UDC 630:528.8

O. TOKAR[1], M. KOROL[2], S. HAVRYLIUK[3], A. CUNJAK[4]

[1] Department of International Information, Lviv Polytechnic National University, 12, S. Bandera str., Lviv, Ukraine, 79013, e-mail: tokarolya@gmail.com
[2, 3] Department of Forest Inventory and Management, Ukrainian National Forestry University, 19, Pryrodna str., Lviv, Ukraine, 79057, e-mail: nikkorol@ukr.net, serhiy_havrylyuk@ukr.net
[4] Department of Land Management and Design, Ecological College of Lviv National Agricultural University, Zamarstynivska str., 167, Lviv, Ukraine, 79068

APPLICATION OF SATELLITE IMAGES FOR THE ESTIMATION OF FOREST INVENTORY INDICES

https://doi.org/10.23939/istcgcap2017.01.084

Purpose. Estimation of the state of forest stands using remote sensing data and statistical inventory data and the comparison of forest inventory indices with forest management materials. **Methodology.** Remote sensing data were used for the investigation of inventory indices. Inventory indices of forest stands of NNP "Skolivsky Beskydy" and ascertain edges of forest massif were done with Landsat ETM+ data (resolution 30 m) and Quick Bird data (resolution 0.6 m). For the image interpretation with the minimal distance algorithm forest stands on sample plots were studied. These sample plots were chosen on the regular network with a pitch of 300 m in QGIS software. Inventory indices estimation was done using common methods in forest management. **Results.** Utilization of satellite images for forest resources investigation was described. Modern approaches and technologies for forest resources investigation were used. It allowed realizing estimation of edges of forest area for Skole forest district of NNP "Skolivsky Beskydy" (Lviv Region) and specifying edges using remote sensing data. Differences of area on digital maps and forest management materials were calculated. **Scientific novelty and practical significance**. The algorithm of using remote sensing data for separation of edges of subcompartments was adapted. Obtained results were compared to the forest management database and respective deviations were estimated. These data and the algorithm can be used for creation of digital maps of forest cover, touristic maps, and separation on functional zones.

Key words: forest vegetation; satellite image; image interpretation; raster; digital map.

Introduction

The present time demands a responsible approach to natural resource usage as well as supporting and saving of ecological balance. The role of forest ecosystems is first of all the accomplishment of protecting, securing, oxygenic, recreation and other helpful functions. Since our forestry is moving to the sustainable development base, the topical task is arising to receive some real data about the forest fund and its dynamics, quality conditions, and volume estimation. Such information is used for conduction of monitoring where the usage of forest resources and analysis of its sanitarian conditions are taken into account.

Exploring forests with remote sensing data usage is conducted in many countries [Coppin, 2004; Vytseha, 2008; Chaskovskyy, 2004] and is topical as well for Ukraine [Havrylyuk, 2007; Horoshko, 2010, 2011; Myklush, 2006; Cunjak, 2013].

Remote sensing data are expanding possibilities of receiving information about forests surface and its edges, for determining quality and quantity characteristics. It improves effectiveness of forest management on the local level from forestry enterprise to different forest subcompartments. Rational usage of forest's resources and moving to the sustainable development base in the forest industry are demanding to receive actual data about the forest fund. Estimation of material's adequacy and the pattern of changes are the main problem for the forest inventory. That is why remote sensing data are playing an important role for receiving accurate data.

Aim

The main aim of our research is to realize the comparative estimation of forest stands' conditions on the part of forest fund of Natural Reserve "Skolivsky Beskydy". It is realized using conducted inventory materials, which are based on remote sensing data, and the official forest database, which contains main cruising indexes of forest stands.

Methodology

Accurate and exhaustive data about the forest stands and their main cruising indexes are received by different ways: whole measuring, selective forest inventory, and visual method of measuring. Nevertheless, these approaches demand considerable consumption of resources, time, and highly skilled functionaries. For the forestry practice all stand characteristics are not completely used. Therefore, for decreasing expenses for the objective estimation of main cruising indexes we can use remote sensing data, in particular satellite images from different cameras. Suitability of satellite images usage for forestry investigation is determined by higher self-descriptiveness and relative cheapness in comparison with traditional methods of aerial remote sensing [Richards, 1999; Stefanski, 2014; Myklush, 2007]. Availability of infrared bands of multispectral images increases their informational content especially for interpretation of vegetation covering the earth surface [Kashkyn, 2001]. Satellite images for forest inventory tasks can be received from different frame camera systems, in particular Landsat, Sentinel, IRS, Spot, EROS, Ikonos, Quick Bird etc.

According to tasks there can be used images of different spatial and radiometric resolutions for forestry, moreover the more common the task is, the lower resolution images are needed. Determining forest massif edges (forest cover land) occurs by taking into account the level of forestry conducting [Horoshko, 2003, 2011]. Images with resolution 0.7–2.0 m (surveying systems on satellites EROS B, Ikonos, Quick Bird) can be used for the level of forestry enterprise. Images with resolution 5–15 m (IRS, Cartosat, Spot, ALOS, MODIS Terra/Aqua) can be used both for the level of forestry enterprise and for the regional level. For the national level more useful are images with the resolution 30–50 m (Landsat, SPOT, Ресурс-О etc.). For our tasks it is better (taking into account the correlation "price/quality") to use satellite images with the pixel size 5–10 m in the panchromatic band and lower in multispectral bands.

