APPLICATIONS OF REMOTE SENSING TO PRECISION AGRICULTURE RECOMMENDATIONS

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APLICAREA TEHNOLOGIILOR GEOSPAȚIALE PENTRU ELABORAREA RECOMANDĂRILOR ÎN DOMENIUL AGRICULTURII DE PRECIZIE

Rezumat. Sistemele geospațiale de informare și de poziționare globală sunt introduse pe scară largă în toate sferele vieții noastre și continuă să se dezvolte în mod activ. În lucrare este prezentată aplicarea metodelor geospațiale de detectare la distanță a suprafeței pământului pentru determinarea umidității solului în funcție de plastica reliefului în combinație cu analiza morfodinamică. În consecință, au fost elaborate recomandările pentru implementarea agriculturii de precizie. Schema propusă permite ajustarea cantității de îngrășăminte pentru fertilizarea solurilor și dezvoltarea unei abordări specifice de irigare pentru a maximiza conservarea resurselor naturale din zona agricolă utilizată.

Cuvinte-cheie: umiditatea solurilor, sistem de poziționare globală a Pământului, geomorfologia, morfodinamica, degradarea solurilor, agricultura de precizie.

Summary. Geographic information systems are already widely introduced in all spheres of our life as well continue to be actively developing. In the paper, the application of remote sensing methods for determination of soil moisture in combination with the relief plasticity and morphodynamic analysis allowed us to take into account the relief of the earth's surface. As a result, a guidelines have been developed for precision agriculture. The proposed scheme permits to adjust the amount of fertilizer for distribution in the soil and to develop an irrigation approach to maximize the conservation of natural resources of the used agricultural area.

Keywords: soil moisture, Remote sensing of the Earth, Geomorphology, Morphodynamic analysis, Soil degradation, Precision Agriculture.

INTRODUCTION

The development of precision agriculture technologies allows both to increase yields and to save the natural resources. In traditional land use each individual field is considered, to which all actions and farm management are applied. Precision land use examines the nature of the individual plots within this field, each of which requires different management measures. Precision land use is carried out for the correct and economical distribution of fertilizers used in agriculture, saving costs and thus aligning the yield across the field.

The introduction of remote sensing of the earth and geographic information systems in the precision farming is considered as one of the most effective method. The article proposes the usage of these methods for studying heterogeneities within each of the selected field and creating a set of recommendations for applying fertilizers and improving irrigation systems. Each separate section of one field has different indicators of soil moisture, its structure and the amount of humus. Thus, housekeeping becomes more environmentally friendly and cost-effective, because of applying of different amounts of water and fertilizer to each section of the field. Taking into account the unevenness of the field allows you to take into account the natural conditions and to reduce the possible changes of a human natural environment. This approach allows decreasing the chemical pollution of soil and groundwater.

The set of elaborated recommendations is based on the indicators of soil moisture in dependence of the field microrelief that has the practical importance and can be used to maintain accurate land treatment by the modern equipment on board of the agricultural management.

Precision Agriculture refers to the revolutionary changes in agriculture [1]. One of the solid advantages of such a revolution is the efficient allocation of resources, which makes it possible to obtain financial benefits. One of the first who began to introduce the concept of precision farming in practice is the Northern States of America.

The majority of the articles over the world demonstrated that the methods of space imagery and geographic information systems (GIS) are most actively used in farm management [2]. A variety of techniques allow us to evaluate the structure of the soil, its fertility, the presence of moisture and humus in the soil, and to determine the chemical composition. Also, much attention is paid to the study of the vegetation cover. Analysis of vegetation cover can show the conditions of yield production, vegetation period of crops, parasites diversity, as well as the human health status. Most often, such studies are carried out with applying of the remote assessment methods. In majority of studies are focused on the non-uniformity of coverage, emphasis is often placed on soil and plant cover heterogeneities, and in very rare cases, the studies take into account the topography of the surface.

Relief has the main influence to the moisture movement, heat and lithodynamic flows in the upper layer of the earth's crust. In our work, emphasis is placed on the topography of the surface, taking into account its irregularities and differences, as well as soil moisture. The purpose of the research work was oriented to the development of the set of recommendations for maintaining precision farming use in a GIS format by combining methods for calculating the water balance of the soil based on multispectral satellite images and the method of relief plasticity.

MATERIALS AND METHODS

The Scientific Center for Aerospace Research of the Earth (CASRE) developed and implemented methods for determining and predicting crop yields based on satellite images, tested and improved effective methods for studying the state of soil including its humidity and degradation processes [3, 4, 5]. V. I. Lyalko, A. I. Sakhatsky and other CASRE researchers developed a methodology for using multispectral satellite images to solve hydrogeological problems.

