Y. Y. Bilinskyi, Dr. Sc. (Eng.), Professor; B. P. Knysh, Cand. Sc. (Eng.), Assistant Professor; Ya. A. Kulyk, Cand. Sc. (Eng.), Assistant Professor

PROCESSING AND USAGE OF THE MULTISPECTRAL IMAGES IN AGROMONITORING

The paper contains the analysis of the process of images processing in agromonitoring, that enables to obtain complex information, regarding the state of the fields and agricultural crops, cultivated on these fields. This implies the passage of several stages of the complex preprocessing, which performs the correction and improvement of the space survey and aerial survey images and subject-related processing, which provides the decoding process or recognition of the objects and phenomena on the space survey or aerial survey images. Each of these stages includes the corresponding types and ways of the realization, besides some methods of image improvement provide the change of the spectral characteristics of the image, that is why, after their application the methods of subject-related processing, based on the analysis of the values of spectral brightness of pixels (classifications, arithmetic transformation of the channels, etc.) can not be used. In the given research on the base of the analysis of the literature sources, types and ways of the multispectral images processing, regarding agromonitoring are distinguished, as the work with such images due to a small number of spectral bands requires less cost for the processing without quality degradation unlike hyperspectral images. Types of the preprocessing stage are considered, namely geometrical correction of the images, radiometric calibration of the images, radiometric correction of the atmospheric impact, restoration of the missed pixels, contrasting by means of the histogram linear spreading, contrasting by means of histogram equalization, filtration. Methods of the subject-related processing stage are considered, namely: color transformation, analysis of the main components, spectral division, classification with and without learning, image indexation, determination of the quantitative indices. Their peculiarities, conditions of usage, etc., are described. The procedure, describing the stages of multispectral images processing in agromonitoring, taking into account all the types and methods of each stage realization, is suggested.

Key words*: vegetation indices, multispectral images, processing agromonitoring, scheme.*

Introduction

Taking into account rapid development of the agrarian business in the world, which nowadays became the motive force of many national economies, such countries as Ukraine became the largest in the world exporters of the agricultural production (sunflower oil, grain, etc.) [1]. This is achieved due to the wide introduction of the site specific crop management, it includes the set of technologies, based on the results of agromonitoring, namely on the accurate data, i. e., on the images from the satellites or unmanned flying vehicles, using the technologies for their processing. Such data of agromonitoring are the images of various coverage areas and wide range of separating power (satellites – from 10 to 1 m/pixel [2], unmanned flying vehicles – less than 1 cm/pixel [3]).

Nowadays the activity is observed in the sphere of image processing in agromonitoring. This is connected with the creation and updating of the hardware and software complexes, development and improvement of the processing methods, improvement of the devices, performing the survey (satellites, unmanned flying vehicles), and ground control stations, constant increase of their number, widening of their functional possibilities and range of the performed tasks. Application of the space satellites and unmanned flying vehicles [4] for the monitoring of the agricultural areas allows to analyzed fields, identify problems (plant pests and diseases, consequences of the bad weather conditions), perform planning and control the crop yield [5].

The process of images processing in agromonitoring is complex, as it requires constant elimination of various atmospheric impacts, distorting the images, in particular, non -uniformities of the illumination, dark or too illuminated areas, etc. Besides, the processing of multi- or hyperspectral images was carried out. These are images where the characteristics of the images are fixed in certain ranges of the wavelengths (multispectral image – from 3 to 15 spectral bands, hyperspectral image – hundreds of spectral bands) [6]. The processing of multispectral images is most widespread, as small amount of spectral bands requires smaller cost for the processing without sacrificing the quality.

In practice, in the process of studying the images, which concern agromonitoring and their further processing there appears the necessity to select the procedure of this processing, as there exists wide spectrum of the specific tasks and, correspondingly, types and methods of their realization [7]. Thus, the **aim of the research** is the analysis of stages of multispectral processing in agromonitoring, taking into account all the types and methods of each stage realization and creation of the procedure, which would most completely highlight the process of multispectral images processing during agromonitoring.

Scheme of multispectral images processing in agromonitoring

Full-fledged process of images processing provides execution of certain complex stages, each of them includes types and methods of these stages realization [8]. This enables to obtain the total array of useful information about the state of fields and agricultural crops, cultivated on these fields in the form of multispectral images.

Generalized scheme of multispectral images processing in agromonitoring can be described as it is shown in Fig. 1.

