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M. Huang[1], Y. Y. Shabala[2]

[1] Taras Shevchenko National University of Kyiv, Kyiv,
Ph. D. student in the Department of Information Systems and Technologies
bao1978@gmail.com
ORCID: https://orcid.org/0000-0002-2365-9815

[2] Kyiv National University of Construction and Architecture, Kyiv,
Associate professor of Department of Cybersecurity and Computer Engineering,
Ph.D. in Engineering, Associate professor
wild_miledi@ukr.net
ORCID: https://orcid.org/0000-0002-0428-9273

CONCEPTUAL MODEL OF GEOGRAPHIC INFORMATION SYSTEM FOR AGRICULTURE

Population growth and nutritional requirements are exacerbating the struggle for scarce land resources. It is important to use land rationally to preserve and increase their productivity and to sustain life in ecosystems. Land use planning is one of the key tools for efficient use of land resources. Important sub-tasks of land use planning are monitoring the status of crops and forecasting their yield. The development of a conceptual model of a geoinformation system for agriculture that addresses these sub-objectives is addressed in this study.

Yield monitoring is considered as a system of observation and measurement of crop growth, taking into account meteorological, agrometeorological, phenological and other indicators based on the analysis of time series images obtained by photographing the acreage, in order to evaluate and predict the potential. Methods for quantifying vegetation using a simple quantitative indicator of photosynthetic active biomass are considered. The methods of calculation of the normalized differential vegetation index are considered. Three main tasks of the geoinformation system for agriculture are formulated: calculation of values of time series NDVI indicators based on snapshots, calculation of land quality indicators based on a priori information about the plot and forecasting of indicators in the following moments of time. Based on the formulated tasks, a three-module conceptual model of the geoinformation system is proposed. The conceptual model defines the functions of each module and shows information interactions between the modules.

Keywords: Geoinformation system, crop photos, vegetation index.

1. Introduction. Population growth and nutritional requirements are exacerbating the struggle for scarce land resources. The desire to maximize profits leads to degradation of land resources, loss of biodiversity. Global climate change is also adversely affected. Therefore, the urgent task is to use land rationally to preserve and increase their productivity and sustain life in ecosystems.

Land resources planning (LRP) is one of the key tools for efficient use of land resources. There are currently many enterprise-level LPR solutions available. But simply combining these solutions is not enough for effective regional or country-level LPR. Given the trend towards globalization, there is a need for global LPR across the planet Earth. This need was formulated and documented in Revision to the World Soil Charter in 2015 [1]. Many international organizations, such as FAO [2], NASA [3], and others, are addressing this pressing challenge.

LPR's important sub-tasks are to monitor the condition of the crops and to predict their yield. The development of a conceptual model of the geoinformation system that addresses these sub-tasks is addressed in this study.

2. Review of sources. WinDisp was one of the first successful attempts to implement management information systems in agriculture. Support for this software was discontinued in the early 2000s because the tools it implemented did not meet the challenges of the time and became obsolete [4].

ArcGIS from the US company ESRI is a successful commercial geo-information system for agriculture [5]. ArcGIS includes a whole line of geoinformation software products used in land management, surveying, land management in general. ArcGIS products have a whole line of add-ons for specific tasks, and there is a separate ArcPad software for laptops. Due to its versatility, ArcGIS can also be used for agricultural purposes, including the management of acreage to produce a planned crop yield.

Digital field imaging provides valuable information on the state of the crop, allows us to evaluate plant health and predict the yield, timing, quantity, and quality of future production [6]. A simple quantitative indicator of photosynthetic active biomass called the Normalized Differential Vegetation Index (NDVI) can be used to quantify vegetation cover [7]. The methods of presenting the sequence of images of the acreage in the form of time series are intensively developed [8]. Such transformation is necessary for the application of appropriate forecasting and decision-making methods in agriculture. The theoretical basis of the study to solve the problem of creating information technology for monitoring crop yields based on the analysis of multispectral images obtained by remote sensing is presented in [9]. This theoretical framework will be used to build a conceptual model of geographic information system for agriculture (GISA).

