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Research Article

Planning and Risk Analysis in Projects of Procurement of Agricultural Raw Materials for the Production of Environmentally Friendly Fuel

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Abstract. The purpose of the research is to substantiate the method of planning the need for technical equipment of corn waste collection projects for the production of environmentally friendly fuel, which is based on simulation of work taking into account the changing design environment. During the research, the methods of simulation modeling of corn waste collection projects for the production of environmentally friendly fuel were used. The methods of probability theory and mathematical statistics were used, which provided the substantiation of models of natural-climatic and production conditions of corn waste collection projects for the production of environmentally friendly fuel. As a result of the conducted research the method and statistical simulation model of planning the need for technical equipment of projects on collecting the waste of corn for production of environmentally friendly fuel has been developed. They provided an assessment of the timely implementation of work in selected fields, taking into account the changing design environment, which leads to the risk of the specific cost of corn waste disposal. A simulated model for the collection of maize waste available for disposal, provided that the balance of organic carbon in the fields is maintained, and tested for adequacy according to the Mann-Whitney test. Based on the use of the developed simulation model, the indicators of the use of technical equipment and the trend of changing the risk of the specific cost of disposal of corn waste are substantiated. Rational scenarios for the implementation of projects for which there are no risks for a given project environment are identified.

Keywords: project, harvesting, corn waste, environmentally friendly fuel, risk

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1. Introduction

There is currently a need to address the EU's environmental security (Alberti *et al.* 2021, Hutsol *et al.* 2021, EBA 2020, GDP, 2020). One of the components of this problem concerns greenhouse gas emissions in various spheres of human activity. This has led to increased EU requirements for the quality of raw materials for environmentally friendly fuels. At the same time, there are a number of scientific and applied tasks for the implementation of European Green Deal projects and risk assessment (Von der Leyen *et al.* 2019, EGD).

Fossil fuels remain the dominant source of raw materials for energy production in many countries (Hutsol *et al.* 2021, Tryhuba *et al.* 2020, Bielski *et al.* 2021). At the same time, it is depleted and more expensive every year, due to their shortage in the market, and also belongs to the environmentally hazardous types of raw materials for energy production (Marks-Bielska *et al.* 2021). At the same time, some European countries pay special attention to alternative raw materials for energy production - agricultural waste (Bielski *et al.* 2021). It is the use of agricultural raw materials for energy production in countries that produce crop products that can ensure their energy security and balance the achievement of their energy policy goals (Winzer 2012, Ang 2015).

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Some authors note that the projects of procurement of agricultural raw materials for energy production are the basic projects of the "European Green Deal", the efficiency of which largely depends on the quality and cost of clean energy (Hutsol *et al.* 2021).

One of the most labor-intensive and costly processes in agricultural waste collection projects is their collection in separate fields (Tryhuba *et al.* 2020, Batyuk *et al.* 2020). Much attention has been paid by scientists around the world to solving the problem of collecting agricultural raw materials. However, each type of raw material, depending on its purpose requires its own technology and organizational features to maintain the quality of the product and ensure minimum costs and its implementation (Tryhuba *et al.* 2019). Similarly, the collection of certain types of agricultural raw materials for energy production has its own characteristics - the content and timing of work, which are due to changing climatic and production conditions (Tryhuba *et al.* 2019, Boyarchuk *et al.* 2020, Gródek-Szostak *et al.* 2019). They determine the need to develop tools for solving problems of planning and organizing the implementation of works in projects for the procurement of agricultural waste, taking into account the available technical means.

Unfortunately, today there are no scientific papers on the coordination of the content and timing of work in projects for the procurement of agricultural waste for energy production with technical equipment and changing climatic and industrial conditions of the region. Each type of agricultural raw material requires the use of separate technologies for their collection and specific technical equipment (Tryhuba *et al.* 2020), which are crucial in the development of tools and efficiency of planning the implementation of relevant works.

One of such tasks is planning the need for technical equipment of corn waste collection projects for the production of environmentally friendly fuel. Its solution requires the development of a simulation model of work taking into account the changing design environment, which causes the risk of the specific cost of disposal of corn waste.

All the above indicates the need to develop a method and statistical simulation model for planning the need for technical equipment of corn waste collection projects for the production of environmentally friendly fuels, which will take into account the changing design environment, which risks the specific cost of maize waste disposal.

2. Analysis of Literature Data and Problem Statement

The analysis of the state of scientific publications shows that some of them relate to the implementation of technologically integrated projects in various applications (Ratushny *et al.* 2018, Lutsiak *et al.* 2021, Batyuk *et al.* 2020). However, there are no publications on the planning of maize waste collection projects for the production of environmentally friendly fuels.

Much attention has been paid to solving the existing problems of crop collection project management. They concerned both the general scientific and methodological principles of management (PMBOK Guide 2018, P2M 2008, Tryhuba *et al.* 2019, Shigenobu 2003, ISO 21500, Korchak *et al.* 2020, Korchak *et al.* 2021, Kowalczyk *et al.* 2021) and individual management processes (content, time, configuration, etc.) of projects (Ratushny *et al.* 2020, Tryhuba *et al.* 2019, Tryhuba *et al.* 2020, Ibrahim *et al.* 2019, Ratushny *et al.* 2019). However, the analysis of scientific works on the management of crop collection projects shows that they did not consider such an important management task as planning the need for technical equipment of corn waste collection projects for the production of environmentally friendly fuel. Other existing methods for planning the need for technical equipment of projects in various sectors of the economy do not take into account the specifics of projects for the collection of corn waste for the production of environmentally friendly fuel.

Some studies which are presented in scientific works (Smith *et al.* 2007, Koch 2007, Gachie 2017, Boyarchuk *et al.* 2021, Komleva *et al.* 2020, Tryhuba *et al.* 2021), relate to the risks of projects and their project environment. It is the quantitative risk assessment that underlies the planning of these projects (Ratushny *et al.* 2020, Tryhuba *et al.* 2020).