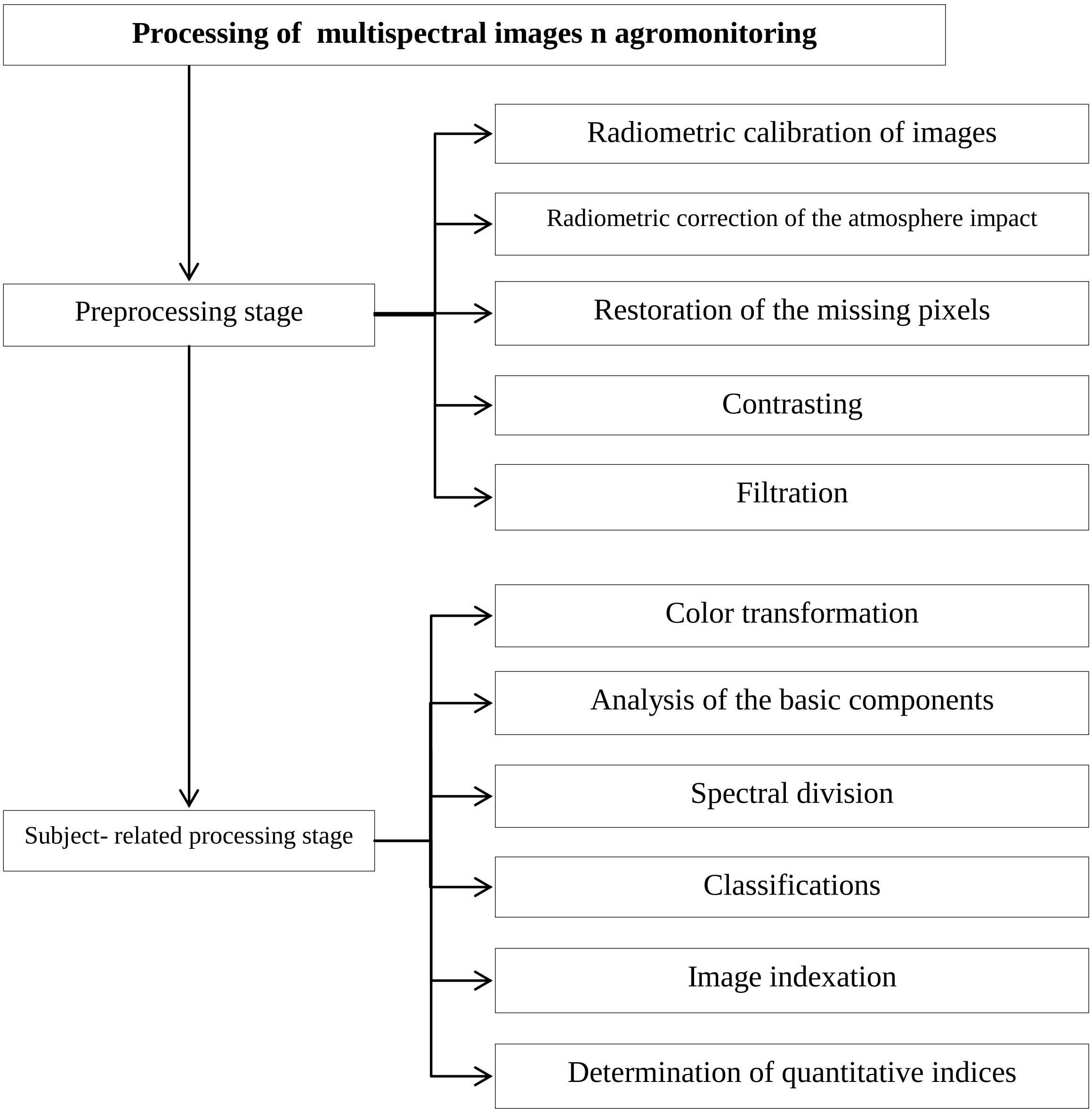


Fig. 1. Scheme of the multispectral images processing in agromonitoring

Main stages of multispectral images processing

Main stages of multispectral images processing provide preprocessing and subject-related processing.

Preprocessing of images is a correction and improvement of the quality of images, obtained as a result of space or aerial survey. However, it should be remembered that certain methods of images quality improvement (filtration, contrast change) provides the change of spectral characteristics of the image, that is why, after the application of these methods, the methods of subject-related processing, based on the analysis of the values of spectral brightness of the pixels (classifications, arithmetic transformation of channels, etc.) can not be used.

