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DATAWARE OF INTERNET-CENTER FOR MONITORING OF LAND RESOURCES USE IN UKRAINE

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ІНФОРМАЦІЙНЕ ЗАБЕЗПЕЧЕННЯ INTERNET-ЦЕНТРУ МОНІТОРИНГУ ВИКОРИСТАННЯ ЗЕМЕЛЬНИХ РЕСУРСІВ УКРАЇНИ

Purpose. To systematize domestic and foreign experience of usage of space remote sensing data, transformation methods for different-level and different-time datasets and program tools for their processing under creation of a national Internet-center of soil state monitoring and development of methods for controlling seasonal dynamics of soil processes.

Methodology. Scientific and theoretical analysis of literature on the researched topic is used. Methodological approaches being formed are summarized. They are aimed at solving the task of identification and forecasting changes in soil characteristics affecting the deterioration of the basic indicators of its physical state.

Findings. The main requirements are formulated and necessary components for creation of architecture of information, methodical and program implementation of the Ukrainian Internet-center for monitoring and analysis of space remote sensing data are determined.

Originality. For the first time in Ukraine the methodological and architectural principles of creation of information system for monitoring and space surveys data analysis are formulated and formalized. One of the most important tasks is to monitor territories in order to increase the efficiency of their use.

Practical value. The received results can be used for preparation and implementation of the main stages of creating the Internet-center for remote sensing data monitoring and analysis in order to solve problems of more efficient use of land resources in Ukraine.

Keywords: *remote sensing, space imagery, different levels and different time data sets, vegetation indices, Internet-center of monitoring*

Introduction. One of the main worldwide trends of the modern period of investigations of global geodynamic processes is using Earth remote sensing (ERS) data for these purposes. They are usually taken from aerospace platforms equipped with various types of remote sensing (RS) sensors and devices (scanners). RS data being processed and corrected allow solving a wide range of applied tasks using geoinformation systems (GIS) and technologies. Due to the ongoing growth in world food prices, the actual problem for society is aerospace monitoring of agricultural objects and earth's surface vegetation cover in general.

Space and aerial survey data of agricultural areas were first used in the US and by the middle of the XX century became the main element of the system of early yield forecasting and managing agricultural production processes for the majority of farmers. During that period they were used to determine crop areas and crop types [1, 2]. With the development of methods of ERS from space, the range of vegetation monitoring technologies has expanded significantly by improving functionality of information, methodological and software content of geoinformation systems and due to geoportals constructed on their basis [2]. In general, the historical use of GIS and ERS can be divided into three wide stages [3].

The first initial stage of development of ERS space data monitoring and processing (1970–1990), is characterized by limited access to the results of surveys and their high cost, and, in some cases, by complexity of making orders. Methods of visual analysis and interactive image processing dominated at that stage. The use of newly created methods and technologies of images decoding at local and regional levels was limited.

The second, transitional, stage (the late 1990s–early 2000s), is characterized by intensive development of Internet- and Web-technologies of cartographic materials dissemination, by creation of automated information systems of RS data processing at continental and global scale, by implementation of large international projects in the field of global mapping and monitoring of geo- and ecosystems.

The third, modern, stage is characterized by the following peculiarities:

- open access to super-large sets of various different-level and different-time geospatial ERS data derived from space or unmanned aerial vehicles (UAVs) and available on geoportals of governmental and private organizations;
- improvement of automation of large data sets processing;
- extensive use of online Web-service and cloud computing, providing different tools of RS data analysis and processing, including those derived from the use of UAVs [4].

Open free data and final products of satellite images processing results from operating RS satellites – Terra, Aqua, Landsat-8, EO-1, Sentinel-1A, Sentinel-2A, as well as space images taken from NOAA, Meteosat, Metop, Jason satellite series are the most widely used in multi-level wideline monitoring process. Open data of radar topographical survey of the most territory of the world resulted from SRTM (Shuttle Radar Topography Mission) mission are of particular note.

Since the process of collecting and archiving of RS data from aerospace platforms is sufficiently developed and well-established, specialized Internet-centers providing operationally ready services based on geoinformation technologies play the increasingly important role in RS data processing.

Creation of such an Internet-center for Ukraine as one of the leading agricultural countries is a relevant and strategically important task.