One of the most important process in the soil related to the water exchange. To determine the moisture in the soil, A. I. Sakhatsky proposed to use the Normalized Water Index (NWI). M.K. Griffin and others (2005) previously proposed it to separate the snow cover that was initially called the Normalized Difference Snow Index (NDSI). In [6, 7], it was demonstrated the possibility to use it for the ground-based field verification studies. To characterize the soil moisture, satellite images Sentinel-2A were selected. The normalized water index was calculated from the spectral reflection difference in the green (GR) and middle infrared (SWIR) spectral bands. The index displays the humidity in the vegetation cover as well as in the upper layer of the open (without vegetation) soil and is calculated by the formula:

$$NWI = \frac{GR(560) - SWIR(1650)}{GR(560) + SWIR(1650)}$$

where GR is the reflection in the range of 540-580 nm in the green spectral band Sentinel-2A;

SWIR-reflection in the range of 1570-1660 nm in the middle infrared band Sentinel-2A.

A positive correlation was obtained between the water index values calculated using the satellite imagery and the humidity values measured in the field. Based on the correlation, a map of soil surface moisture was obtained. More details are described in [6, 7]. The humidity values are divided into five classes from the minimum to maximum percentage of moisture content. Such a map allowed us to display the uneven distribution of humidity, and its accumulation in areas of low relief, which represent the main factors of soil degradation.

The relief was studied by the method of plasticity relief, which was originally introduced by Stepanov I.N., as a method of the soil mapping [8]. This method is also used to study both the soil cover and the soil degradation [9, 10, 11, 12]. The method is based on a topographic map, the contours of which simulate the surface relief [8]. To study the soil, was introduced a line, which represent the derivative of the contour lines of the topographic map. The method of plastic relief based on the elements of the relief determine the properties of soils and their spatial and temporal distribution. The relief plasticity map is supplemented with morphometric values that reflect the physical, energetic, and chemical concentration and distribution of the elements of the soil layer depending on the microrelief. The difference in height of the relief in this method is considered as a physical field.

The structure of the horizontals of the earth's surface used in the method of the relief plasticity, allows you to identify even a slight excess or decrease. In our case, instead of the topographic map traditionally used in this method, a digital elevation model based on space radar topographic survey (SRTM) was taken. The obtained plastic map of the relief was supplemented with elements of morphodynamic analysis, and models the features of surface runoff and soil [13, 14].

RESULTS

The study area is located in Baryshevsky district of Kiev region. This is a typical representative area of the forest-steppe, which occur in the Eastern part of Europe (Ukraine, Moldova), in the considerable area of Russia and United States of America. Within the forest-steppe zone predominate the various kinds of chernozem (black soil), formed on the loess. The area is characterized by ravines, manifestations of water erosion and the presence of microdepression relief

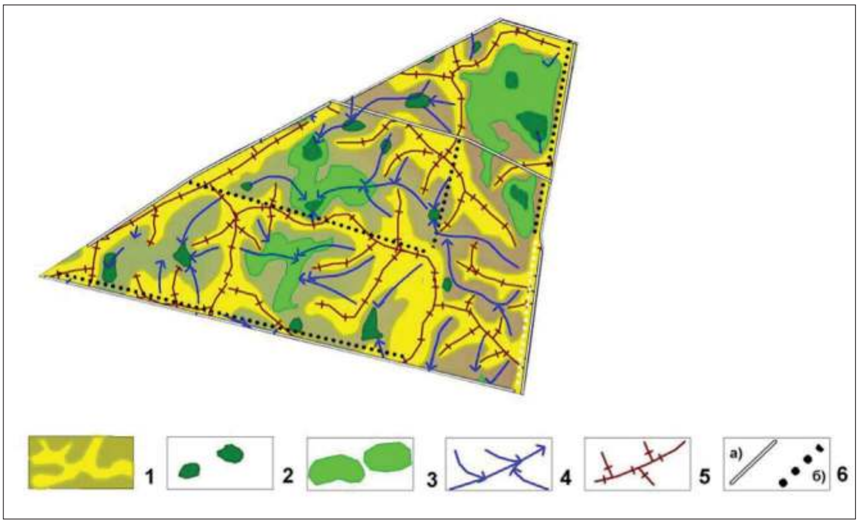

Figure 1. Relief plasticity map with elements of morphodynamic analysis.
Legend: 1 – relief plasticity; 2 – microdepressions; 3 – cavities; 4 – drainage (keel) lines;
5 – ridge lines; 6 – a) roads; b) woodland belts.

forms. For the research were selected agricultural areas in the spring not covered with vegetation, or with weak vegetation cover.

