Forecasting the Duration of Work in Plant Protection Projects

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Abstract

An approach, an algorithm, and an intelligent management decision support system are proposed for predicting the time fund for the implementation of plant protection. They are based on database formation and weather knowledge from the OpenWeatherMap service for individual countries and their regions. Based on computer modeling, they provide the formation of databases and knowledge for a given country or its region, taking into account the characteristics of natural, climatic, and production conditions. The proposed intelligent management decision support system systematically analyzes variable agrometeorological components and their impact on the time frames of relevant works in the plant protection project. The developed intelligent management decision support system made it possible to forecast the time fund for plant protection given natural, climatic, and production conditions. A model of climatically permissible time fund for the protection of plants during the day of June, described by Weibull distribution, is substantiated. The results of the obtained studies can be used by managers of agricultural enterprises during project management. In particular, during the process of forecasting the duration of plant protection projects. The developed intelligent management decision-making support system provides further research on the prediction of the plant protection implementation time fund and the justification of its models in different countries and their regions

Keywords 1

Forecasting, content, time, project, plant protection, management.

1. Introduction

Agricultural enterprises involved in the production of plant products experience losses every year and lose a significant amount of crops due to weeds, pests, and diseases. According to the FAO (Food and Agriculture Organization), more than 40% of crops globally are lost to pest activity each year, i.e. approximately 37% - before harvest and 9% - during storage. Adjusted losses from loss of crop yields are estimated at $30 billion. At the same time, the losses caused by diseases in agricultural plants amount to 25 billion dollars [1-3]. The protection of plants is carried out to prevent and prevent crop damage from pests. At the same time, the content and time planning of the work on the protection of the plant is carried out in advance. Qualitative planning of the mentioned processes can be carried out only with a known fund of time for the implementation of plant protection [4-6]. Forecasting the time frame for the implementation of plant protection is a complex management task. This is due to the influence of many variable factors of the agrometeorological component on the performance of plant protection, which requires time-consuming calculations using probability theory and mathematical statistics [7-9]. The above indicates that there is a need to confirm the characteristics of timely fund forecasting for the implementation of plant protection, as well as for the development of computer-

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based application software due to the presence of time-consuming calculations. This is done based on modeling the agrometeorological component of the plant protection system.

2. Literature analysis and problem statement

Many works are devoted to solving problems of time pool forecasting for work in various applied fields, taking into account their characteristics [10-12]. They are based on developed mathematical models and methods which are partially idealized and take into account the specifics of specialized production conditions.

There are several scientific publications [13-14] that justify the need to develop a general toolkit for predicting working time irrespective of the specifics of the application domain. It is because of this that specifics of the agrometeorological component of plant protection systems are not fully taken into account.

Available publications [15-17], which relate to forecasting in various branches of production, deserve special attention. Some of them are related to crop production and take into account the specifics of the industry. However, they cannot be fully used to predict the timing of plant protection implementation because they do not take into account the specifics of the agrometeorological component of the plant protection system.

There are several scientific works [18-20] in which the authors discuss the peculiarities of agrometeorological conditions for various systems of agricultural production. They are used in intelligent driving decision support systems. However, regarding the consideration of agrometeorological component features in intelligent decision support systems, they are not for plant protection. In particular, existing intelligent decision support systems are designed for strategic and tactical planning of work performance [21-24].

The task of operational forecasting of the fund of time for the implementation of plant protection requires taking into account the natural, climatic, and production conditions of individual countries and their regions and conducting relevant research, which ensures the creation of an adequate database. and knowledge that is the basis of an intelligent decision support system for predicting the timing of plant protection under given conditions.

Therefore, the existing approaches to plant production planning decision-making and intelligent support systems do not fully take into account the natural-climatic and production-changing conditions of individual countries and their regions, which determine the timely foundation for the implementation of plant protection [25-28]. This is one of the main reasons for poor management decisions in the operational planning of plants, as well as for crop losses due to the timely reduction of pests and plant diseases.

Currently, there is a scientific and applied task to substantiate the approach to predicting the time fund of plant protection, as well as due to the need for time-consuming calculations, the development of application software based on computer modeling of the agrometeorological component [29-32]. About the mechanized protection system of plants of individual countries and their regions. Solving this scientific and applied problem has both scientific and practical importance.

