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REMOTE SENSING OF WASTE DUMPS IN ECOLOGICAL SAFETY MANAGEMENT SYSTEMS

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Abstract. The paper describes an improved general model which is based on methods of remote scanning of Earth surface obtained by Space satellites with combination with GIS-technologies and methods of mathematical modeling. This model allows allocating and analyzing characteristics of carbon containing and organic components of places of accumulation of solid waste of domestic and industrial genesis of illegal waste dumps on Space images and also determining values of its area and dynamics of growth for monitoring of ecological safety level of urban systems.

Key words: ecological safety; Earth remote scaning; waste dumps; space image; GIS-technologies.

Introduction

Relevance of the study. One of the important directions of waste handling area is ensuring complete waste collection for their in-time deactivation and disposal with abidance of ecological safety regulations. Nowadays due to different reasons there is a great number of illegal dumps. The term “dump” refers to the area of spontaneous accumulation of waste. The areas of location of sanitary polygons which are in exploitation in accordance with ecological regulations are known. Unlike them dump places are unknown and ecological consequences from it are not predictable.

As a rule, waste dumps are detected accidentally. Wherein, the rate of decomposition of different substances in the total mass of waste is not the same. That is why the influence of individual fractions of waste on formation of filtrate is different. That means that time period from the start of dump formation till the start of penetration of filtrate into ground waters is unknown. Therefore at the moment of dump detection negative consequences of filtrate influence on environment may be significant. Thus the early detection of places of illegal accumulation of different kinds of waste as well as its continuous monitoring are relevant tasks in the area of ensuring ecological safety.

Literature analysis. Data of remote scanning of the Earth (RSE) from space is such source of information that allows getting actual operative picture of places of location of illegal waste dumps with lower time expenses. Articles [1, 2] are dedicated to analysis and search of possibilities of application of multi-spectral space images for identification of illegal dumps by defining its brightness characteristics. Articles of foreign scientists [3, 4] are dedicated to decoding of space images.

RSE methods in combination with Geo Information Systems (GIS) and methods of mathematical modeling give an opportunity to comprehensively explore sources of environmental hazard formation and make decisions about how to deal with them. The use of the worded above methods is proposed in the works of Trofymchuk A. N., Gotynjan V. S., Grekov L. D., Fedorovsky A. D., Jakovjev E. A. and ect. Method of allocation of contour of dumps using both brightness and texture methods is presented in works [5, 6]. Wherein constructing of artificial brightness attributes is possible.

The purpose of the study is the research of the possibility of using wide access data of remote scanning of the Earth and GIS-technologies for operative detection of places of illegal accumulation of waste as sources of formation of technogenic danger.

Theoretical part

Development of the model of illegal dump detection on the space image. For successful carrying out of tasks of the study it is necessary to use space images of ultrahigh spatial resolution (0.5–15 m) in spectral diapason 0.4–1.1 microns, namely QuickBird, World View, GeoEye, Pleiades, Ikonos and etc. Such images can be obtained from archive data bases of cartographic servers in Internet web. The most available source of these images is online free service Google Earth.

Instead of digital equivalents of brightness directly in the image points, average values of brightness in the surroundings of these points or median of sequence of brightness of elements in the surrounding of the point can be used. The histogram of brightness, that is, average value of brightness, dispersion, coefficient of asymmetry, and excess are used as brightness attributes of the objects which include some multiplicity elements of the image:

$$m = \sum I_{i,j} / (n-1), \tag{1}$$

$$D = \sum (I_{i,j} - m)^2 / (n-1), \tag{2}$$

$$S = \sum (I_{i,j} - m)^3 / [(n-1) \cdot D^{3/2}], \tag{3}$$

$$Kr = \sum (I_{i,j} - m)^4 / [(n-1) \cdot D^4], \tag{4}$$

where m – average value of pixels in the scanning window; I – value of pixel brightness; i, j – coordinates of pixels in the scanning window; n – quantity of pixels in the scanning window; D – dispersion of value of brightness; S – asymmetry; Kr – excess.

