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# Classical and Modern Remote Mapping Methods for Vegetation Cover

*Algimantas Česnulevičius, Artūras Bautrėnas,  
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## Abstract

Plant classification is quite complex and multilevel. All living organisms are divided into domains, kingdoms, types, classes, ranks, families, tribes, and species. This classification complexity is also reflected in the classification of biogeographic maps, which is much simpler. Based on floristic dependence, vegetation is grouped by connecting it into spatial (territorial) complexes. This paper presents the interfaces of mapping methods with taxonomic vegetation types at different hierarchical levels. At the same time, examples of vegetation mapping techniques from national and thematic atlases of different countries are presented in this article. UAV aerial photographs are widely used for local mapping of vegetation areas. The authors of this article propose a new methodology that can be used to assess the ecological condition of young trees and the volume of mature forest wood. The methodology is based on the separation of tree crown areas in UAV aerial photographs and photo color analysis. For automated area calculation of young trees, a PixRGB software has been developed to determine the area of pixels of the same color in aerial photographs. The software is based on the comparison of young tree crown area calculations in AutoCAD software and area measurements of individual color spectrum pixels. In the initial stage, aerial photographs are transformed to the exact size of the photographed area. Transformations were performed with an error of less than 2–3 cm. The transformation of the spectrum of aerial photographs allowed to concentrate the color of the image of young trees in a relatively narrow color range. Studies performed in 2019–2020 to assess the ecological condition of trees and the amount of wood using UAV INSPIRE 1 and PixRGB color analysis software showed the effectiveness of the applied methodology.

**Keywords:** methods of vegetation mapping, UAV, aerial imagery, automated color analysis

## 1. Introduction

Plant classification is quite complex and multilevel. All living organisms are divided into domains, kingdoms, types, classes, ranks, families, tribes, and species. This classification complexity is also reflected in the classification of biogeographic

maps, which is much simpler. Phenomena describing vegetation and fungus are mapped in geobotanical maps. The distribution of natural vegetation and its change is usually mapped in these maps. Vegetation types and species composition are determined by ecological conditions that vary in different parts of the Earth and determine the productivity of the entire biological ecosystem. Biological productivity is determined by a complex of environmental conditions sets. On the other hand, the biological abundance of plants directly affects the environmental conditions. The basic elements of the areas covered by vegetation (vegetation cover) are the respective plant species, which differ in their appearance, stems, leaves, size. These indicators determine the appearance and structure of the entire local vegetation cover. Based on floristic dependence, vegetation is grouped by connecting it into spatial (territorial) complexes.

The first biogeographical maps focused on forest mapping. Later, the content of these maps was expanded: mapped shrubs, wetlands, meadows, detached trees. Contemporary biogeographical maps acquired modern content in the 19th century, when classification of vegetation indicators began to be applied to their compilation. The first floristic biogeographic mapping methodology was applied by the Danish botanist Joachim Frederik Schouw (1789–1852), who developed the basics of phytogeography. He compiled the phytogeographical World atlas (*Pflanzengeographischer Atlas zur Erläuterung von Schouws Grundzügen einer allgemeinen Pflanzengeographie*) with 22 global maps. This atlas was published in 1823 in Berlin.

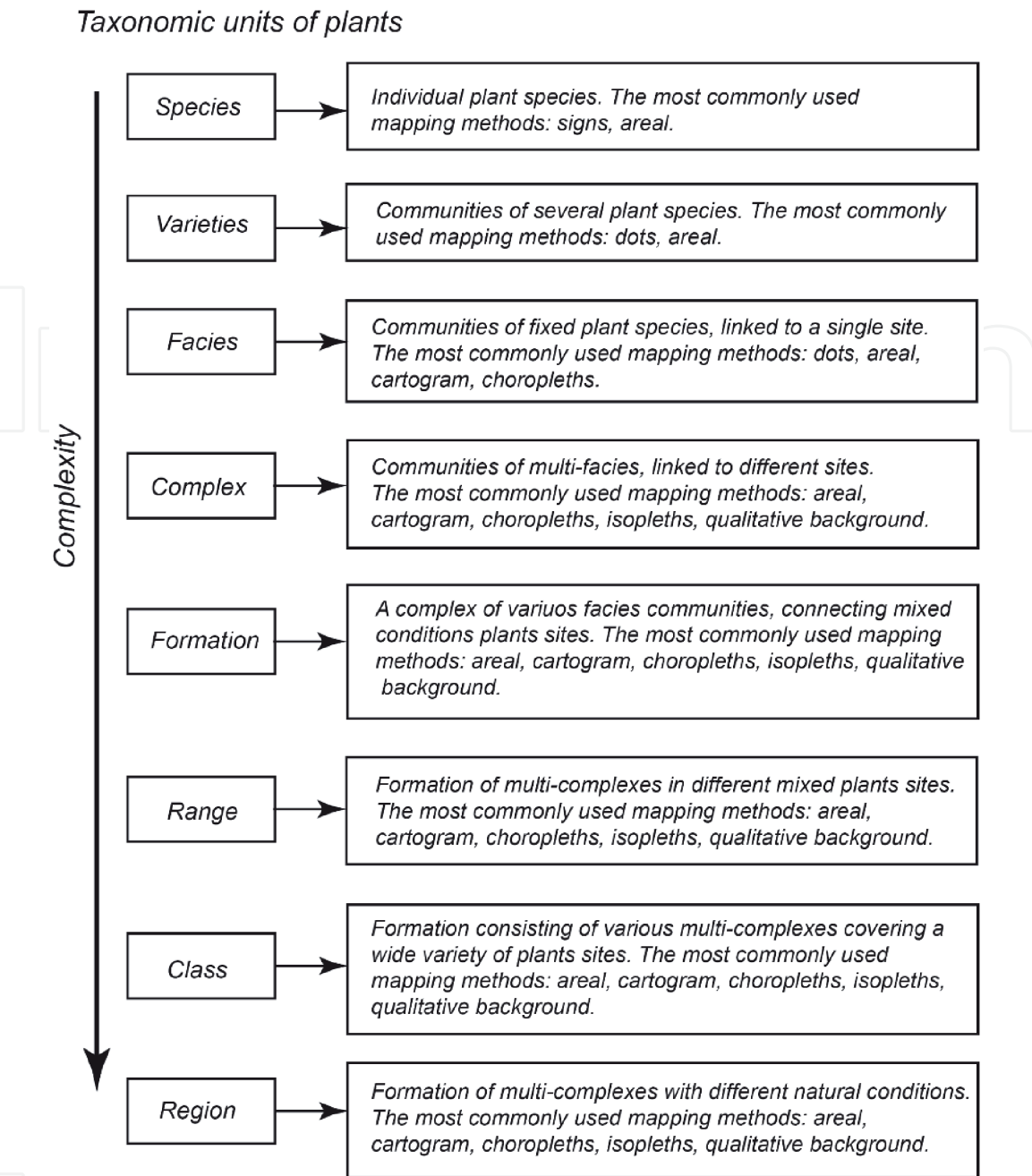
Between 1837 and 1848, six geobotanical maps were printed in the Berhaus Atlas. In a later edition from 1886 to 1892, geobotanical maps covered the entire fifth volume of the atlas. Five biogeographic maps were published by Alvin J. Johnson in *Family Atlas* (1843). The *Atlas of Gymnasiums and Real Schools* by Richard Andree and Friedrich Wilhelm Putzger (Germany, 1879) contains biogeographical and World vegetation zone maps. Richard Lüddecke and Herman Haak in *Deutscher Schulatlas Mittelstufe* (1895) published a floristic map of Europe.