3. The purpose and objectives of the research

The purpose of this work is to develop an approach to predicting the terms of work in plant protection projects and an algorithm for an intelligent management decision support system. To achieve the goal, the following tasks must be solved:

1. Develop an approach and algorithm for forecasting work in plant protection projects, taking into account the climatic conditions of the region;
2. To Develop an intelligent decision-making support system for predicting working hours in plant protection projects and, based on it, justify the model of the permissible duration of plant protection.

4. Approach, algorithm, and intelligent system of forecasting the time of work in plant protection projects

During the season of action of harmful objects on crops of certain crops, there is a time interval during which the protection of plants is possible or impossible. With this in mind, the naturally defined time fund for plant protection is the time (in hours) during which the technological operation of crop spraying can be carried out [33-35].

The formation of a naturally permissible time fund for the implementation of plant protection takes into account several climatic factors that reflect the meteorological conditions of a particular region:

$$f_T^{xo} = f\ (O,\ R,\ V,\ T, I), \tag{1}$$

where O – is the presence of precipitation, R – is the presence of dew; V – wind speed; T – air temperature; I – time of day (light or dark).

The peculiarity of the protection of plants by spraying is their high sensitivity to weather conditions and the state of the surface layer of the atmosphere [36]. So, rainy weather, fog, increasing heat flows, and wind belong to unfavorable conditions that can completely neutralize the efficiency of processing and cause negative ecological consequences. Adverse weather conditions significantly affect the rate of pesticide application and the environmental friendliness of plant protection processes.

In case of wind speed of more than 4 m/s, the sprayed mixture of the boom sprayers will be carried away from the field, polluting the environment. At air temperatures above +25 °C, drops of the working fluid evaporate quickly. During excessive humidity and precipitation, the working fluid is washed away from the plants, reducing the efficiency of cultivation and polluting the soil.

It is known that in some countries there is a constantly changing state of the atmosphere, which is determined by an alternating stochastic sequence of naturally acceptable and unacceptable time for the implementation of protection of plants, as in terms of individual calendar days. and specific calendar period (plant development phase) [37].

The determination of the naturally permissible time fund for the implementation of the protection of plants is carried out according to the course of weather conditions and can be graphically displayed on the calendar axis of the start time and duration of action of individual agrometeorological factors, both separately and collectively (Figure 1).

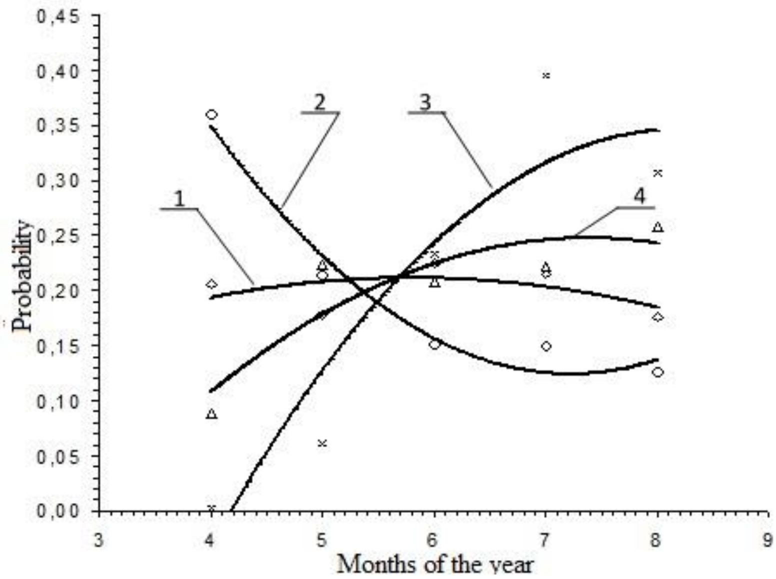

Figure 1: Dependence of the probability of occurrence of certain agrometeorological factors during protection on the calendar period (April-August) on the conditions of the western forest-steppe of Ukraine: 1 – the presence of precipitation; 2 – excessive wind speed; 3 – excessive average daily air temperature; 4 – the presence of dew

Precipitation (short-term or long-term and its intensity) plays a key role in the formation of the naturally permissible time fund for the protection of plants, which determines the waiting time after its completion (Drying time of soil and plants).

The action of agrometeorological factors during the period of growing crops (April-August) is characterized by probability [38]:

$$P(A)=\frac{m_A}{n}, \tag{2}$$

where n – is the total number of cases investigated; m_A – the number of occurrences that correspond to a certain event.