Ukraine has wide experience in the use of ERS data from space to solve agricultural problems thanks to the works of Lyalko V. I., Tarariko A. G., Voloshin V. I., Bushuev E. I., Stankevich S. A., Sakhatsky A. I., Popov M. A., Kussul N. N., Shelestov A. Y., Skakun S. V., Sirotenko A. V. and other Ukrainian scientists. Practical participation has been taken, for example, in such international projects as INTAS–TLCC Project (Technology of Land Cover Classification), FP7 of European Commission, JECAM, HORIZON-2020, etc., the GEO-Ukraine project was implemented during the last years [5].

However, in Ukraine there is still no national Internet-center of data monitoring and analysis to meet the agricultural challenges, similar to, for example, the American CropScape project [6].

In particular, this is suppressed by specific complex technological peculiarities of processing the RS data obtained from satellite platforms with different structure and equipped onboard with unique multifunctional facilities, which, in turn, causes:

- different resolution of imaging equipment (spatial, spectral, radiometric, temporal);
- different levels of processing data provided to the user;
- different levels of data correction (geometric, radiometric, atmospheric, gray-tone);
- different amount of initial and postprocessed data;
- different formats of data and metadata files.

The indicated peculiarities affect significantly the decisions of developers when choosing a configuration of software and hardware for many well-known monitoring systems [1, 6], and should always be taken into account in the formation of information, methodical and software content of the domestic Internet-center of complex processing of multi-level and multi-temporal data from different RS satellites [7, 8].

RS information products. Classification results for different types of land cover, forecasting maps of yield and state land fund, and especially – digital maps of various indicators – indices are the most valuable in agricultural monitoring.

Digital maps of indices are used the most frequently in the tasks of yield forecasting and identifying crop lesion focuses caused by diseases or natural disasters, as well as directly in the process of classification, clustering and recognition of land cover types, ecological monitoring of territories, geological studies, as well as in combination with other results of RS data transform.

One of the best known indices associated with vegetation characteristics quantification is Vegetation Index (VI) and its variants (e. g., Normalized Difference Vegetation Index – NDVI).

The NDVI index was first described in the early 1970s in the work of Dr. John Rouse and his colleagues [9], who was processing data from Landsat-1 satellite (ERTS-1) and calculated vegetation and transformed vegetation indices from the Landsat-1 MSS multispectral scanner bands.

Nowadays there are many varieties of indices, most of which are represented in the corresponding database (http://www.indexdatabase.de). By the end of 2015 the database contained more than 500 varieties of them applicable for calculation using multi- and hyperspectral RS data. Peculiarities of VI calculation and use are discussed in detail, for example, in [10, 11].

Let's consider some key moments of their use.

The most extensive study to assess the green biomass capacity and aimed at climate monitoring was started from the beginning of the 1980s, using the AVHRR multispectral scanner of the NOAA satellite group. Since that time calculation of global VI maps (GVI, Global Vegetation Index) has been performed based on the received data. The calculations are based only on NDVI values and do not include different measurements in infrared spectrum, successfully used in land cover and climate monitoring. In this regard NOAA proposed new data sets called GVHP – Global Vegetation Health Product which include additional data model described by Felix Kogan in [12]. Kogan in his works brings and validates such indices as VCI (Vegetation Condition Index), TCI (Temperature Condition Index) and VHI (Vegetation Health Index).

The FAO (Food and Agriculture Organization) international organization founded in 1945 and acting under the patronage of the United Nations has contributed greatly to the development and monitoring of global agriculture. A specialized resource GIEWS (Global Information and Early Warning System, http://www.fao.org/giews/) operates under the FAO. It provides the ability to monitor indices both for the whole world and for territories of different countries. Besides NDVI, the organization offers digital maps of various indices including VCI and VHI. According to the FAO: "The vegetation indicators (NDVI, VCI and VHI) provide alternative measures of the relative vegetation health. These indices can be used to monitor areas where vegetation may be stressed, as a proxy to detect potential drought. The precipitation indicators present a global analysis of the absolute (mm) and relative (%) rainfall levels per decade, in addition to the long-term average precipitation levels (mm)". The FAO has been calculating NDVI, VCI and VHI based on 10-day data from the METOP-AVHRR sensor at 1000 m resolution since 2007.

The FAO also runs activities with the use of Agricultural Stress Index (ASI) based on the integration of two measurements of VHI index being essential to assess time and space risks of drought. ASI is based on RS data and allows detecting abnormal growth of vegetation and estimating its potential for arable land in drought conditions over a vegetation period [13]. One of the FAO best known published techniques [14] describes the procedure of reference evapotranspiration and crop evapotranspiration calculation from various metadata. Thus, in [14] the process of evapotranspiration and factors influencing it are examined in detail, and models of calculation are proposed and justified.