The vegetation cover of a specific area is assessed and mapped in two aspects:

1. Floristic, when the vegetation cover is associated with the species composition of the plants.
2. Phytocenotic, when assessing the totality of plant species of a certain habitat with its characteristic structure and environment.

The plant species is considered to be the basic vegetation classification element - phytotaxone. From the phytocenotic point of view, the heterogeneity of the vegetation cover is assessed. It is highly dependent on the area of vegetation cover: for the larger the area characterized the greater heterogeneity of the vegetation cover. On the other hand, for each study area, are distinguished of diagnostic plant species, basis of which the vegetation areas are assigned to the respective formations. The groups of plant species that dominate the vegetation habitats reflect the relevant biocenotic homogeneity or heterolyticity of the site and are taxonomic indicators of vegetation cover. Cenotic vegetation derivatives are at several hierarchical levels: species, varieties, facie's, plant complexes, plant formation, plant range, plant class, and floristic region (**Figure 1**).

At the same time, are applied the different classifications of vegetation cover, which reflects the indicators of plant density and their height. Based on this classification, the territories divided on different types of vegetation land cover: forests, shrubs, semi-shrubs, meadows.



**Figure 1.**  
*Phytocenotic types of vegetation.*

## 2. Methodology

Thematic maps of geobotanical, forestry, relevant sections of national atlases and separately published maps were analyzed for the evaluation of traditional vegetation mapping methods. The main source of information was thematic atlases, in which vegetation cover was mapped in many aspects: dispersal of vegetation types and complexes, dispersal of plant association, dispersal of individual plant species, vegetation resources and dispersal of vegetation resources, dispersal of rare and protected vegetation species, economic use of vegetation types and complexes.

The analysis was performed using a summary of quantitative indicators. Were calculated different mapping methods of maps and summarize the collected statistics data, which allowed to evaluated the most widely used traditional mapping methods. Publications of other countries researchers have also been used for the analysis [1–4].

The analysis of the application of modern research methods was performed by summarizing numerous publications on the using of multispectral aero- and space images in the separation of vegetation type aerals or individual plant species. The possibilities of applying remote sensing methods are widely studied in numerous publications on forest management, assessing the amount of wood in forests, the ecological condition of trees. The authors of the article discuss in more detail one of the methodological variants that they applied in the assessment of the ecological condition of trees and wood volume.

### **3. Vegetation mapping techniques and image generalization**

The sign method is used to map the location of special (rare, unique) plants. In the case where the relevant plant species do not form a continuous cover and the plants are scattered over a wide area, the habitat method is used to map the distribution of the species. The boundaries of the habitats are drawn in lines of different colors and structures, and inside them are drawn signs, reminiscent of a plant species, or the names of plant species are written. Using cartodiagrams, cartograms and habitat methods are mapped the number of plants, the number of their habitats sites, the number of plant species or the covered area (**Figures 2 and 3**).

