DETERMINING THE IRRIGATION TIMING OF AGRICULTURAL CROPS BY REMOTE SENSING OF IRRIGATED AREAS

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Abstract: The timing of maize irrigation based on the results of thermal remote sensing of the irrigated area coincides in critical period of water consumption by plants and provides additional production of 3.2 t/ha of green mass with a content of 0.16 feed units. The cost of purchasing a quadcopter with a Flir–Boson thermal imaging camera and “Irrigation Technology” mobile application in the amount of 600 thousand roubles is paid off during one growing season. The mobile app is easily compatible with iPhone and Android phone, and allows you to make a diagram of the irrigation timing and monitor the quality of irrigation with high performance (flight range up to 14 km, maximum recording time of 26 minutes).

Keywords: remote sensing, irrigation, timing of irrigation of agricultural crops

1 Introduction

The Republic of Tatarstan is one of the regions of the Russian Federation where the construction of reclamation objects is carried out purposefully and effectively/ For example, in recent years, new irrigation systems have been commissioned on an area of 35 thousand hectares, 250 dams have been repaired for a total of 10.8 billion roubles [M. S. Memon, Z. Jun, C. Sun, C. Jiang, W.м, Q. Hu et al. (2019).]. In the future, according to the target program "Land Reclamation of the Republic of Tatarstan for 2020-2025", it is planned to build new and restore 50 old ponds, purchase pumping stations and implement sprinkler machines of the Kazan irrigation equipment plant (KZOT) in the ratio of 50:50 (50% of budget funds and 50% of the costs of specific farms), and annually put into operation 5 thousand hectares of irrigated land in the amount of 600 million roubles (120 thousand roubles/ha).

Consequently, land reclamation was and remains a capital-intensive industry [M. S. Memon, Z. Jun, C. Sun, C. Jiang, W.м, Q. Hu et al. (2019).]. Therefore, in order to accelerate the recoupment of these expenses on reclaimed lands, it is necessary to introduce the latest achievements of science and technology [7, 8], including thermal sensing of irrigated areas, in order to determine the optimal irrigation timing of agricultural crops [Abdullaeva T.K. (2014) ;Salima, Y., Peira, J. F. M., Horra, G. R. D. L., & Ablanque, P. V. M. (2019).].

2 Methods and Conditions Of The Research

Studies to determine the timing and quality of irrigation using thermal imaging were conducted in the fields of LLC "Kyrlay" in Arsky municipal district of the Republic of Tatarstan. The target of research was corn for silage, cultivated using grain technology (with corn cobs in milk-wax ripeness) with the introduction of calculated norms of mineral fertilizers for the planned biomass yield of 50 t / ha. The technology of maize cultivation is generally accepted and consisted of disking after harvesting annual grasses, flat-cut processing with a deepening of the arable layer, moisture closing, pre-sowing cultivation, seeding at a soil temperature of +12 °C, harrowing before and after emergence of seedlings and inter-row processing with ammonium nitrate phosphate fertilizer (N16P16K16).

To solve this problem, the irrigated area with a total area of 250 ha was divided into 2 parts (125 ha each). The irrigation period of the first part was determined by the actual soil moisture using a moisture meter "Dniester-1", and for sounding the second part, a quadcopter " Di-phantom 4 Pro" equipped with a thermal imaging camera" Flir – Boson " was used (Fig. 1).

Fig. 1 Quadcopter "Phantom 4 Pro" with thermal imager “Flir-Boson”

In order to comply with the principle of "the only difference" on both sites, watering was carried out by "Kazanka" sprinkler machines.

Agrometeorological conditions in the years of research (2018-2019) were typical for the Republic of Tatarstan and were characterized by a lack of precipitation at the beginning of the growing season (May-June) and excessive moisture during the harvest (September).

3 Results and Discussion

Thermovision inspection is a type of thermal monitoring of an irrigated area using a special camera that takes pictures of crops and then uses the program to display the thermogram of the research object with an accuracy of ± 1 °C [Lanya, N. Subadiyasa, K. Sardiana, G. Ratna Adi (2019) ; R. Neswati, S. Baja, A. Ramlan, S. Arif (2019).].

There is a direct relationship between soil temperature and humidity: the lower the moisture content, the higher the soil temperature. According to this regularity, the diagram of scale for determining the irrigation timing in the range from + 25 to + 45 °C was calculated and transferred to the “Irrigation Technology” mobile app [Vozdushnyj kodeks Rossijskoj Federacii, st. 18.1 ;Zemel'nyj kodeks Rossijskoj Federacii. Federal'nyj zakon ot 25.10.2001 ;Abdullaeva T.K. (2014)] (Fig. 2).