There are scientific papers related to risk assessment of projects and project environment of agricultural production (Tryhuba *et al.* 2019, Boyarchuk *et al.* 2020, Gródek-Szostak *et al.* 2019, Wójcik *et al.* 2018, Sikora *et al.* 2020, Kovalenko *et al.* 2021) and other areas of human activity (Ratushnyi *et al.* 2019, Bashynsky *et al.* 2020, Ratushny *et al.* 2020, Tryhuba *et al.* 2020, Kovalenko *et al.* 2021, Yermakov *et al.* 2021, Jewiarz *et al.* 2020, Szufa *et al.* 2021). However, to use them to predict the risk of the specific cost of disposal of corn waste is impossible due to a number of shortcomings. In particular, the authors do not pay attention to the peculiarities of the design environment of corn waste collection projects for the production of environmentally friendly fuel. This makes it impossible to qualitatively substantiate the risk of the specific cost of corn waste disposal. In addition, it is not expected to forecast the risk of climatic and industrial conditions, which significantly affects the risk of the cost of corn waste disposal.

In some works it is proposed to use simulation to predict the use of technical equipment and work planning, which is the basis for qualitative determination of cost indicators taking into account the available resources and the characteristics of their design environment. This eliminates a number of shortcomings of existing methods for assessing the risk of cost of corn waste disposal. At the same time, to take into account the stochastic natural and climatic conditions of the region, where it is planned to implement the projects for the collection of corn waste for the production of environmentally friendly fuel, it is proposed to use statistical data from meteorological stations in the region. Methods of probability theory and mathematical statistics provide substantiation of models of natural-climatic and production conditions of corn waste collection projects for the production of environmentally friendly fuel.

Therefore, there is a need to develop a method and statistical simulation model for planning the amount of technical equipment involved in maize waste collection projects for the production of environmentally friendly fuels. This method should take into account the specific design environment, which includes changing climatic and production conditions of the region of procurement of raw materials. They determine the content and timing of work in these projects. Taking into account these features will eliminate the shortcomings of existing tools for planning the need for technical equipment of corn harvesting projects for the production of environmentally friendly fuels in some regions.

The aim of the work is to substantiate the method of planning the need for technical equipment of corn waste collection projects for the production of environmentally friendly fuel, which is based on simulation of work taking into account the changing design environment, which risks the specific cost of corn waste disposal.

To achieve this goal, the following tasks should be solved:

- to suggest a method and statistical simulation model of planning the need for technical equipment of corn waste collection projects for the production of environmentally friendly fuel, which take into account the changing design environment, which causes the risk of the specific cost of disposal of corn waste;
- substantiate the indicators of the use of technical equipment of corn waste collection projects for the production of environmentally friendly fuel for a given design environment and trends in the risk of the risk of the specific cost of corn waste disposal.

3. Method and statistical simulation model of planning the need for technical equipment

The proposed method of planning the need for technical equipment of maize waste collection projects for the production of environmentally friendly fuel, taking into account the climatic and industrial risks of their components of the design environment involves the following four stages (Figure 1).

Stage 1. Forecasting of changing climatic conditions of the region and determining the time fund for work in corn waste collection projects is based on the formation of a database and knowledge about the weather conditions from the OpenWeatherMap service for individual countries and their regions. This takes into account the peculiarities of the process of mechanized collection of corn waste, which has a high sensitivity to weather conditions and the state of the surface layer of the atmosphere, as described by the authors of the scientific work (Tryhuba *et al.* 2021). Thus, rainy weather, fog, heat fluxes, wind and the presence of dew are among the unfavorable conditions of the process of mechanized collection of corn waste, which reduce the efficiency or make it impossible to perform. Adverse weather conditions significantly affect the duration of use of technical equipment during certain days and, accordingly, determine the time fund for the implementation of works in maize waste collection projects. To perform this stage of the method of planning the need for technical equipment of corn waste collection projects for the production of environmentally friendly fuel, we used the approach, algorithm and intelligent system to support management decisions, which were previously substantiated and described in detail in scientific work (Tryhuba *et al.* 2021). This provides a definition of the duration of non-rainy periods of time, which underlie the modeling of work using the specified technical equipment.

Stage 2. Determining the available volumes of corn waste for disposal while maintaining the balance of organic carbon concerns the assessment of the production component of the design environment.

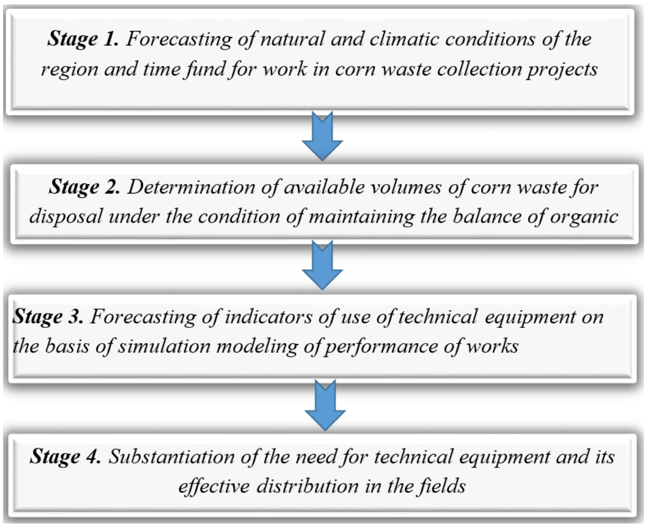

Fig 1. Stages of the method of planning the need for technical equipment of corn waste collection projects for the production of environmentally friendly fuel

The specific amount of corn waste, which is available for disposal, provided that the balance of organic carbon in the field, depends on the yield of corn grain and is based on the formula: k_{us}^i

$$q_w = M\left[Y_g^i\right] \cdot k_{dm}^i \cdot k_{us}^i , \qquad (1)$$

where -… mathematical expectation of the predicted yield of corn grain in the i-th field, t / ha; - coefficient that takes into account the period of harvesting corn relative to its ripeness according to the Food and Agriculture Organization of the United Nations (FAO) in the i-th field; k_{us}^i - the coefficient of available volumes of disposal of corn waste, provided that the balance of organic carbon in the i-th field, which depends on the balance of humus, which is characterized by organic carbon in the soil.

Corn is very conveniently classified according to the FAO system, the number of which is given in the "passport" of any hybrid. The introduction of such a classification was made possible by the biological characteristics of the corn plant and favorably distinguishes it from other crops. This made it possible to determine the duration of the growing season of a particular hybrid in different climatic conditions. The classification is based on the sum of active temperatures required for the plant to successfully pass all phases of development and maturation. In total, according to the FAO, there are six maturity groups of maize hybrids (in our conditions, the first four prevail, from FAO to 399). Using the FAO indicator and the average long-term temperature of the growing area, it is possible to calculate the date of ripening not only for different weather conditions, but also for different sowing dates. Based on the FAO of a particular hybrid, the planned maturity dates are calculated. Hybrids of different maturity groups enter certain phases of maturation with an interval of 7…10 days. Therefore, the terms of their harvest must fit into these intervals, otherwise - the inevitable loss of grain is possible.