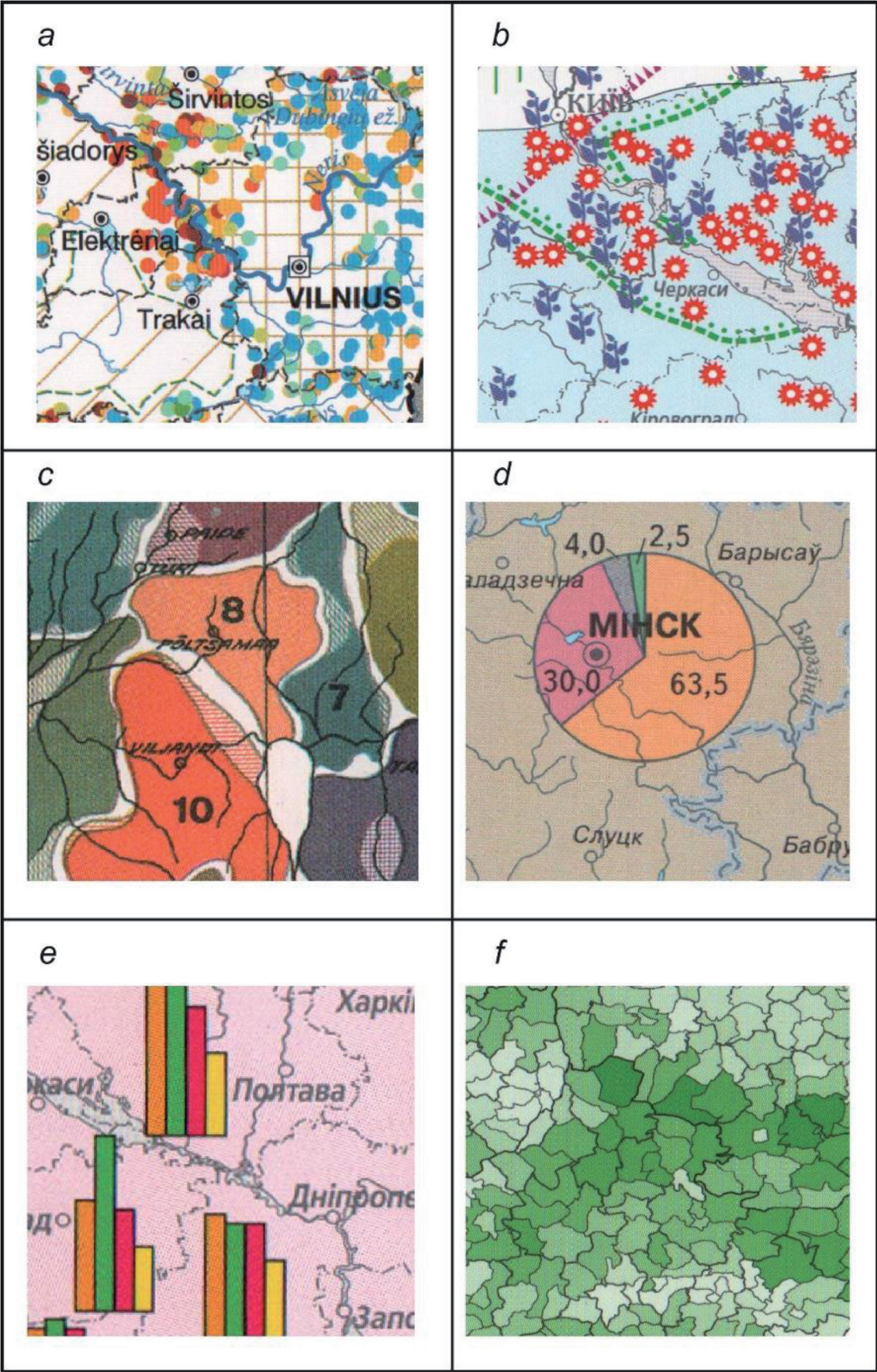
Areas of natural vegetation where dominated by plants of one species shall be assigned to the relevant vegetation type. In phytocenological maps, homogeneous territorial formations are mapped using the qualitative background method. This method of mapping is supplemented by symbols (images, letters or geometric signs), numbers, raster backgrounds (dots, lines, small figures of simple shape) or inscriptions (classification name of the predominant species or vegetation type). Using the qualitative background method, the colors of areas of different vegetation types are selected on the basis of isomorphism: “cold” colors (blue, green) are used to mark areas of wet-loving plants, “warm” colors (yellow, pink) are used to mark areas of dry-loving plants.

In cases where vegetation communities form mixed structures (types), strip coloring or raster and color techniques are applied together. Rare plant habitat sites, small areas of concentrated species distribution and taxonomically important plant sites generally are mapped using the sign method.

The spatial structure of the vegetation is mapped using identical methods, and the methods of cartograms and cartographies are used to quantify the spatial structure, giving the absolute values of rare plants in the standard area (cartodiagrams) or the percentage structure of plant species (choropleths, cartograms). Various methods of vegetation mapping have been used in the Atlas of Forests of the USSR [11]. A detailed analysis of vegetation mapping methods for Italian territory has been performed by Franco Pedroti [12].

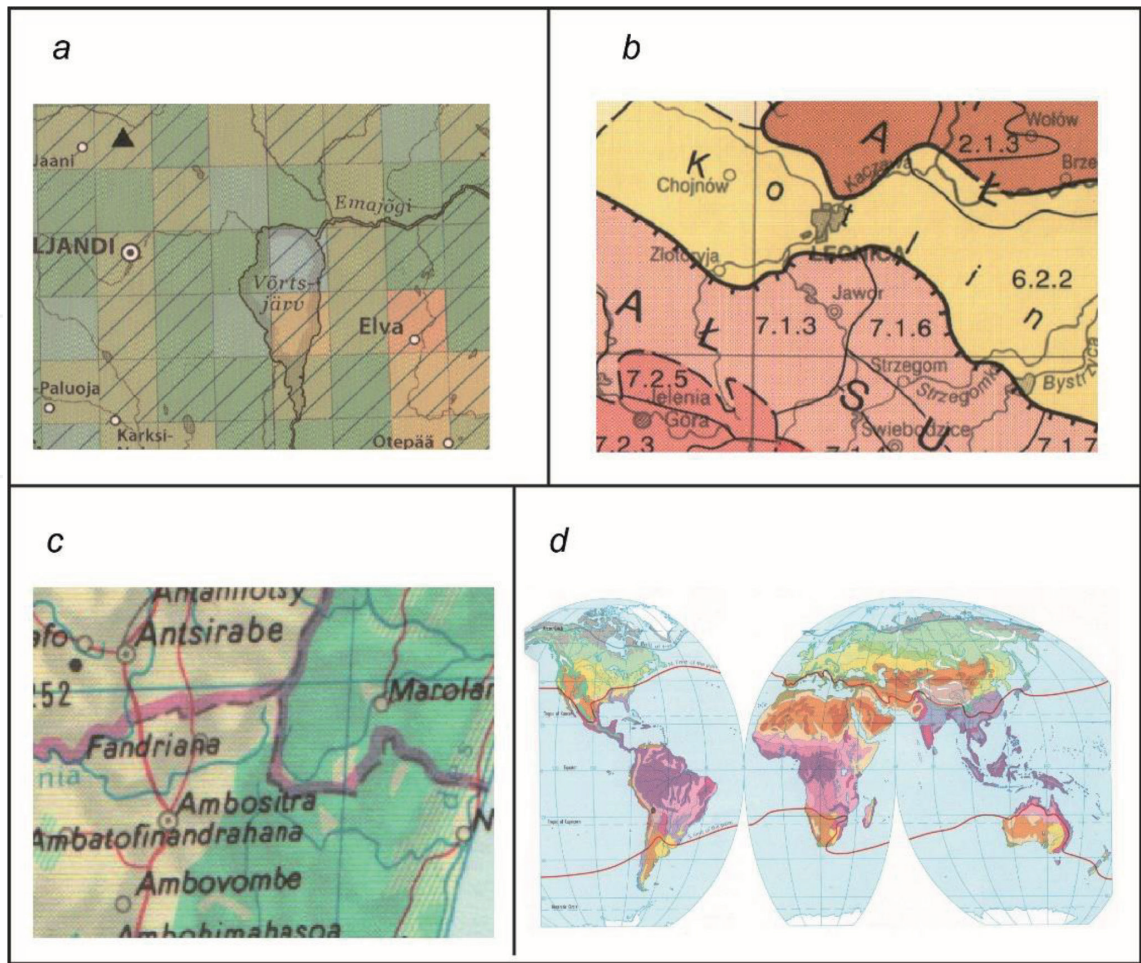
An important aspect is the generalization of vegetation maps. It is performed by grouping and connecting small territorial areas into higher-ranking larger formations. Particular attention is appoint for latitudinal and vertical differentiation and spatial spread of vegetation type. For compiling of vegetation maps are distinguished geographical variations of plant species, plant species adapted to grow at different heights or characterized by differences in seed and fruit abundance. Grouping of taxonomic areas is performed by combining homogeneous vegetation types into more complex spatial formation. This also determines the mapping methods: the areas of vegetation types mapped by choropleths, isopleths and habitat methods on large-scale maps and by non-scale signs on small-scale maps. Landscape complexes or natural regions are mapped on the smallest scale





