evaluation. Application of the method will improve the quality of regulatory assessment of land settlements, the mechanism of economic regulation of land relations, and the efficiency of land use system in whole.

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USING GIS FOR THE EVALUATION OF THE CROP RESIDUES ENERGY POTENTIAL

This article suggests some features of the use of geographic information systems to assess and to analyze the energy potential of crop residues. The features of the analysis of this type of potential are defined at different levels of government: national, provincial, and district. Methods for assessing the energy potential of crop residues in this study suggest the use of a series of satellite images to identify crops that takes into account the nature of the areal distribution of this type of waste.

Keywords: crop residues, energy potential, bioenergetics, GIS, satellite imagery

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ВИКОРИСТАННЯ ГІС ДЛЯ ОЦІНКИ ЕНЕРГЕТИЧНОГО ПОТЕНЦІАЛУ ВІДХОДІВ РОСЛИННИЦТВА

У статті розглянуті деякі особливості використання геоінформаційних систем для оцінки та аналізу енергетичного потенціалу відходів рослинництва. Визначено особливості аналізу цього типу потенціалу на різних адміністративних рівнях: загальнодержавному, обласному, районному. Методи оцінки енергетичного потенціалу відходів рослинництва в цьому дослідженні базуються на використанні серії супутникових знімків для ідентифікації сільськогосподарських культур. Це дозволило врахувати характер площинного розподілу цього виду відходів.

Ключові слова: відходи рослинництва, енергетичний потенціал, біоенергетика, ГІС, супутникові знімки

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ИСПОЛЬЗОВАНИЕ ГИС ДЛЯ ОЦЕНКИ ЭНЕРГЕТИЧЕСКОГО ПОТЕНЦИАЛА ОТХОДОВ РАСТЕНИЕВОДСТВА

В статье рассмотрены некоторые особенности использования геоинформационных систем для оценки и анализа энергетического потенциала отходов растениеводства. Определены особенности анализа этого типа потенциала на различных административных уровнях: общегосударственном, областном, районном. Методы оценки энергетического потенциала отходов растениеводства в этом исследовании предполагают использование серии спутниковых снимков для идентификации сельскохозяйственных культур. Это позволило учесть характер площадного распространения этого вида отходов.

Ключевые слова: отходы растениеводства, энергетический потенциал, биоэнергетика, ГИС, спутниковые снимки

Introduction. Bioenergy is one of the most promising types of renewable energy sources in the world and in Ukraine. Significant components of bioenergy are agricultural waste, particularly crops.

The urgent problems still are increasing percentage of biomass in the total energy consumption of the country in general and the practical aspects of scheduling bioenergy plants that leads to the need to assess the energy potential at various levels, from the national to the regional and local. GIS is an effective tool at such critical stages as capacity assessment, analysis of the potential distribution, scheduling facilities on the territory, and others. In this paper, we focus on the first two aspects, such as the evaluation and analysis of the placement of the energy potential (EP) of crop waste.

Literature review. Questions towards assessment of the energy potential of crop waste were presented at the national level in the works of G.G. Geletukha, T.A. Zheleznaya, Z.A. Martsenyuk, P.A. Kapustenko, A.K. Cusin, and others. The demand for research at the regional level is justified by V. V. Verbinskiy, M.G. Zemlyanoy, A.I. Bashtovoy, O.S. Tretyakov, and some other researchers. Hereby, the analysis of the spatial distribution of crop waste EP (especially at the district administrative level), and the possibility of using GIS for this purpose is still relevant.

The purpose of the study. The aim of this study is to improve the methodology for assessing and analyzing the distribution of the energy potential of crop residues on the regional and district administrative levels through the applications of GIS using remote sensing data.

Methodology and discussion. Existing approaches to the assessment of the energy potential crop residues is based primarily on the use of statistical data on the gross crop (Table 1). Herewith, at the national level, it is appropriate to calculate the total potential of the areas for the development of the national strategy on the bioenergy development (Geletukha, 2002, 2013). To visualize the distribution of EP methods of cartograms and cartodiagrams can be used which allows to display the potential distribution by administrative areas. Analysis of the EP on the basis of statistical data is also done in the context of administrative districts.

At the regional level study, the preference is given to the calculation of the capacity according to the gross yield of agricultural enterprises with the reference of the obtained figures to the addresses of these enterprises (Tretyakov, 2009). In this case, density fields are used to analyze the distribution of the EP.

A more accurate picture of the potential spatial distribution can be obtained using information about crops on the fields. This approach allows taking into account the nature of the areal distribution of this type of resources, which is particularly important at the local level. In addition, this information allows eliminating possible unreliability and lack of data on the gross yield of the enterprises that it is also important at the regional level.

