Assessment of the state of engineering systems based on remote sensing data

Kristina Semenova*

Russian State Agrarian University - Moscow Timiryazev Agricultural Academy, Moscow, 127550, Russia

Abstract. The composition of melioration systems includes underground pipelines, drains, hydraulic structures that may fail and require repair, but it is impossible to detect a problem area without monitoring the area of the system by antediluvian methods or conducting survey work. The purpose of the work: to justify the use of soil moisture maps obtained by the DJI PHANTOM 4 MULTISPECTRA UAV to identify problem areas of the reclamation network or vice versa absence. Aerial photography was carried out in May 2021 on the treated section of the drainage and humidification network of the Yakhrom floodplain of the Moscow region. As a result of the survey, a digital terrain model, an operational humidity map based on the calculated NDWI water index were obtained. The flight altitude of the quadcopter was 180 m above the earth's surface, the pixel size of the image of the earth's surface to be 7.9 cm. According to the results of aerial photography on the selected site, the absolute marks of the earth's surface vary from 134.67 to 135.23. On average, the slope of the earth's surface of the selected site is 0.002 in the direction from northwest to southeast. There are no pronounced microforms of relief moisture in the surface layer of the soil obtained in the field corresponds to the variety of color areas of the NDWI water indices highlighted on the operational humidity map. In the soil conditions of the studied area, the moisture content of the surface soil layer is logarithmic with the normalized difference water index NDWI. The correlation coefficient is 0.9 ± 0.06, which indicates a very high relationship between the studied indicators. Such a map can be used to identify problem areas of the reclamation network.

1 Introduction

It is possible to ensure the effective use of reclaimed agricultural lands through constant monitoring of the condition of land plots and cultivated crops, the operation of the melioration system in real time using available modern digital technologies. Currently, various methods for monitoring agricultural lands are used, among them the remote sensing method. The increased quality of the obtained sounding data (high spatial resolution) allows a more detailed determination of the state of agricultural land and the dynamics of their change over time. Constant monitoring of lands using modern equipment and digital

* Corresponding author: kristi11.05.88@yandex.ru

technologies, as an important tool for the development of the agro-industrial complex of the future, makes it possible at the stage of their occurrence to identify problems that negatively affect the production of agricultural products, assess the condition of reclaimed lands, and also make a forecast of the current situation for timely decision-making, allowing promptly plan and organize measures to eliminate adverse consequences.

2 Objective

Justify the use of moisture maps in the surface layer of soil obtained by the DJI PHANTOM 4 MULTISPECTRA UAV to identify problem areas of the reclamation network.

3 Research materials and methods

Melioration system is a complex of engineering structures and devices that ensure the creation of the required water, air, thermal and nutrient regimes of soils. Melioration systems include underground pipelines, drainages, and hydraulic structures that may fail and require repair, but it is impossible to detect a problem area without monitoring the area of the system using antediluvian methods or carrying out survey work. In the spring before sowing crops or in the autumn after harvesting, it is possible to identify problem areas of the melioration system and carry out restoration measures, troubleshoot the system depending on the volume of work, or exclude areas from agricultural use.

Some of the main reasons for the decrease in the performance of closed drainage of the reclamation system are: siltation; overgrowing of drains with plant roots; change in drain slope as a result of soil subsidence; soil suffusion; clogging of the pores of filter materials. These faults are difficult to identify, especially in large reclamation systems.

Remote monitoring methods include surveillance systems using unmanned aerial vehicles, satellites and remote sensing data processing systems using water indices. [1,2,3,4,5,6,7,8,9,10]. Satellite images have a low spatial resolution from 1 to 30 m. These images cover significant viewing areas, but problems arise with the appearance of clouds in the images instead of the studied area, although there are programs that can eliminate this problem, but information about the object is distorted. Aircraft-type unmanned aerial vehicles (UAVs) can be used in cloudy weather, the spatial resolution is higher from 3 to 20 cm (RGB), multispectral - from 8 to 50 cm. Airplane-type UAVs survey 700 ha / h, and with multispectral survey - 350 ha/h and more often used to determine high-precision coordinates of the earth's surface and are suitable for creating a digital terrain model.

Images from multi-rotor UAVs (quadcopter, hexacopter, drones) can be used in cloudy weather. But these aircraft are not resistant to gusts of wind speeds above 10...15 m/s. The images are quite detailed and are less than 3 cm for RGB, and less than 8 cm for multispectrum. The problem with using drones and quadcopters is their short flight time (up to 1 hour), which results in reduced productivity (less than 100 hectares) per flight; large areas require frequent flight interruptions and battery changes.