For the efficient usage of remote sensing data these images should be preprocessed (geometric, radiometric correction etc.). First of all, this depends on the type of remote sensing system. Preprocessing of satellite images allows increasing of informational content and respectively its fitness for the image interpretation [Richards, 1999; Aronoff, 2005]. Usually users receive images with some level of preliminary processing that are geometrically and radiometrically corrected. Algorithms exist for increasing the informational content of satellite images. One of them is the resolution merge algorithm for merging panchromatic and multispectral bands [Havrylyuk, 2007]. For this purpose, there are realized a few algorithms for image merging (Principal Components, Brovey Transform etc.). For example, the spatial resolution of multispectral bands of Landsat images is equal to 30m, panchromatic – 15m. We receive a multispectral image with the spatial resolution 15 m as the result of merging. Usage of these images increases the accuracy of contour image interpretation, since a multispectral image with a higher spatial resolution is used.

For the detailed vegetation research, including forest cover, it is reasonable to use multispectral and synthetic bands together. These synthetic bands are formed based on the algebraic transformation of coefficients of spectral brightness. Most useful is the NDVI (Normalized Difference Vegetation Index). Many researchers say that usage of this index is expanding possibilities of vegetation extraction on remote sensing images. In particular Hildebrand (1997) says that the most informative is the NDVI band, created from near infrared and red spectral ranges together with original multispectral image.

The usage of remote sensing data presupposes the availability of ground sample points with known characteristics (for forest stands with known main cruising indexes) as etalon. For these there are prepared ground investigations on sample plots with the known coordinates of its center.

At present, forested countries accomplish their forest inventories on different size permanent sample plots. For different countries the system of sample plots is different. It is worth noting that results of ground inventory are precise only for big areas and including a lot of sample plots. For the smaller territory we can use remote sensing data (Landsat images) together with cartographic materials of the forest inventory (digital forest maps). For mountains these digital maps must be based on digital elevation models [Kopiy, 2006; Khlian, 2009; Cunjak, 2013].

For our investigation there were used Landsat 7 ETM+ images with 30m resolution for the estimation of forest massif of Natural Reserve "Skolivsky Beskydy" which more precisely define its edges (Fig. 1). To make more accurate image interpretation results we used Quick Bird images in Google Earth with the spatial resolution of 2 m in multispectral and 0,6m in panchromatic bands.

This necessity arises because the spatial resolution of Landsat images is equal to 28.5 m and the area on the ground is equal to 812 square meters. The area of ground sample plots, which are the basis of signature creation for image interpretation, are equal to 500 square meters (round sample plot with 12.,62 m of radius) [Havrylyuk, 2011; Strochinskii, 2001]. It means that the spatial resolution of Landsat images is not enough.

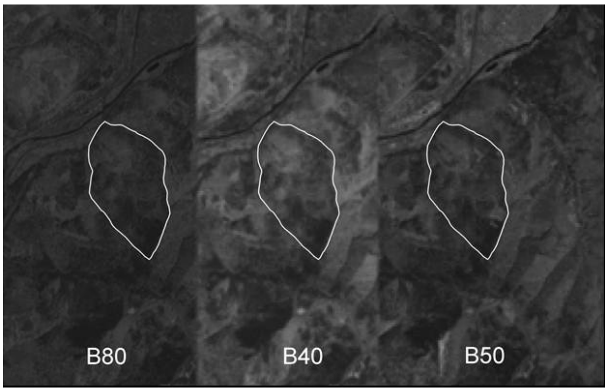

Fig. 1. Study area on Landsat image (B80, B40, B50)

That is why there was a need to accomplish the image fusion using the panchromatic band of high spatial resolution (14.25 m) and the multispectral band with spatial resolution 28.5 m. For that purpose, we applied Nearest Neighbor technology, which is used for linear dividing of pixels into equal parts (spatial resolutions of entrance images must be divided exactly) [Myklush, 2006]. For the next image interpretation there were used enhanced multispectral images with the spatial resolution of 14.25 m. These enhanced images were interpreted.

On the first stage the photosynthesis vegetation cover was extracted from other ground cover classes, which are present on the satellite image. There are a few approaches towards the image interpretation. S. I. Myklush and others indicate that for the "forest mask" extraction it is reasonable to use Knowledge Based Image Analyse [Myklush, 2006]. R. L. Lawrence and others investigated the land cover on hyperspectral images using the Random Forest classifier which showed satisfactory results [Lawrence, 2006]. The advantage of this algorithm allows the possibility to use it with the limited ground data for the signature creation. In this work there was used a supervised classification for the interpretation of vegetation on the territory of Natural Reserve "Skolivsky Beskydy". For the forest cover lands there were randomly chosen 700 points according to proposal of P. H. Swain'a i S. M. Davis'a [Swain, 1983] since for the nest image interpretation there were used 7 bands of satellite image. Provisionally generated points were converted to the shape in Erdas Imagine software (aoi – area of interest) which were the base for signature creation. These signatures were used for the next image interpretation and extraction of "forest mask".