A wide range of end products of satellite image processing used in vegetation monitoring applications is provided by USGS and NASA organizations. In particular, this refers to Level 3 and Level 4 products of the Terra / Aqua MODIS scanner data processing. For example, the next products may be of particular interest to researchers:

- MOD13Q1 (Level 3) – 16-day composite NDVI and ENVI indices at 250-meter spatial resolution from Terra MODIS scanner data;
- MOD11A2 (Level 3) – 8-day composite Land Surface Temperature (LST) of survey surface and Emissivity at 500-meter spatial resolution from Terra MODIS scanner data;
- MOD15A2H (Level 4) – 8-day composite simulation results of LAI and FPAR values at 500-meter spatial resolution from Terra MODIS scanner data;
- MCD15A3H (Level 4) – 4-day composite simulation results of LAI and FPAR values at 500-meter spatial resolution from Terra and Aqua MODIS scanner data;
- MOD17A2H (Level 4) – 8-day composite simulation results of Gross Primary Productivity (GPP) and Net Photosynthesis (PSN) values at 500-meter spatial resolution from Terra MODIS scanner data etc.

The data listed above are freely available through the USGS server: https://lpdaac.usgs.gov/.

Particular attention should be paid to the EVI (Enhanced Vegetation Index), LAI (Leaf Area Index) and FPAR (Fraction of Photosynthetically Active Radiation) indices, which are described in detail, for example, in [15], as well as to a very important GPP model data showing total primary production and NPP – Net Primary Productivity of vegetation.

Primary productivity is a rate of biomass accumulation. GPP is a total amount of energy produced by vegetation partially used for plants growth. NPP is a part of the energy remaining after this process and represented by dry vegetation biomass.

Evaluation and usefulness of GPP and NPP are considered, for example, in [16, 17], in the Globe Carbon Cycle (University of New Hampshire, http://globecarboncycle.unh.edu/) materials and in other sources.

It should also be noted that nowadays no product in the world, except MOD17A2H and MOD17A3H can provide global 8-day generalization on vegetation productivity and carbon balance.

Yield forecast. According to the authors, one of the most significant and urgent problems to be solved under preparation for creation of the National Internet-center of monitoring and agricultural data analysis is automation of yield forecast using RS data. The simplest approach to solving this problem consists in creating a simple or multiple linear regressions of yield indicators on spectral characteristics of vegetation and soil [18]. VI (primarily NDVI) and temperature indicators are estimates of such characteristics**.**

Regression models are usually of local scale and are created for particular agricultural areas and crops that assume preliminary automated creation of crop masks [19]. The process of creating regression models requires time series of seasonal and weekly VI values, temperature measurements, and archival yield statistics [20].

Meteorological data (air temperature, precipitation level, soil moisture reserves), used both as independent predictors, and in combination with RS data, can improve forecast accuracy, but require additional computational expenditures on their preprocessing [21, 22]. It is recommend the use regression models in the middle of spring (winter crops yields forecasting) [23] or closer to maturation period (spring crops yield forecasting) due to similarity of spectral characteristics of different crops.

Forecasting by year-analogue [20, 24] is based on the analysis of dynamics of vegetation state indicators for different monitoring periods and selected crops. It is expected that similar VI values in the current and previous seasons describe similarities of crop growth conditions (weather conditions, fertilizer applying modes, cultivation technology, etc.) and corresponding crop capacity.

Quite accurate results of yield forecasting, assessment of coming-up state and crop growth can be provided by: simulation models, dynamic models of biophysical processes, mechanical models of growth, adaptive trend and probabilistic models, etc. [12].

Simulation models express dependence of plant accumulated biomass on efficiency of solar radiation use. Dynamic models of plant biophysical processes and mechanical growth models allow estimating the value of crop biophysical parameters (yield, biomass, water content, etc.), taking into account information on soil type, soil characteristics, composition of fertilizers, crop type, meteorological data, dates of sowing, young growth, flowering, maturity phase, etc. [21]. The main difficulty in the application of such models is complexity of their calibration, based on the necessity to obtain information on soil and crop types, meteorological data, agro-technologies (dates of sowing, young growth, flowering), etc. [18]. For this reason, regression models could be recommended for implementation in the proposed works on creation of the National Internet-center since such models do not require ground observation data, access to which in some cases is limited or absent.

Crop types recognition. Yield forecasting models are local and intended to assess the level of crop production for individual lands. The accuracy of forecasting results depends largely on the availability of information on land areas and type of agriculture. In the cases of lack of a priori information on these areas, land contours are constructed automated and crop types are recognized based on characteristics of seasonal dynamics of their spectral reflection according to RS data using classification methods [25].