Information about the crops is often unavailable for use, or available only at a limited number of farms. To solve this problem, remote sensing data is used. In this case, the identification of crops by satellite images is done before the calculation of energy potential. Within the framework of this method, the use of GIS is playing a significant role.

The following stages of crop waste EP evaluation using GIS and remote sensing data can be determined:

1. Identification of crops of the selected area based on a series of multispectral images (image classification, algorithm identification of crops).
2. Assessment of the total crop waste EP in selected territorial units based on EP calculated for each crop waste.
3. Analysis of the distribution of crop waste EP (density fields' creation, isolinear visualization).

Initial data for the identification of crops includes satellite imagery, information about local agriculture peculiarities (particularly crop production), as well as test territories with known crops.

Identification of crops on the fields consists of two main stages:

4. The classification of satellite images;
5. Combination of classification results for individual images by assigning the values of crop to individual pixels.

The technique is based on the identification of cultures with an unsupervised classification of images with the ISODATA method. Test territories are used to specify the classification may also be conducted.

Table 1

Features of the analysis of the energy potential of crop waste at different administrative levels

Levels	State	Regional	Administrative district	Administrative district and regional level
Initial data	Gross yield of crops by regions	1. Gross crop yields by region 2. Gross crop yields in agricultural enterprises	Gross crop yields in agricultural enterprises	Statistical data on crop yields Data on crop sowing on the fields
EP data binding	Areas	1. To the administrative districts 2. To addresses of the agricultural enterprises	Addresses of agricultural enterprises	Two points on the fields occupied by any agricultural culture
Methods of cartographic visualization of the potential distribution	Cartograms, cartodiagrams	1. Cartograms, cartodiagrams 2. Isolinear (density field)	Isolinear (density field)	Isolinear (density field)

* *Analysis of the potential at these levels is based on remote sensing data*

The choice of satellite imagery for the purposes of the study is based on several factors. A high spatial resolution that is sufficient for identification of individual agricultural fields. Spectral channels should be available, which are informative for the study of vegetation (at least - red, near-infrared, perfect — boundary-red). In addition, the important point is the temporal resolution, sufficient to identify the main patterns of crop development. One of the important factors is the availability of images and their cost. Because of the specified parameters images of Landsat 5 TM, Landsat 7 ETM+, SPOT 2/4, and Landsat 8 were used in the study, and the preference was given to images to be found in the public domain.

For classification, it is necessary to determine the list of major crops grown in the study area, as well as a list of those crops, waste of which can be used for energy purposes. The feature of the identification of cultures to assess the crop waste EP is essential for recognition of just a limited number of crops, namely those that waste are efficient to be used for energy production. It is important to take into consideration the agricultural specialization of the region (crops, livestock), because this causes the structure of farmland. For example, in Brittany (France), which has a livestock specialization, a significant proportion of farmlands consist of pastures, and this causes the assignment of this particular type of land among others. Thus, the assumption was made that the spectral characteristics of the pastures throughout the year (several years) varied the least. Another important point is the presence of intercropping in the crop rotation of the region. Excluding this factor, the recognition of crops will be invalid. Again, in Brittany different algorithms would be used: for the identification of winter grain crops with and without intercropping. And finally, the basis of the analysis of the results of satellite image classification is particularities of the calendar cropping: dates of planting and harvest, the ripening period, which is largely due to the natural area the study area.

The classification was done using ENVI 5.0 software package. Herewith, the analysis of the spectral characteristics of crops on each shooting date for the study area was made, which allowed forming their time spectral images (Balynska, Tretyakov, 2013).

Working with images of different satellite systems had its own peculiarities.

Initially to develop a crops identification algorithm on series of images, imagery of Landsat 5 TM and Landsat 7 ETM + was used. The defect of the images associated with the breakdown of the scanner ETM +, significantly complicated the processing and evaluation of the classification results. As a result, during the processing of the identification results, carried out on the basis of Landsat 7 ETM + imagery, and the calculation of the potential an additional step was required — interpolation and subsequent sampling of the surface.

The results of the classification of satellite images SPOT 2/4 are similar to the results of the classification of Landsat images. The segregation of vegetation and soil turned out to be possible, as well as the separation of vegetation on the projective cover (see Fig. 1). The main problem that arose when working with images SPOT 2/4, was the fact that these images do not cover the whole territory of the studied areas and provided for a limited number of periods. Therefore, the construction of temporary spectral images of cultures in their division and the identification was impossible.