Points, where there were spent ground investigations, were randomly generated. This type of point placing guaranteed a chance of land covering which is also important in statistical research. For marking of places of sample plots investigation there was used a random network with 300 m steps in vertical and horizontal directions. This network was prepared in Quantum GIS software (Fig. 2).

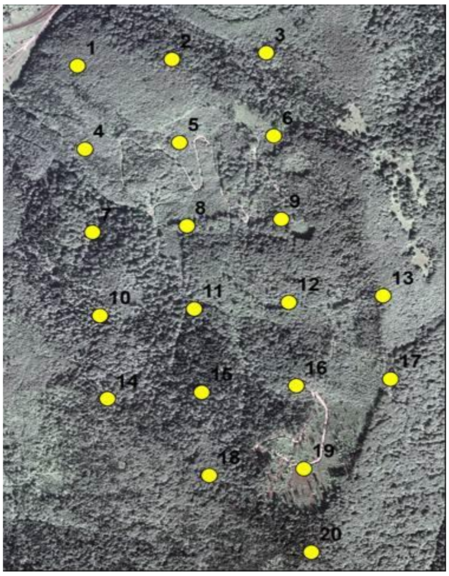

Fig. 2. Study area with a regular network

For the image interpretation it is necessary to choose a class signature – statistical parameters for the pixel classification to some previously defined class. For its forming there were used previously generated points in aoi-format. The software is taking spectral characteristics of points for forming signature. The covariance matrix was not calculated, so we used "Minimal distance" algorithm for the classification.

For higher accuracy of research a classification of two images was used: the original multispectral image and the image with the additional NDVI-band, which is calculated as [NDVI]:

$$NDVI=(NIR - RED)/(NIR + RED)$$

where *NIR* – spectral characteristics (coefficient of spectral brightness) of the near infrared band; *RED* – spectral characteristics of the red band.

As a result of classification we receive thematic maps of forest cover. Checking of these maps is conducted with high spatial resolution images QuickBird.

Comparative analysis of forest inventory matherials

Based on materials of the conducted forest inventory and documents of forest managementa comparative estimation of forest stand conditions was accomplished in the Natural Reserve "Skolivsky Beskydy".

For determination of edges of study area and places of sample plots in forest subcompartments forest maps and satellite images were used for the territory of Skole forest district. The satellite image of the Scole forest district of NR "Skolivsky Beskydy" with the high spatial resolution is received with SAS Planet software. This image is connected with the international coordinate system UTM WGS-84 (Fig. 3).

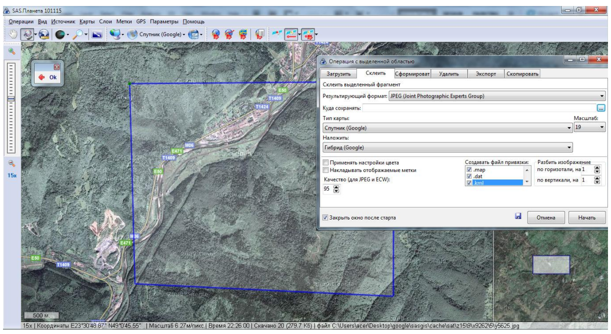

Fig. 3. Limited area for setting parameters in Quick Bird image using SAS.Planet

The forest maps were layed on QuickBird images using QGIS software. It is accomplished manually using special tools in QGIS, because forest maps do not have any geographical surveying.

This surveying was accomplished by using typical points well visible on both materials: forest maps and satellite images (Fig. 4).

Fig. 4. Geocoding forestry map to satellite image

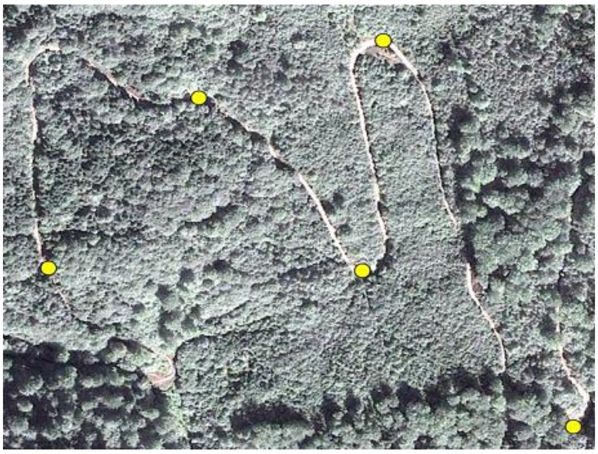

Fig. 5. Typical points on forest road for accurate geocoding

As you can see in Figs. 4 and 5 above the typical points are well presented on the satellite image, in particular are seen the road detours. It allows stating the high accuracy of GPS surveying and fixing of typical points. After geocoding of forest maps to satellite image there was revealed some contradiction of the situation on forest maps and the satellite image (situation on the ground). Even though typical points on crossing of forest compartments on image and forest maps are matched, the forest subcompartment's network is not matched with the situation on the ground. Figure 6 illustrates these differences between forest subcompartment's networks on the forest map and on the ground.

