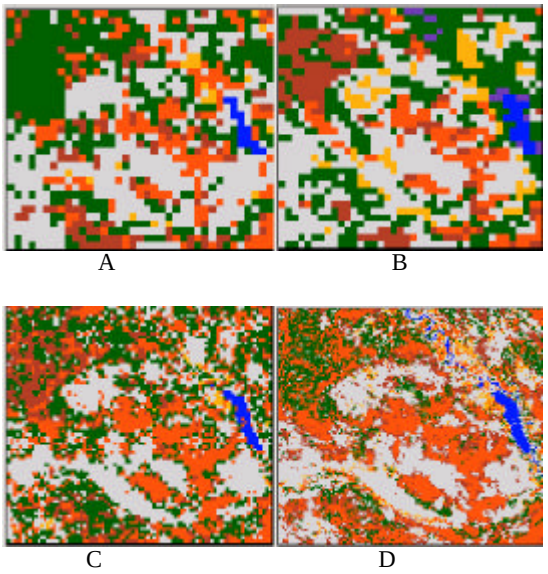


Figure 1. Results of minimum-distance classification based on MERIS image (April 16th , 2004) – A, AVHRR image (April 15th , 2004) - B, MODIS (500m) – C and MODIS (250 m) –D (April 15th , 2004) for Chernobyl test polygon
Legend: coniferous forests -red; deciduous forests – dark green; mixed forests - brown; long-fallow land – light gray; built-up areas - orange; water – blue.

The difference is found only for NOAA/AVHRR classification which in general very good estimate coniferous forests and practically match with Landsat-7/ETM classification result. But for another classes the results are worse. As in Chernobyl test polygon the deciduous forests, grassland, cutting downs, arable lands are overestimated by MERIS and MODIS images classification and the coniferous forests are underestimated in compare with classified Landsat image. MODIS (500) data in general show better result as within Chernobyl test polygon.

Table B. Results of images classification within Carpathian test polygon

*Land cover	MERIS (RR) For Area 12549 sq. km %	AVHRR For area 12414 sq. km %	MODIS 500m for area 12375 sq. km %	MODIS 250m For area 12312 sq. km %	Landsat For area 12284 sq. km %
1	19,6	29,8	24,1	14,2	29,4
2	25,2	17,9	23,2	23,9	21,8
3	43,3	45,5	43,4	53,1	37,4
4	6,9	2,67	2,5	5,4	6,0
5	0,1	0,03	2,2	0,1	1,1
6	4,9	4,1	4,6	3,3	4,1
7	0	0	0	0	0,2
Total	100	100	100	100	100
*1 – coniferous forests; 2 – deciduous forests; 3 – grassland and arable land; 4 - built-up areas; 5 – water; 6 – snow; 7 - clouds					

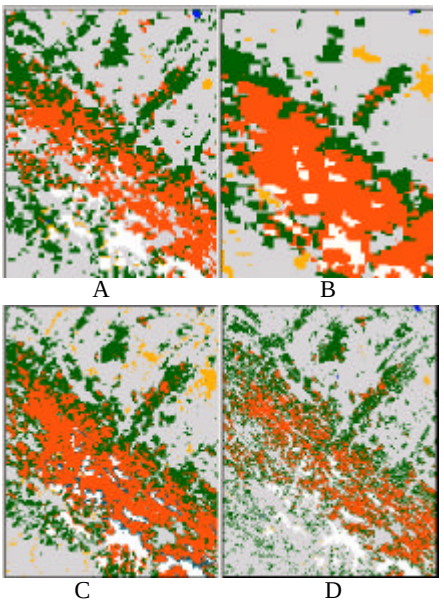


Figure 2. Results of minimum-distance classification based on images: MERIS - A, AVHRR –B, MODIS (500) – C, MODIS (250m) – D for Carpathian test polygon
Legend: coniferous forests -red; deciduous forests – dark green; grassland and arable land – light gray; built-up areas - orange; water – blue; snow – white.

3.3 Results for territory of North and West Ukraine

The minimum-distance decision rule for classification of coarse and medium resolution images within whole territory of North and West Ukraine was applied for evaluation of coniferous and deciduous forests spreading. The table C shows the results of classification. Main confusion occurred between deciduous forests and grassland and arable lands on MERIS classification (Figure 3) according the topographic maps and results of classification of another images. This confusion can be explained by similarity of spectral signatures and mentioned also in paper (Clevers et al., 2005).