Based on the analysis of remote sensing UAVs, high detail of the studied objects due to high spatial resolution allows data from multispectral UAVs: drones and quadcopters. Using a quadcopter, you can change the resolution of images depending on the tasks, for example, work at a lower altitude and speed, which allows you to obtain images of maximum detail. Any user of such an aircraft can conduct land surveys and carry out the corresponding processing and calculations in a special program. A DJI PHANTOM 4 MULTISPECTRA quadcopter was used for the study, due to the availability of information and the possibility of receiving it regularly.

A survey of the agricultural lands of the Bunyatino agricultural company was carried out using a DJI PHANTOM 4 MULTISPECTRA quadcopter. This drone is very light, take-off weight is up to 1.5 kg, maximum speed reaches 50 km/h, maximum flight time is up to 27 minutes. The flight processes are fully automated, which makes working with the drone productive and safe. DJI TimeSync technology is used to synchronize the system to constantly align the flight controller, RGB and NB cameras, and RTK module, capturing positioning data in the CMOS center, and ensures that every shot uses the most accurate metadata. Positioning accuracy using the RTK system is ±0.1 m.

The clarity and detail of data collection depends on the maximum working area during flight, the altitude, and the resolution of the photographic equipment used. If the drone flies at an altitude of 180 m, then the maximum operating area for one flight is 0.47 km² (47 hectares), the length of one pixel on the map (GSD) is about 9.52 cm/pixel. The ground surface pixel size (GSD) is equal to at least (H/18.9) cm/pixel, where H is the height of the drone in relation to the study area, m.

4 Results

Aerial photography was carried out in May 2021 on a cultivated area of the double-acting irrigation system of the Yakhroma floodplain of the Moscow region, owned by the Bunyatino agricultural company. The flight altitude was 150 m; cabbage seedlings were planted in the study area. The images are quite detailed and high resolution, the pixel size on the earth's surface is 150/18.9 = 7.9 cm. The images were combined and processed in a program for agricultural mapping, aerial crop analysis and digital farming - PIX4Dfields. The application allows you to calculate a wide range of spectral indices: NDVI, NDRE, SIPI2, LCI, TGI, VARI, BNDVI, GNDVI.

Based on the results of aerial photography from a UAV, a digital model of the terrain of an area of 8 hectares was obtained (Fig. 1). In the selected area, the absolute elevations of the earth's surface vary from 134.67 to 135.23 in the direction from northwest to southeast. On average, the slope of the earth's surface is 0.002; there are no pronounced microforms of relief where surface and underground runoff can accumulate.

Fig. 1 Digital terrain model

One of the main indicators for determining the state of the melioration system is ensuring the required water regime, namely soil moisture. In the spring, on waterlogged lands, the soil loses its bearing capacity, and agricultural machinery is not able to perform the required work. Providing the required soil moisture with the help of melioration systems determines the growth and development of agricultural crops during the growing season.

To assess the condition of the underground drainage network, Normalized difference water index (NDWI) was calculated in the PIX4Dfields program – a normalized difference water index. The NDWI indicator is sensitive to changes in humidity and allows you to identify areas of flooding (formation of high water), wetlands and, conversely, dry areas that require moisture.

After calculating the NDWI index, an operational humidity map was compiled (Fig. 2). Each NDVI color raster has a numerical value; in the context of a specific site, the readings vary from soil moisture conditionally very dry to conditionally very wet (from -0.43 to -0.22). The bright red color indicates the presence of an open water surface, very turbid, which is present in channels at shallow depths. Dark orange areas of the map with a value of -0.37 are characterized as waterlogged, and green areas indicate conditionally very dry soil – -0.22, and conditionally dry soil – -0.27.

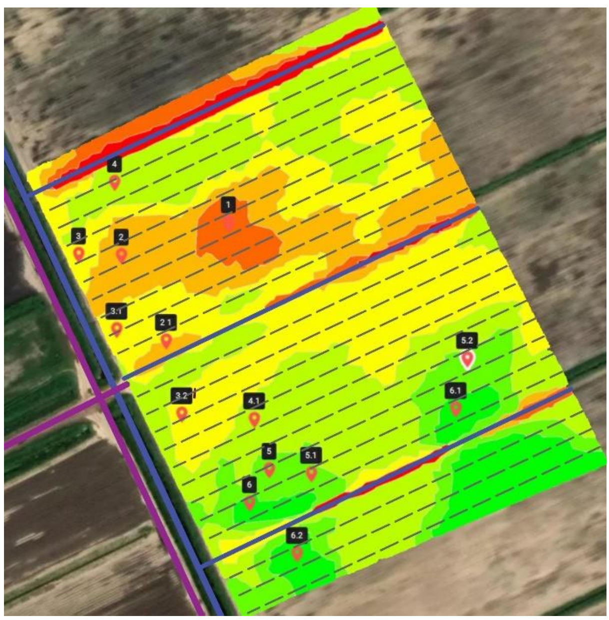

Fig. 2 Humidity maps (obtained as a result of calculating the normalized water index NDWI)