Afterwards on the image with forest subcompartments network there was put a layer with coordinates of sample plots' centers. These coordinates were taken by the GPS-receiver directly on the forest ground. This enabled to learn the forest subcompartment where there are founded the sample plots (Fig. 7). This information was adapted in MS Office software and later was converted to QGIS.

For the comparative characteristic there was used different types of information: data base of the permanent forest inventory (base conditions on 2011) and results of adapted sample plots. Comparative characteristics of main forest cruising indexes (average diameter, average height and average tree volume) are present in Tables 1, 2 and 3.

The analysis of the above data shows that the maximum deviation for diameter is on the sample plot N 4 (-76.0 %), minimum – SP 13 (-1.3 %). The maximum deviation for height on sample plot N 13 is (-59.0 %) with a minimum of SP 1 (-8.5 %). Maximum deviation for the tree volume on the sample plot N 9 is (66.7 %) and the minimum for SP 7 (5.8 %).

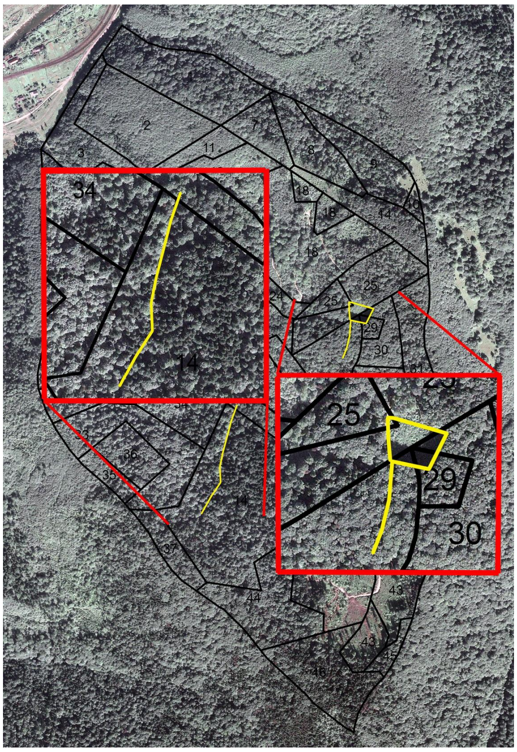

Fig. 6. Edges of subcompartment in forest management materials and the real edge on image

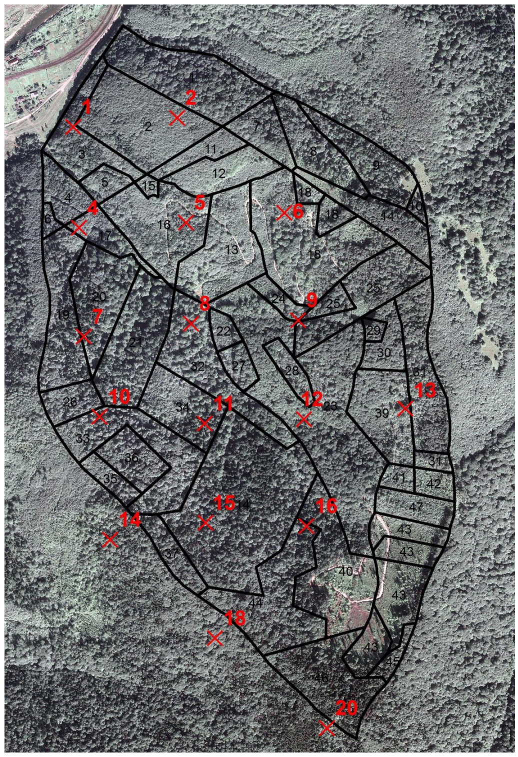

Fig. 7. Centers of sample plots

Table 1

Comparative characteristics of diameter

N of SP*	Average diameter			
	FI**	SP***	deviation	
			abs.	%
1	20	23,2	3,2	16,0
2	22	19,7	-2,3	-10,5
4	60	14,4	-45,6	-76,0
7	52	32,3	-19,7	-37,9
9	28	29,3	1,3	4,6
10	52	37,4	-14,6	-28,1
12	34	28,5	-5,5	-16,2
13	32	31,6	-0,4	-1,3
14	28	23,1	-4,9	-17,5

Where N of SP* – number of sample plots;
FI** – permanent forest inventory data;
SP*** – sample plots data.