To apply computer processing of structure attributes of the images it necessary to use special procedures of its formalization. At formalization of the attribute of the character of brightness distribution on the surface of the object, the procedure of decomposition of the field of the image brightness into specter of spatial frequencies is used. For linear processing by sliding square window the brightness of the transformed image is defined as:

$$f(i,j) = \sum_{i=i_0-w}^{i_0+w} \sum_{j=j_0-w}^{j_0+w} \begin{pmatrix} F(i,j)H \times \\ \times(i-i_0+w+1, \\ j-j_0+w+1) \end{pmatrix}, \tag{5}$$

where H – predetermined matrix of size $(2 \cdot w + 1) \times$ $\times (2 \cdot w + 1)$ – mask of the operator of linear transforming; f – field of parameters of the transformed image.

Transformation is the operation of discrete convolution of the image with mask H. For decomposition of the field of image $F(j, k)$ into specter of spatial frequencies, different procedures of unitary transformations are used: Fourier, Hadamard, Haar and oblique transformation. In general case for a sliding window of a square form of $N´N$ size, spectral coefficients $f(u, v)$ are defined by the following formula:

$$f(u,v) = \frac{1}{N} \sum_{j=0}^{N} \sum_{k=0}^{N} F(j,k) A(j,k,u,v), \tag{6}$$

where $A(j, k, u, v)$ – core of direct transformation.

A set of spectral coefficients is the attribute which most fully characterizes changing of brightness on the surface of the image. For formalization of that attribute simplified approaches are also used. Essence of one of them is the use of the value of brightness gradient. For its implementation, the procedure of spatial differentiation of the analyzed fragment of the image is carried out, that is, derivations dF/dx and dF/dy are found by convolution of the image with gradient masks Hx and Hy. The values of dF/dx and dF/dy and the values of the gradient module and tangent of the angle of its declination to axis *Ox are* directly used as formalized attributes.

The most difficult task is formalization of the image texture, that is, the object that characterizes the form, size and relative position of the elements which make up the object. Spatial repeatability of local structure of brightness field is typical for the texture. Therefore the qualitative characteristic of the texture is the value of the period of repeatability.

For automation of the process, the attributes were integrated into Erdas in Model Maker program space. Using histograms (see Fig. 2 in [7]) for determination of the parameters for detection of the places of waste accumulation, the general model is created and allocate waste dump from other objects. Such approach allows detecting the dump, determining its area size and dynamics of its growth. But it is impossible to identify the sources of ecological danger formation and determine the degree of danger.

Further development of the above-described system of recognition of places of illegal waste accumulation is in classification of the objects of dump on the basis of the degree of their influence on ecological safety level of urban systems.

Direct allocation of the zone of carbon containing substances and organic components of the dump from the other inorganic part of the dump is the task that is implemented with a large number of errors of the 1st kind. This is due to the fact that organic components of the dump on space images are almost equal by brightness and texture parameters to surrounding vegetation (grass, forest, gardens) [5]. Taking into account scientific and practical studies, accumulated to the present moment, the question arises about the possibility of indirect determination of aerials of organic components of the dump.

To determine the aerials of observation we propose the method that assumes excluding ("cutting-out") from the image the areas of the dump with low degree of ecological danger, such as construction debris and rock masses. Such waste is less dangerous for the environment and is easily identified against the background of vegetative surface by its special brightness and texture attributes due to high contrast (threshold value) against the background.

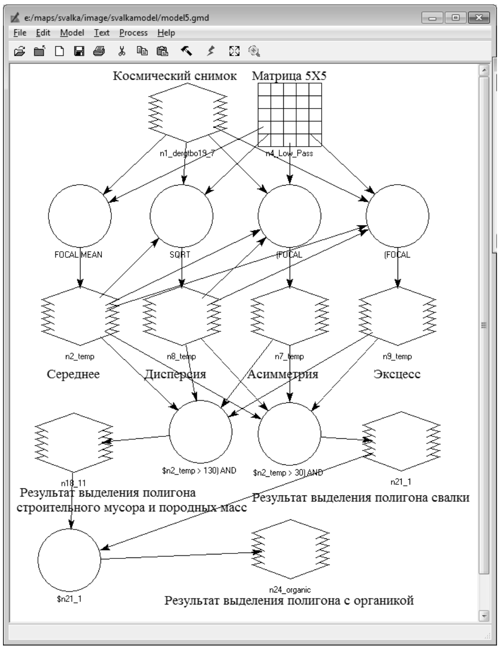
To determine the area with construction debris and rock masses it is necessary to split the surface of the histogram into sub-diapasons or again create a database of diapasons of statistical moments of the identified objects by allocation of its objects on the image, obtaining the diapasons by the histogram. After identification of sectors with construction debris and its contouring by excluding from the general contour of the landfill, we determine the other part of the dump area such as its carbon containing and organic components. As a result, we obtain the image of the part of the dump with predomination of its organic components. Fig. 1, ***a*** presents a scheme of the model of automated recognizing of polygon with organic component on the dump territory.