-0.22 – the soil is conditionally very dry, -0.27 – the soil is conditionally dry, -0.30 – the soil is conditionally fresh, -0.31 – the soil is conditionally wet, -0.33 – the soil is conditionally damp, -0.37 – the soil is conditionally wet, -0.43 – the soil is conditionally very wet, – drainage, – open channel, – road, 5.2 – soil sampling point.

To assess the color diversity of the operational moisture map readings and compare them with the moisture in the surface layer of soil in the field, soil sampling points indicated in Figure 2 were established. After conducting aerial photography at the marked points, samples of the surface layer of soil were taken in a weighing bottle and in the thermostat laboratory. soil moisture was obtained using the gravimetric method. For the accuracy of the experiment, samples were taken in triplicate, and for some color areas, 2 to 3 points were assigned for refinement. The measurement results are presented in Table 1. Based on the data obtained, a graph of the dependence of soil moisture determined in field conditions and the normalized difference water index NDWI was constructed (fig. 2).

Table 1. Data on surface soil moisture obtained in the field and values of the normalized difference water index NDWI.

№	point number in the figure	Soil moisture in triplicate, %	Average soil moisture, %	Average soil moisture value according to the color scheme of Figure 1, %	Normalized difference water index NDWI, %
1	1.0	47.0	48.9	48.9	-0.37
		50.9			
		48.9			
2	2.0	31.6	29.8	29.8	-0.33
		29.0			
		28.8			
3	3.0	23.5	23.9	24.4	-0.31
		25.2			
		22.9			
	3.1	23.3	23.2		
		22.7			
		23.6			
	3.2	26.8	26.2		
		26.1			
		25.7			
4	4.0	19.9	20.5	20.7	-0.3
		21.1			
		20.4			
	4.1	22.4	22.0		
		21.6			
		22.0			
5	5.0	17.0	18.2	18.8	-0.27
		19.3			
		18.2			
	5.1	18.2	18.7		
		18.7			
		19.1			
	5.2	16.5	19.5		
		22.6			
		19.5			
6	6.0	13.8	14.1	14.7	-0.22
		14.3			
		14.2			
	6.1	11.8	13.5		
		15.1			
		13.5			
	6.2	17.6	16.4		
		15.1			
		16.4			

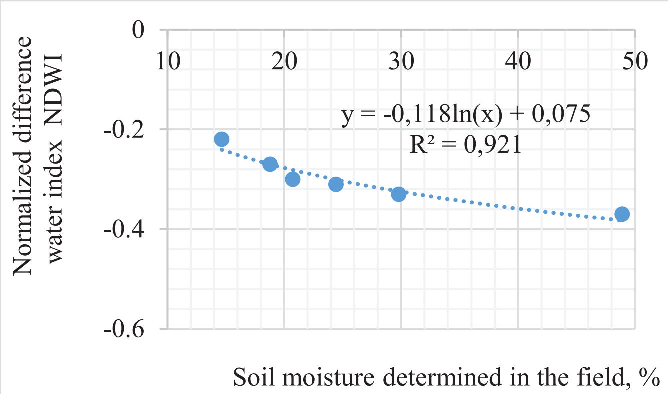

Fig. 3 Relationship between soil moisture determined in the field and the calculated normalized difference water index NDWI

In the soil conditions of the study area, the moisture content of the surface soil layer is in a logarithmic relationship with the normalized difference water index NDWI (table 1 and fig. 2). The correlation coefficient is 0.9±0.06, which indicates a very high close relationship between the studied indicators. The coefficient of determination is 0.92, i.e. in 92% of cases, fluctuations in the normalized difference water index NDWI in the conditions under consideration are due to fluctuations in humidity in the surface layer of the soil.