Studies by American scientists (Marks-Bielska *et al.* 2019) show that when determining the available amount of waste, the main limiting factor is to ensure the balance of humus, which is characterized by organic carbon in the soil. When re-growing corn and traditional tillage technology, about 8.5 t / ha of corn straw should be left, while with canning and No-till - 6 t / ha. And when growing corn after soybeans during plowing it is necessary to leave about 14 t / ha, and with canning and No-till technology - 8.75 t / ha.

Stage 3. Forecasting of indicators of use of technical equipment on the basis of simulation modeling of performance of works provides planning of the necessary quantity of technical equipment. To plan the required amount of technical equipment (energy and vehicles), which significantly affects the timeliness of work in projects for the collection of corn waste for the production of clean fuel, it is necessary to establish the average daily productivity of each r-th technical equipment available to the agricultural enterprise, on a given field:

$$W_{\gamma kj} = f\left(U_{k\gamma}, \delta_{k\gamma}, L_{\gamma}, F_d, \Delta t_T\right), \quad (2)$$

where L_{γ} - is the length of the run on the γ-th field, m; F_d - average daily fund of time of corn waste collection for production of environmentally friendly fuel, h / day, Δt_T - average duration of downtime of technical equipment due to untimely removal of corn waste, h.

In addition, it should be noted that this productivity largely depends on the deposition of the stem culture in a particular field, as well as on the presence of obstacles (for example, power poles) on it (Bioenergy Technologies Office, Martinov, DuPont).

The daily productivity $\left(W_{\gamma kj}\right)$ of the r-th technical equipment on the γ-field depends on the average $\left(\Phi_з\right)$ daily fund of corn harvest time of the k-th ripeness group, which is determined by the time of emergence and dew duration of each day of the harvest season, as well as on the planned start time and $\left(t_p^d\right)$ daily equipment (collection and transport complexes). Each individual day of the harvest season in the absence of bad weather is characterized by a certain time situation with the presence of dew and the planned start $\left(\tau_з^n\right)$ and $\left(\tau_з^з\right)$ end of harvesting on certain days (organizational mode of harvesting).

Hourly productivity $W_{rk\gamma}^{г}$ of the r-th technical equipment in the j-th field during harvesting of corn of the k-th group of ripeness is implicitly expressed by the formula

$$W_{rk\gamma}^{г} = f\left(U_{k\gamma}, \delta_{k\gamma}, L_{\gamma}, \Delta t_T\right). \quad (3)$$

Thus, the daily (2) hourly productivity (3) differs in the absence F_d.

On the eve of the harvest (at least two to three weeks before the start) for each agricultural enterprise it is possible to have sufficiently reliable information about the future flow of requirements for the implementation of harvesting corn in individual fields:

$$\Omega_{II} \leftarrow \left[\left(k_1, S_1, t_1, U_1, \delta_1\right), \left(k_2, S_2, t_2, U_2, \delta_2\right), \ldots, \left(k_{\gamma}, S_{\gamma}, t_{\gamma}, U_{\gamma}, \delta_{\gamma}\right)\right], \quad (4)$$

where $k_1, \ldots, k_{\gamma}$ - the name (species, variety) of corn grown on the 1st, ..., γ-th field of an agricultural enterprise; $S_1, \ldots, S_{\gamma}$ - field area, ha; $t_1, \ldots, t_{\gamma}$ - time of harvest in each of them, days; $U_1, \ldots, U_{\gamma}$ - yield, c / ha; $\delta_1, \ldots, \delta_{\gamma}$ - stalk coefficient.

The display of maize waste collection for the production of environmentally friendly fuel by the set (3) with the specified characteristics of its components is the main basis for forecasting the efficiency of the grain harvesting project, based on which the decisions on the feasibility of harvesting and parameters of harvesting complexes. To this end, first of all, develop a project implementation plan, in which on the basis of virtual (imaginary) distribution of technical equipment and vehicles available in the agricultural enterprise determine a possible change in the calendar time axis of corn waste collection rate for production of clean fuel untimely harvested areas, the need for technical equipment and vehicles, as well as due to the lack of which and the possible loss of crops. The basis for the development of such a plan is data on the time between the beginning of the time of crop ripening in individual fields of the production program - $\left(t_{k2}, t_{k3}, \ldots, t_{k(\gamma-1)}\right)$ the area of individual fields under these crops ($S_{k\gamma}$), their $\left(U_{k\gamma}\right)$ yield and stem $\left(\delta_{k\gamma}\right)$. In other words, the plan is based on the projected characteristics of the seasonal flow of requirements for harvesting corn waste for the production of environmentally friendly fuel.

Having a certain amount (park) of technical equipment and vehicles for the removal of corn grain and its waste for the production of environmentally friendly fuel,it is necessary to determine the possible duration of harvesting corn k-th maturity group in each γ-th field, provided no impact on the harvesting weather:

$$t_{k\gamma}^{c} = f\left(N_{K\gamma}, N_{T\gamma}, S_{kj}, U_{k\gamma}, \delta_{k\gamma}, O_{\gamma}\right), \quad (5)$$

where $N_{K\gamma}, N_{T\gamma}$ - the number of technical equipment and vehicles planned to work in the j-th field, units; O_{γ} - organizational mode of use of technical equipment and vehicles in the γ-th field (h / day).

Stage 4. The next stage of the proposed method involves justifying the need for technical equipment and determining its effective distribution in the fields. Given the loss of both maize grain and its waste, provided that the day, available technical and transport equipment should be distributed in the fields in such a way that these losses are minimal (if possibly absent). To this end, for each field,it is necessary to determine the minimum number of technical and transport means required to collect it within ten days:

$$\left(N_{K\gamma}, N_{T\gamma}\right) = f\left(S_{K\gamma}, \omega_{k\gamma}^{n}\right), \quad (6)$$

where $\omega_{k\gamma}^{n}$ - the required rate of corn harvesting of the *k*-th group of ripeness in the *γ*-th field, which allows harvesting of the grown crop within ten days (without losses), ha/day.