According to the statistical data of the reporting period (April-August [39]), the number of events that met a certain condition (exceeding the permissible values of limiting factors) on a separate calendar day. The total number of days studied was determined. Certain regularities can be observed in nature, for example, if there is dew, there is no rain, and vice versa, the time exceeding the permissible air temperature is observed only in the middle of the day (when the sun is relatively at its highest point. to the horizon).

Along with the increase in the probability of the maximum average daily air temperature, due to the increase in the height of the sun above the horizon, the probability of exceeding the allowable values of wind gusts decreases simultaneously, but at the same time the occurrence of dew increases. On the other hand, it can be safely said that precipitation is slightly dependent on other agrometeorological factors (average daily air temperature, dew point, excessive wind flow), as evidenced by the correlation coefficient (Table 1).

Table 1

Probability equations and correlation coefficients of individual agrometeorological factors during the implementation of protection of plants from the calendar period (April-August)

Indicator	Equation	Correlation coefficient
Wind	$P(A) = 0.0217m^2 - 0.3137m +1.2569$	0,981
Dew	$P(A) = -0.0122m^2 + 0.1797m - 0.4154$	-0,882
Average daily air temperature	$P(A) = -0.0217 m^2 + 0.3549m -1.1042$	-0,931
Precipitation	$P(A) = -0.0055m^2 + 0.0642m + 0.0253$	-0,52

Therefore, the simultaneous consideration of agrometeorological factors is quite difficult. However, without this, it is impossible to objectively substantiate the effective complex of plant defense mechanisms by spraying. The derived regularities are the first step towards modeling the action of these factors and probabilistic estimation of the time pool naturally allowed for spraying plants.

The established regularities of the occurrence and progression of individual agrometeorological factors in time are the first step in the way of reflecting the naturally determined time frames of plants for the implementation of protection of plants by spraying. It is assumed that such agrometeorological factors as mean daily air temperature (correlation coefficient – 0.931), excessive wind speed (correlation coefficient – 0.981), and dew (correlation coefficient – 0.882) depend on calendar time. The simulation model takes into account the particularity of agrometeorological conditions in each region, and can objectively demonstrate the necessity the need for technical means of protection of plants by spraying.

To predict the pool of plant protection times during which weather conditions are favorable for plant protection by spraying, statistical data on weather conditions are collected from the OpenWeatherMap service for individual countries or their regions.

Based on the above, the following conditions were considered favorable for the implementation of technological processes of protection of plants: air temperature +5°... +25°C; absence of precipitation and fog; wind speed 0...4 m/s; Lack of thermal flow in the surface layer of the atmosphere.

A block diagram and algorithm for predicting the climatically acceptable time fund for the implementation of protection of plants by spraying on a separate day was developed based on substantiated methods and models of the characteristics of natural-climatic and production conditions [40]. The block diagram consists of 19 blocks (Figure 2).