Table 2

Comparative characteristics of average height

N of SP	Average height			
	FI	SP	deviation	
			abs.	%
1	20	18.3	-1.7	-8.5
2	20	17.4	-2.6	-13.0
4	35	14.8	-20.2	-57.7
7	31	13.7	-17.3	-55.8
9	26	16.6	-9.4	-36.2
10	35	15.9	-19.1	-54.6
12	31	19.8	-11.2	-36.1
13	30	12.3	-17.7	-59.0
14	27	13.3	-13.7	-50.7

Table 3

Comparative characteristics of tree volume

N of SP	Average tree volume			
	FI	SP	deviation	
			abs.	
1	460	408	-52	-11.3
2	377	493	116	30.8
4	572	355	-217	-37.9
7	396	419	23	5.8
9	300	500	200	66.7
10	532	289	-243	-45.7
12	510	624	114	22.4
13	605	529	-76	-12.6
14	572	442	-130	-22.7

These differences between the permanent forest inventory data and data of our field investigation are caused by a few factors. In particular forest inventory jobs are not deficient of subjective influence, for example abilities and experiences of forest cruisers. Our investigation used highly accurate measuring instruments and has more objective character. But we need to accentuate this fact that it possible to get the sample plots in the area with different characteristics (different forest subcompartments) or in the atypical for this subcompartment place. That means that these data have only a comparative character.

Results

For the image classification process of geometrically corrected Landsat images Minimal Distance algorithm was used. According to classification results of the satellite image Landsat 7 we can indicate (see Fig. 8) that sample plots are placed in typical points for in mixed forests, beech forests and coniferous forests. For this supposition there are conformed stand compositions on sample plots.

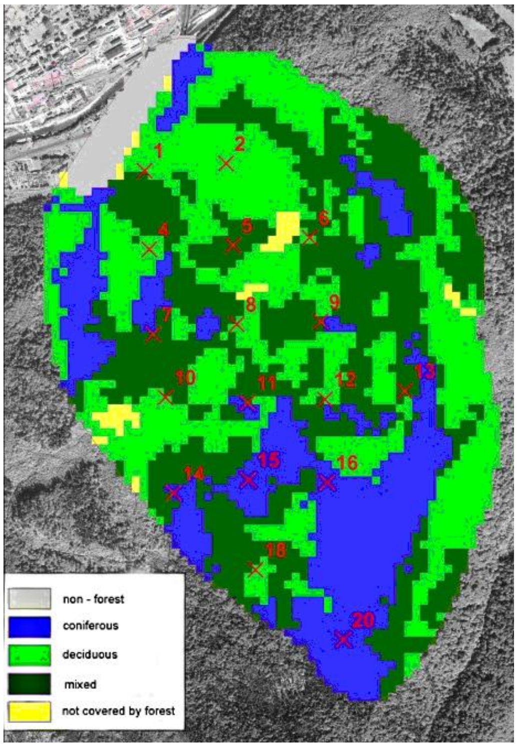

Fig. 8. Location of sample plots on the image interpretation thematic map

Visual estimation of classification results showed better results with additional NDVI-band in the band composition for group species interpretation. Therefore, comparisons of received results were done with this thematic map. Verifying the accuracy of the performed classification was achieved by using common coefficients – User's accuracy, Producer's accuracy, Overall accuracy and Kappa-Koehen index (Aronoff, 2005; Havrylyuk, 2007). These data are lightly calculated in confusion matrix.

In the research process there were revealed some peculiarities of forest inventory works and inaccuracies of forest inventory materials. Firstly there was revealed a conditional establishment of forest subcompartment borders on forest maps. It is mainly tied to different sources of information for georeferencing. Usually materials of land tenure of past forest inventory are used.

Using results of prepared classification and analyzing data with satellite images QuickBird there was created a new subcompartment network and calculated areas. Numeration of subcompartments was accomplished according to forest inventory demands (Fig. 9). Satellite images with a high spatial resolution are handy for these aims, because they represent the horizontal stand structure in a proper way, visually interpret tree species and their age structure, good visible cutting, creeks and others elements of relief.

According to results of investigation there was created a new subcompartmental network with the area 173.5 ha in contrast to 177 ha by data of the permanent forest inventory. Deviation is located in limits of admissible error (for 177 ha it equal 3.5 ha). But as it can be seen in Fig. 4 and Fig. 9 the boundaries of forest subcompartments were considerably changed as a result of classification in comparing with materials of forest inventory in investigated area.

When determining the boundary of in forest subcompartments it should be taken into account that the main influence on the accuracy is caused by subjective factors which include the experience and skills of the forest cruiser. For the forest map production materials of instrumental surveying, materials of the system of land tenure, materials of the previous forest inventory, topographic maps, and false-color or monochromatic aero photo images are used.

Laying the forest subcompartmental network on the thematic map of classification showed that mostly boundaries of classified classes are quite precise and conform to the situation in area (Fig. 10).