Based on the combination of methods of the remote sensing and GIS, a plasticity relief map was elaborated, which was supplemented by elements of morphodynamic analysis (figure 1).

The yellow color on the map shows the top layer of the relief (figure 1, legend 1, 5). They represent the elevated watershed ranges, from where the removal and movement of soil masses, surface waters and also applied fertilizers to lower areas of the relief occurs. The bottom, background color highlighted directly image of the DEM. These areas are more hydrated and are characterized by increased soil humus content. The keel line vectors (Fig. 1, legend 4) determine the directions of runoff. In addition, the map is complicated by drainless microdepressions and lowlands (figure 1, legend 2, 3).

Just in these lower areas the soil and fertilizer particles are washed away from the elevations. In low areas, water accumulates and stagnates, especially in spring and autumn. In this way, irregular and uneven distribution of moisture in the soil and fertilizer were observed. The amount of moisture and the concentration of fertilizers in the depressions are usually

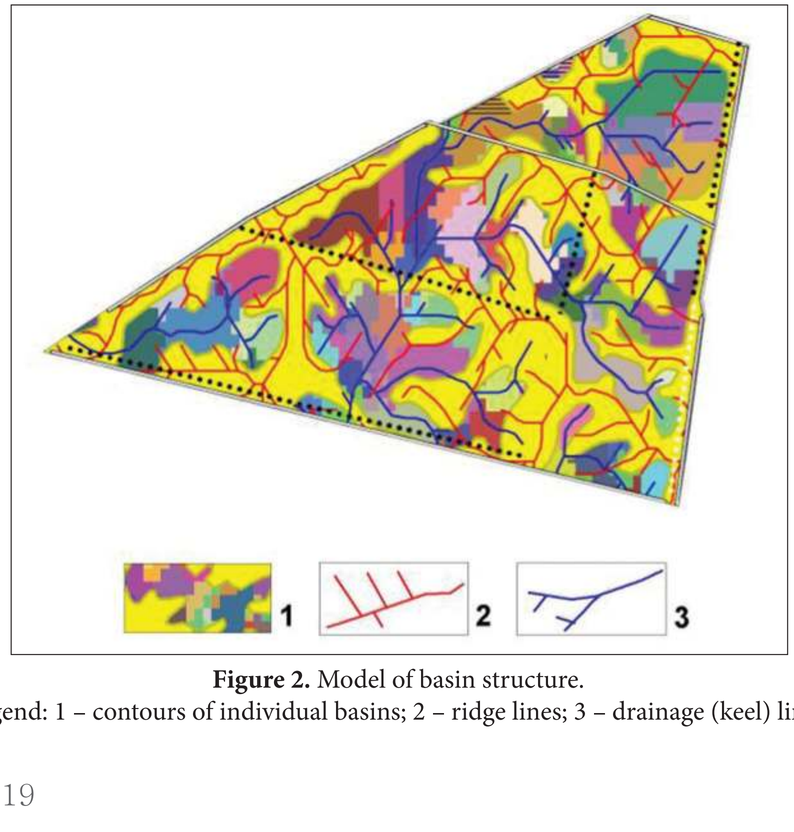

Figure 2. Model of basin structure.
Legend: 1 – contours of individual basins; 2 – ridge lines; 3 – drainage (keel) lines.