At a preliminary stage of classification methods applying, pixels of space images affected by clouds and snow, shadowed areas are excluded from consideration, composite images are created and VIs are calculated.

Inductive approach to crop type recognition includes neural network techniques (for example, Kohonen maps, multilayer perceptron, etc.) [26]. The result of neuronet classification is information on object-class membership on the basis of a posteriori information maximum.

Methods of object-oriented classification of aerospace images allow working with a set of pixels (objects), combined according to some similarity criterion, based on indicators of vegetation and soil state, temperature data, etc. Objects can be interpreted in terms of farmlands or certain areas with different conditions of crop growth [27]. Objects formation allows creating a mask of areas of interest for further analysis.

The LAGMA (Locally Adaptive Global Mapping Algorithm) algorithm of locally-adaptive supervised classification is proposed in [28] for processing large areas. It takes into account spatial variability of farmland characteristics caused by physical and chemical features of geographical conditions of vegetation growth. The peculiarity of the algorithm is mixed pixels elimination from training set on the basis of histogram filtering algorithm using additional criteria. In particular, it takes into account spatial surrounding of pixel of reference class and brightness boundary values. Pixel, adjacent to pixels of another class, or going beyond the boundaries of empirically established range of VI values is excluded from training set. A built-in mechanism of taking into account spatial variability of spectral-reflection characteristics of similar types of land cover allows mapping vegetation on a global scale [29].

Simultaneously with "pixel-based" ("per-pixel") and "NDVI-based" approaches, actively used to retrieve information during images analysis, there is a shift in a structure of scientific knowledge towards application of Object-Oriented Image Analysis – OOIA or Object-Based Image Analysis – OBIA paradigm [30, 31], and from it – to Geographic Object-Based Image Analysis – GEOBIA paradigm [31, 32]. This process is caused mainly by several important factors [33]: a) by 2009 advanced classification methods (using neural networks, fuzzy logic elements and expert systems) included the review of 63 sub-approaches – per-pixel (17 pcs), sub-pixel (7 pcs), per-field (6 pcs), contextual based (13 pcs), knowledge based (6 pcs), combinational approaches (14 pcs); b) the amount of RS materials is increasing at an unprecedented rate due to the involvement of a broad class of different purpose aircrafts; c) expansion of nomenclature used by RS sensors; d) involvement of RS data of different nature and different scale in the process of analyzing.

Expansion of quantitative composition of interacting components and scientific ideas, involved into a process of extracting information from RS data within GEOBIA, requires development of new approaches to describe the whole complex of elements of technological cycle being used. Multi-level ontologies are actively involved for this purpose [34, 35]. In general, the use of ontologies in different domains is quite extensively developed and studied [36, 37]. However, a number of specialized ontologies actualized for RS needs have been formed recently [38]. Architecture, formed by joint efforts of specialists in different subject areas, provides higher-level ontologies of functional areas (top-domain ontologies) OBOE (Extensible Observation Ontology) and SWEET (Semantic Web for Earth and Environmental Terminology, http://sweet.jpl.nasa.gov/), subject domain ontologies (vegetation, studied images, space-time connections, used protocols, as well as sensors) [38]. It should be noted that SWEET-ontology is proposed and supported by NASA. It is implemented using the ontology description language OWL (Ontology Web Language), is available to researchers and, in turn, is divided into nine top-level ontologies, covering more than 6000 concepts.

A methodology for assessing crop yields has already been generated on the basis of results obtained by researchers within the GEOBIA paradigm application [39]. Open source software components and tools based on the Python language also keep improving [40].

Software. Methods of crop yield forecasting and crop types recognition can be implemented using program and functional tools of specialized GIS such as ESRI ArcGIS, Quantum GIS (QGIS), ERDAS Imagine, ENVI, GRASS GIS, SAGA GIS and others. For example, ESRI ArcGIS features: a) possibility to build forecasting models by means of Exploratory Regression tool implemented in Python and aimed at assessing dependence, for example, of the crop yield value on soil and vegetation indicators; b) Shape Recognition tool used to delineate automatically contours of spatial objects (e.g., agricultural land) from raster aerospace data.

As a part of freely-distributed open source QGIS there are special-purpose plugins for classification of raster data of agricultural aerospace monitoring. In particular, a Semi-Automatic Classification Plugin implements methods of minimum distance, maximum likelihood and can be used in crop type classification. The plugin uses USGS Spectral Library (http://speclab.cr.usgs.gov/spectral-lib.html), as well as program toolkit of GDAL, OGR, Numpy, SciPy and Matplotlib libraries.