3. Formulation of GISA tasks. The main tasks of GISA are formulated in [10]: Agricultural land monitoring, soil monitoring and mapping, crop area estimation, production forecasting, plant disease detection. That is, the system must monitor and predict the yield by analyzing rows of images. Yield monitoring will mean a system for monitoring and measuring crop growth, including meteorological, agro-meteorological, phenological and other indicators based on the analysis of time series images obtained from crop photography to evaluate and predict crop potential. Not only satellite images [11] but also photos taken from drones [12] are promising.

Typically, field images taken in different spectra are used to monitor the condition of the fields. Normal color images encoded in a particular color system (RGB, CMYK, YIQ, YUV, YCrCb, etc.) are possible. It is also possible to use snapshots using special filters in different bandwidths. In particular, the Moderate Resolution Imaging Spectroradiometer (MODIS) provides images of the Earth's surface obtained from the EOS AM-1 satellite in 36 range spectra with a length from 0,4 mkm to 14,4 mkm. The image extension is between 250 m and 1 km. This allows the vegetation indices to be calculated as the difference of the intensities of the reflected light in the respective ranges, divided by the sum of their intensities. That is, the index β_{rq} is calculated by the formula:

$$\beta_{rq} = \frac{R_r - R_q}{R_r + R_q}, \tag{1}$$

where R_r *and* R_q – light intensity in different ranges. Typically, the visible red (630-690 nm) and infrared (760-900 nm) spectra ranges are determined for NDVIs.

For convenience, denote the index calculated for the specified ranges simply β.

The digital image is a finite matrix of pixels m*n. Therefore, we consider the image as a function of F(x, y) , where x defines the coordinate of the abscissa $x \in X = \{x_1, x_2, \ldots, x_m\}$, and y – is the coordinate of the ordinates on the plane y $\in Y = \{y_1, y_2, \ldots, y_n\}$. The function value is a set of intensities $<r_1, r_2, \ldots, r_w>$, where r_q – is a real number that determines the light reflection intensity in a given spectrum range, and w – is the number of spectrum ranges. To calculate the reflection intensity of a plot in a given spectrum, it is necessary to find the sum of the intensities of the corresponding component in all pixels belonging to the plot. Let D be some area of the image corresponding to the area where the agricultural crops are grown. Then the plot can be defined as $D \subset X \times Y$, and the intensity of reflection of the plot in the given range of the spectrum is calculated by the formula:

$$R_q = \sum_x \sum_y^{(x,y)\in D} r_q\left(x, y\right), \; q = \overline{1, w}, \tag{2}$$

then the index can be regarded as a function of the image B$(F\left(x, y\right))$. But plant development is a dynamic process, that is, it changes over time. Therefore, the index must be regarded as a function of the image and the time $\mathrm{B}\left(F\left(x, y\right), \; t\right)$.

Let

$$\begin{aligned} \beta &= \left\{\beta_1, \beta_2, \ldots, \beta_n\right\}, \\ \beta_i &= \; \mathrm{B}\left(F\left(x, y\right), \; t_i\right), \end{aligned} \tag{3}$$

Where β is a discrete NDVI time series fixed at specified times t_1, $t_2, \ldots$, t_n, a β_i are NDVI at time t_i.

t is then shown that there is a functional relationship between land quality, management efficiency, NDVI and site yield:

$$V = g\left(\beta, Z, M\right), \tag{4}$$

Where β is the NDVI time series from sowing to harvest, Z is land quality indicators, M is management parameters (irrigation, fertilizer, pesticide, etc.).

The following three main GISA objectives can thus be formulated:

1) Calculation of NDVI time series metrics based on snapshots that are obtained at regular intervals. The problem is solved by calculations by formulas (1)-(3).

2) Based on forecasting at times t_{n+1}, t_{n+2}, ... the problem is solved with the help of certain forecasting models, in particular [9, 13] proposing to use the Breaks For Additive Seasonal and Trend (BFAST) method.

3) Calculation of land quality indicators Z based on a priori land information. For example, Earth Observation (see fig. 1) provides information on the latest 36-month period of seasonal, vegetation and precipitation indicators [14].