**Figure 2.**  
Examples of plant mapping methods: a – Dots (fragment of natural meadows and pastures map from National Atlas of Lithuania, 2017), b – Dots and areas (fragment of Areal of herbal plants map from National Atlas of Ukraine, 2008), c – Qualitative background (fragment of regions of vegetation map from [5]), d – Cartodiagram (fragment of afforestation map from [6]), e – Cartodiagram (fragment of forests age map from National Atlas of Ukraine, 2008), f – Cartogram (isopleths) (fragment of forestation map from [7]).





**Figure 3.**  
*Examples of plant mapping methods: a – Formal cartogram (isopleth) (fragment of Flora map from [5]), b – Qualitative background (fragment of Geobotanical division of Silesia map from [8]), c – Areas (fragment of Madagascar general map from Haack [9]), d – Qualitative background and areas (fragment natural vegetation map from [10]).*

vegetation maps (**Figure 1**). The main grouping criterion in the vegetation maps is the percentage of the respective vegetation type in the whole mapped area.

In cartographic generalization process small vegetation types and their individual habitats sites are combined into complex formations or completely eliminated. The area of the complex carved surface is dominated by small mosaic habitats of vegetation types. In this case, the generalization of vegetation types is carried out on the basis of the diversity of relief complexes. This means that vegetation types are combined into complexes based on orographic criteria rather than floristic ones.

**4. Sources of information**

Classical floristic maps are compiled on the basis of field research, where typical plant species are identified in 10 × 10 km areas and the area covered by them is drawn. The boundaries of the habitats sites are determined on the basis of the distribution of the respective soils and the geomorphological features of the relief. A unified transverse cylindrical Mercator projection is often used to construct global floristic maps.

Floristic information is collected through a terrestrial plant distribution inventory and the use of multispectral aero- and space images. Its essence: a well-studied area in terms of vegetation species is photographed, followed by a floristic

interpretation of the studied areas based on external identification features (color, color saturation, contour image). Interpretation of multispectral aero- and spatial images allows the identification of vegetation types areas, but the identification of individual plant species is complicated and unreliable. It is particularly difficult to distinguish individual tree species in multi-species tropical and equatorial forests.

At the beginning of the 21st century, unmanned aerial vehicles (UAV) were widely used to assess the prevalence of relatively small plant species areas. They can be used to obtain chromatographic and multispectral large-scale images in which species identification is simpler and more reliable. Aerial photographs of UAV are most widely used in forest management, assessing the amount of wood in forests, the ecological condition of trees.

## **5. Methodological features of UAV aerial photography**

The application of UAV images to vegetation mapping is carried out in several directions:

1. Assessment of plant species composition.

2. Assessment of the ecological status of plants.

3. To assess the amount of wood in growing forests.

1. Mapping of plant species composition (individual tree species) may be performed only in large (M 1: 10 000) or very large (M 1: 5 000) scales. Alternatively, when the scales of the maps are smaller, the mapped area is divided into phytocenotic combinations areas. The boundaries of these combinations are mapped on a map. In this case, the map resembles a “frock - coat”, where each patch is a territorial combination of phytocenosis. Maps with a scale of 1:25,000 and smaller can be used to phytocenoses contours mapping, the target sizes of which are measured in hundreds of meters or kilometers. Where phytocenosis contours are smaller (several tens of meters), it can be mapped only at the scale of topographic plans: 1: 1,000–1: 5,000.

2. An accurate indicator of wood volume calculation is necessary for the assessment of the ecological condition of trees [13]. It is related to the diameter at breast height (DBH) parameter of the tree trunk and the total tree height (H) [14–17]. Many studies have shown that biomass models with DBH and H parameters are more reliable in determining tree biomass and assessing its viability [18–21].

3. Most common ground-based method is clinometric measurements that does not require cut off of tree. This method has one drawback: it is necessary to see simultaneously the base of the trunk and its top during the measurement. In boreal forests such a requirement is difficult to realize, and in equatorial forests it is practically unenforceable. In addition, the accuracy of over-ground trees height measurements deteriorates with increasing tree height [22].

