Methods for processing data for monitoring condition and use of agricultural areas

R S Shirokov¹,² and P P Lepekhin¹

¹ State University of Land Use Planning, 15, Kazakova str., 105064, Russia
² Earth Cryosphere Institute, Tyumen Scientific Centre SB RAS, 86, Malygina str., box 1230, Tyumen, 625000, Russia

E-mail: Shirokov@guz.ru

Abstract. The collection of data on the current state of agricultural lands and their subsequent farming is an integral part of the information-resource digital platform for intelligent management of farming systems. Despite the significant increase in food production over the past half century, one of the most topical issues faced by the human community is the problem of feeding the population. To determine the current state of agricultural lands, a whole complex of contact and surface measuring systems is needed to measure the state and physical parameters of the soil environment and crops. The proposed methodology includes a set of methodological materials for collecting and processing data based on many years of research on the development, methods, technologies and algorithms for monitoring the quality of land for the purposes of effective land use, improving the cadastral registration of land, monitoring negative processes. Having applied the proposed methodology for collecting and processing long-term data, the results were obtained that make it possible to identify the most significant loads on agricultural landscapes.

1. Introduction

The collection of data on the current state of agricultural lands and their subsequent processing are an integral part of the information-resource digital platform for intelligent management of the farming systems.

Despite the significant increase in food production over the past half century, one of the most important issues faced by the human community is the problem of how to feed the population.

The goal for the agricultural sector is not only to achieve maximum yield, but also to optimize production rate in landscape complexes, agricultural development, environmental safety, guarantee of social justice and food consumption.

An innovative option for the development of agriculture implies a transition to a highly productive agricultural sector of a new technological mode, providing an increase in crop yields, high quality of products with minimal negative impact on the environment [1, 2].

For the transition to a new highly productive agricultural sector, it is necessary to assess the entire set of characteristics of the growing environment of cultivated crops. For this reason, at the first stage, it is necessary to collect data on the current state of agricultural lands and carry out their subsequent processing, leading to a form that can be processed by an information resource digital platform intelligent management of farming systems and make optimal recommendations to achieve targets regarding agricultural production rate.
It should be borne in mind that a highly productive agricultural economy is impossible without the regulation of the water-air, nutrient and thermal regimes of soils, which is carried out on reclaimed lands. Assessment of the actual state of reclaimed lands allows making decisions on the timing of stopping water runoff from drained areas, accumulation of drainage runoff, determining the time of additional humidification and prompt removal of excess moisture in flood situations [3].

To determine the current state of agricultural lands, a whole complex of contact and surface measuring systems is needed to measure the state and physical parameters of the soil environment and crops. To assess the parameters of soil fertility and the state of crops in large areas, surface measuring instruments are supplemented with laboratory and analytical measurements and information from satellite and aviation sounding systems, and spatial positioning systems. Comparison of information from surface meters and aerospace sounding systems allows one to calibrate remote measurement data and build electronic maps of the state of crops and soil fertility.

The proposed methodology includes a set of methodological materials for the collection and processing of data based on many years of research by the State University of Land Management on the development of methods, technologies and algorithms for monitoring the quality of land for the purposes of effective land use, improving the cadastral registration of land, monitoring negative processes.

The use of UAVs in agriculture has great potential and interest in their use, which is growing every year. Over the past 5-6 years, much has been done to develop this branch of mechanical engineering. This allows one to consider this industry to be rapidly developing with great opportunities in terms of variety of design solutions, including solutions aimed at application in agriculture.

2. Materials and methods
In the process of work carried out in various studies, two types of unmanned aerial vehicles were used. One of them was aircraft, with the help of this type of UAV, summer aerial photography was carried out. The launch of the apparatus is carried out using a catapult; this requires a sufficiently open space and the absence of any obstacles to climb in the direction of launch.

Landing, upon completion of the flight mission, is carried out automatically using a parachute when descending to a given altitude or in manual mode, at any time, regardless of the flight altitude. In windy weather conditions, the described landing modes often lead to negative side situations. The flight task is carried out using a special software application.

Another type of UAV that was used was the Phantom 4 Pro V2.0 multi-rotor UAV.

The manufacturer of this unit is the world-famous Chinese company DJI. For safe takeoff and landing of the aircraft at the launch site, a 1.5 meter radius of open space is sufficient. Flight control in manual and automatic mode is carried out using a control panel equipped with a touchscreen monitor.