Standard tools of existing GIS can be updated and expanded with program realization of forecasting and recognition methods, for example, using ERDAS IMAGINE Modeller tool, Python scripting language integrated in ESRI ArcGIS and QGIS etc.

Structure of organization of Internet-center of RS data monitoring and analysis for agricultural tasks solving. Food security is one of the key aspects of husbandry development in many regions of the globe. Therefore, more and more individual countries and organizations begin to form integrated tools of agro- forecasting [41]. The most advanced yield monitoring and analysis systems are CropScape and VegScape (USA), MARS (Monitoring Agriculture with Remote Sensing) as a part of MCYFS (Mars Crop Yield Forecasting System) system (EU) and several others. Functioning of such systems is based on RS data, as well as (in varying degrees of applicability) on elements of Web-interface, data organization and processing using geoinformation technologies, special mathematical information support and a variety of modeling and software tools of data analysis.

Table shows comparative characteristics of the best-known information products as well as systems of crop yield monitoring and analysis.

Performance of a number of test tasks using multi-level and multi-temporal RS data, as well as processing tools of the information systems mentioned above has showed that:

a) their architectures differ significantly;

b) functional connections between software components and the final recipients of monitoring data (government agencies, scientific groups and individual users are different) vary significantly;

c) processes of preparation, collection, storage and use of the entire range of RS products (data) for solving increasingly complex tasks of agricultural monitor-

Table

Comparative characteristics of the best-known systems of crop yield monitoring and analysis

Title	Architecture	Access	Presentation of results
JECAM (UN, one of the project participants – Ukraine), http://www.jecam.org http://jecam.org.ua/	geoportal	Web service	annual reports, periodically updated data
CropScape (USA), https://nassgeodata.gmu.edu/CropScape/			annually updated data layers
VegScape (USA), https://nassgeodata.gmu.edu/VegScape/			daily updated vegetation indices
Global Information and Early Warning System – GIEWS (UN, FAO), http://www.fao.org/giews/			annually updated statistical data, vegetation indices of the world countries
MARS (MCYFS), (European Union), https://ec.europa.eu/jrc/en/mars/bulletins, http://marswiki.jrc.ec.europa.eu/agri4castwiki/index.php/Crop_Simulation	complex of programs + personal GIS	Web site	monthly bulletins, data of calculations for any period
VEGA (Russian Federation), http://pro-vega.ru/	satellite service of vegetation analysis	Web service	periodically updated and accumulated data
Agromonitoring (Ukraine), http://agro.ikd.kiev.ua/		Web site	test data

ing are considerably high-cost at the current stage of technology development.

Therefore, it is proposed to decentralize RS data and distribute geoportal and individual components of solution of certain problems in order to ensure the effective functioning of Internet-center being created (Fig. 1).

A typical solution for creation of a Center network infrastructure can be a set of communication tools including high-speed, preferably fiber-optic, gigabit transmission lines and switching devices (switches, routers). The scheme of the Internet-center functional elements is shown in Fig. 2.

As it can be seen from the scheme (Fig. 2), in the base case the computer network uses four subnets and it can be expanded by data nodes allocated and grouped by any features in a subnet forming the infrastructure of data pools. An individual subnet should include managing and client workstations.

One of the main subnets includes replicated Web-servers on the basis of which the specialized mapping services are deployed. For example, Web Map Service uses WMS protocol and provides access to raster-to-vector geodata layers stored on particular data nodes. Data warehouses are proposed to be combined with each other into unified disk storage of a network file system accessed, for example, with NFS (Network File System) Protocol. High performance operating systems of the Unix or GNU/Linux (Ubuntu Server, CentOS, FreeBSD, etc.) classes may serve for a flexible and functional data flow management using NFS.

Well-proven in the cases of large loads nginh server is proposed to be used as a Web-server (HTTP-server), and friendly GeoServer – as a software providing access to geodata with WMS protocol. It is also proposed to expand an additional cloud service based on ownCloud free software, which allows connecting to the data store for completion the base from outside of the Internet-center.

It is also possible to expand the infrastructure of the above-mentioned Center on the basis of ready information solutions in the form of geoportals (for example, Open Source Geospatial Content Management System GeoNode).

Conclusions. Based on the study, generalization and comprehensive assessment of the use of GIS and ERS at the present stage of development, it is possible to draw the following conclusions.

1. Existing developments of domestic and foreign researchers allow actualizing the process of creating the National Internet-center for agricultural areas integrated monitoring.