It is calculated from the ratio (Tryhuba *et al.* 2019):

$$\omega_{k\gamma}^{n} = S_{k\gamma} / 10 \quad (7)$$

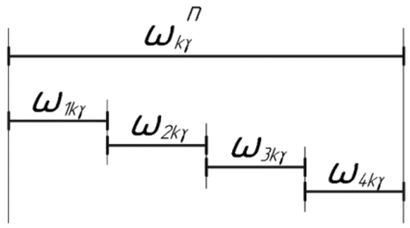

Fig 2. Graphic interpretation of the procedure for determining the required amount of technical equipment for timely harvesting of corn of the k-th group of ripeness in the γ-th field

This rate of harvesting $\omega_{rk\gamma}$ is determined by data on the performance of technical equipment in each field by selecting their number (Figure 2).

$$\omega_{k\gamma}^{n} \le \sum_{r} \omega_{rk\gamma} \,, \qquad (8)$$

where $\omega_{rk\gamma} = 10W_{rk\gamma}$.

Having substantiated the necessary quantity of technical equipment for each separate field of a seasonal stream of requirements for collecting corn waste for the production of environmentally friendly fuel it is necessary to define their calendar need for all seasonal stream (Figure 3).

According to the schedule of calendar needs for technical means for timely collection of corn waste for the production of environmentally friendly fuel in all fields of the seasonal flow of requirements (seasonal program) (Figure 2, c) it is necessary to assess the feasibility of harvesting project, as well as the technical means from the outside (in the formations serving agricultural enterprises). It is defined as the difference between the maximum need of an agricultural enterprise for technical means, determined graphically, and their available number.

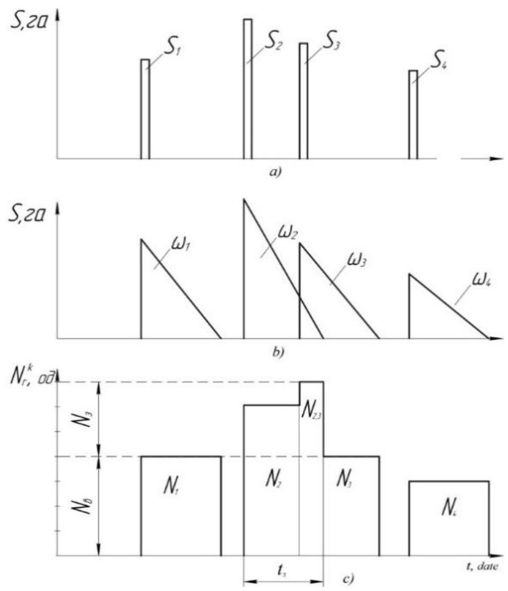

Fig 3. Graphical interpretation of the flow of requirements (a) for the collection of maize waste for the production of environmentally friendly fuel, ensuring (b) the timeliness of the process and the required amount of technical equipment (c): $N_{в}$ - the number of own technical means, units; $N_{з}$ - number of involved technical means, units; $t_{з}$ - planned term of work of the involved technical means, days.

To substantiate decisions on the distribution of technical and transport means in the fields, you need to know the efficiency of the harvesting process for a given distribution of technical means. These indicators, as it was already mentioned, can be determined on the basis of modeling the work of each technical means in separate fields. To do this, we have developed a computer program for statistical simulation of technical equipment in a particular field (Figure 4).

This program provides five main blocks:

1. input of initial data;
2. generation of agrometeorological conditions of the j-th day and determination of the organizationally adjusted fund of working hours of technical means;
3. modeling of technical means during the j-th day;
4. checking the presence of fine days;
5. output of simulation results.

The first block concerns the maintenance of the initial data. These data are divided into three groups. The first group involves entering data on the characteristics of the field. These characteristics include the area of the field, the length of the field, the slope of the field, the group of corn ripeness and its yield and stem. The second group provides for the input of data on the parameters of technical means. These parameters include the capacity of technical means, their width, hopper capacity, engine power, weight and number of drums for threshing corn.

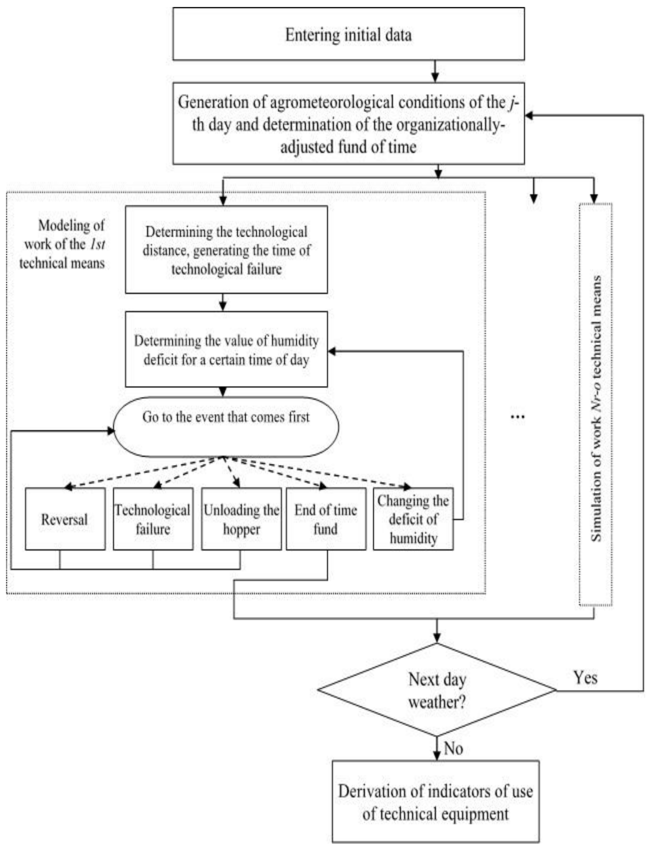

Fig 4. Block diagram of a statistical simulation model of corn waste collection for the production of environmentally friendly fuel by specified technical means in a separate field

The third group involves the entry of data on the allowable deadlines. They are taken from technological regulations that depend on both the natural and climatic conditions of the region and the technology of collecting corn waste for the production of environmentally friendly fuels. Agrometeorological station data are used to assess the natural and climatic conditions of a given region. Statistical processing of the obtained data makes it possible to establish the laws of distribution of the predicted values of good and bad weather periods for the performance of work on the collection of corn waste.