GISA can also be part of the Decision Support Systems (DSS). The main task of DSS is the task of maximizing productivity

$$V \to max, H\left(M\right) = 0$$

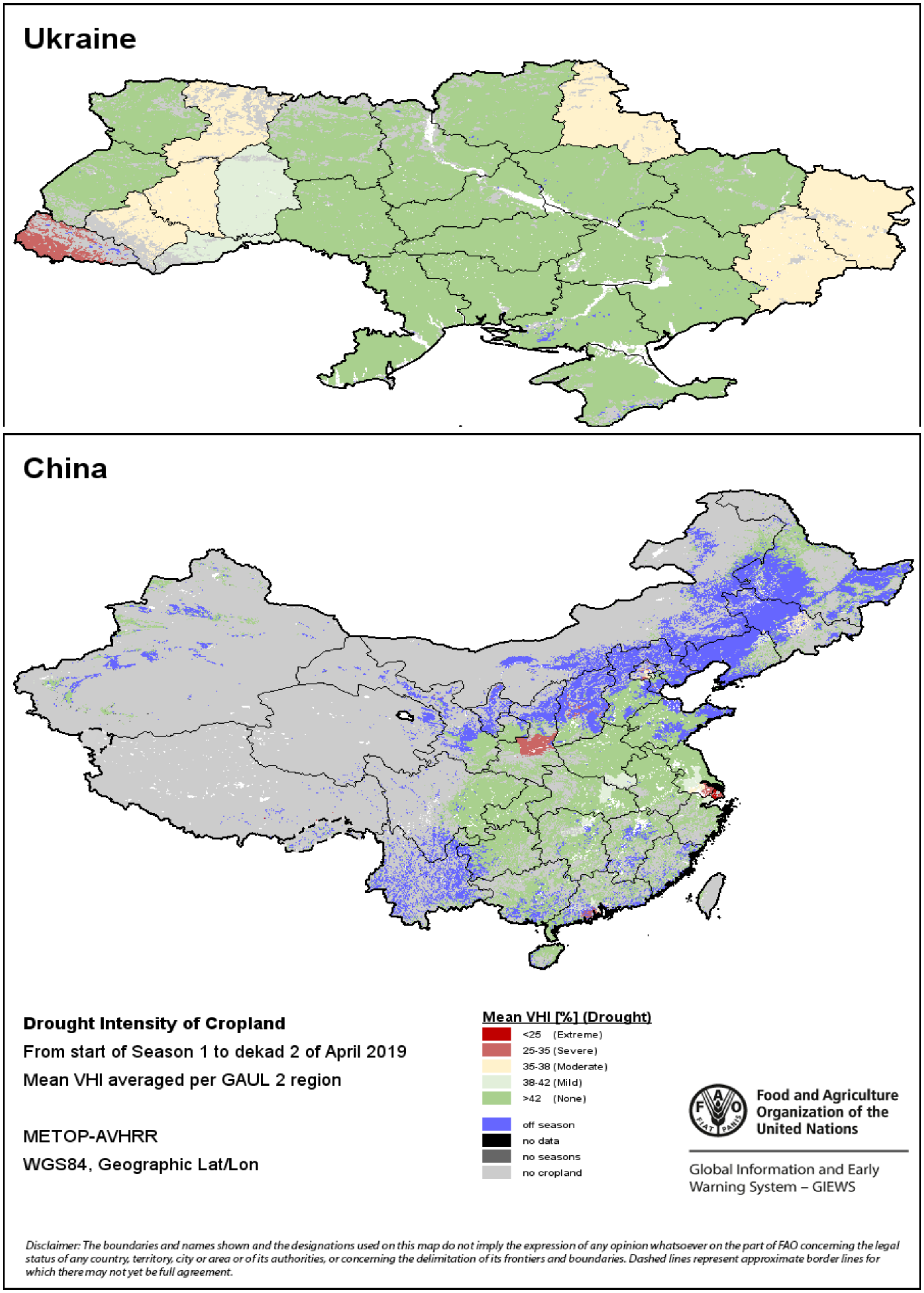

Fig.1. Example of agricultural drought intensity maps of Ukraine and China for first decade of April 2019

where H is a function that specifies the control parameters.

4. Construction of conceptual model and GISA. Construction of conceptual model and GISAAccording to the stated tasks it is necessary to develop GISA. A three-module system is proposed. According to this structure, we will develop a conceptual model of the system, which consists of 3 modules (Fig 2).

1) Data in unit provides data collection, including aerospace and space action sequences, regional soil data, weather forecasts, and more. The data should be brought into a single format, including the transformation of global coordinates into local ones. The module also records the collected data in the database.