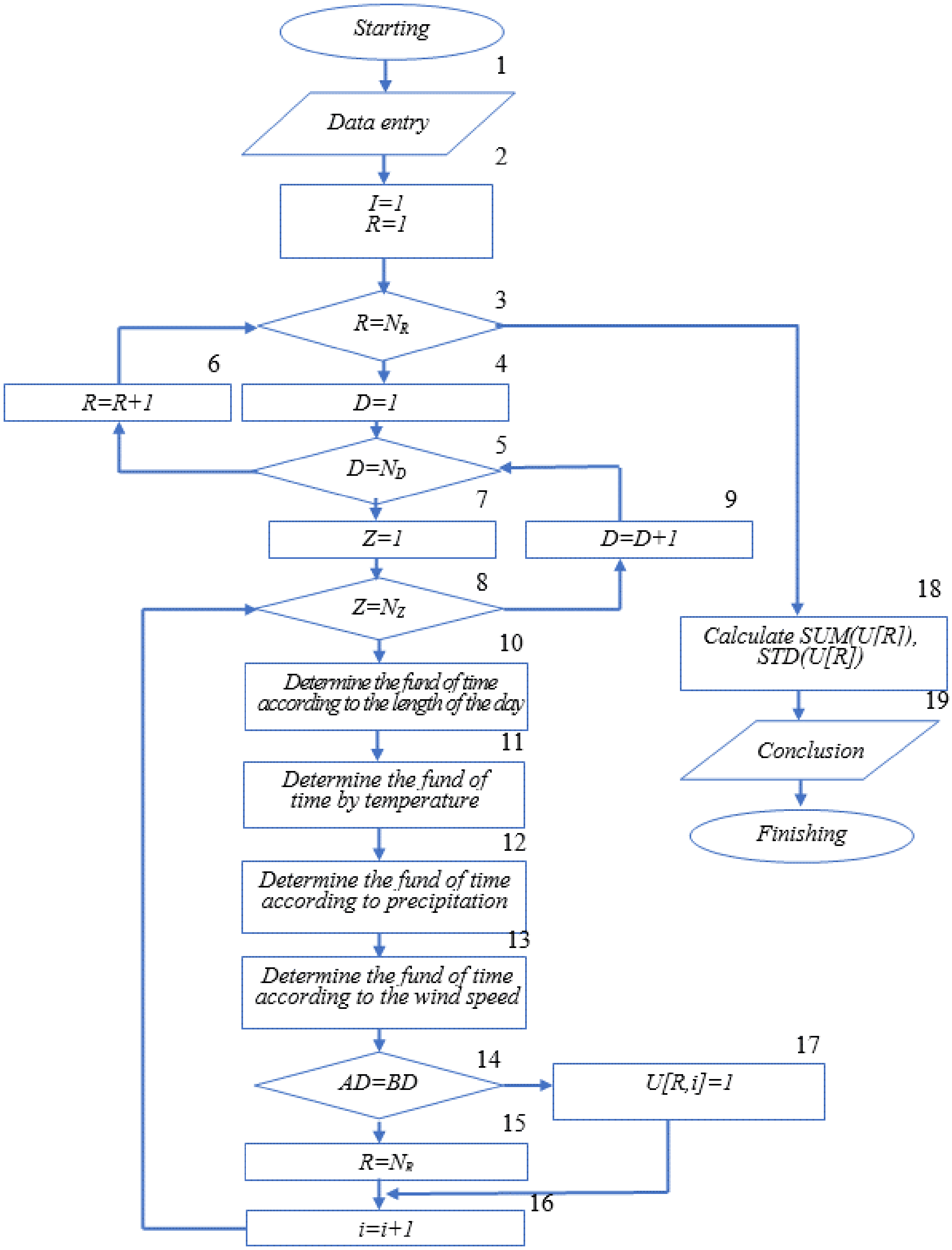

Figure 2: Block diagram of the computer modeling algorithm of the agrometeorological component and forecasting of the climatically permissible time fund for the implementation of protection of plants by spraying on a separate day

The first block is intended for entering initial data into the computer memory: length of daylight hours; the presence of dew; air temperature; Wind speed and precipitation.

Blocks 2-9 are intended for the formation of agrometeorological numerical series and for checking the correspondence of their values.

Blocks 10-13 are designed to perform protection of plants to determine the climatically acceptable time fund by spraying on a separate day, respectively, according to the length of daylight hours; the presence of dew; air temperature; Wind speed, and precipitation.

Blocks 14-17 are designed to carry out the protection of plants by spraying on a separate day to check compliance with the values of the climatically acceptable time fund.

The 18th block aims to check the state of completeness of the implemented implementation and to determine the climatically permissible time for the implementation of protection of plants by spraying on a separate day.

Block 19 is intended for displaying the results of calculations.

5. The results of the development of an intelligent decision support system for predicting working hours in plant protection projects

Based on the disclosure of the content of the blocks shown in the block diagram, an algorithm for computer modeling of the agrometeorological component was developed and a forecast of the climatically permissible time fund for the implementation of plant protection by spraying on a separate day was made. The proposed intelligent management system for forecasting the fund of time required for plant protection is developed in Python 3.9, the working window of which is shown in Figure 3.