Tree height is one of the most important indicators for evaluation of forest wood resource. Along with other key characteristics (diameter at chest height (DBH), tree species), tree height allows evaluate other important indicators: tree age, wood amount, biomass. In this case, the accuracy of the measurements



becomes a very important factor. For the assessment of wood amount, the accuracy index becomes as important or even more important than the determination of tree species [23–25].

Measurement accuracy is enhanced by laser scanning (LiDAR) based on active sensing technology. This method has several advantages [26]:

1. A direct 3D image is obtained where measurements can be made with centimeter accuracy.
2. Determine the real surface on which the forest grows and thus adjust the height of the trees.
3. Application of automated calculation methods to facilitate large area surveys.

On the other hand, laser scanning equipment is quite heavy, so the possibilities of such a method for UAV are limited.

## 6. Methodology for applying UAV aerial photographs to assess the ecological condition of trees and wood amount

Various methodologies are currently used to assess the ecological condition of trees and wood amount. Their application possibilities are determined by the available equipment and its price: UAV and its carrying capacity, camera capabilities, software used for aerial images analysis. The methodology for assessing the ecological condition and trees wood amount developed at the Institute of Geosciences of Vilnius University. It is based on the use of widely available and relatively inexpensive equipment.

Aerial images obtained with the UAV DJI Inspire 1, with an RGB Zenmus X3 camera, are used to calculate the wood volume. The technical parameters of equipment are given in **Table 1**.

UAV orthophoto and perspective images were used to calculate wood amount. In the overlapping images, the crowns of individual trees were separated and the height of the trees was determined using photogrammetric methods. For more accurate calculation of the scale of photo images, Ground control points (GCP) were used. The position of GCPs were additionally measured using a GPS device Trimble R4. Based on the coordinates of the GCPs, the whole 3 D tree crown model was refined. Pix4D Mapper photogrammetric software was used to calculate the height and volume of tree trunks [27].

The crown of a particular tree was treated as a regular cone that could be divided into plan and profile segments (**Figure 4**). Knowing the area  $S_1$ , it is possible to calculate the diameter of the base of the cone of a tree crown (formulas (1) and (2)):

$$R = \sqrt{\frac{S_1}{\pi}} \quad (1)$$

$$D = 2R \quad (2)$$

where  $S_1$  is the base area of the tree crown ( $m^2$ ),  $R$  is the radius of the cone ( $m$ ),  $D$  is the diameter of the cone ( $m$ ).

When the area of the crown cone  $S_2$  is known, the height of the cone can be calculated (formula (3)):

$$L = \frac{S_2}{R} \tag{3}$$

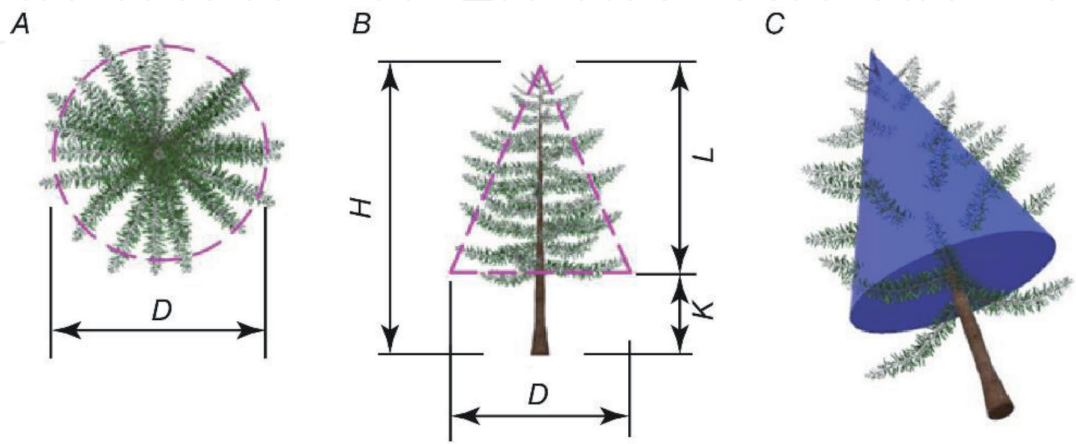
where  $L$  is the height of the crown cone (m),  $S_2$  is the area of the crown cone ( $\text{m}^2$ ),  $R$  is the calculated radius of the base of the cone (m).

The obtained indicators allow estimate the volume of the tree crown (the total amount of green tree mass) (formula (4)):

$$V = \frac{1}{3} \pi R^2 L \tag{4}$$

Hovering accuracy (GPS mode)	Vertical: 0.5 m; Horizontal: 2.5 m
Max angular velocity	Pitch: 300°/s; Yaw: 150°/s
Max tilt angle	35°
Max ascent and descent speed	5 m/s; 4 m/s
Max speed	22 m/s
Max wind speed resistance	10 m/s
Max service ceiling above take-off point	120 m
Type and model	X3; FC350
Total and effective pixels	12.76 M; 12.4 M
Max capacity	64 GB
Maximal image size	4000x3000
ISO Range	Photo - 100-1600; Video - 100-3200.
The electronic shutter speed	8 s - 1/8000 s
A field of view (FOV)	94°
Supported file formats	Photo: JPEG, DNG; Video: MP4/MOV (MPEG-4 AVC/H.264)

**Table 1.**  
The specifications of UAV DJI Inspire1 and RGB Zenmus X3 camera.



**Figure 4.**  
Quantitative indicators of the tree crown: A - top view, B - side view, C - crown cone 3D.

where  $V$  is the volume of the crown cone ( $m^3$ ),  $R$  is the calculated radius of the base of the cone ( $m$ ),  $L$  is the calculated height of the crown cone ( $m$ ).

The photogrammetric methods allow determined tree height and calculate the height of the tree trunk ( $K$ ) up to the base of the tree crown.

$$K = H - L \tag{5}$$

where  $K$  is the height of the trunk to the base of the crown ( $m$ ),  $H$  is the height of the tree measured photogrammetric methods ( $m$ ),  $L$  is the calculated height of the crown cone ( $m$ ).