2) Calculation unit provides NDVI calculations, determines land quality indicators and forecasts for next

3) The data out unit should provide information in a user-friendly way. Specifically, build NDVI maps, soil maps, and plot dynamic change. This module should also contain ARIs for exporting data to both DSS and other GIS.

The conceptual model defines the functions of each GISA module and shows information interactions between modules.

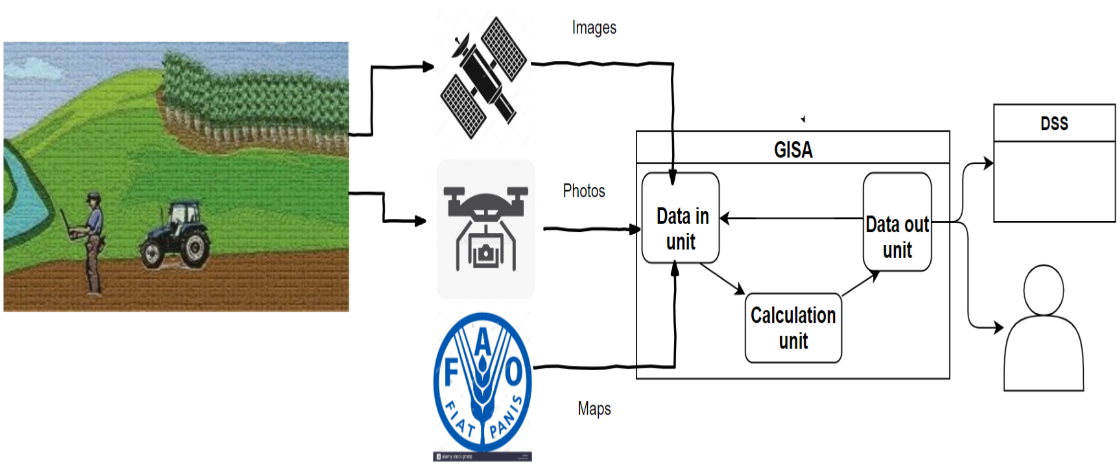

Fig. 2. Conceptual model of geograpic information system for agriculture

5. Conclusions and prospects for further research. The article deals with the development of a conceptual model of geoinformation system for agriculture. For this purpose, three main tasks are formulated and methods are proposed for solving them. A conceptual GISA model is proposed, which consists of 3 modules. In the future, it is necessary to implement each of the three modules. In particular, methods of rapid batch image processing should be considered. Scaling up the system also requires additional scrutiny. Looking into the ways of integrating GISA to DSS seems promising.

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Хуан М., Шабала Є. Є. Концептуальна модель геоінформаційної системи для сільського господарства.

Концептуальна модель геоінформаційної системи для сільського господарства. Зростання населення та вимог до якості харчування є причиною загострення боротьби за обмежені земельні ресурси. Актуальним є раціональне використання земель для збереження та збільшення їх продуктивності і підтримки життя в екосистемах. Планування використання земельних ресурсів є одним із ключових інструментів для ефективного використання земельних ресурсів. Важливими підзадачами планування використання земельних ресурсів є моніторинг стану посів та прогнозування їх врожайності. Розробці концептуальної моделі геоінформаційної системи для сільського господарства, яка розв'язує ці підзадачі, присвячене дане дослідження.

Розглянуто моніторинг врожайності як систему спостереження та вимірювання за станом зростання сільськогосподарських культур, враховуючи метеорологічні, агрометеорологічні, фенологічні та інші показники на основі аналізу зображень часових рядів, отриманих в результаті фотографування посівних площ, з метою оцінювання та прогнозування потенційної врожайності культури. Розглянуто методи для кількісного оцінювання рослинного покриву використовуючи простий кількісний показник фотосинтетичної активної біомаси. Розглянуто методи розрахунку нормованого диференційного вегетаційного індексу. Сформульовано три основні задачі геоінформаційної системи для сільського господарства: розрахунок значень показників часового ряду NDVI на основі знімків, розрахунок показників якості земельних ресурсів на основі апріорної інформації про ділянку та прогнозування показників в наступні моменти часу. Базуючись на сформульовані задачі пропонується трьохмодульна концептуальна модель геоінформаційної системи. Концептуальна модель визначає функції кожного із модулів та показує інформаційні взаємодії між модулями.

Ключові слова: Геоінформаційна система, фотографії посівів, індекс вегетації.

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