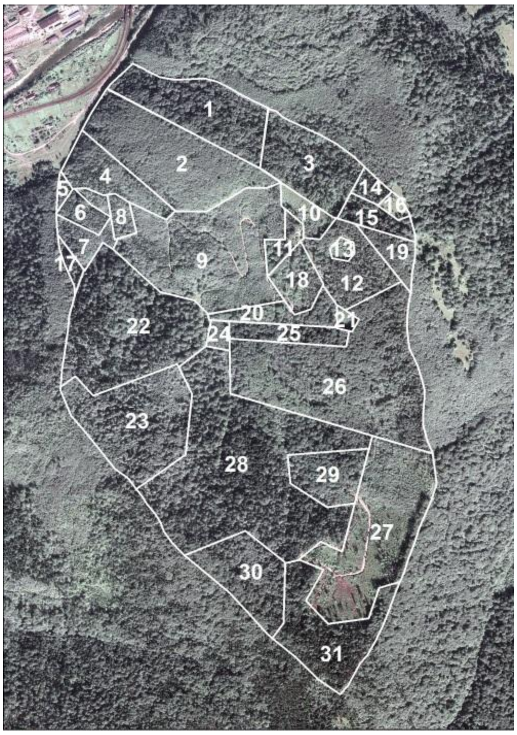

Fig. 9. New subcompartmental network on Quick Bird satellite image

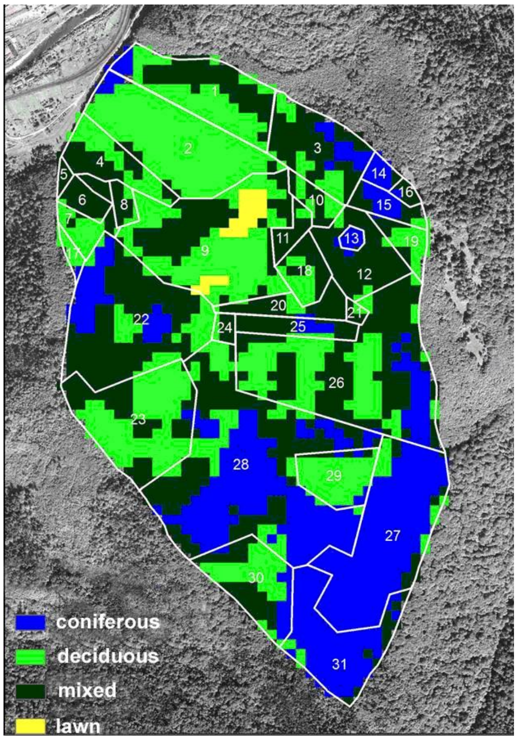

Fig. 10. Landsat image interpretation results on Quick Bird image

The method of extracting forest subcompartment boundaries together with the field observation can be applied effectively for the forest inventory and other forestry work. It is possible to create a digital forest subcompartment network by adding specified typical points for the area by marking them on the GPS-receiver. This network can be used in forestry repeatedly in the future. The approaches used can become the basis for creation of different materials such as a digital forest map or touristic maps of Natural Reserves.

Scientific novelty and practical meaning

One of the urgent issues of practical forest management is the imperfection of forest cartographic materials. Usually subcompartmental networks are formed based on the instrumental measurement or the visual measurement. It causes some errors in borders defining which later result in differences of area, especially in time of forest economic actions. Therefore, the question of accuracy in forest maps today is of great importance. This problem increases taking into account the tendency to forming acts of the land use which will be a base for many years in the future.

That is why we proposed an adapted algorithm of using remote sensing data for the forest massifs investigation. It has allowed this research to accomplish the adequate estimation of borders of forest subcompartments of the part of Skole forest district of the Natural Reserve “Skolivsky Beskydy”, define its shapes and estimate the main cruising indexes of forest stands. This algorithm consists of using available remote sensing data, in particular Landsat satellite images, for interpretation of species groups. This allows seeing borders of these classes on thematic maps and compares it with the forest subcompartment’s network. Received results and the algorithm itself can be used for creation and definition of existing digital forest maps and touristic maps.

Conclusions

Comparing of materials of our forest inventory in forest stands on sample plots of Natural Reserve “Skolivsky Beskydy” showed considerable deviations with the permanent forest inventory data. In our opinion this occurs since the visual approach to estimation of main cruising indexes is subjective. On the other hand, errors are arising for definition borders of forest subcompartments and its spatial disposition. Errors are increasing owing to the small area of the researched territory. Therefore, for the similar research it is necessary to expand the area of the instrumental research to objectively compare it with permanent forest inventory materials.

The difference in borders of subcompartments on the cartographic forest inventory materials was shown as well by the thematic map of performing classification with Minimum Distance algorithm of the satellite image Landsat. For the interpretation of the forest cover lands it is better to use the geometrically corrected images with the additional NDVI-band.

Generally speaking, in our opinion, the used approaches for the group species estimation and determination of borders of the forest compartments can be used for the next inventory work and for the creation of cartographic materials of the forest management.

REFERENCES

Aronoff S. Remote sensing for GIS managers. 1sted. Redlands, California: ESRI Press, 2005, 490 p.