For assessment and analysis of the energy potential of crop waste for districts of Kharkiv region in 2013, Landsat 8 images are selected. The important point is the lack of banding of the images of this system. The main negative factors are the lack of shooting speed and

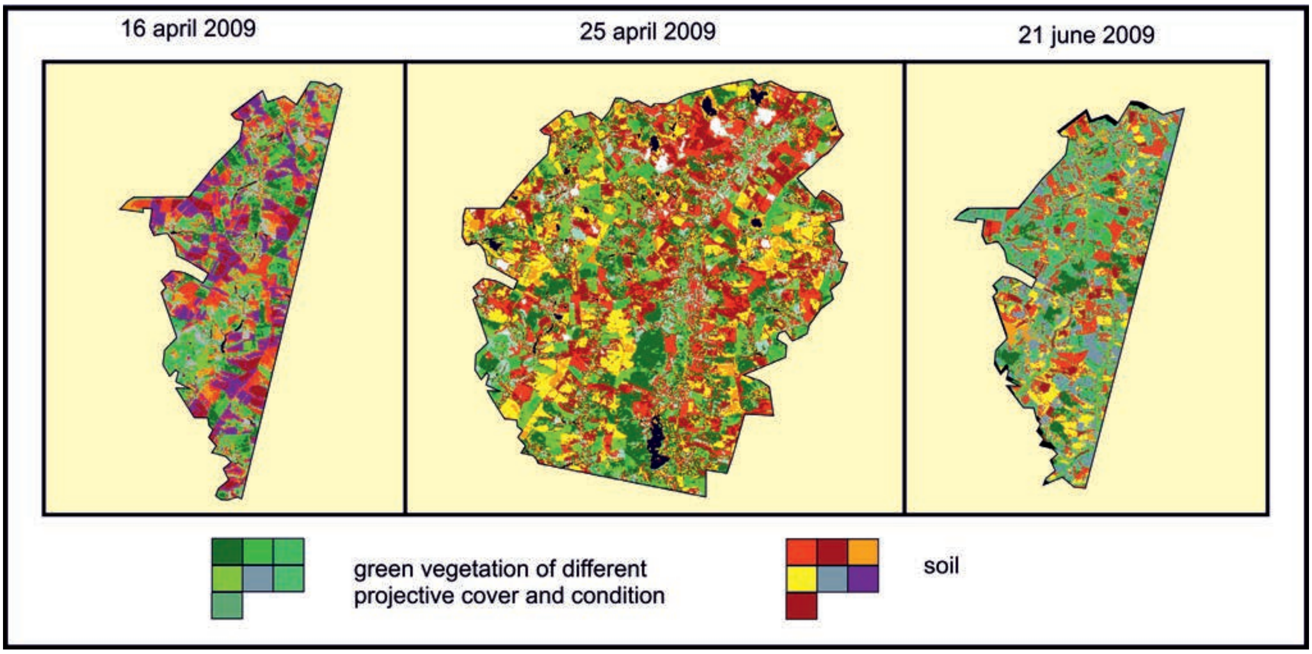

Fig. 1. The results of SPOT 2/4 images classification

clouds on most materials. These factors lead to ambiguity in the recognition of cultures at a considerable number of fields.

After the classifications correspondence between crops and classes were defined, which it is presented on each shooting date with. In a simple version, this correspondence is determined by whether the field is occupied by green vegetation on the date of recording, or represented with soil or yellow/dry vegetation. At the same time within the greenery, the main differences are due to an estimated coverage (sprouts, dense vegetation). A more detailed analysis requires high repeatability shooting, which will fix the spectral features of the different crops in the phenophase, as well as the obligatory presence of the test territories.

The following operations were carried out in the GIS MapInfo Professional using the additional software module. To automatically assign the pixel values of the culture the following algorithm is used:

If (on the image 1, the value at point A equals class a or the value at the point A is equal to class b), and (on the image 2 the value at the point A is equal to class a or the value at the point A is equal to the class d) and (on the image and the value at the point A is equal to class n), then the point A - is a crop V (Fig. 2). The algorithm is applied to each point, and therefore, each of them is identified as a particular crop (see Fig. 3).

Depending on the specific crop, each pixel classified is assigned an EP value of this type of crop waste in terms of pixel area.

may2009	jun112009	jun272009	jul2009	oct2009	Culture	Energ_pot_kWh_pixel
3	4	7	6	7	Pshen_oz	0,2478
3	4	7	6	7	Pshen_oz	0,2478
3	4	5	6	7	Pshen_oz	0,2478
3	4	5	6	5	Pshen_oz	0,2478
3	4	5	6	5	Pshen_oz	0,2478
5	3	5	6	5	Yach_Yar	0,212397
5	3	5	6	5	Yach_Yar	0,212397
5	5	5	6	7	Yach_Yar	0,212397
5	3	5	6	7	Yach_Yar	0,212397

Fig. 2. Sample table with the results of the automatic assignment of the pixel values of the crops and EP