The second block on the basis of the distributions of the forecasted values of fine and non-rainy intervals of time for performance of works on collection of corn waste substantiated in the first block provides generation of agrometeorological conditions of the j-th day. This is the basis for determining the organizationally adjusted time fund of technical equipment. At the same time, the beginning and duration of the best time period of the j-th day (allowable time fund of this day) and the organizationally adjusted time fund of technical means during the day are determined.

In the third block simulation modeling of technical means during the j-th day is carried out. First of all, for the given conditions of work of equipment, technological distance for filling of the bunker is defined. The next step is to generate the time of occurrence of technological failures and determine the value of the humidity deficit for a certain time of day. The obtained indicators provide determination of the speed of technical means and the formation of an array of their productivity. After that, the event is determined from among the given set (technological failure, filling the hopper, reversal, change of moisture deficit, the end of the daily fund of time), which occurs first. In case of the occurrence of each of them, the duration is determined before the elimination of the specified event and the adjustment of the array of productivity of technical means, taking into account its losses.

The fourth block concerns the verification of the conditions, whether the next day is fine and whether the collection of corn waste has been performed in a given field. If so, it is necessary to return to generating agro-meteorological conditions the next day. If not, the next day is set and the specified condition is checked. If you collect corn waste in a given field, move on to the fifth block.

The fifth block provides the output of simulation results. In this case, the user has the opportunity to obtain any of the indicators of the use of technical equipment, which are given in formulas (2-6).

As a result of modeling the work of technical means in each field with the harvest reached at a certain time, the volume $Q_{\text{з}k}$ of the harvested corn of the k-th maturity group (grain and waste for production of environmentally friendly fuel) and the possible volume Qвk of the lost harvest during a certain (current) time tпр work of technical means for a given j-th distribution of them in the field Valuation of expected income $C_{n\rho}(\sum_k Q_{\text{з}k})$ and losses $C_{\text{в}\rho}(\sum_k Q_{\text{в}k})$ allows to justify the effective distribution of technical equipment in the fields during the implementation of projects for the collection of corn waste for the production of clean fuel:

$$\rho^{efekt} = f\left[C_{n\rho}(\sum_k Q_{\text{з}k}) - C_{\text{в}\rho}(\sum_k Q_{\text{в}k})\right] \rightarrow \min \qquad (9)$$

The minimum value of function (9) determines the effective distribution of technical equipment in the fields of the production program only for a certain point in time - until the event occurs in the project, which will change this distribution.

4. Results of substantiation of indicators of use of technical equipment and tendencies of risk changes

Based on the disclosure of the content of the blocks shown in the block diagram (3), a computer program of statistical simulation modeling of corn waste collection for the production of environmentally friendly fuel by technical means in a separate field was developed. It is based on the method of planning the need for technical equipment of maize waste collection projects for the production of environmentally friendly fuel described above. Using a computer program, a study of the need for technical equipment of corn waste collection projects for the production of environmentally friendly fuel for a given design environment (conditions of LLC "Lutsk Agrarian Company" Volyn region, Ukraine). The simulation was performed using the technology of corn waste collection, which provided for the collection of corn for grain and waste for the production of environmentally friendly fuel (Table 1).

Table 1
Technology and technical equipment for harvesting corn for grain and waste for the production of environmentally friendly fuel

Name of technological operation	Technical equipment	Brand of equipment	Cost, thousand euros
Harvesting corn for grain	combine	Claas Lexion 770	320
	reaper	Conspeed 8-70 FC	47
Transportation of corn grain	tractor	Claas Arion 640	90
	trailer	Krone	15
Baling	tractor	NH T7060	102
	mulcher	Hiniker 5620	36.5
Collection, loading and transportation of bales at a distance of up to 25 km	tractor	Claas Arion 640	90
	baler	Claas Rollant 620	40

At the same time, natural and climatic conditions for a given region were studied when using the data of the Lutsk Agrometeorological Station. Statistical processing of the obtained information on sunny and non-rainy time intervals made it possible to determine their numerical characteristics, as well as to substantiate the theoretical distribution laws (Figure 5-6), which agree on Weibull distribution laws, the density function of which is:

- for clear periods of time

$$f\left(t_n\right)=0.303\left(\frac{t_n-1}{3.667}\right)^{0.113}\times\exp\left[-\left(\frac{t_n-1}{3.667}\right)^{1.113}\right], \quad (10)$$

- for rainy periods of time

$$f\left(t_н\right)=0.712\left(\frac{t_н-1}{1.622}\right)^{0.154}\times\exp\left[-\left(\frac{t_н-1}{1.622}\right)^{1.154}\right]. \quad (11)$$

The statistical characteristics of these distributions are as follows: estimates of mathematical expectation - $M\left[t_n\right]=4.53$ days and $M\left[t_н\right]=2.54$ days; estimates of standard deviation $\sigma\left[t_n\right]=3.22$ - days and $\sigma\left[t_н\right]=1.35$ days.

From the presented histogram and the theoretical curve of the obtained distribution (Figure 5) it is clear that for the studied region the maximum duration of clear periods of time for harvesting corn for grain and waste is 2…2.5 days (probability 21.5%) and 0.8…1.9 days (probability 20%). At the same time, with a high probability of 72%, it can be stated that the duration of clear periods of time for harvesting corn for grain and waste will be in the range of 1…5 days. There is also a low probability - 5% that the duration of clear periods of time for harvesting corn for grain and waste will be more than 7 days.

