How to Help Agriculture in the Context of a Changing Climate and Increasing Number of Natural Hazards?

E. D. VIAZILOV
National Oceanographic Data Centre
All-Russian Research Institute of Hydrometeorological Information – World Data Centre
6, Koroleva, 249035, Obninsk, Kaluga region
RUSSIA

Abstract: - The aim of the article is to consider the development of decision support based on the use of hydrometeorological information in the activities of agricultural enterprises. Agriculture is increasingly dependent on weather and climate change, making adaptation to weather conditions increasingly important. The article considers problems of using the issued hydrometeorological information for the needs of agriculture, methodological foundations of adaptation of agriculture to natural conditions. The use of damage assessment models in the form of assessments of possible impacts of natural hazards on the activities of agricultural producers, calculations of damage from natural hazards and the cost of preventive actions is shown. A methodology for creating a decision-making support system for organizing the adaptation of agriculture to natural hazards and climate change is proposed. An example of a description of the agricultural situation "Damping off" is given, which occurs in autumn-winter-spring periods. Experimental knowledge base of local threshold values of natural hazard indicators in agriculture and a database of the impact of natural hazards on the activities of agricultural enterprises and recommendations for decision-making before, during and after the natural hazard at three levels of dangerous are created. Informing agricultural producers about agrometeorological conditions should be based on identifying natural hazards for a specific type of activity or the state of grain growth. Because of implementing such a technology for hydrometeorological support of agricultural producers, the awareness of enterprise managers will increase due to the prompt provision of data, their compact visualization and providing impact forecasts and recommendations.

Key words: - Agriculture, natural hazards, climate change, impact assessment, recommendations, decision support.

Received: April 9, 2024. Revised: March 2, 2025. Accepted: April 9, 2025. Published: May 21, 2025.

1 Introduction

The increasing dependence on various natural hazards is explained by:

– the intensive development of agriculture; the use of new, more weather-dependent agricultural technologies;

– the lack of methods for autonomously taking into account hydrometeorological conditions when making decisions.

A situation has arisen in which the collection, accumulation, applied processing of data, obtaining generalizations, short-term, long-term and ultra-long-term weather forecasts are developing, and damage from natural hazards in agriculture continues to increase.

Some natural hazards, such as heavy hail with hailstones larger than 2-3 cm in diameter, can destroy the entire crop in open ground. Crop yields and plant health deteriorate in the long term if plants are not watered on time. Watering is a costly undertaking, with over $2 billion spent on irrigation in the United States. Sowing and harvesting times can increase crop losses if the weather is not suitable.

Farm managers must organize adaptation to natural hazards and extreme climatic events related to climate change based on information products received from Roshydromet and other sources.

Dozens of books and thousands of articles have been written on the topic of research individual natural hazards and for natural emergencies in general. Unfortunately, these publications focus on either climate change or decarburization. With much, less attention paid for adaptation to climate change and especially to support for solutions. Available information on the impact of natural disasters on agricultural activities and recommendations are scattered across various sources and are not formalized. Farmers themselves must search for and use hydrometeorological information (HMI) to make decisions to reduce or prevent impacts of natural disasters. Much has been written about the adaptation of agriculture to climate change, but such information has not yet been collected and systematized.

Climate change affects ecosystems, economies and human societies. The most critical consequences are the impact on food security in many countries. Help is needed to help the population and agricultural managers adapt to changing climate conditions. For example, if the average air temperature increases by 2 degrees, the global grain harvest will decrease by 8-10%. In addition, in some regions where droughts are common, losses can reach 15-25%. The success of the adaptation strategy depends not only on the correct assessment of climate change in the near future, but also on technological innovations in the field of creating a decision support system (DSS) taking into account indicators of extreme climate events and generalizing the existing practical experience in carrying out preventive actions.

Farm managers face the following questions.

How can we obtain information about the possible impacts of natural hazards on agricultural enterprises?

How much will it cost to refuse to carry out preventive actions before a natural hazards or extreme climatic events?

Measurement devices installed on various observation platforms – hydrometeorological stations, satellites, aircraft, research vessels, buoys, unmanned aerial vehicles, and weather radars help collect hydrometeorological data, issue forecasts of varying lead times, obtain climate data and deliver them to agricultural producers.

The aim of the article is to develop decision support based on the use of hydrometeorological information in the activities of agricultural enterprises.

The study aims to demonstrate the possibilities of creating a DSS to take into account the impacts of natural hazards on the agricultural sector and issue recommendations.

2 Statement of the problem

Farm managers need to understand impacts of weather on their daily operations to optimize their operations. Managers must strive to consider the weather and know how it will affect them today, tomorrow and in the future.

This is useful, but not enough to help them quickly and effectively use data to make various decisions. To do this, they need to understand.

Does a rainfall forecast in five days mean you should adjust manager irrigation levels today?

Should a manager plan to plant a week earlier due to rising temperatures?

Can early autumn frosts ruin the harvest if it is not harvested before frosts start?

Research in the field of using HMI in the activities of agricultural enterprises is being conducted quite actively. Roshydromet data deliver to agricultural enterprises in the form of bulletins, via websites, portals. Data in grid points can already be issued with a resolution of up to 2-8 km can be received using API-services on the user's computer or directly into the information system, or by subscription delivered to email or an ftp server.

The services on the website of the Hydrometeorological Centre of Russia [1] provide hydrometeorological products in the form of current weather, forecasts and summaries. Current weather includes:

– synoptic map;
– animation of current radar observations;
– images from geostationary satellites;
– meteorological extremes;
– archive of actual weather;
– maps of average monthly values and anomalies of meteorological values for the Northern Hemisphere;
– current agrometeorological conditions in Russia;
– fire hazard in forests across Russia.