Subject-related processing of images is the process of decoding or objects and phenomena recognition on the images. As the processing of the color image is performed, different systems, such as CMY and CMYK, HIS, RGB, system of pseudo colors, brightness transformation in color, etc. are used. For instance, for the system RGB color image on the monitor is formed by means of adding of three basic colors, which correspond to monochromatic radiation with the wavelength of 0.7 μm (red – R); 0.5461 μm (green – G); 0.4358 μm (blue – B) [9, 10].

Preprocessing of multispectral images

Preprocessing of multispectral images is carried out to prepare the image for the direct analysis to identify or recognize the objects and phenomena, determination of the quantitative indices, etc. Basic methods of preprocessing of multispectral images is radiometric calibration, radiometric correction of the atmospheric impact, restoration of the missing pixels, contrasting, filtration.

Radiometric calibration of the images provides that the images, obtained from the devices, which perform the survey are recorded in the form of «raw values» of the brightness DN (Digital Number). Data in such format can be adequately compared with the data of the other surveys. The task of radiometric calibration is to reduce these values to physical units. Formula of the calibration of multispectral images in optical range:

$$B_z = K_z \cdot DN + C_z ,$$

where B_z – is energy brightness for the spectral zone Z; K_z – is calibration coefficient, which depends on the spectral zone Z; C_z – is calibration constant, which corresponds to minimal brightness value, registrated, depending on the spectral zone Z [6, 10].

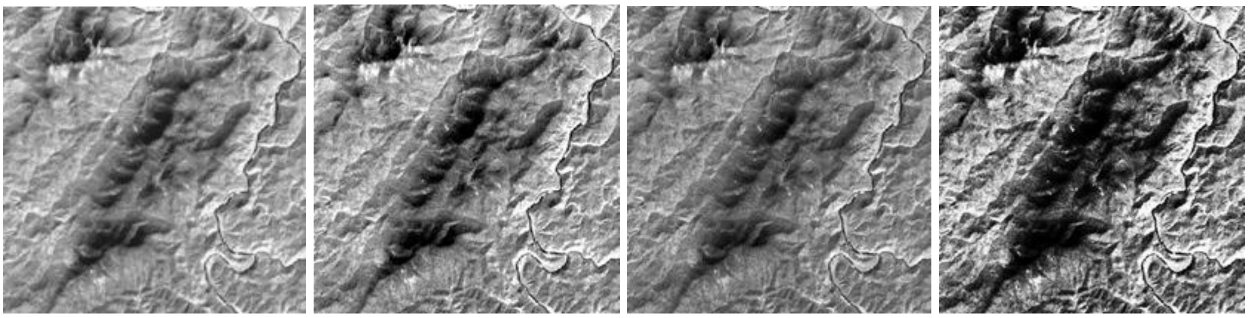
Basic atmosphere impacts, distorting the images are absorption and dissipation of the electromagnetic waves which pass through ozone, water vapor, carbon dioxide, oxygen, methane, dust, fume and cloudiness, which is an obstacle while taking photos in optical band. Radiometric correction of such phenomena impact is performed as a result of using mathematical methods of the atmosphere state models construction, taking into account the types of the dispersion in the air, season of the year, metrological data. For the updating of such models ground measurement of the objects reflectance during the flight of the vehicle, performing the survey, is used. Clouds and fog are well seen on the background of water as in the red and infrared emissions the water surface by its optical characteristics is close to absolute black body. That is why, the content of the water vapor and aerosols (fume) in the atmosphere can be assessed by the images, where the sections of seas and oceans are available [8, 10].

One of the main problems of the preprocessing of multispectral images is elimination of various faults on the images, in particular, missing pixels, feeble contrast, noise, etc.

Missing pixels may appear in the process of the survey or data transfer. The replacement of the brightness values of the whole row by the values of the neighboring row also may happen. Such phenomena may become an obstacle in the process of the subject-related image processing. Missing pixels can be restored by the interpolation with a certain error [9, 10].