Studies have shown that on the Fourth of July 2018 the average soil temperature was at +25 °C and according to the irrigation timing scale, corn did not need additional moisture. Subsequent thermal remote sensing of the irrigated area was performed after 8 days and it was found that 30 % of the area is not sufficiently provided with moisture, and 15 days after the first survey, 8% of crops reached the critical level of moisture deficit (Fig. 3).

An important indicator of the mobile application developed by Farm at Hand Inc. is the uniformity of the interface style, focus on solving individual problems, differences in computer architectures, and accelerated start-up and response time of the device.

In addition, this mobile app can be easily combined with iPhone and Android phones. Its ATiImageon graphics processor allows you to work with 2D and 3D graphics. All these features give an opportunity to make a diagram and to control the quality of corn irrigation (Fig. 4, 5).

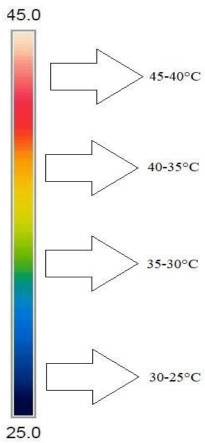

Fig. 2 The Scale of the temperature regime of the thermal imager

Analysis of the diagram (Fig. 5) based on thermovision measurements shows that. on 12 July 2018, humidity 35 % of area of the irrigated plot lowered to extremely low humidity (humidity of plants wilting).After watering on July 19, 2018, on the contrary, 15 % of the arable land was too wet, and 5% needed additional moisture, and only 80% of the crops had optimalhumidity (75% of the lowest moisture capacity).Uneven soil moisturization after irrigation is explained by the presence of small-deepenings and elevations on corn crops areas, different infiltering capacity of thesoil cover.

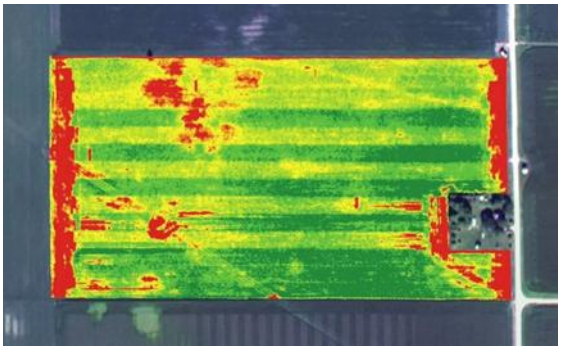

Fig. 3 Image of the heat chamber on July 19, 2018

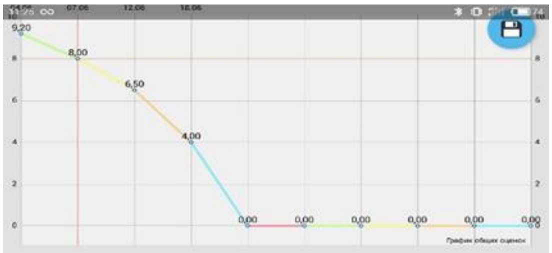

Fig. 4 Graph of the overall assessment of corn irrigation in the mobile app

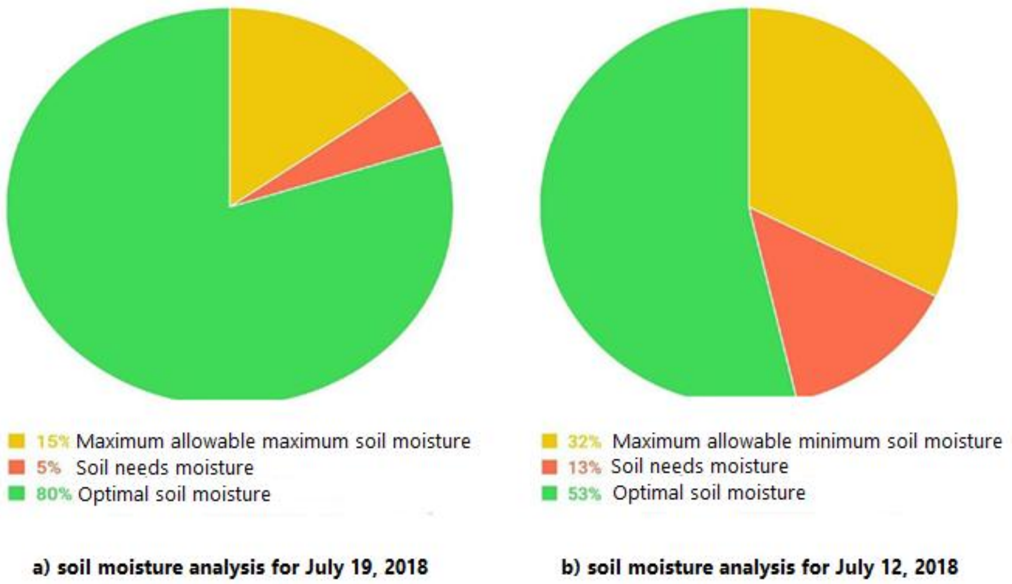

Fig. 5 Diagrams for estimating irrigation timing and quality of maize irrigation by the «Irrigation Technology» mobile application