Cunjak A. M., Chaskovskyy O. G., Korol M. M. *Rozpodil nazemnoho vkryttia Stryisko – Sianskoi Verkhovyny na osnovi suputnykovykh znimkiv LANDSAT* [Landcover distribution of Stryj-Sjan sublimity on the basis of Landsat satellite images]. Scientific Bulletin of Ukrainian National Forestry University. 2013, no. 23.14, pp. 27–32.

Chaskovskyy O. G., Myklush S. I. *Zastosuvannia hiperspektralnykh suputnykovykh znimkiv dlia sposterezhen za lisovymy masyvamy* [Application of hyperspectral satellite images for supervision over forests stands]. *Naukovyi visnyk NLTU Ukrainy* [Scientific Bulletin of Ukrainian National Forestry University]. Lviv : *UkrDLTU*, 2004, no. 14.6, pp. 190–193.

Coppin P., Jonckheere I., Nackaerts K., Muys B., Lambin E. Digital change detection methods in ecosystem monitoring: a review. International Journal of Remote Sensing, 2004, vol. 25, pp. 1565–1596.

Havrylyuk S. A., Myklush S. I. *Klasyfikatsiia zemel lisovoho fondu Zakhidnoho Lisostepu Ukrainy za materialamy dystantsiinoho znimannia* [Classification of Forest Cover Types of Western Steppe of Ukraine Using Remote Sensing Data]. Scientific Bulletin of

Ukrainian National Forestry University. Lviv*: NLTUU*. 2007, no. 17.3, pp. 26–35.

Havrylyuk S. A., Khomyuk A. P. Realization of statistical inventory of the virgin beech forest in Uholsko-Shyrokoluzhanskyi massif. Forestry, Forest, Paper and Woodworking Industry). Lviv: *NLTUU.* 2011, no. 37.2, pp. 38–41.

Horoshko M. P., Myklush S. I., Chaskovskyi O. H. *Dystantsiini sposterezhennia za hirskymy terytoriiamy baseinu Verkhnoi Tysy* [Remote sensing of the territory of Upper Tysa river]. Scientific Bulletin of Ukrainian National Forestry University.– Lviv: *UkrDLTU.* – 2003. – No. 13.1. – P. 58–61.

Horoshko M. P., Vytseha R. R. *Osoblyvosti inventaryzatsii hirskykh lisiv u systemi rehionalnoho monitorynhu* [Peculiarity of mountain forests inventory in the regional monitoring system]. *Promyslova hidravlika i pnevmatyka: vseukrainskyi nauk. tekhnichnyi zhurnal.* [Industrial hydraulics and pneumatics: Ukrainian scientific and technical journal]. 2010, no 4 (30), pp. 12–14.

Horoshko M. P., Vytseha R. R. *Otsinka urbanistychnykh protsesiv hirskykh landshaftiv suchasnymy zasobamy lisoinventaryzatsii* [Estimation of urban processes of mountain landscapes by modern facilities of forest inventory]. *Naukovyi visnyk NLTUU: zb. nauk.-tekhn. prats.* [Scientific Bulletin of Ukrainian National Forestry University]. Lviv, 2011, no. 21.16, pp. 85–90.

Kashkyn V. B., Sukhynyn A. Y. *Distancionnoe zondirovanie Zemli iz kosmosa* [Remote sensing of Earth from space]. Moscow: *Lohos*, 2001, 264 p.

Khlian Ya. O. *Praktychni aspekty zastosuvannia kosmichnykh metodiv u monitorynhu navkolyshnoho seredovyshcha* [Practical aspects of using space methods for environment monithoring]. *Heodeziia, kartohrafiia i aerofotoznimannia* [Geodesy, cartography and Aerial Photography]. Lviv, 2009, No. 71, pp. 78–80.

Kopiy L. I., Chaskovskiy O. H., Kopiy S. L. *Vykorystannia suputnykovykh znimkiv Landsat-TM ta Landsat-ETM dlia optymizatsii lisystosti porushenykh landshaftiv Yavorivskoho raionu* [Using of Satellite Images Landsat-TM and Landsat-ETM for the Optimisation of Afforestation of Brocen Landscapes Yaworiv Regions]. *Naukovyi visnyk NLTU Ukrainy*.Scientific [Bulletin of Ukrainian National Forestry University]. 2006, no. 16.5, pp. 11–17.

Lawrence R. L., Wood S. D., Sheley R. L. Mapping invasive plants using hyperspectral imagery and Breiman Cutler classifications (Random Forest). Remote Sensing of Environment. 2006, vol.100, pp. 356–362.

Myklush S. I, Havrylyuk S. A. *Vydilennia "lisovoi masky" dlia Zakhidnoho Lisostepu Ukrainy* [Separation of "forestry mask" for Western Forest-Steppe of Ukraine]. *Lisivnytstvo i ahrolisome-lioratsiia* [Forestry and Forest Melioration]. 2006, no. 110, pp. 60–66.