In the surface layer of the soil, conditionally very dry corresponds to a moisture content of about 15% (table 1, fig. 1), which indicates the good operation of the closed drainage network. This moisture provides the necessary bearing capacity of the soil for the passage of equipment in the spring. Near the canal, drying of the surface layer of soil is observed, and additional checking of the moisture content of the root layer of soil is necessary; for growing crops additional moisture may be required by supplying water to the regulating network.

According to Table 1 and Figure 1, conditionally wet soil (marked in dark orange) corresponds to a moisture content in the surface layer of soil of about 49%; deeper along the soil profile the moisture value is higher, which indicates a waterlogged state of the soil. There was no precipitation during the day before the measurements. Provided there is no additional closed drainage between the open channels in the middle, the draining effect is weaker, the groundwater level is closer to the surface of the earth. Closed drains have been built on the site, but high humidity remains in places. This means that the drains in the designated area do not remove water from the soil. When examining the wellhead structures of the waterlogged area under consideration, the drains did not discharge water, unlike the others. During the day, high soil moisture remained; perhaps siltation occurred in the drains, deformation of the drainage and filter, or another emergency situation; accordingly, the drains did not fulfill their functions.

The drains were flushed. As a result, it was possible to clean the regulating network hydraulically and achieve the creation of the required soil moisture.

5 Conclusion

1. Based on the results of aerial photography in May 2021, a digital terrain model was obtained using a quadcopter. In the selected area, the absolute elevations of the earth's surface vary from 134.67 to 135.23. On average, the slope of the land surface of the selected area is 0.002 in the direction from northwest to southeast; there are no pronounced microforms of the relief.

2. As a result of aerial photography carried out in May 2021 at an altitude of 150 m, an operational humidity map was obtained. The pixel size of the image over the earth's surface was 7.9 cm. Under the soil conditions of the study area, the moisture in the surface soil layer is in a logarithmic relationship with the normalized difference water index NDWI. The correlation coefficient is 0.9±0.06, which indicates a very high close relationship between the studied indicators.

3. Operational moisture map based on the calculated NDWI index) allows you to assess the moisture content of the surface layer of soil, and identify areas of waterlogging that require checking the performance of the drainage network, as well as identify overdried areas that require additional analysis of the moisture content of the root layer of soil for additional moistening measures, by supplying water through the channels of the drying-humidifying network.

4. The method of remote sensing of the earth using a quadcopter can be used to monitor the condition of the reclamation system.

Acknowledgements

The work was supported by the Russian Science Foundation grant no. 23-29-00928, https://rscf.ru/project/23-29-00928/ .

References

1. Amine Saddik, Rachid Latif, Mohamed Elhoseny, Abdelhafid El Ouardi, Sustainable Computing: Informatics and Systems, **30**, 2021, 100506.
2. Balogun Emmanuel Taiwo, Abdulla - Al Kafy, Ajeyomi Adedoyin Samuel, Zullyadini A. Rahaman, Ologun Emmanuel Ayowole, Mahir Shahrier, Bushra Monowar Duti, Muhammad Tauhidur Rahman, Olarewaju Timilehin Peter, Olamiju Olayinka Abosede, Environmental and Sustainability Indicators, **18**, 2023, 100248.
3. D. Choudhury, K. Das, A. Das,The Egyptian Journal of Remote Sensing and Space Science, **22 (2),** 2019, pp. 203-218
4. Francisco J. Peña, Clara Hübinger, Amir H. Payberah, Fernando Jaramillo, International Journal of Applied Earth Observation and Geoinformation, **126**, 2024, 103624
5. Kamran Jafarpour Ghalehteimouri, Faizah Che Ros, Shuib Rambat, *Flood risk assessment through rapid urbanization LULC change with destruction of urban green infrastructures based on NASA Landsat time series data: A case of study Kuala Lumpur between 1990–2021*, Acta Ecologica Sinica, 2023
6. Mehmet Akif Günen, Umit Haluk Atasever, Science of The Total Environment, **926**, 2024, 172117
7. Semenova, K.S., Kablukov, O.V., IOP Conference Series: Earth and Environmental Science, 2022, **981(2),** 022021
8. Pritam P. Patil, Megha P. Jagtap, Narendra Khatri, Hakka Madan, Aditya Abhiram Vadduri, Tarun Patodia, Case Studies in Chemical and Environmental Engineering, **9**, 2024, 100573
9. Subrata Haldar, Somnath Mandal, Subhasis Bhattacharya, Suman Paul, , Regional Sustainability, 2023, **4 (2),** pp.150-172
10. Semenova, K., Zhuravleva L., E3S Web of Conferences, 2023, **390**, 01028