The calculation of tree trunk volume was performed analogously to the calculation of tree crown volume (formulas (1)–(4)). In this case, a very important condition is to measure as accurately as possible to the ground.

Crown areas  $S_1$  and  $S_2$  are calculated using the specialized software Pixel Color Analysis (PixRGB) (Figures 5 and 6), which also allows to calculate the trunk thickness. The total crown volume is calculated together with the part of the trunk in the crown, so for more accurate estimation, the trunk volume is eliminated from the calculated cone volume.

To reduce the number of analyzed pixels, only parts of the analyzed tree and GCPs are distinguished in the original photo images (Figure 7). The original scaling and resolution of the images are not changed during the calculations. This means that the pixels in all the selected parts will be the same size and will correspond to the scaled images adjusted with the help of GCPs. The software (PixRGB) allows automatically determine the size of one pixel area and calculate the areas of the extracted parts.

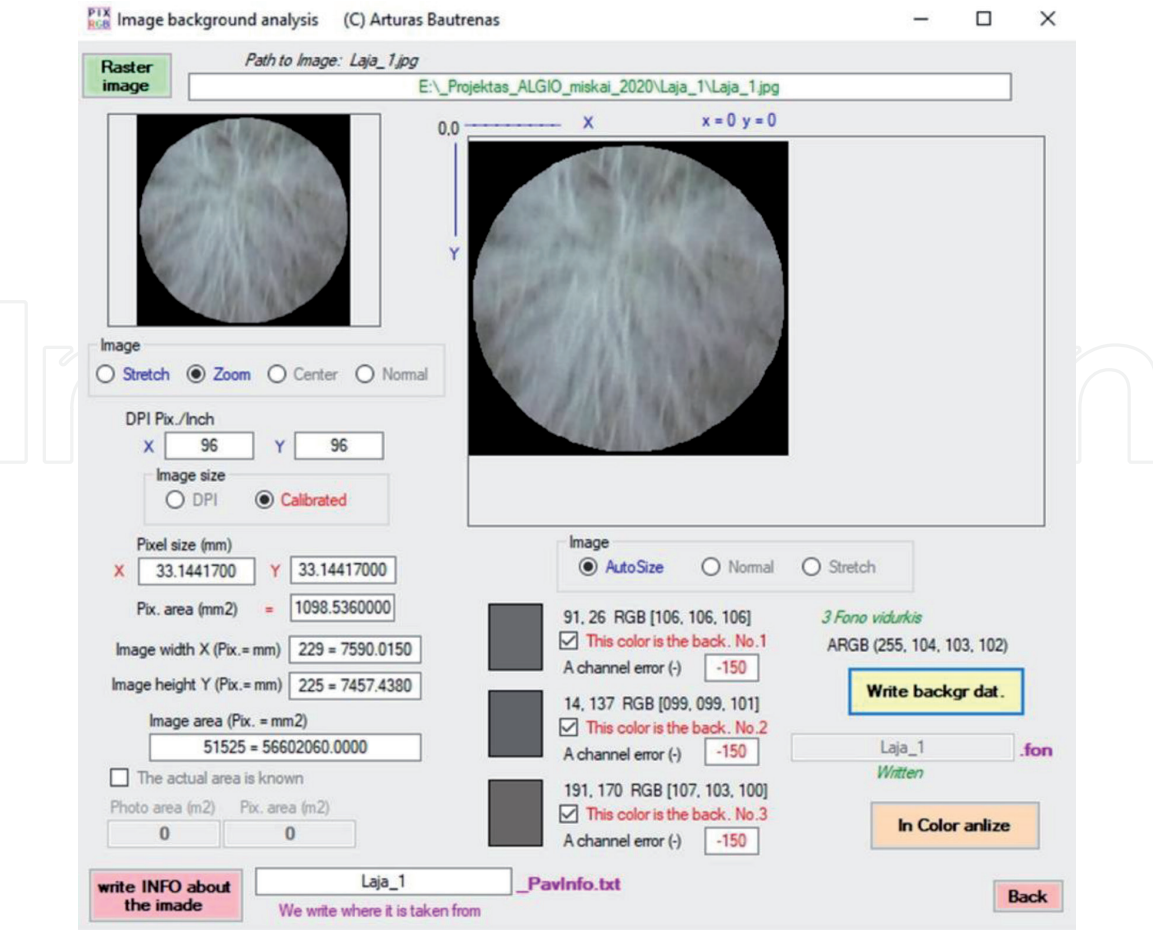
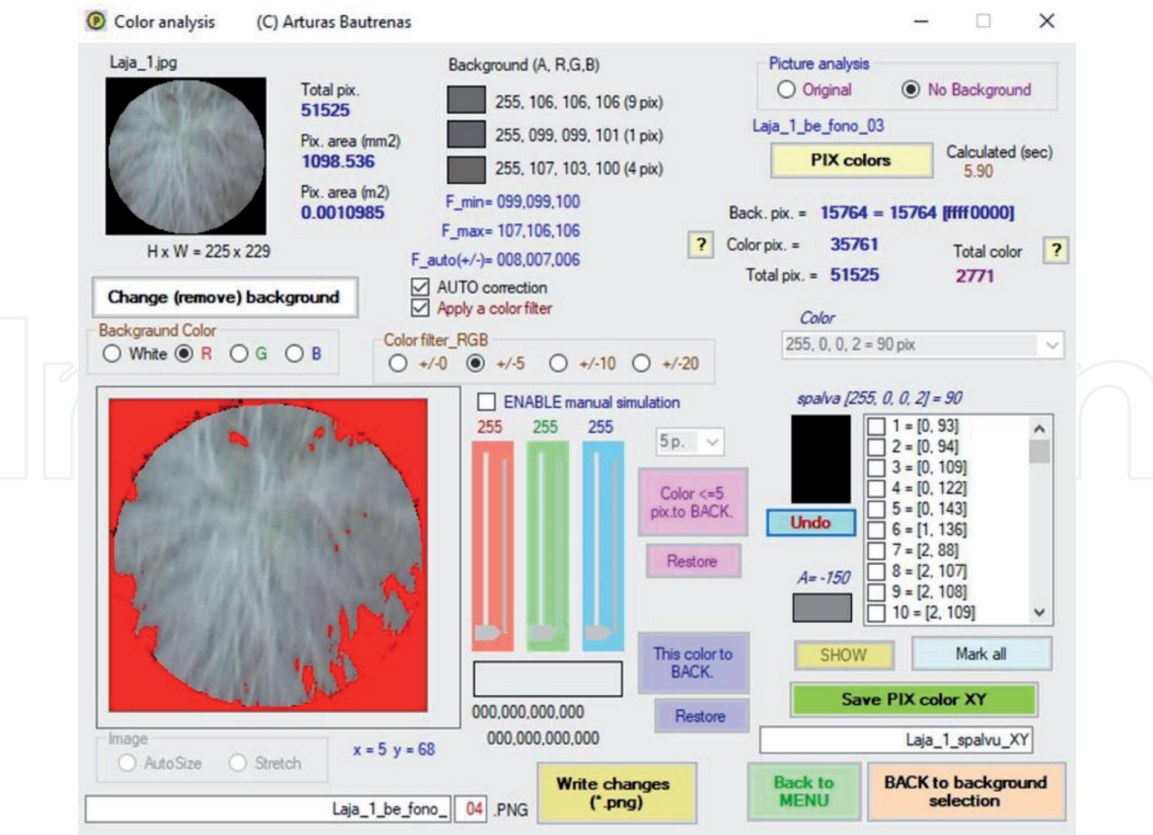
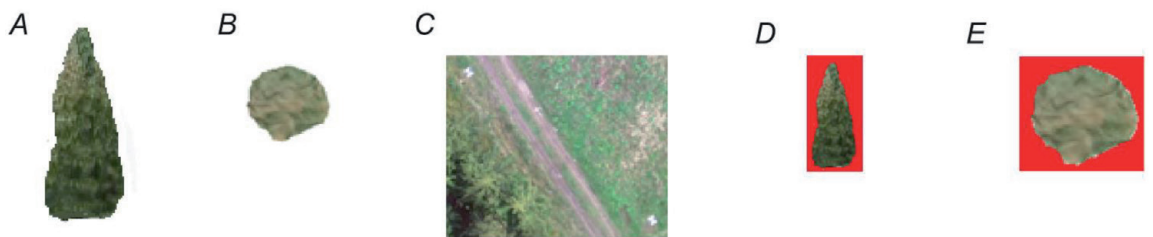