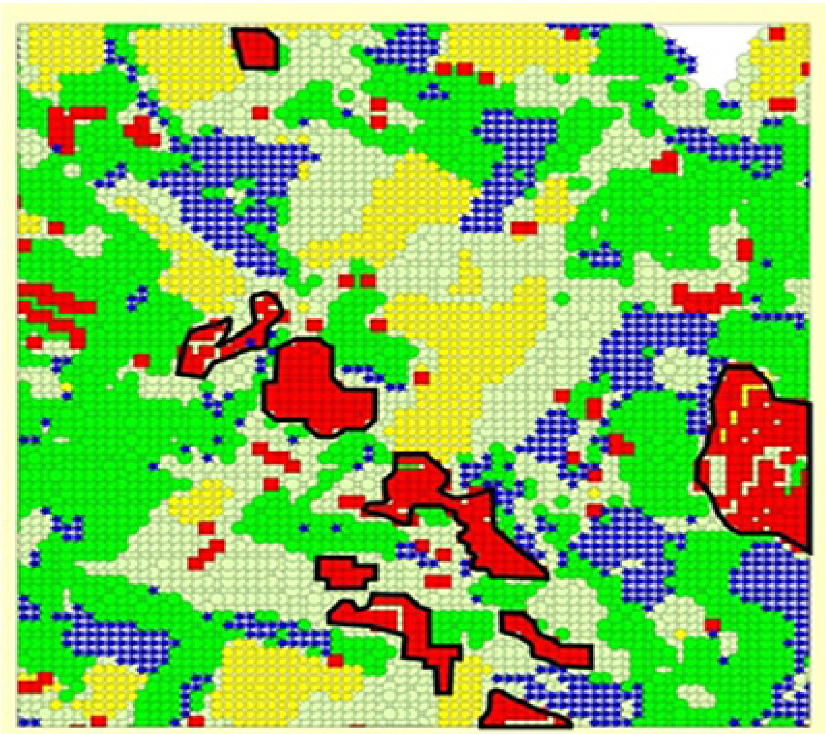

Fig. 3 An example of the identification results
(red — corn grain, yellow — corn fodder, blue — winter grains, green — pastures, light green — not identified sites)

The assessment of the energy potential of crop waste in the case of thermochemical conversion is based on the use of a number of coefficients: waste, accessibility, consumption their own waste by farming (Soufer and others, 1985, Geletukha and others, 2002).

$$EPc = Ycp * IW * AI * IF * EI * AE \qquad (1)$$

where *EPc* — the energy potential of crop waste;
Ycp — crop yields (1 ton per 1 pixel);
IW — index of waste;
AI — accessibility index;
IF — index of consumption of their own waste by farms;
EI — the energy intensity;
AE — an average efficiency of the power plant.

The resulting set of points with the calculated parameters allows conducting further analysis and mapping of the EP at the level of the administrative district and at the regional level. The latter provides the ability to calculate the total potential of the region as a whole and for each district separately and display them using the method or cartograms and cartodiagramms. For the analysis of territorial differences both within the region and within the administrative district, a density field construction is effective.

In this study, the analysis of features of distribution of the crop waste EP of the territory was based on the construction of the density fields by the method of a sliding circle. The construction data was run in GIS MapInfo Professional using the additional software module Density Fields (Tretyakov, 2007). The network of control points was created, and the choice of parameters (grid reference points and radius of the sliding circle) was based on the scale of the observed territory. Then between the control points interpolation was done while preserving the values in the original points.

Analysis of the distribution patterns of crop waste EP within the administrative area allowed to identify a number of factors. A leading role in the spatial distribution of the density of the crop waste EP in the district is played by the factors that cause a decrease of the area under agricultural land: percentage of forest land and the density of settlements. In turn, the maximum is confined mainly to the areas with a low density of settlements and forests.

The relationship between relief (height, dismemberment) and the distribution of the crop waste EP is established. The developed ravine system leads to the withdrawal of large areas of land from active agricultural use, and therefore – to decrease in yields density. Elevated terrains (watersheds) are characterized by the presence of maximum density potential. Lowered areas (beams, river valleys) correspond to minimum values. In addition to direct removal of land from agricultural use, the risk of erosion of land leads to changes in crop rotations, particularly to increase identification of crops (grass, peas), having a smaller energy potential.

Conclusions. Evaluation of the crop waste energy potential at different administrative levels has its own characteristics: the initial data, the sort of cartographic mapping of the potential distribution, and others. In the transition to the regional and especially the district level the use of geographic information systems becomes increasingly important.

Involvement of remote sensing data in the assessment of the energy potential of the region or district provides a more accurate assessment of the potential, as well as obtains the distribution of EP on this area, which is useful for allocation of bioenergy plants.

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