To detect the place of waste accumulation and determine the area of that territory it is necessary to implement spatial reference of space image.

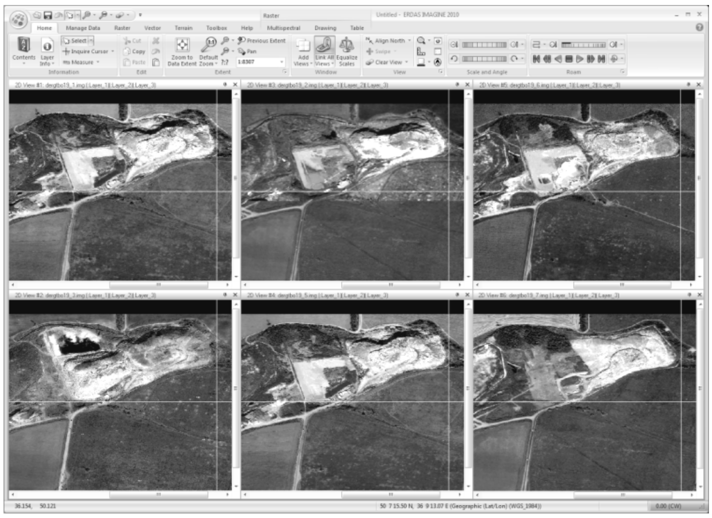
At the 1st stage the investigated area is visually analyzed for the presence of objects similar to unauthorized places of waste accumulation. In case of detection of such objects, this area is allocated, spatial reference is made and the image is saved for further processing.

Results

Practical realization of the developed model of waste dump detection and its parameters determination. For example we implemented the research of Dergachi polygon of solid domestic waste (SDW) (Kharkiv region) (see Fig. 1, *b*).



a

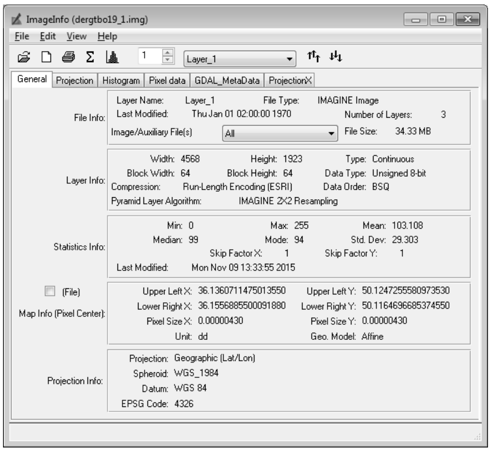


b

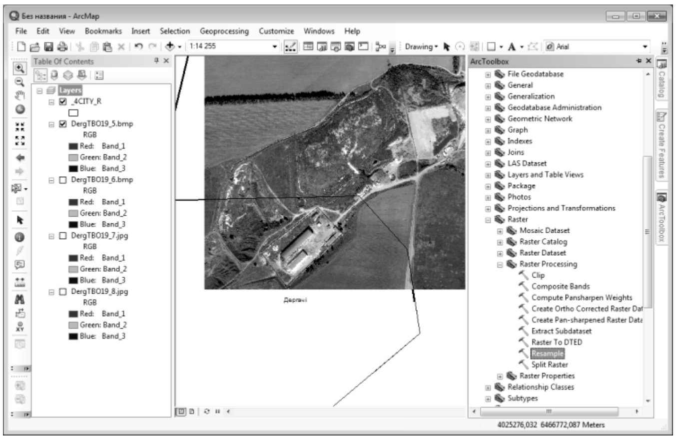
Fig. 1. Scheme of the model of automated recognizing of the polygon with organic component on the dump territory (a) and space images of Dergachi SDW polygon (b)

Spatial reference of the image was performed also to determine the area of the polygon (see Fig. 2, *a*). Program ArcGIS allows transforming the type of reference.*w (reference in external file) into format *.img with reference in internal file (see Fig. 2, *b*). After starting ERDAS program it is necessary to download space image into it by the following sequences of actions: File/Open/Raster_Layer/Image_file_name. Spatial references of full set of space images were transformed into references of geographical type WGS_84.