The Phantom 4 Pro V2.0 remote controller uses the OcuSync HD video transmission system, which uses a time division multiplexing mechanism to simultaneously send a control signal and receive a video signal. This system is capable of operating at 2.4 GHz and 5.8 GHz. The maximum signal transmission range is 7 km.

Depending on the environmental conditions, the machine selects the best channel to reduce the noise level. The drone’s camera was supplemented with a 1-inch CMOS sensor with the resolution of 20 megapixels. The lens consists of eight lenses arranged in seven groups. For the first time in the DJI camera of this size, a mechanical shutter was used to capture fast-moving subjects and capture high-speed shots without the floating shutter effect. The drone camera is in no way inferior to standard cameras. A more powerful video processing system allows you to shoot H.264 video in 4K quality at 60 fps and a maximum bitrate of 100 Mbps, as well as H.265 in 4K quality at 30 fps. Improved matrix and processing technology allows for more detailed images and data, providing even more freedom during the editing phase.

The lens resolution and contrast are important factors in image quality. Only a high-quality lens can capture crisp, rich, high-resolution photos. The newest Phantom 4 Pro V2.0 camera is optimized for aerial photography with an f/2.8 aperture with a focal length of 24mm (35mm equivalent). The lens consists of 9 elements in 7 groups, including 2 aspherical lenses, housed in a more compact body. The
For the first time ever, DJI is revealing the lens layout to give a better understanding of lens quality. The Phantom 4 Pro is the first drone to use a mechanical shutter and high quality lens. The minimum shutter speed of the mechanical shutter is 1/2000 s, eliminating motion blur, as well as the ‘jelly’ effect, which is usually caused by fast movement relative to the subject and the ‘rolling shutter’ of the electronic shutter. The electronic shutter has also been redesigned to achieve a minimum shutter speed of 1/8000s and a new burst mode up to 14fps at 20MP.

For this type of UAV, there are many software applications aimed at generating tasks for performing aerial photography and flight control. Among them, the most advanced and the most user friendly are the following three: Pix4Dcapture, DroneDeploy and DJI GS PRO.

This application appeared recently (at the beginning of 2017) and not many people are familiar with it, meanwhile, this application has many advantages. In windy weather with this application, flights on the intended course are most stable. With the help of this application, flights were completed on the test section of JSC Michurin, when the weather (11 November 2018) for flights worsened due to the increased wind. Most of the work related to flights was carried out using the DroneDeploy software application [4].

The interfaces of the applications are quite similar and, therefore, the same flight parameters, as well as aerial photography parameters, can be easily set in each of the programs.

The methodology itself includes a set of methodological materials for the collection and processing of data based on many years of research by the State University of Land Management on the development of methods, technologies and algorithms for monitoring the quality of land for the purposes of the effective land use, improving the cadastral registration of land, monitoring negative processes.

The methodology for collecting and processing data on the current state of land includes the following methods and techniques:
- Methodology for obtaining yield maps and subsequent data processing.
- Methodology for agrochemical survey of agricultural land with geo-informational reference.
- Methodology for survey of drainage reclamation systems by remote methods.
- Monitoring of the condition of reclaimed lands.
- Survey of reclamation systems by remote methods.
- Survey of lands to calculate heights and boundaries on agricultural lands.
- Digital models of relief and watercourses of fields.
- Remote monitoring of water protection zones.
- Simulation of various indices.
- Methodology for calculating the NDVI index based on the remote sensing data.
- Methods based on the analysis of the reflection of electromagnetic waves by the surface of soils and crops.
- Methods based on GPR profiling.
- Methods based on the use of field sensors.

Agricultural production is a serious source of environmental pollution, so it must be not only highly efficient, but also highly environmentally friendly. This is based on the systematic and objective information on the observance of regulated indicators characterizing the state and level of agricultural system performance, resource use, the degree of utilization of technological waste, which is the basis for ensuring the required level of safety and developing a set of environmental protection measures. For these purposes, it is necessary to create a reliable system of environmental monitoring based on UAVs. The proposed system will allow observing, recording and forecasting the ecological state of agricultural lands in order to produce safe food and reduce the harmful effects of these facilities on the environment.

The system operates in full or local monitoring modes, in which the UAV flies around the surveyed area in accordance with the program.