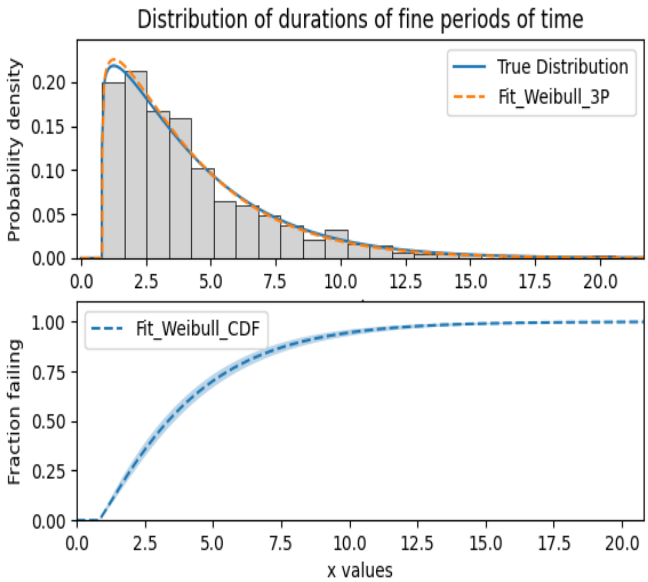

Fig 5. Histogram and theoretical distribution curve of durations clear t_n periods of time

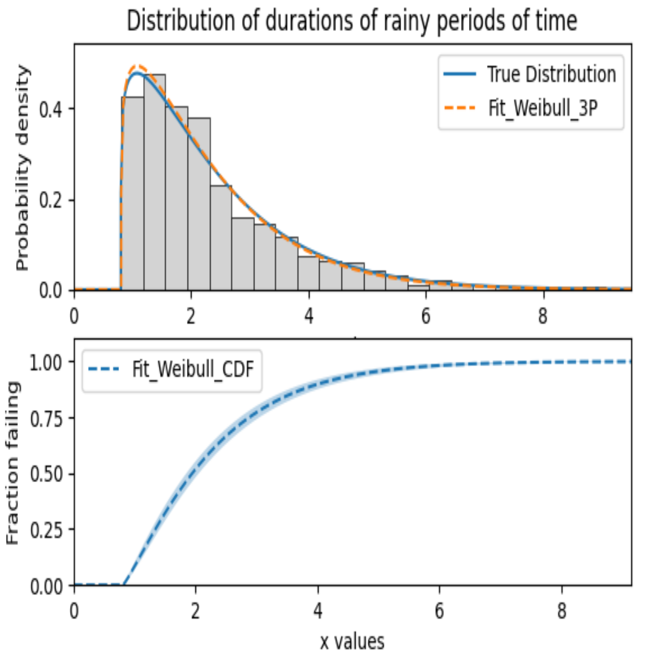

Fig 6. Histogram and theoretical distribution curve of durations of rainy periods of time

From the presented histogram and the theoretical curve of the obtained distribution (Fig. 6) it is clear that for the studied region the maximum duration of non-rainy periods for harvesting corn for grain and waste is 1.0…1.5 days (probability 48%) and 0.6…0.9 days (probability 42%). At the same time, with a high probability of 82%, it can be stated that the duration of non-rainy periods of time for harvesting corn for grain and waste will be in the range of 0.6…1.7 days. There is also a low probability - 5% that the duration of non-rainy periods of time for harvesting corn for grain and waste will be more than 2.5 days.

The value of Pearson's agreement criterion is 8.53<9.23 and 5.01<6.25, respectively, which indicates that the hypothesis corresponds to Weibull's theoretical law.

The study assumes that the grain yield of corn varies within 100…160 c / ha. At the same time, the production of corn waste available for disposal provided that the balance of organic carbon is maintained depends on the yield of corn grain Bioenergy Technologies Office (Bioenergy Technologies Office) and is described by the equation:

$$q_w=-0.118\cdot Y_g+3.913\cdot Y_g-23.376\,, \quad (12)$$

where q_w - the specific amount of corn waste that is available for disposal, provided that the balance of organic carbon in the field, c / ha; Y_g - corn yield per grain, c / ha.

Based on the use of the developed computer program, simulation modeling of corn harvest was performed, which was tested for adequacy according to the Mann-Whitney test. The deviation of the forecasted productivity of the Claas Lexion 770 combine from the real data of Lutsk Agrarian Company LLC did not exceed 4.2%.

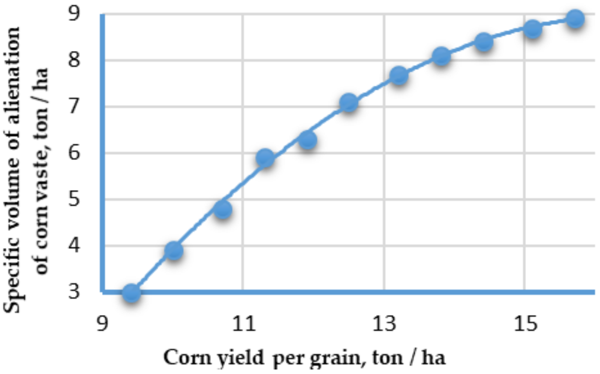

Fig 7. Dependence of available maize waste for disposal under the condition of maintaining the balance of organic carbon

Statistical processing of the obtained data on the distribution of the predicted productivity of the Claas Lexion 770 combine made it possible to determine the numerical characteristics, as well as to substantiate the model (Figyre 8), which is described by the normal distribution law with differential function

$$f\left(Q_k\right)=0.443\cdot exp\left(-\frac{\left(Q_k-5.3\right)^2}{1.62}\right), \qquad (13)$$

where Q_k - hour productivity of the Claas Lexion 770 combine, on / hour.

The verification of the adequacy of the theoretical distribution of the predicted productivity of the Claas Lexion 770 combine (Figure 8) with respect to empirical data was performed according to the Pearson's Chi-squared criterion. It is established that the deviations do not exceed 3.8%, which is considered an acceptable value.

The main statistical characteristics of the distribution of the predicted productivity of the Claas Lexion 770 combine are the following: estimation of mathematical expectation - 5.3 ha / h; dispersion - 0.815 ha / h; estimation of the standard deviation - 0.902 ha / h.