The function of files stapling in accordance with spatial coordinates allows precise matching pixel on one image with the same one on the other picture and trace its changes.



a



b

Fig. 2. Information about geographical reference of image of Dergachi SDW polygon (a) and conversion of image formats into ArcGIS for further processing that are united by geographical reference for different time periods (b)

But, as it can be seen, in the case of application of automatic classification of objects on the processed apace image, roads and waste are painted the same color. Consequently, we can not allocate the dump using the universal method.

So we implemented allocation of presumably place of waste accumulation using the model based on the analysis of statistical moments of different orders (average value, dispersion, asymmetry and excess). To solve the task we will act in accordance with the following algorithm:

– find the average number of pixels in a specific part of the by developing its model in program Toolbox/Model maker using the command Focal Scan/Fokal Mean;

– mark on the image the sector of the polygon that corresponds to the selected model to calculate the average number of pixels;

– develop the model of dispersion in Focal Scan/Focal Standard deviation and present it on the picture and then select the diapason of values of dispersion using histograms;

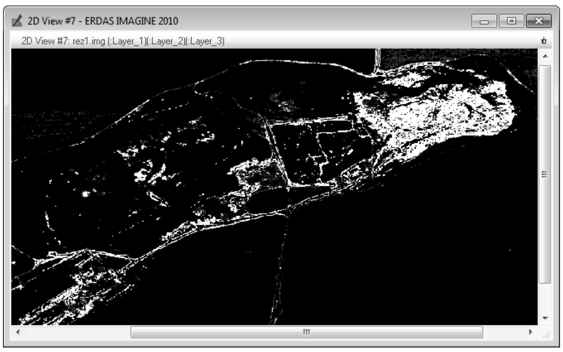
– determine in accordance with histograms the required parameters to detect the area of waste accumulation (see Table 1) and then allocate it from other components of landscape (see Fig. 3, *a*);

– upload the image into ArcMap program, create shape-files and conduct classification (see Fig. 3, *b*), vectorization and calculation of the area.

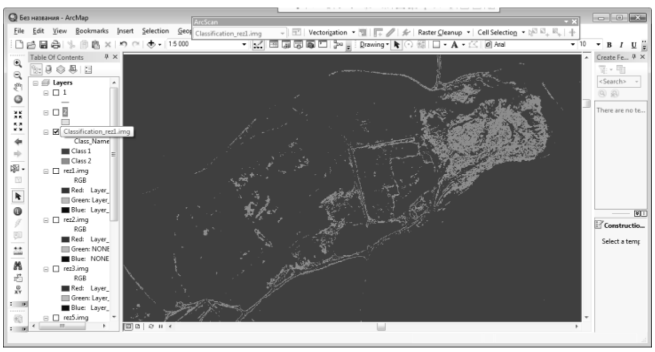
Table 1

Diapasons of values of parameters of general model of detection of waste dump on the space image

Parameter	Diapason in accordance with histograms
Average number of pixels	130–196
Dispersion	6–30
Excess	0–4
Assymetry	0–14



a



b

Fig. 3. Borders of the dump detected on the space image (a) and the classified polygon (b)

Conclusions

1. Research and analysis of characteristics of places of waste accumulation show that materials and substances are heterogeneous. Consequently, application of the method of universal classification of the image to detection places of waste accumulation and determine its area with the necessary accuracy does not give a positive result.

2. General model based on methods of remote scanning of the Earth combined with GIS-technologies and methods of mathematical modeling allows to allocating the waste dump on images and also determining its area and dynamic of growth. But this model does not allow identifying the elements which are sources of formation of ecological danger because this task is solved with a large number of errors of the 1st kind.

3. The developed model based on the method of exclusion ("cutting-out") from the image sectors of dump with low degree of danger such as construction debris and rock masses allows to allocating the areas of carbon containing materials.

4. The general model of detection of places of waste accumulation using space images in the form of specialization of allocation of the aerials of dump with carbon containing materials has been further developed. That allows increasing the efficiency of implementation of ecological monitoring and using the detected carbon containing wastes for obtaining fuel products [8].

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