Weak contrast ratio of the images is the most common fault, as the contrast ratio is the difference between maximal and minimal values of the brightness. There exist several methods of the contrast improvement (Fig. 2) by means of digital processing:

- linear stretching of the histogram – all the brightness values are assigned new values in order to embrace the whole possible interval of the brightness change (0, 255);
- normalization of the histogram – on the whole possible interval of the brightness change not the whole histogram is stretched but only its section with the highest intensity;
- histogram equalization – change of pixels brightness values so that the same amount of pixels were for each brightness level [10 – 12].



a b c d

Fig. 2. Methods of the image contrast ratio increase: a – initial image; b – image after linear stretching of the histogram; c –image after normalization of the histogram; d – image after equalization of the histogram

It is natural for the real images to possess the faint objects, random obstacles (noise), etc. Filtration enables to eliminate the similar faults. One of the simplest methods of filtration is the transformation in the sliding window. At such transformation brightness values of all pixels of the image are calculated, and if the given pixel is the central in the window which «moves» on the image, it is assigned new value, which is the function of the values of neighboring pixels (weight coefficient). The size of the window may be, for instance, 3x3 or 5x5 pixels. Every time, the window is displaced at one pixel and moves until it passes the whole image [9 – 12]. In general, for all the pixels of the window weight coefficients may be defined, proceeding from the aim of the decoding.

Subject-related processing of the multispectral images

Subject-related processing pass multispectral images, prepared at the previous stage, this enables to obtain complex information, regarding the state of fields and agricultural crops, cultivated on these fields. Main method of the subject-related processing of multispectral images is color transformation, analysis of the basic components, spectral division, classifications, image indexation, determination of the quantitative indices.

Color transformation enables to allocate visually the objects, which do not differ greatly by the brightness in the half-tone image. This process provides painting of the image in natural and non-natural colors [12]. If in R, G, B channels of the image the values R, G, B channels of the image are substituted, then the image is presented in natural colors. If in R, G, B channels of the image other channels of the image are substituted, then the image is presented in non-natural colors. For instance, in the channel of the image R the channel of the image where the values of pixel brightness are high is substituted, and in the channels G and B the channels with low brightness values are substituted, then the image with be painted mainly in red tones. Thus, it is expedient to define objects in the images in natural colors and perform their division or contour allocation is more convenient in the images in non-natural colors [9, 10].

One of the widely spread methods of subject-related processing of the multispectral images is the analysis of the main components, namely, the analysis of the multispectral correlated data, i. e., when the brightness of the pixel in one spectral channel increases, the brightness values in other spectral channels grow. Possibilities of the analysis of the main components:

- If the image contains more than three spectral channels, color image from three main components can be created, as in a typical multispectral image, as a rule, first two or three components are able to describe practically the whole change of spectral characteristics. Other components are subject to noise impact. Rejecting these components the volume of data can be reduced, without loosing considerable volume of information.
- Such transformation is performed for the series of the multidate images, reduced into the single unified coordinate system to identify the dynamics, which is manifested in one or two components [11].

One pixel of the image may represent from several square meters to thousands of square meters of the surface and contain information not about one object but a group of objects, located at a corresponding territory. That is why, method of spectral division is used for the recognition in the images the objects, size of which is far smaller than the size of a pixel. The essence of the method is the following: mixed spectra are analyzed, comparing them with the known pure spectra, for instance, from the spectral libraries of the pure materials. Quantitative assessment of the ratio of the known (pure) spectrum and admixtures in the spectrum of each pixel is performed. After performing such assessment the image, painted in such a way that the color of the pixel will denote, what component prevails in the spectrum of this pixel, may be obtained [9 – 11].

During the image processing they often should be decoded. This problem is solved by the classification, it enables to perform the process of the automated distribution of all the pixels of the image into groups (classes), which correspond to different objects [13]. Main types of the classifications are with learning and without learning.

Classification with learning it is a process when the comparison of the brightness value of each pixel with the samples takes place, as a result each pixel is referred to the most suitable class of objects. Classification with learning can be used if it is known what objects are on the image; there is a small number of classes on the image (up to 30); these classes are clearly distinguished in the picture. Classification without learning – it is a process when the distribution of the image pixels takes place automatically, on the base of the analysis of statistic distribution of the pixels brightness. Classification without learning is applied if it is not known what objects are in the image ; there is a great number of objects (more than 30) with complex boundaries; as the previous stage before the classification with learning [2, 10].

In the process of objects study according to the multispectral pictures, when not absolute values but characteristic ratios between the object brightness values in different spectral zones are important, the images indexation is used. It provides calculation of the brightness value of each pixel by means of application of the arithmetic operations over the brightness valueы of the specific pixel from different channels of the image. In such images the searched objects are allocated brighter and with higher contrast as compared with the output image [11 – 13]. Table 2 contains some indices, used for image indexation.