In the same natural and climatic conditions, the measurement of soil moisture using the "Dniester-1" humidity meter showed the need to irrigate the research object in 20 days earlier than the results of thermovision inspection.

This contradiction is probably explained by the fact that the average daily air temperature reaches maximum values in our region in the second half of July and coincides with the critical period of moisture consumption of this crop (the period of the greatest moisture consumption due to intensive accumulation of biomass). In addition, with the traditional definition of irrigation timing, it was required to perform 5 irrigation operations against 3 as per soil temperature, and the irrigation rate (water consumption for irrigation during the growing season) decreased by 850 m3/ha.

As a result, both early periods and multiple watering caused a decrease in the active soil layer (the soil layer in which the bulk of the root system is located), since plants stop searching for additional moisture and nutrients from deep soil layers [F.N. Safiollin, M.M. Hismatullin Sistema meliorativnogo zemledeliya v Respublike Tatarstan (2015).].

For this reason, the yield of green maize mass was 3.2 t / ha higher when the timing of the studied crop was determined by thermal images (Table 1).

Table 1. The productivity of corn, depending on the methods for determining the irrigation timing

Indicators	Unit of measure ment	Watering time	
		By actual soil moisture	By soil temperature
Planned yield	Tonne/Hectare	50	50
Actual yield	Tonne/Hectare	44.6	47.8
Percentage of planned yield	%	89.2	95.6
Feed units' content	Tonne/Hectare	0.14	0.16
Gross collection of feed units	Tonne/Hectare	6.2	76.5

Before starting to analyse the results of research, it should be noted that the actual corn yield does not correspond to the planned one. For example, irrigation based on actual soil moisture provides 89.2% of the planned yield, which is 6.4% lower compared to the irrigation timing based on thermovision surveys of the irrigated area.

Moreover, the standard indicator of productivity of 6.5 t / ha of feed units in the first variant was not reached (6.2 t / ha), while when watering as per soil temperature, this indicator was 7.65 t/ha. This is due to an increase in the growing season with frequent watering, which is why the corn on the cob does not reach a milky-waxy ripeness by harvest. The same results were obtained in the 2019 studies.

The recommended method for determining the optimal watering timing of the research object not only allows you to make decisions quickly, but also has a high economic potential (Table 2).

Table 2. Economic indicators for determining the timing of irrigation of corn with thermovision zoning of the irrigated area

Economic indicators	Unit of measurement	Final result
Survey area	Hectare	125
Cost of the additional gross production	Thousand roubles	384
Cost of a thermovision Flir – Boson camera	Thousand roubles	450
Cost of the Diphantom 4 Pro quadcopter	Thousand roubles	100
Cost of the "Irrigation Technology" mobile application	Thousand roubles	50
Total costs	Thousand roubles	600
Payback period	Years	0,6
Profitability	%	64

The cost of the additional gross production (CAGP) (384 thousand roubles) was calculated using the following formula:

$$CAGP = A \times YG \times CFU \times 6 \text{ thousand roubles}$$

where

A – area of irrigated field plot (125 hectares).

YG – yield gain (3,2 tonne/hectare).

CFU– content of feed units in the green mass of corn grown using grain technology (0,16).

6 thousand roubles – sale price of oat grain.

The total cost of acquiring the quadcopter with the thermovision device and a mobile application at the prices of 2018 amounted to 600 thousand roubles.

The profitability (64 %) of thermovision imaging of the irrigated area was determined by the formula:

$$P = TACD / SAGP$$

where

P - profitability

TACD – total acquisition costs of the devices (600 thousand roubles).

To calculate the payback period (0.6 years), the cost of additional products was divided by the total cost of expenses.

4 Conclusions

The use of thermovision remote sensing allows you to make an operational decision on irrigation timing of maize, which, unlike the traditional method for making decision on soil moisture, coincides with the critical period of water consumption of this crop and provides additional products in the amount of 384 thousand roubles with the 64 percent profitability on biomass production.

The cost of purchasing additional equipment and mobile application (600 thousand roubles) is repaid during one growing season (0,6 years).

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