Myklush S. I, Havrylyuk S. A. *Vydilennia riznykh katehorii zemel lisovoho fondu dystantsiinymy metodamy* [Separation different categories of forest cover using remote sensing data]. *Tezy dopovidei uchasnykiv konferentsii naukovo-pedahohichnykh pratsivnykiv, naukovykh spivrobitnykiv i aspirantiv ta 61-oi studentskoi naukovoi konferentsii* [Thesis of conference of scientists, teachers and postgraduate students and 61 student's scientific conference]. Kyiv: *NAU.* 2007, pp. 42–43.

NDVI – theory and practice. Electronic resources. Available at: http://www.gis-lab.info/qa/ndvi.html.

Richards J. A., X. Jia. Remote sensing digital image analysis: an introduction. Berlin; Heidelberg; New York; Barcelona; Hong Kong; London; Milan; Paris; Singapore; Tokyo : Springer, 1999, 363 p.

Stefanski J., T. Kuemmerle, O. Chaskovskyy et. al Mapping Land Management Regimes in Western Ukraine Using Optical and SAR Data. Remote Sens. 2014, vol. 6, Issue 6, pp. 5279–5305. Available at: doi:10.3390/rs6065279

Strochinskii A. A., Pozyvailo Y. M., Jungst S. E. Forests and forestry in Ukraine: standing on the brink of a market economy. Journal of Forestry. 2001, vol. 99, pp. 34–38.

Swain P. H., Landhrebe D.A., Phillips T. L., Hoffer R. M, Lindenlaub J. C., Silva L. F.; Editors:.Swain P. H, Davis S. M. *Distancionnoe zondirovanie: kolichest-vennyj podhod* [Remote sensing: The quantitative approach. Moscow: *Nedra*, 1983, 415 p.

Vytseha R. R., Hrynyk H. H. *Natsionalna inventaryzatsiia lisu v Finliandii, Shvetsii, Lytvi ta Danii* [National forest inventory in Finland, Sweden, Lithuania and Denmark]. Scientific Bulletin of Ukrainian National Forestry University. Lviv, 2008, no. 18.11, pp. 141–148.

О. ТОКАР[1*], М. КОРОЛЬ[2], С. ГАВРИЛЮК[3], А. ЦУНЯК[4]

[1*] Кафедра міжнародної інформації, Національний університет “Львівська політехніка”, вул. С. Бандери, 12, Львів, Україна, 79013, ел. пошта: tokarolya@gmail.com
[2, 3] Кафедра лісової таксації та лісовпорядкування, Національний лісотехнічний університет України, вул. Природна, 19, Львів, Україна, 79057, ел. пошта: nikkorol@ukr.net, serhiy_havrylyuk@ukr.net
[4] Відділення землевпорядкування та дизайну, Екологічний коледж Львівського національного аграрного університету, вул. Замарстинівська, 167, Львів, Україна, 79068

ВИКОРИСТАННЯ СУПУТНИКОВИХ ЗНІМКІВ ДЛЯ ОЦІНЮВАННЯ ТАКСАЦІЙНИХ ПОКАЗНИКІВ ЛІСОВИХ НАСАДЖЕНЬ

Мета. Оцінка стану лісових насаджень за матеріалами космічних знімків та статистичної інвентаризації, порівняння отриманих результатів (лісівничо-таксаційних показників) з матеріалами лісовпорядкування. **Методика**. Для дослідження таксаційних показників деревостанів використано матеріали дистанційного зондування Землі (ДЗЗ). Лісівничо-таксаційну оцінку деревостанів НПП “Сколівські Бескиди” та уточнення контурів масивів здійснено з використанням космічних знімків Landsat ETM+ із розрізнювальною здатністю 30 м, а для перевірки – зображення Quick Bird – відповідно 0,6 м. Для проведення дешифрування за алгоритмом мінімальної відстані досліджували деревостани на тестових ділянках (пробних площах), які закладали по перетинах растрової сітки з кроком 300 м у вертикальному та горизонтальному напрямку, яку згенеровано у програмному продукті QGIS. Визначення основних лісівничо-таксаційних показників здійснювали згідно з прийнятими у лісовій таксації та лісовпорядкуванні методиками. **Результати.** Описано застосування космічних знімків для дослідження лісових насаджень. Використано сучасні підходи та новітні технології для дослідження лісових ресурсів, що дало змогу провести адекватну оцінку меж ділянок лісової рослинності фрагменту Сколівського лісництва НПП “Сколівські Бескиди” Львівської області та уточнити їх контури із використанням космічних знімків. Обчислено різницю площ за електронними картами та за матеріалами лісовпорядкування. **Наукова новизна і практична значущість**. У статті адаптовано алгоритм використання матеріалів ДЗЗ для виділення меж таксаційних виділів. За результатами проведеної інвентаризації на дослідних ділянках здійснено порівняння основних таксаційних показників з матеріалами повидільної бази даних лісовпорядкування та визначено відхилення. Отримані дані та алгоритм можна використати для створення цифрових карт насаджень, туристичних карт парку, розподілу на функціональні зони тощо.

Ключові слова: лісова рослинність; супутниковий знімок; дешифрування; растр; цифрова карта.

Received 18.04.2017