It is worth mentioning that among the considered methods of the subject-related image processing for agromonitoring the most common is images indexation, namely, application of the vegetation indices (EVI2, GNDVI, NDVI, NDVI contrast, etc.) [16]. Fig. 3 presents the comparison of the field image [16] in natural colors with the analog but processed images, applying vegetation indices EVI2, GNDVI, NDVI, NDVI contrast.

Table 2

Indices of image indexation

Name	Definition	Usage
Index of the ferric oxide content	Ratio of the brightness values in red (R) channel to the values of brightness in blue channel (B): R / B	For determination of the ferric oxides content
Index of the clay minerals content	Ratio of the brightness values in the limits of average infrared channel (AIC): AIC1 / AIC2, where AIC1 – is a band from 1.55 to 1.75 μm and AIC2 – is a band from 2.08 to 2.35 μm	For determination of the clay minerals content
Index of the ferriferous minerals content	Ratio of the brightness value in the average infrared channel (AIC1) to the brightness value in the near IR-channel (NIC): AIC1 / NIC	For determination of the ferriferous minerals content
Normalized differential vegetation index (NDVI) [14]	Chlorophyll in the leaves of plants reflects radiation in near IR-range (NIRC) of electromagnetic spectrum and absorbs in the red (R) band. Ratio of the brightness values in these two channels enables to separate plants from other natural objects and analyze them: NDVI = (NIRC - R) / (NIRC + R)	Shows the availability and the state of the vegetation. Value of NDVI varies within the limits from -1 to 1
Normalized differential index of show (NDSI) [15]	NDSI –it is a relative value, which is characterized by the difference of the reflective power of show in red (R) and shortwave infrared (SIR) bands: NDSI = (R - SIR) / (R + SIR)	Used for the allocation of the territories, covered with snow. For snow NDSI > 0.4
Water index (WI)	WI = 0.9 μm / 0.97 μm	Used for the determination by hyperspectral images the content of water in the vegetation

As it is seen in Fig. 3, in the image the section of the field with the building is shown in natural colors, in the image, processed, using vegetation index EVI2 the building is brightly shown and atmospheric impacts are reduced, in the image, processed, using vegetation index GNDVI the uniform humidity content is shown on the section, in the image, processed using vegetation index NDVI thick vegetation is shown in dark tone, and in the image, processed, using vegetation index NDVI contrast ill plants are shown in red color.

Processing of the multispectral images in agromonitoring enables to define problematic sections of the field, that provides the possibility to detect and prevent various factors of the crop losses or violation of the normal development of the plants [17].

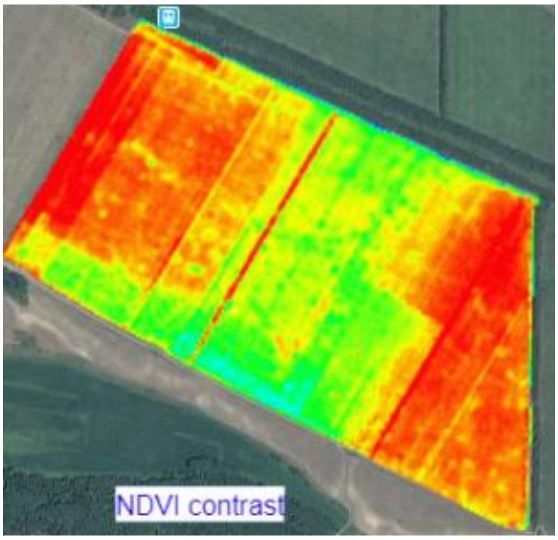
The most important method of the subject-related processing of multispectral images in agromonitoring is determination of the quantitative indices. It enables to obtain various data, regarding the contours of the fields, quality of crops, availability of weeds, diseases or other problems in the field, need of applying fertilizers, etc.

a

b

c

d



e

Fig. 3. Image of the field in natural colors (a) and processed image using vegetation indices EVI2 (b), GNDVI (c), NDVI (d) and NDVI contrast (e)

Non-correspondence of the cultivated and legal area of the farm land, scales of agribusiness and dynamics of changes in the land bank create the necessity of the regular renovation of the fields contours. Availability of the real contours, precise area and boundaries of the cultivated fields enables to avoid excessive expenditures for «nonexistent» hectares and is the base for the introduction of the site specific crop management at the enterprise. For instance, Fig. 4 shows the results of the field image analysis [18], these results allow to define quantitative indices, which characterize the efficiency of its area.