Figure 5.  
The window of tree crown element analysis (software PixRGB).





**Figure 6.**  
The window of color analysis (software PixRGB).



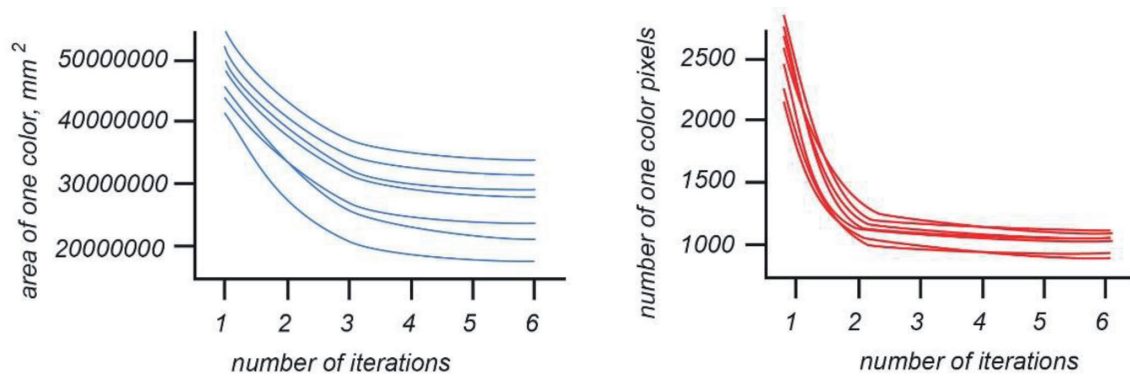
**Figure 7.**  
Parts or photo-images: A - side view, B - top view, C – control, D – subtracted side view, where pixels in red marked rejected as background, D – top view, where pixels in red marked rejected as background.

Several levels of iteration were applied to color analysis. Repeated iteration showed that a satisfactory accuracy result was achieved after the third level of iteration (**Figure 8**).

The extraction of background pixels and their elimination provides information about the area covered by the crown of a particular tree. This indicator is related to the ecological condition of the tree: the denser the crown shown the better the condition of the tree. Such a methodology allows with sufficient accuracy assess the condition of forest seedlings (very young trees), which is important from the forest management point of view.

Elimination of background pixels also allows highlight the trees crown color and connected it with the trees species composition. Studies have shown that the crown colors of deciduous and coniferous trees in the green spectrum range vary depending on the species composition.

Spectral transformation of the photo-images was performed with Adobe Photoshop software by Mode, Adjustments, Hue/Saturation, Color Balance, Brightness/Contrast, Selective Color, and Channel Mixer tools. The Mode tool changed the color separation model. The most suitable for UAV images analysis



**Figure 8.**  
Effect of repeatedly iterations.

is the RGB color model. The tools in the Adjustment group allowed to change the Color Intensity (Levels), Color Balance, Brightness/Contrast, Hue/Saturation.

Experiments have shown that the following aerial image transformations are necessary:

1. Using Adobe Photoshop software changes to RGB color spectrum indicators.
2. The Mode tool sets the RGB color model.
3. Using Adjustments toolbox will made following changes:
  - The Input Levels tool in the (Levels group) changed the whole RGB color spectrum. The Output Levels tool narrows the RGB colors spectrum.
  - The Hue/Saturation tool sets the final RGB color model.

In the transformed aerial photographs, calculations of the area covered by young tree crowns were performed using AutoCAD software and created investigated forest plot database.