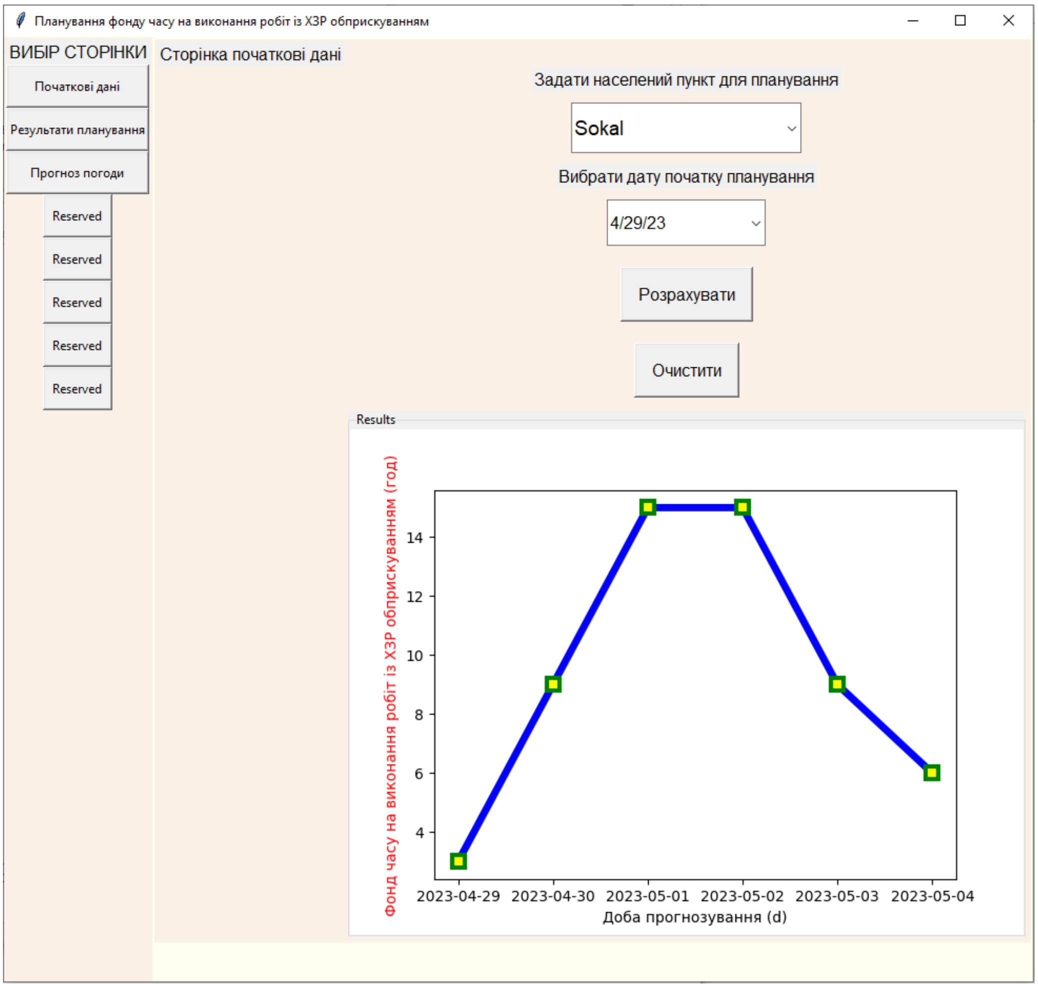

Figure 3: The working window of intelligent management decision support system in forecasting the time fund of plant protection on a separate day

The probability of favorable conditions for the protection of plants is greatest in the morning and evening hours. Considering this, it is advisable to divide the work into half shifts (3 hours in the morning and 3 hours in the evening). Half-shift duration is set in hours (by default, half-shift duration is 3 hours).

The developed intelligent management decision-making support system for plant protection implementation time fund forecasting performs the necessary calculations and provides climatically acceptable time fund determination and visualization for plant protection implementation. A separate day for a given country and its region.

According to the Mann-Whitney criterion, the suitability of the proposed intelligent management decision support system for the conditions of Sokal United Territorial Community (Ukraine), was tested. At the same time, the deviation between the predicted plant protection implementation time limit and the actual value does not exceed 4%, which proves its adequacy.

Based on the application of the developed intelligent management decision support system for time fund forecasting, a computer simulation of the agrometeorological component was carried out in the conditions of the western forest-steppe of Ukraine on different days of the plant protection season.

The conducted study provided for the construction of the histogram and theoretical distribution curve of the climatically permissible time fund for the protection of plants during the day of June (Figure 4).