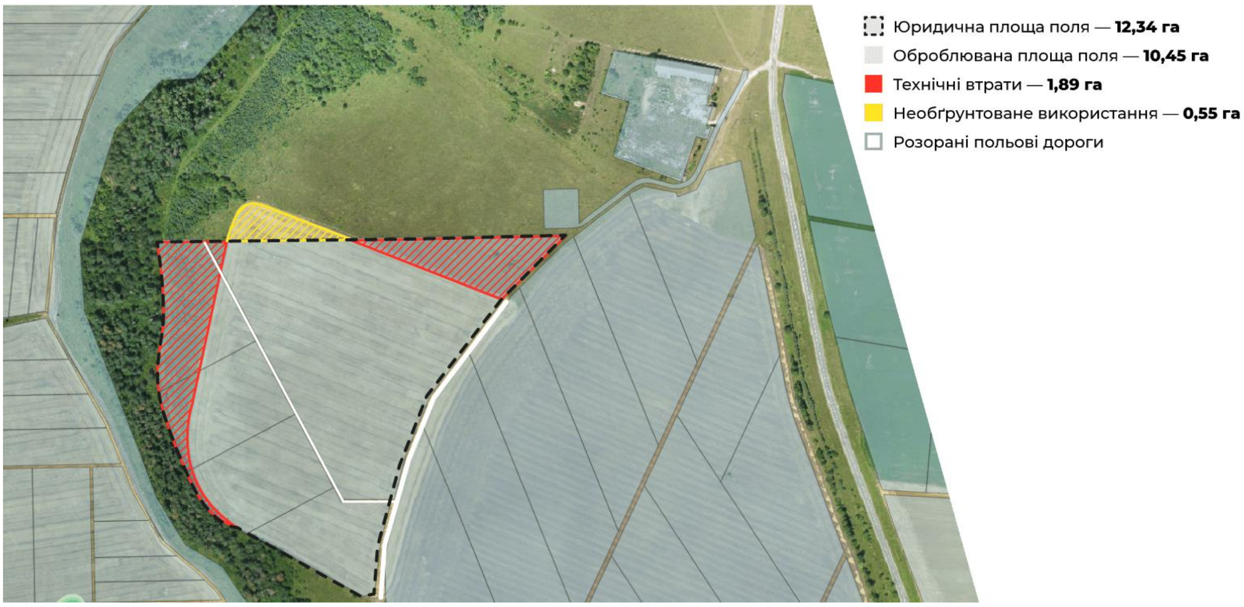


Fig. 4. Analysis of the field for its area efficiency

Overgrowing of the boundaries of the fields by the wood line, shrub around the supports of the transmission lines on the field, alkali soils and marshy areas are the typical examples of the productive soil losses. Thus, on average, the discrepancy between the legal and actually cultivated area is 2 – 5% [18].

Processing of the multispectral images in agromonitoring enables to assess the factors of total losses from the pests, diseases or weeds, the share of losses, caused by weeds is approximately 30%. Fig. 5 presents the image of the field [5], affected by the weed.

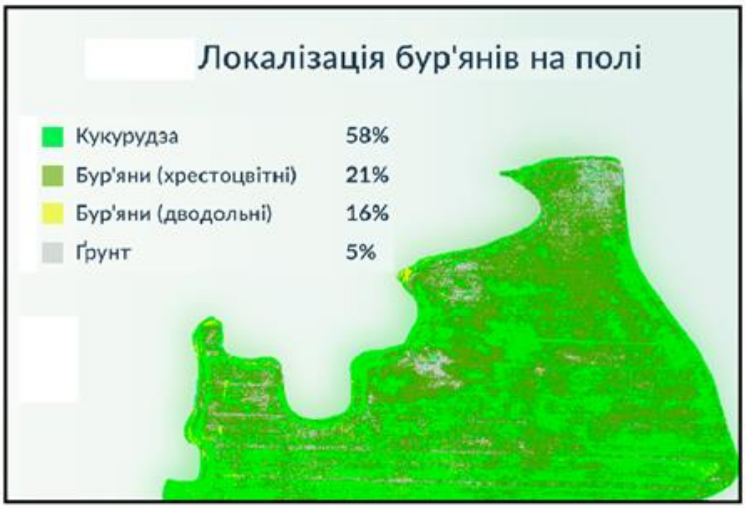


Fig. 5. Image of the field, affected by the weed

For the quantitative assessment of the field littering its multispectral images are used, these images are processed by means of vegetation indices, this enables to identify, prevent the spreading of weeds, distinguish them from crops, determine their portion and sometimes, type. As a result, specialist-agronomist, obtaining more accurate information, can timely introduce the correct norm of the herbicide [5].