2. Day-to-day RS data collection should be carried out at several levels: global (covering the whole territory of Ukraine), regional (covering each region of the country), local (representing certain areas of the region). Open data used to solve this task are publicly available on geoportals and in the archives of public and private organizations: on a global scale – Terra satellite data with a spatial resolution of 500–1000 meters; on a regional scale – Landsat-8 satellite data with a spatial resolution of 30 meters; on a local scale – Sentinel-2A satellite data with a spatial resolution of 10 meters. Furthermore, it is possible to use all-weather radar imagery data from Sentinel-1 series satellites (GRD product).

3. Experience of long-term operation with existing systems of agricultural monitoring shows that the main problem, as well as in terms of financial cost, is organization of storage and use of accumulated heterogeneous data that is leveled, for example in the MARS system, by

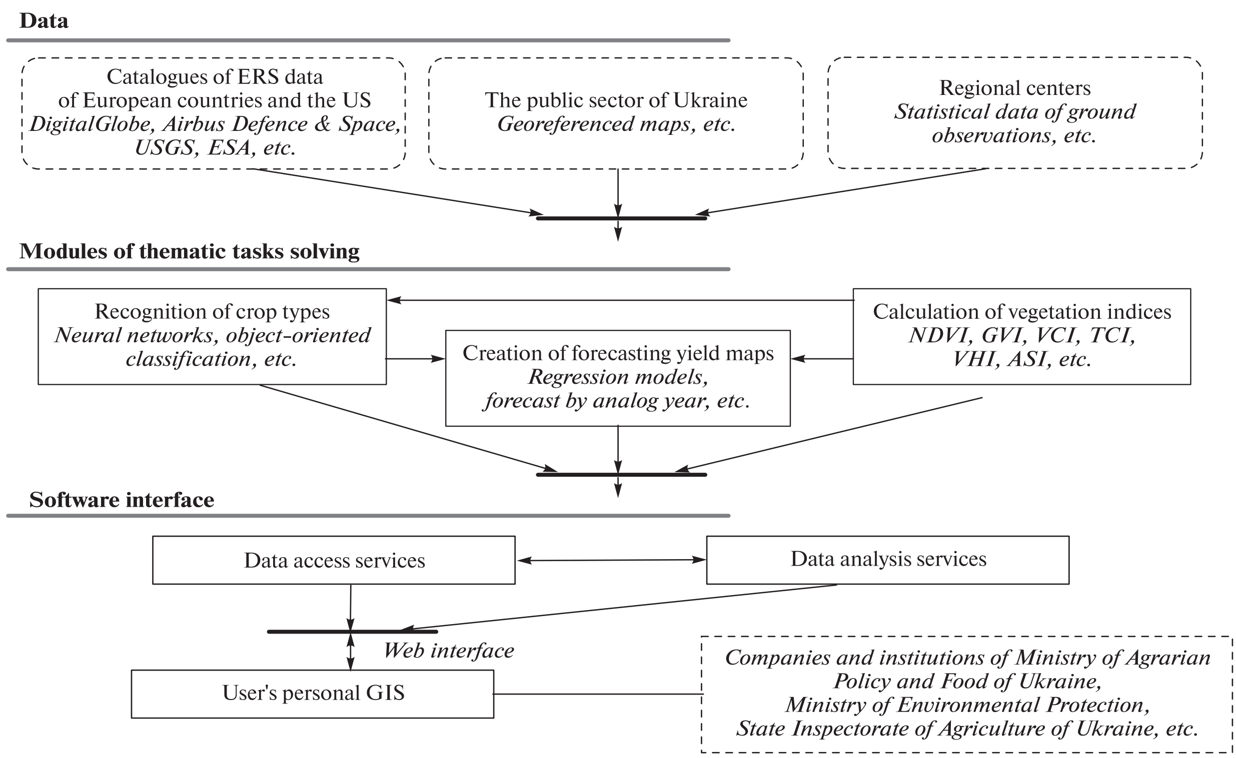

Fig. 1. Formalized block diagram of Internet-center organization and interaction of its principal components