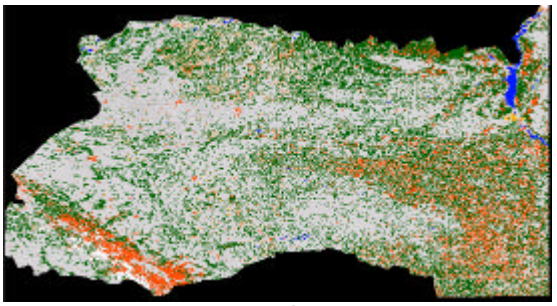
Table C. Results of images classification within North and West Ukraine

*Land cover	MERIS (RR) for area 227670 sq. km %	AVHRR for area 226196 sq. km %	MODIS 500m for area 224945 sq. km %	MODIS 250m for area 219812 sq. km %
1	6,3	4,1	8,5	6,5
2	31,9	22,4	18,9	21,2
3	52,9	66,5	65,1	65,0
4	7,9	5,6	6,3	6,2
5	0,6	1,0	0,8	0,8
6	0,4	0,4	0,4	0,3
Total	100	100	100	100
*1 – coniferous forests; 2 – deciduous forests; 3 – grassland and arable land; 4 - built-up areas; 5 – water; 6 – snow				

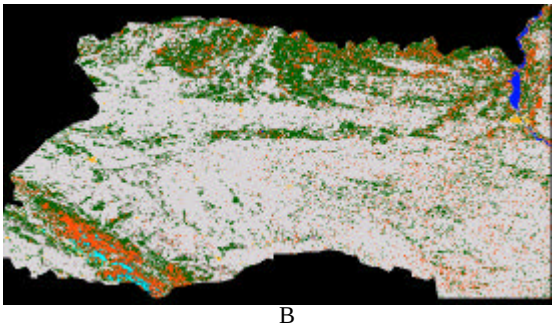
Taking into account the results within test polygons it is expected that the most accurate result was obtained on the

base of MODIS (500) classification with little bit underestimation of coniferous forests and overestimation of deciduous forests as well as grasslands and arable lands.

The forests occupy approximately 30 % of investigated area. However, for whole territory of Ukraine this relation is much less taking into account that the research area contain about 75 –80 % of Ukrainian forest fund.



A



B

Figure 3. Results of minimum-distance classification based on images: MERIS - A, MODIS (500) – B, for North and West Ukraine
Legend: coniferous forests - red; deciduous forests – dark green, grassland and arable land – light gray; built-up areas - orange; water – blue; snow – white.

4. CONCLUSIONS

The classification of images with different spatial and spectral resolution Landsat-7\ETM, SPOT XI, TERRA/MODIS, NOAA/AVHRR, ENVISAT/MERIS have been carried out within Chernobyl test polygon, Carpathian test polygon and for territory of North and West Ukraine.

As a result of the researches the areas occupied by coniferous, deciduous and mixed forests were specified within the limits of investigated regions. The changes in different kinds of vegetation spreading were observed that is necessary for an estimation of an ecological condition of territory and carbon cycle assessment.

The comparison of results of classification have been done for evaluation of accuracy of estimation of classes of coniferous, decidius forests, grasslands, arable lands, built-up areas etc. on the base of coarse, medium and high resolution data to improve methodology of land cover mapping and monitoring on regional and global levels.

This study should be considered as preliminary results for classification of investigated area using images with different spatial and spectral resolution and especially MERIS reduced resolution data. Future studies should plan investigation of full resolution MERIS data for forests state monitoring taking into account that spatial resolution and spectral resolution is a key factor for the results as it was shown. Also the analysis of multitemporal MERIS data should be wide sphere for research.

5. REFERENCES

1. J.G.P.W. Clevers, H.M. Bartholomeus, C.A. Mucher .& A.J.W. de Wit, "Land covers classification with the Medium Resolution Imaging Spectrometer (MERIS)". In New Strategies for European Remote Sensing, Oluic (ed.) Millpress, Rotterdam, ISBN 90 5966 003 X , p.p.687-694 , 2005.
2. V. I. Lyalko, S.Nilsson, A. I. Sakhatsky, A.Shvidenko, J.McCallum, A. Ja. Hodorovsky & O. G. Harechko, "Earth observation of Ukraine and Siberia for an estimation of their state, fire risk and carbon cycle,", In New Strategies for European Remote Sensing Oluic (ed.) Millpress, Rotterdam, ISBN 90 5966 003 X , p.p. 269-277 , 2005.
3. MERIS USER GUIDE. http://envisat.esa.int / dataproducts /meris /CNTR1.htm.