One of the variants of elimination of the similar negative factors during vegetation period of the agricultural crops is the control over the introduction of the fertilizers and herbicides. For this purpose the field image is processed to determine the quantitative indices of the norms of active substance introduction. In particular, Fig. 6 contains the map of fertilizers introduction [19], this map is the processed multispectral image of the field.

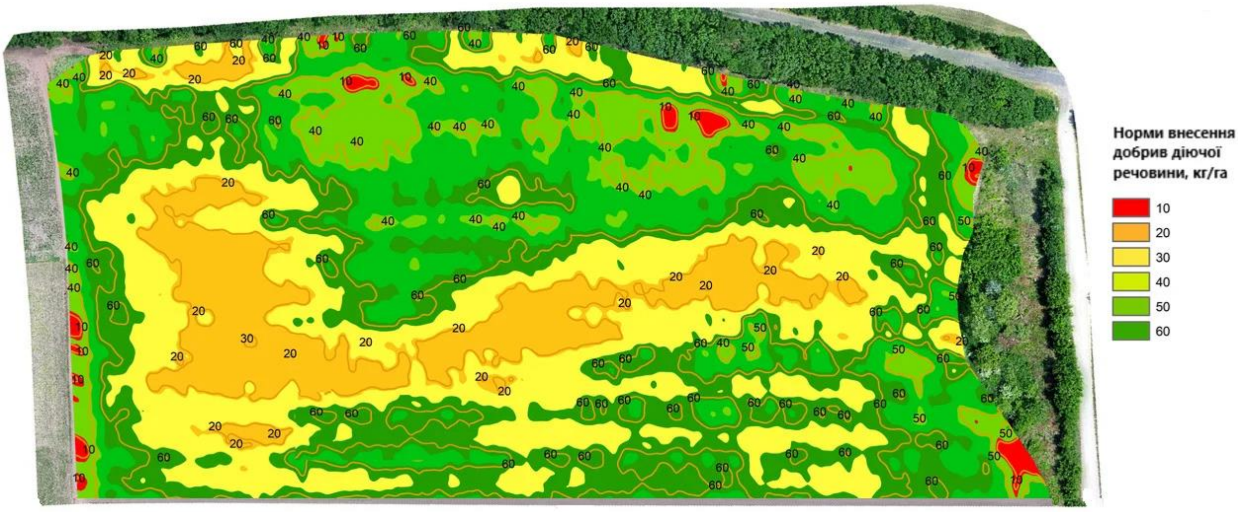


Fig. 6. Map of fertilizers distribution

As it is seen from the Fig. 6, the quantitative indices of the fertilizers distribution norms, values of which are the information parameters for the optimization of plants nutrition, saving the fertilizers and fuel [19] are allocated.

Conclusions

The research analyses of the processing of agromonitoring data, the analysis, carried out, enables to obtain complex information, regarding the state of fields and agricultural crops, grown in these fields. Data are presented in the form of multispectral images, which pass certain stages of processing. Each of these stages includes corresponding types and ways of realization, certain methods of image improvement provide the change of spectral characteristics of the image, that is why, after their application the passage to the next stages of processing is not possble. The research highlights types and methods of multispectral images processing, concerning agromonitoring, on the base of the analysis of literature sources. The characteristics of these methods, application conditions are described. Scheme, which describes the processing stages of multispectral images, taking into account all the types and methods of each stage realization, is suggested. Thus, the conclusion can be made, that the suggested scheme highlights most completely the process of multispectral images processing in agromonitoring.

REFERENCES

1. Agricultural in Ukraine [Electronic resource]. – Access mode : https://dlf.ua/ua/silske-gospodarstvo-v-ukrayini/#main. (Ukr).

2. Methods and technologies of the processing of the multispectral data of the Earth remote sensing of high resolution / O. I. Potaturkin, S. M. Borzov, A. O. Potaturkin [et al.] // Computation Technologies. – 2013. – V. 18. – P. 60 – 67. (Rus).