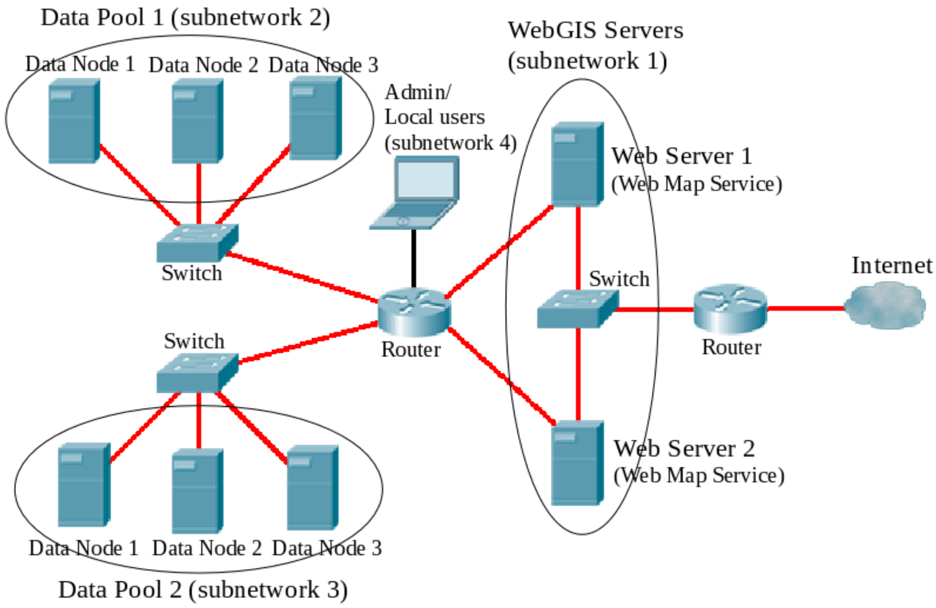

Fig. 2. Proposed scheme of the Internet-center functional elements

providing each user of personal GIS with individual data sets. At the same time, software is modular and varies from task to task. Therefore, a particular problem that goes beyond the scope of this article, consists in developing the specifications and architectural organization of interacting components and technologies used to format infrastructure of technical support of operation of the monitoring information system being created (cloud services, data transmission protocols, etc.).

4. Commercial software tool based on ESRI ArcGIS product and Oracle corporate database, or freely available open source tools based on MapServer or GeoServer, used together, for example, with the PostgreSQL database and its extension PostGIS, can be recommended to perform a software realization of the Internet-center Web-services. At the same time computational models of yield forecasting for different regions with different meteorological conditions and soil types must be well substantiated and verified; appropriate evaluation criteria for certain methods of classification and recognition of crop, vegetation stages must be developed, etc.

5. Operation of the Internet-center must be based on a set of pre-designed classifiers and codifiers approved by relevant structures, where end-users will be provided with the requested information. The American CropScape system can serve as a good example for future development. Its architecture and operation are described in detail in [6].

The first attempts to create elements of information system of agriculture monitoring using RS data have already been taken in Ukraine. The example is electronic resource, created by researchers of the Department of Software Engineering of the National University of Life and Environmental Sciences of Ukraine under the international JECAM project (pshenichne.jecam.org.ua). But this is still a test fragment.

It should also be noted that the task of creating a national Internet-center of monitoring and agricultural data analysis in the light of existing variety of different paradigms, methodologies, approaches and methods of using RS data, is complex and difficult. Therefore, its solution must be preceded by a number of legal procedures regulating, inter alia, funding and functioning issues of the Center being created.

Authors invite various interested organizations to join our efforts in this line.

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Мета. Систематизувати вітчизняний та закордонний досвід використання даних дистанційного зондування Землі з космосу, методів перетворення різнорівневих та різночасових наборів даних і програмного інструментарію для їх обробки при створенні Національного Internet-центру моніторингу стану ґрунтового покриву та розробки методів контролю за сезонною динамікою ґрунтових процесів.

Методика. Виконано науково-теоретичний аналіз літератури із досліджуваної проблеми, узагальнені сформовані методологічні підходи до вирішення завдань ідентифікації та прогнозування змін характеристик ґрунтового покриву, що впливають на погіршення основних показників його фізичного стану.

Результати. Сформовані основні вимоги та визначені необхідні компоненти для формування інформаційного, методичного й програмного наповнення Internet-центру моніторингу та аналізу даних дистанційного зондування Землі з космосу.

Наукова новизна. Уперше в Україні запропоновані, сформульовані та формалізовані принципи організації інформаційного, методичного та програмного наповнення інформаційної системи моніторингу й аналізу даних космічної зйомки, одним з найважливіших завдань якої є моніторинг територій з метою підвищення ефективності їх використання.

Практична значимість. Отримані результати можуть бути використані для підготовки й реалізації основних етапів створення Internet-центру моніторингу та аналізу даних дистанційного зондування Землі з космосу, для вирішення завдань підвищення ефективності використання земельних ресурсів України.