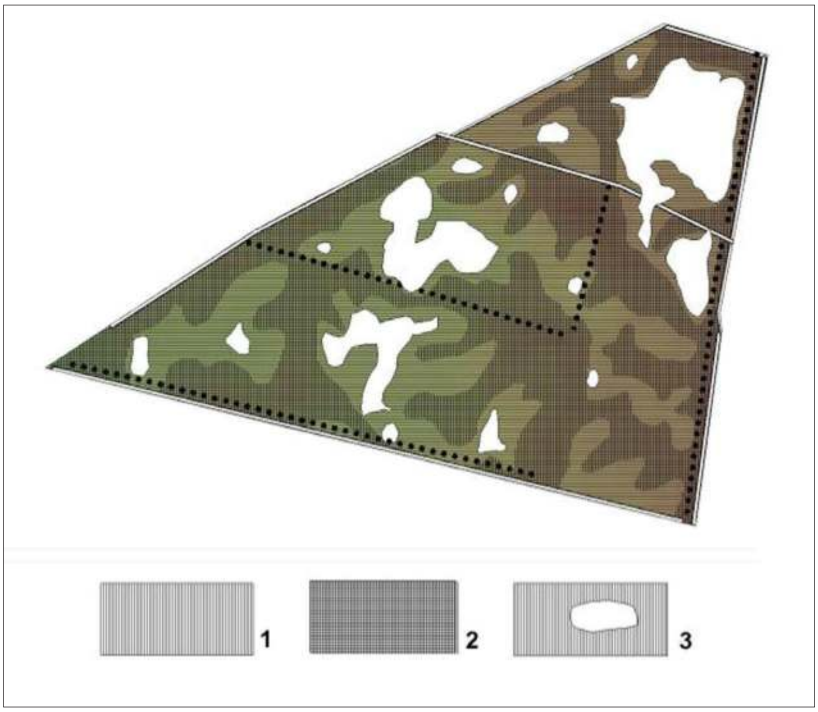

Figure 3. Scheme of recommendations for precision agriculture.
Legend: 1 – elevated areas, areas of demolition; 2 – low areas, areas of accumulation; 3 – microdepressions, areas of infiltration.

two times higher than at the watersheds of the fields. Through microdepressions infiltration and migration of fertilizers into groundwater occurs, it creates an unsafe environmental situation.

Based on the digital elevation model, the surface runoff model was also created. A map has been elaborated of the basin structure of the studied area as a result of the separation of the drainage system and separate basins of surface runoffs (figure 2). The map displays a system of drainage lines and ridge lines (figure 2, legend 2, 3). The drainage system has a complex structure. Regions of different shades display fragments of valleys, depending on their order. The structure of the drainage lines, laid on the smallest surface areas determines the direction of flow. The areas surrounding the drainage lines, respectively, have an increased soil moisture. This model must be considered to determine the direction of runoff of surface and groundwater, which carry particles of soil masses and fertilizers.

Based on the research studies, which included the creation of a soil moisture map, relief plastics and a model of a basin structure with the different content, but nevertheless complement one another, a set of recommendations in a GIS format was developed for precise agriculture (figire 3). The scheme consists three layers, which define areas removal, accumulation and infiltration. The highest areas correspond to the zone from which the demolition of soil particles and the leaching of fertilizers occur. Water accumulated in lower areas in dry periods have higher soil moisture values. The lowest areas represent the zones of microdepression forms of the relief. These are drain less zones, where the infiltration of groundwater occurs as well.

Elevated areas of the surface are characterized by relatively less moisture from which the permanent demolition and movement of soil particles and applied fertilizers is happened. The conditions for soil depletion are developing on these plots and therefore constant fertilization is required. Within the lower areas, highlighted in the scheme by horizontal shading, fertilizers are applied from the areas that are located above. These plots may receive a relatively lower rate of fertilizers that will not affect the yield. The plots affected by microdepressions on the scheme are marked in white, where the accumulation and infiltration processes take place. Besides, they are characterized by excessive moisture and accumulation of soil and fertilizer particles washed off from rises. It is recommended the limited application of fertilizers in these areas to prevent pollution of groundwater. The density of crops should also depend on the fertile properties of the soil, moisture reserves, and the relief of the field.

The established set of recommendations for maintaining accurate land use will increase the potential of the field by differentiating the rate of fertilizers application, which will lead to their economical consumption and increase in yield.

CONCLUSION

The ecological aspect of precision farming increases yields while saving resources, protecting the environment, especially groundwater from fertilizers applications on the surface and plant protection products from pests.

Satellite imagery data can be effectively used to determine the uneven distribution of moisture in the surface layer of the soil. Remote data can be used to improve the theory and practice of displaying the structure of the soil cover for the implementation of accurate land use and all its constituent elements.

The method of relief plasticity in combination with other methods introduces detail and significant adjustments to the principles of accurate land use. Morphodynamic analysis determines the direction of surface flow structures, which allows zoning within each field to make differential fertilization.

The proposed set of methodological approaches can be applied in territories with similar climatic and natural-territorial conditions, as well as with similar risks of soil degradation and forms of relief, such as Ukraine, Moldova, Romania, Russia and other countries.

The conducted research allow improving the theory and practice of mapping the structure of the soil cover for the introduction and maintenance of precision agriculture. The use of materials for remote sensing of the Earth contributes to the further introduction and implementation in practice the concept of precision farming. This will lead to the yield increasing, taking into account the natural features of the described factors and reducing the costs of human efforts. In the future, precision agriculture should became the usual technology that ensures stable land use, high yields, minimal damage and preservation of natural resources.

The methods proposed in the article contribute to implementation of the recommendation set for applying of modern technology as a basis for the development of precision farming. The elaborated recommendation set laid the ground for optimal application of fertilizers, as well as for adjustment of irrigation systems for its greater efficiency. For the territories with similar geomorphological characteristics, is recommended to introduce drip irrigation instead of uniform intensive irrigation.

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