For automated calculation of young trees areas, a PixRGB software has been identified the area of the same color pixels in aerial images. The software is based on the comparison of young tree crown area calculations in AutoCAD software and one color pixel area measurements. In the initial stage, aerial images are transformed to the exact size of the photographed area. Transformations were performed with an error of less than 2–3 cm.

The transformation of the areal image color spectrum allowed to concentrate the image color of young trees in a relatively narrow color range. In addition, an error of  $\pm 5$  color coordinates was allowed, the magnitude of which was determined after testing several analysis variants. After the analysis, pixels of different shades were distinguished, eliminating pixels of a specific color, the location of which obviously does not correspond to the analyzed areas. The remaining color pixels formed the total area covered by all young tree crowns.

Comparing the calculations of the area covered by young tree crowns performed with AutoCAD software and applying the automatic analysis of pixel areas of the defined color, it was found that the error rate does not exceed 3%.

Investigations, which performed in 2019–2020 to assess the ecological condition of trees and the amount of wood using UAV INSPIRE 1 and the PixRGB software showed the effectiveness of the applied methodology. The species composition of the trees was assessed with the help of aerial images taken during the summer, and the amount of wood was assessed with the help of images taken during the autumn.

## 7. Discussion

The geobotanical map reflects the heterogeneity space of vegetation cover and is the basis for geobotanical zoning. Hierarchical vegetation cover classification is most commonly used when developing vegetation cover maps. The main element of the content of geobotanical maps is a set of autotrophic plants, which is typical of the habitats of the area. Vegetation mapping in classical ways is based on a chain of corresponding actions: the area is segmented into phytocenoses and their combinations; their boundaries are fixed in the area; based on the position of the topographic objects, the boundaries are transferred to the working map; creation of the final map version. The maps created in this way are reminiscent of a “patch wrap” in which elemental phytocenotic territorial structures are distinguished. The detail content of a map, which created in this way will largely depend on the scale of the map. Detailed elemental phytocenoses mapping is possible only on a very large scale (1: 5,000).

When creating smaller-scale (1: 10,000 or 1: 50,000) maps, the primary image must be generalized by combining elemental phytocenoses into microcomplexes and mesocomplexes. Their boundaries are usually fixed on the basis of the boundaries of the topographic objects of the area; terrain lines, hydrographic network lines, roads, settlement boundaries and the like. In small-scale maps, the degree of content generalization is even higher, so that vegetation meso-complexes are joined into macro-complexes or mega-complexes. A very wide range of plant communities (phytocenoses and their meso-combinations) are found in each of these contours. The legend described only the most common plant communities for that contour. It should be noted that such a map is only approximate characterized to the vegetation area, and the individuality of small areas in such maps completely disappears.

In this case, various combinations of mapping techniques are used to highlight the unique individual characteristics of the vegetation. Such methods are widely used in vegetation maps of small-scale thematic atlases and national atlases ([8, 28], Atlas Republiky [6, 29–31]). In many cases, synthetic derivatives are also used to map the productivity of natural vegetation, wood growth in forests, and so on.

Remote vegetation mapping poses other problems: satellite image quality, cloud areas covering the surface image, accurate identification of vegetation types and species, UAV aerial imagery for small areas only, accuracy and reliability of extrapolation of data collected in Ref. areas. These problems are presented in numerous publications on land cover structure and vegetation area analysis [32], forest inventory and timbering volume estimation [33], increment of adjustment of wood volume [34], accuracy and reliability of laser scanning models for forest wooden evaluation [35], complex application of UAV aerial images and ground-based measurement methods [26, 36], assessment of underwood influence on UAV aerial images [37], for the application of high-resolution space images to the mapping of grassland plant communities [38].

All the mentioned research directions are focused on the accuracy of measurements and data, lower time costs. The methodology of tree ecological condition and wood volume assessment proposed by the authors is based on the use of medium-class UAVs and the application of widely available equipment for image analysis. In addition, the presented methodology is suitable for estimating the amount of wood growth at all seasons of the year. Images taken in spring and autumn have the highest accuracy in identifying tree species.

Of course, the application of remote sensing methods is very effective, but the reliability of the identification of individual areas of the space images that are used for the analysis of land use/land cover data is a problem. Faster use of remote



sensing data and methods helps to make the process of spatial analysis faster and more powerful, but the increased complexity of the methods also creates the potential for higher errors.

## 8. Conclusions

Mapping of individual plant groups and vegetation cover has old traditions. Forest distribution was mapped in the Finnish National Atlas. This atlas is the first national atlas in the World, published in 1899 (Atlas [39]). Vegetation maps published in the some national atlases of the countries in the first half of the 20th century: Czechoslovakia (Atlas Republiky [29]), France (Atlas [40]), Germany [41], Great Britain [42], Romania [43]; Argentina [44], Mexico [45], Brazil [46] and others). These maps provide floristic and phytocenotic information.

Subsequent national and regional atlases and specialized thematic atlases have mapped the distribution of individual vegetation species, usually rare and protected. Traditional habitat and sign methods were used to map them.

In the second half of the 20th century, monochromatic (black - white) and panchromatic aerial images were used for floristic mapping, and from the 1980s, were also used space images. Landsat, SPOT, Terra (EOS AM-1), Aqua (PM-1), IKONOS, QuikBird satellite sensors were introduced for the mapping of vegetation cover developed in the eighties, with the help of which high-resolution images were created. Recently, images that can determine the normalized difference vegetation index (NDVI) have been widely used for phytocenotic mapping of vegetation. This is a convenient way to map the phytocenotic state of vegetation, but has its limitations. Restrictions relate to classifications of land cover, heterogeneity of floristic or whole vegetation classifications [47–52].


UAVs are used for floristic and phytocenotic mapping of small vegetation areas. The possibilities of their use were expanded by panchromatic images, which allow to identify individual plant species (mostly trees), to evaluate the phases of plant phenological process and to evaluate the amount of wood in forests by photogrammetric methods.

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