Ключові слова: *дистанційне зондування, космозйомка, різнорівневі та різночасові набори даних, вегетаційні індекси, Internet-центр моніторингу*

Цель. Систематизировать отечественный и зарубежный опыт использования данных дистанционного зондирования Земли из космоса, методов преобразования разноуровневых и разновременных наборов данных и программного инструментария для их обработки при создании Национального Internet-центра мониторинга состояния почвенного покрова и разработки методов контроля за сезонной динамикой почвенных процессов.

Методика. Использован научно-теоретический анализ литературы по исследуемой проблеме, обобщены сформировавшиеся методологические подходы к решению задач идентификации и прогнозирования изменений характеристик почвенного покрова, влияющих на ухудшение основных показателей его физического состояния.

Результаты. Сформулированы основные требования и определены необходимые компоненты для формирования информационного, методического и программного наполнения Internet-центра мониторинга и анализа данных дистанционного зондирования территории Украины из космоса.

Научная новизна. Впервые в Украине предложены, сформулированы и формализованы принципы организации информационного, методического и программного наполнения информационной системы мониторинга и анализа данных

космической съемки, одной из важнейших задач которой является мониторинг территорий с целью повышения эффективности их использования.

Практическая значимость. Полученные результаты могут быть использованы для подготовки и реализации основных этапов создания Internet-центра мониторинга и анализа данных дистанционного зондирования Земли из космоса, для решения задач повышения эффективности использования земельных ресурсов Украины.

Ключевые слова: *дистанционное зондирование, космосъемка, разноуровневые и разновременные наборы данных, вегетационные индексы, Internet-центр мониторинга*

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NONLINEAR DYNAMICAL ANALYSIS OF ABRUPT WELDING TEXTURE CHANGE

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НЕЛІНІЙНИЙ ДИНАМІЧНИЙ АНАЛІЗ ТЕКСТУРНИХ ЗМІН НЕРІВНОСТЕЙ ЗВАРЮВАННЯ

Purpose. Owing to its diversity, the texton of weld image is not very salient, and weld defects are difficult to detect automatically. The goal of this work is to identify the weld image texture change for such flaw detection and to determine the optimal number of elements, in particular, in a chaotic dynamic mode.

Methodology. The texture is characterized by the approximate entropy, which is calculated in phase space. The time series are reconstructed with the entropy of sub-image values for choosing the proper texture parameters. Applying the chaotic theory, we proposed the abrupt texture change area detection method.

Findings. We first get the approximate entropy in phase space, and then by using the abrupt texture change area detection method, we obtained the abrupt texture change area.

Originality. We pursued a study of the abrupt texture change area. We discussed a reconstruction of the principle of time series, approximate entropy mutation threshold determination. The research on this aspect has not been conducted before.

Practical value. In practice, it is essential to reconstruct the time series with the entropy of sub-image values in a first step, these results of approximate entropy in phase space are much more accurate within abrupt texture change areas.

Keywords: *texton, texture change, chaotic dynamic mode, approximate entropy, time series, sub-image values*

Introduction. Quality monitoring and controlling in weld defects detection, especially electric arc and welding process stability analysis and evaluation, is an important factor in achieving higher productivity, lower cost and greater reliability of the welded equipment. Textural patterns can often be used to recognize familiar objects in an image or to retrieve images with similar texture from a database. Texture patterns can provide significance and abundance of texture and shape information. Literature depicts that previous work has been explored in huge amount on various aspects of modelling, simulation and process optimization in image texture.

Four technical components to improve graph cut based algorithms are combining both colour and texture information for graph cut, including structure tensors in the graph cut model, incorporating active contours into the segmentation process, and using a "soft-brush" tool to impose soft constraints to refine problematic boundaries by Zhou [1]. The integration of these components provides an interactive segmentation method that overcomes the difficulties of previous segmentation algorithms in handling images containing textures or low contrast boundaries and producing a smooth and accurate segmentation boundary.

Asha V. proposed a new machine vision algorithm for automatic defect detection on patterned textures with the help of texture-periodicity and the Jensen-Shannon Divergence, which is a symmetrized and smoothed version of the Kullback-Leibler Divergence [2]. In order to determine the texture periodicity, the texture element size and further characteristics like the area of the basin of attraction in the case of computing the similarity of a test image patch with a reference, the presented method is proposed by Stübl G. with the properties of a novel metric, the so-called discrepancy norm [3]. Due to the monotonicity and Lipschitz property the discrepancy norm distinguishes itself from other metrics by well-formed and stable conver-