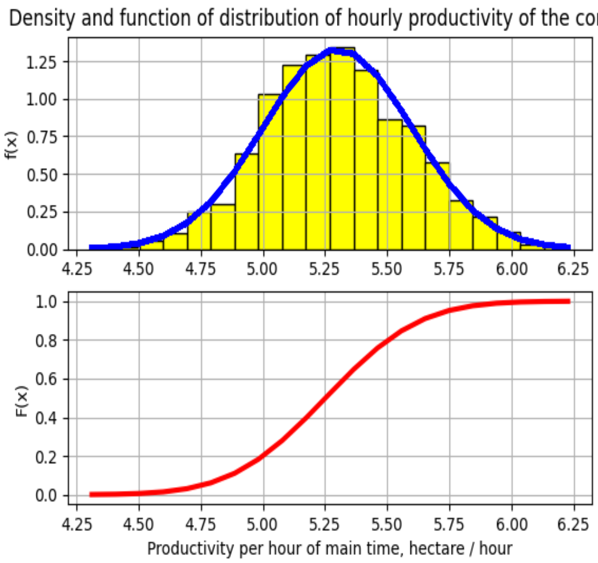

Fig 8. Histogram and theoretical distribution curve of the predicted productivity of the Claas Lexion 770 combine, ha / h

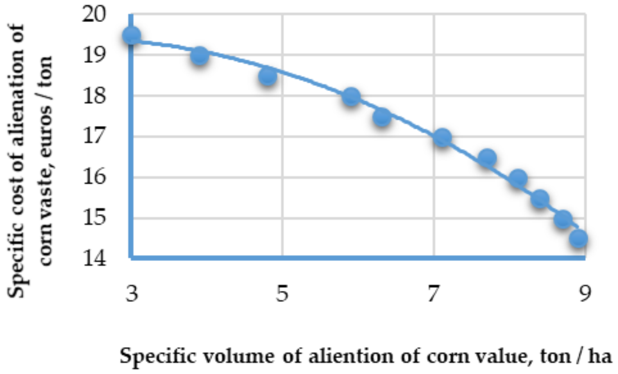

Fig 9. Dependence of the specific cost of alienation of corn waste on the specific volume of alienation, provided that the balance of organic carbon in the fields

Based on simulation modeling of corn waste collection available for disposal, provided that the balance of organic carbon in the fields is maintained. This made it possible to construct the dependence of the specific cost of alienation of corn waste on the specific volume of alienation, provided that the balance of organic carbon in the fields (Figure 9).

The obtained dependence of the specific cost of disposal of corn waste on the specific volume of disposal provided that the balance of organic carbon in the fields is described by the equation:

$$C_w = -0.1\cdot q_w + 0.419\cdot q_w + 18.985,\; R^2 = 0{,}99 \qquad (14)$$

where C_w - specific cost of corn waste disposal, euro / t; q_w - specific volume of corn waste, which is available for disposal under the condition of maintaining the balance of organic carbon in the field, c / ha.

Based on the analysis of the obtained results of simulation modeling of corn waste collection, available for utilization under the condition of maintaining the balance of organic carbon in the fields, visualization was made in Python 3.9 programming language using matplotlib, numpy and scipy libraries. Maize waste: 3 t / ha, 6 t / ha and 9 t / ha (Figure 10).

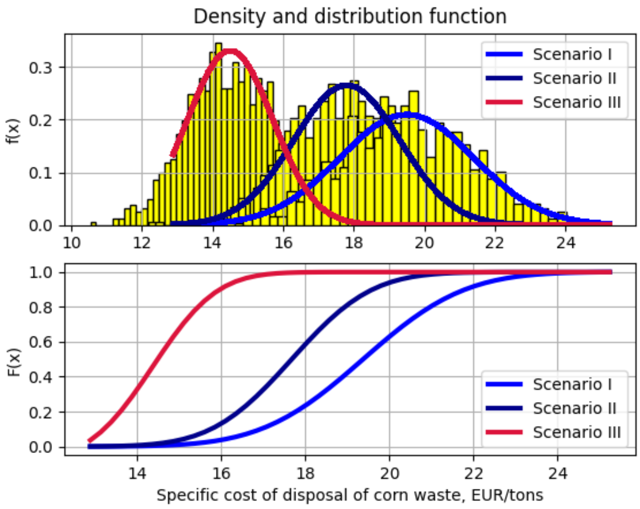

Fig 10. Density and function of distributions of specific cost of corn waste disposal: scenario I - specific volume of corn waste 3 t / ha; scenario II - specific amount of corn waste 6 t / ha; scenario III - specific volume of corn waste 9 t / ha

Table 2
The results of forecasting quantitative indicators of the risk of the specific cost of disposal of corn waste

Indicator	Options for the specific cost of disposal of corn waste						
	1	2	3	4	5	6	7
Planned unit cost of maize waste disposal, Euro / tons	24	22	20	18	16	14	10
Scenario III - specific waste of corn waste 3 t / ha							
Probability of obtaining the planned specific cost of disposal of corn waste	0.0	0.0	0.0	0.0	0.12	0.65	1.0
The risk of obtaining a specific cost of disposal of corn waste	critical	critical	critical	critical	critical	allowable	absemt
Scenario II - specific waste of corn 6 t / ha							
Probability of obtaining the planned specific cost of disposal of corn waste	0.0	0.0	0.08	0.59	0.88	1.0	1.0
The risk of obtaining a specific cost of disposal of corn waste	critical	critical	critical	середній	minimum	absemt	absemt
Scenario I - specific waste of corn 9 t / ha							
Probability of obtaining the planned specific cost of disposal of corn waste	0.01	0.11	0.37	0.78	0.96	1.0	1.0
The risk of obtaining a specific cost of disposal of corn waste	critical	critical	high	allowable	minimum	absemt	absemt

The conducted computer experiments made it possible to predict the risk indicators of the specific cost of disposal of corn waste (Table 2). According to the obtained research results (Table 2), the tendencies of change of quantitative risk indicators of specific cost of alienation of corn waste were established. In particular, this risk largely depends on the scenario of the maize waste collection project available for disposal, provided that the balance of organic carbon in the fields is maintained. In addition, this risk largely depends on the requirements of project stakeholders in terms of maize waste. The data presented in table. 2 show that if the average unit cost of corn waste disposal is planned at 18 euros / ton, there is a critical risk in the fields that provide 3 tons / ha of corn waste (the probability of obtaining the planned unit cost of corn waste disposal is 0.0). This indicates that in such fields it is not possible to plan the average specific cost of corn waste disposal (18 euros / ton). There is an average risk of increasing corn waste production to 6 t / ha, but the probability of obtaining the planned specific cost of corn waste disposal is slightly higher and it is 0.59. If the volume of maize waste production increases to 9 t / ha, there is a permissible risk, as the probability of obtaining the planned specific cost of maize waste disposal is 0.78.