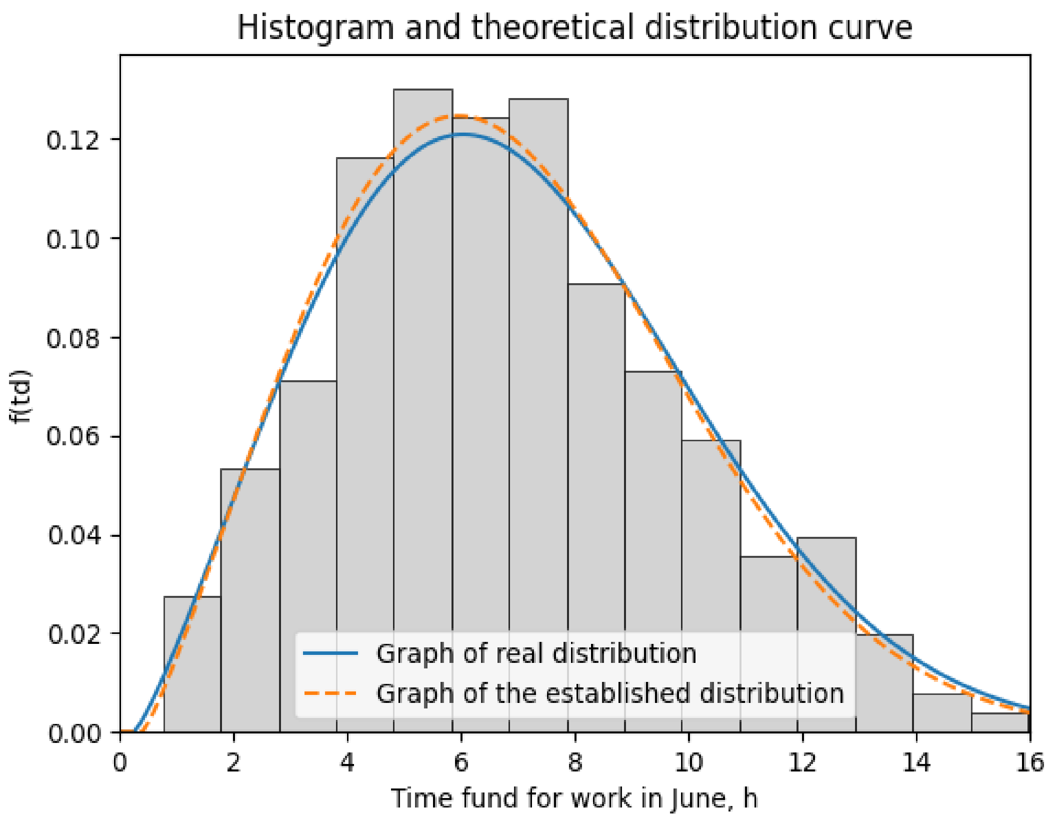

Figure 4: A fund model for the climatically acceptable time of protection of plants during the day in the month of June

The statistical processing of the received data on the fund of protection of plants by the climate during the day made it possible to determine the numerical characteristics, as well as to justify the model (Figure 4), which is described by the Weibull distribution. with the differential function:

$$f(t_d) = 0.343\left(\frac{t_d - 1}{5.26}\right)^{0.71} \times \left[-\left(\frac{t_d - 1}{5.26}\right)^{1.71}\right]. \tag{3}$$

The main statistical features of the climate-suitable time distribution for plant protection in June are mathematical expectation estimate - 8.7 hours; dispersion - 11.2 hours; mean square deviation - 3.43 hours. A reasonable approach to forecasting the time fund for the implementation of plant protection and the algorithm and the intelligent management decision support system developed on its basis provide a high-quality forecast of the time fund for the implementation of plant protection. Features of the agrometeorological component of individual countries and their regions.

6. Conclusions

1. The proposed approach, algorithm, and intelligent management decision support system for predicting the duration of work in plant protection projects are based on the formation of a database and knowledge of weather from the OpenWeatherMap service for individual countries and their regions. The main feature of the proposed approach is that databases and knowledge are formed for a given country or its region, based on computer modeling, taking into account the characteristics of natural, climatic, and production conditions. This ensures that the set of variable agrometeorological components of the plant protection system and their influence on the forecast fund of the time of execution of the respective works are systematically considered. The proposed approach fully takes into account the peculiarities of the subject area. It provides a high-quality database and knowledge formation, as well as the creation of an intelligent system that provides accelerated and high-quality management decisions related to predicting the duration of work in plant protection projects.
2. Based on the application of the developed intelligent management decision support system, the duration of work in plant protection projects and given natural-climatic and production conditions was determined. This substantiated the model of the climatically acceptable time fund for Plant Protection Day in June. The obtained model is described by the Weibull distribution with the main statistical characteristics: estimation of mathematical expectation – 8.7 hours; dispersion – 11.2 hours; estimate of root mean square deviation – 3.43 hours. The obtained research results can be used by managers of agricultural enterprises during the management processes of predicting the duration of work in plant protection projects.

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