An unmanned aerial vehicle is a versatile and very effective tool for obtaining data on the state of the atmosphere, soil, water, vegetation, including those for hard-to-reach areas.
The refinement of the elements of the measurement methodology was carried out within the framework of the project for mapping the territories near the settlement of Spas-Doschaty according to the procedure for collecting, analyzing data, processing and building a model for the predicted state of agricultural lands [5-7]:

1) The initial data for mapping were obtained by the aerial photogrammetric method using an unmanned aircraft of an aircraft type, as well as by field methods and from open sources. The data obtained were used to create a cartographic base, which can be used as a basis for creating GIS for the purposes of the land cadastre, as well as for on-farm land management, the creation of peasant farms and other land management activities, as well as for statistical analysis to build a predictive model of the state of agricultural lands. The data are collected on a monthly basis for several years (up to 12 years, to take into account crop rotation), for the study area according to the indicators [8].

   Data were collected in numerical form, either in vector form with subsequent conversion to numerical values, or in raster form with subsequent conversion to vector and numerical, respectively.

2) The following was used for processing: creation of a dense cloud of points in the AgiSoft program for the purpose of further orthomosaic construction; transfer of aerial photography data to ArcGis for the purpose of further vectorization of individual areas; creation of a cartographic basis and necessary databases in the MapInfo software environment; data analysis in the Statistica program.

3) Then, the collected data were organized in a tabular form and the average value for the year was displayed.

4) After that there were determined the farms with the district average revenue per hectare of sown areas in the district for the same years as for the territory of interest. Besides, the tabular data were collected.

5) As the next step there was determined the average value of indicators for all analyzed years in the territory of interest, as well as the average value of indicators for the region.

6) The indicators collected in the general table were heterogeneous in units of measurement, which complicated further calculations, so the next step was to standardize the data. In this case, the maximum-minimum standardization method was used, where the minimum value in the original population was 0, and the maximum value was -1. Next, the average value for each field was displayed to build up a rating. Those fields whose rank is higher than the average for the district were recognized as potentially suitable for farming. For a field below the district average, further research was being conducted to determine the cause of the rating drawdown and the possibility of improving its rating.

7) Further, to simplify the presentation, a map of fields was created based on the compiled rating.

8) The next step was to check the indicators for the normal distribution of data to select a criterion for further analysis. For this calculated mean and standard deviation.

   After that, a cluster analysis was carried out based on the use of the Ward’s method for the smallest increase in the total amount of distances and a clustering was obtained according to similar indicators.

Cluster analysis is one of the approaches for processing a large amount of information in order to select the most representative sets of indicators to reduce the amount of data processed.

Due to its size, the processing of a large amount of ecological and geographic information may ultimately yield inaccurate results, distorted due to the multiplicity and repeatability of the initial data. To isolate the most representative indicators from the entire data set, the analysis of the correlation matrix, factor analysis and predictive neuroanalysis using the software Statistica v.10.0, Minitab and JMP Statistical Discovery were further used.

At the next stage, the predictive neuroanalysis was performed to determine indicators, the influence of which could be leveled out over time.

Based on the performed neuronanalysis, those indicators are selected that will continue to influence the area of interest.

At the next stage, factor analysis is performed using the software Statistica v.10 and JMP Statistical Discovery to reduce the indicators. Factor analysis allows one to calculate factor loadings for each variable, i.e. to determine the correlations between indicators and the most informative indicators in a given set of variables. In this regard, since our indicators are heterogeneous in units of measurement,
nonparametric methods of analysis are used for further analysis: correlation analysis based on the Spearman coefficient. The analysis shows which indicator has a greater influence on each other, depending on the angle of the circle, the power of the impact is determined, the smaller it is, the stronger the indicators interact (for example, in the case of an indicator that is compared with itself, the circle will be stretched into a line) [9].

To simplify the visualization of the results obtained, a cluster analysis of variations is carried out.

To identify the main factors, the criterion of scree was used, and then the obtained factor loads, which have load values exceeding 0.7, were considered the most significant.

3. Conclusion

As a result of applying the proposed methodology for collecting and processing long-term data, the results were obtained that make it possible to identify the most significant loads on the agricultural landscapes.

Besides, to determine the potential development of indicators over time, the predictive neuroanalysis is performed using the ANOVA method. In the process of this analysis, it can be concluded about the likely potential development of indicators that affect the state of agricultural landscapes and the conduct of agricultural production.

The output data of the Methodology are cartographic materials in various graphic formats (pdf, tiff, jpg, etc.) as well as explanatory notes in text formats (doc, docx, etc.)

Thus, according to the proposed method, it was possible to obtain scientific results on the current state of the land.

The proposed methodology contains a set of methods for determining such parameters as: erosion, deflation, salinization, land overgrowth, calculations of the NDVI index, agrochemical indicators, the state of reclamation systems, systems and methods of precision agriculture.

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