Based on the obtained results of forecasting quantitative indicators of risk $R(P_s)$ of specific cost of disposal of corn waste, it is established that these risks are absent when planning the specific disposal cost of corn waste:

- scenario I (specific amount of corn waste 9 t / ha) – 16 euros / ton;
- scenario II (specific volume of corn waste 6 t / ha) – 14 euros / ton;
- scenario III (specific volume of corn waste 3 t / ha) – 10 euros / ton.

5. Discussion of research results

Today, the vast majority of countries around the world care about their energy security and implement programs to attract alternative and at the same time environmentally friendly energy sources. One such program in the EU is the European Green Deal, which provides for projects to make the European continent climate-neutral by 2050. At the same time, many scientists in their works (Ang *et al.* 2015, Boyarchuk *et al.* 2020, Hutsol *et al.* 2021, Winzer 2012) point out that special attention should be paid to the use of crop waste to provide environmentally friendly energy to regions and industries. At the same time, a number of scientific and applied problems remain unsolved. One of such tasks is to plan the need for technical equipment of corn waste collection projects for the production of environmentally friendly fuel, which requires the development of appropriate tools.

Our research substantiates the method and statistical simulation model of planning the need for technical equipment of corn waste collection projects for the production of environmentally friendly fuel. They are based on the methodologies of a systems approach, project management and probability theory, which takes into account the changing design environment of individual regions, which is the basis for accurate forecasting of risks of the specific cost of crop waste disosal. It is about the feasibility of such studies indicated in (Hutsol *et al.* 2021, Tryhuba *et al.* 2020, Bielski *et al.* 2021).

Our proposed method and simulation model provide coordination of the content and timing of work in projects for the procurement of agricultural waste for energy production with technical equipment and changing natural, climatic and industrial conditions of the region. They provide for the formation of a database and knowledge of climate conditions from the OpenWeatherMap service for individual countries and their regions. This service, as noted in (Tryhuba *et al.* 2021), today is one of the most accurate sources of predicted information on weather conditions, and at the same time determines the naturally allowed time for work in corn waste collection projects for the production of environmentally friendly fuel.

In addition, the main feature of the proposed method is that planning the need for technical equipment of corn waste collection projects for the production of clean fuel involves the formation of databases and knowledge for a given country or region, taking into account the characteristics of climatic and industrial conditions based on simulation. It is the use of simulation, as noted in (Ratushny *et al.* 2020, Bashynsky *et al.* 2020. Ratushny *et al.* 2021), that provides a systematically accountable set of variable factors of efficiency of complex organizational and technical systems, which include the system of waste collection of corn for the production of environmentally friendly fuel. In addition, such tools take full account of the specifics of the subject area, as well as provide a qualitative definition of performance indicators that are variable in nature.

A well-founded method of planning the need for technical equipment of corn waste collection projects for the production of environmentally friendly fuel and based on it developed a statistical simulation model provide qualitative forecasting of quantitative $R(P_s)$ risk indicators of the specific cost of corn waste disposal taking into account the natural components of individual countries and their regions.

Based on the proposed tools, the indicators of the use of technical equipment of corn waste collection projects for a given design environment and the trend of changing the risk of the specific cost of disposal of corn waste are substantiated. The determining indicator is the accuracy of forecasting the volume of work performed, which in corn waste collection projects for the production of environmentally friendly fuel is determined by the amount of alienation of raw materials in individual fields. It is known (Jeschke *et al.* 2011) that the volume of waste disposal of crop products largely depends on a number of factors. American scientists (Marks-Bielska *et al.* 2019) point out that when determining the available amount of waste, the main limiting factor is to ensure the balance of humus, which is characterized by organic carbon in the soil. In addition, the period of crop waste collection, due to the FAO, is important. We propose to take into account these components, which ensure the accuracy of forecasting the volume of work in projects for the collection of corn waste for the production of environmentally friendly fuel.

The obtained research results, in the form of models presented in Figures 5-10, are the creation of intelligent systems for risk forecasting in maize waste collection projects for the production of environmentally friendly fuels, which will ensure accelerated and high-quality management decisions on their planning.

There are currently no scientific papers on forecasting quantitative indicators of the risk of the specific cost of corn waste disposal. However, there are scientific papers related to forecasting quantitative risk indicators of investors in biohydrogen production projects from agricultural raw materials. In particular, in our research we used the criterion (measure) of risk proposed in the scientific work (Tryhuba *et al.* 2021). In particular, the probability of benefit for stakeholders (obtaining the planned unit cost of disposal of corn waste) is less than expected, then the quantitative values of the corresponding risk can be estimated by. For practical purposes, an empirical scale of risk levels (risk probabilities) was used:

Region I – $R(q)=0\div 0.2$ – minimal risk;

Region II – $R(q)=0.2\div 0.4$ – tolerable risk;

Region III II – $R(q)=0.4\div 0.6$ – medium risk;

Region IV III – $R(q)=0.6\div 0.8$ – high risk;

Region V – $R(q)=0.8\div 1.0$ – critical risk.

The main disadvantages of the proposed method and research include the fact that they are based on specific experiments to determine the characteristics of climatic and industrial conditions, and also require simulation to predict the use of technical equipment, which without the development of a computer program requires conducting time-consuming calculations. However, the proposed method and stages of the study underlie the development of a computer system to support management decisions, which will significantly speed up the management decision-making process to determine the use of technical equipment in the given production conditions, risk planning and increase their accuracy.

For the first time for the conditions of Ukraine (western region) it is established that without risks for stakeholders it is possible to plan a specific cost of corn waste disposal 16 euros / ton in fields that provide collection of corn waste in the amount of 9 t / ha, 14 euros / ton in fields that provide collection of corn waste in the amount of 6 t / ha and 10 euros / ton in fields that provide collection of corn waste in the amount of 3 t / ha.

The conducted research will be useful for project managers involved in the implementation of corn waste collection projects for the production of clean fuel, as well as for the management of agricultural enterprises that plan to sell crop waste for the production of clean fuel.

6. Conclusions

The proposed method and statistical simulation model of planning the need for technical equipment of corn waste collection projects for the production of clean fuel are based on the results of forecasting the basic events of the internal design environment and deterministic method of planning the need for technical equipment. changing design environment, which causes the risk of the specific cost of corn waste disposal.

Based on the use of the developed simulation model of corn waste collection available for disposal under the condition of maintaining the balance of organic carbon in the fields, for given climatic and production conditions, the indicators of technical equipment use and the tendency of risk change of specific cost of corn waste disposal are substantiated.

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