3. Aerial survey by means of unmanned flying vehicles (UFV) [Electronic resource]. – Access mode : https://www.bkc.com.ua/news-type/aerofotozjomka-za-dopomogoju-bla-bpla. (Ukr).

4. Knysh B. P. Assessment of the objects state by means of unmanned flying vehicles / B. P. Knysh, M. A. Alekseev // Bulletin of Vinnytsia Politechnic Insitute. – 2019. – № 2. – P. 58 – 65. (Ukr).

5. Unmanned flying vehicles and satellites [Electronic resource]. – Access mode : https://smartfarming.ua/insayty/drony-i-suputnyky-monitorynh-stanu-posiviv-vprodovzh-sezonu. (Ukr).

6. Garzelli A. Pansharpening of Multispectral Images Based on Nonlocal Parameter Optimization / A. Garzelli // IEEE Transactions on Geoscience and Remote Sensing. – 2015. – № 4 (53). – P. 2096 – 2107. https://doi.org/10.1109/TGRS.2014.2354471.

7. Study of the multispectral images in agromonitoring [Electronic resource] / B. P. Knysh // Scientific-engineering conference of the subdivisions of Vinnytsia National Technical University, Vinnytsia, 2021. – Access mode : https://conferences.vntu.edu.ua/index.php/all-frtzp/all-frtzp-2021/paper/view/11349/9482. (Ukr).

8. Ris U. G.Fundamentals of the remote sensing / U. G. Ris. – M. : Tekhnosphere, 2006. – 336 p. (Rus).

9. Gonsales R. Digital processing of images / R. Gonsales, R. Woods. – M. : Tekhnosphere, 2006. – 1072 p. (Rus).

10. Modern methods of the intelligent processing of the remote sensing data / N. S. Abramov, D. A. Makarov, A. A. Talaleev [et al.] // Programming systems: Theory and application. – 2018. – V. 9, № 4 (39). – P. 417 – 442. (Rus).

11. Processing of the Earth remote sensing data – stages of data processing [Electronic resource]. – Access mode : http://mapexpert.com.ua/index_ru.php?id=26&table=Menu. (Rus).

12. Bibikov S. A. Recognition of the vegetation cover on hyperspectral images by the coefficient of contingency / S. A. Bibikov, N. L. Kazanskiy. V. A. Fursov // Computer optics. – 2018. – V. 42, № 5. – P. 846 – 854. (Rus).

13. Krasilenko V. G. Modelling of the methods of recognition and classification of the fragments of color images of the agricultural lands in the process of their remote monitoring / V. G. Krasilenko, R. O. Jatskivska, V. I. Jatskivskyi // Systems of information processing. – 2017. – № 5 (151). – P. 55 – 61. (Ukr).

14. Cherepanov A. S. Vegetation indices / A. S. Cherepanov //Geomatics. – 2011. – № 2. – P. 98 – 102. (Rus).

15. NDSI [Electronic resource]. – Access mode : https://eos.com/uk/ndsi/. (Ukr).

16. Broadband Greenness [Electronic resource]. – Access mode : https://www.l3harrisgeospatial.com/docs/BroadbandGreenness.html#Differen.

17. Vegetation indices of new generation EVI2, GNDVI in IoT platform "Agrocontrol" [Electronic resource]. – Access mode : http://blog.agrocontrol.net/?p=1861. (Rus).

18. Fields measurement [Electronic resource]. – Access mode : https://smartfarming.ua/upravlinnya-zemel-nym-bankom/inventarizatsiya-zemel-noho-banku/obmir-poliv. (Ukr).

19. Efficiency of applying fertilizers [Electronic resource]. – Access mode : http://agro-business.com.ua/agro/mekhanizatsiia-apk/item/14705-efektyvnist-vnesennia-dobryv.html. (Ukr).

Editorial office received the paper 18.12.2020.
The paper was reviewed 23.12.2020.

Bilinskyi Yosyp – Doctor of Science (Eng), Professor, Head of the Chair of Electronics and Nanosystems.

Knysh Bogdan – Cand. Sc. (Eng.), Assistant Professor with the Chair of Electronics and Nanosystems, tutmos-3@i.ua.

Kulyk Jaroslav – Cand. Sc. (Eng.), Assistant Professor with the Chair of Automation and Intelligent Information Technologies**.**

Vinnytsia National Technical University.