Forecasts include [1]:

– daily hydrometeorological bulletin,
– forecast of most important natural hazards;
– forecast for regions;
– bulletin of dangerous and unfavorable hydrometeorological phenomena for the territory of Russia;
– weather bulletin for the Central Federal District of Russian Federation;
– natural hazards.

On the Unified system of information about state World Ocean (ESIMO) portal [2] you can obtain observed, analytical, forecast and climate data on one map for any point in Russia. The system uses already calculated statistical characteristics - climate norms, extreme values of parameters, their frequency and the probability of natural disasters. The system implements an experimental model for autonomously identifying dangerous levels of hydrometeorological parameter values and forecasting possible impacts and issuing recommendations for decision-making.

Agriculture is becoming more automated through more accurate weather forecasting for crop management, early yield forecasting, crop problem detection, and the use of micro-drones for plant pollination.

If you spray plants before the rain, the effect of such an event will be low. If it will be rains and the manager wants to urgently harvest a large number of fields, then to reduce financial risks, you need to harvest crops that are more expensive first.

Companies “Rusagro Tech” and “Infosystems Jet” have created a yield forecasting system that processes data on the properties and value of agricultural crops, weather conditions, equipment availability, and provides recommendations - on which fields and when harvesting can be done. The system is based on a meta-algorithm, which using linear programming. The system processes and generates:

– field work plans for each production site;

– provides recommendations on prioritizing work taking into account crop cultivation technology and crop rotation;

– builds optimal routes for equipment movement during field work and when moving from one field to another.

Depending on the long-term forecast, it is possible to plan work not only for the current season, but also for the next one. Other criteria are also used, for example, account additional time costs when changing field work plans due to weather conditions.

Droughts pose risks to agriculture, energy facilities, and the population. Scientists from Skoltech, together with Sberbank [3], have proposed deep learning models for medium- and long-term drought forecasting based on climate data for a period of several months to a year. Long-term forecasts are needed by agricultural enterprises to plan their activities, and by insurers and banks to assess the corresponding risks and refine the credit ratings of corporate borrowers. The time of each operation in the field, its timing relative to other actions, and their feasibility are taken into account. The entire technological chain of fieldwork and the order of its implementation are presented in the DSS in the form of recommendations. The implemented preventive actions, formed based on the recommendations issued by the system, are analyzed daily with the manager of production sites, who confirm their correctness.

Hardware and software complex of the Weather service of the Farmlink Company based on Yandex-weather data receives actual weather and a two-day forecast for the coordinates specified by the user, and selects the optimal time intervals for use of plant protection tools.

Company “Er-Telecom Holding” solves tasks of agrometeorological monitoring in the Republic of Bashkortostan in order to reduce dependence on weather conditions and significantly increase the efficiency of work with hydrometeorological data. The project allows evaluating the diversity and value of the data obtained for planning agricultural activities and decision-making [4].

Unmanned aerial vehicles and other robotic devices - autopilots also need modern hydrometeorological support. Icing, low clouds, poor visibility and other phenomena affect unmanned aerial vehicles flight safety. Unmanned aerial vehicles operate only in certain ranges of threshold values of environmental indicators. When an airplane flies, the pilot himself makes a decision to change the altitude or direction of the flight depending on the received information about cyclones, fronts, clouds, atmospheric phenomenon. The unmanned aerial vehicles have a microprocessor on board that analysis developing weather situations. If any weather indicator goes beyond the threshold values, the command to change the flight parameters is transmitted to the actuators that perform physical actions to control the flight. The decision to change the altitude or direction of the flight is made based on forecast data. The unmanned aerial vehicles must receive forecast information on the point where it is or will be during the period of time for which the weather forecast is issued. The forecast data, as well as the current data, are analyzed for the possible presence of the unmanned aerial vehicles in the zone of dangerous threshold values of weather indicators. For such dynamic objects, data from meteorological locators are needed, allowing to receive data on thunderclouds every 10 minutes and, accordingly, to have a forecast for every 20 minutes during the next two hours. Such information allows seeing very precisely by place and time the approach of a thundercloud or simply clouds with precipitation.

Artificial intelligence (AI) opens up great opportunities for considering weather conditions in agriculture. The Russian company “MTS” has developed for the Federal Scientific Centre of Agroecology of the Russian Academy of Sciences of the hardware-software complex, which allows accelerating the process of processing data on the state of natural communities in thirteen regions of Russia. Based on the analysis of information, a forecast is made and recommendations are issued for the effective fight against environmental problems, desertification and drought. The hardware-software complex uses 100 neural networks. The hardware-software complex continuously processes and stores information on changes in natural ecosystems, received through satellite monitoring.

Machine and deep learning work in tandem with the Internet of Things with connected sensors measuring grain moisture, temperature and soil composition to optimize production and implement recommendations for adding moisture to the soil. Machine vision, based on aerial photographs, assesses the quality of crops and fieldwork, and identifies plant diseases. Thanks to this, farmers quickly adjust the doses of fertilizers and plant protection tools used and give recommendations for agricultural activities.

Save4AllAfrica project aims to implement and accelerate climate change adaptation through impact assessment and enterprise-level decision making. The Neuralgia AI engine uses generative adversarial networks to statistically upscale climate forecasts, providing high-resolution sub-seasonal predictions. It uses climate data and digital elevation models to improve accuracy. For this purpose, the Save 4 All Africa project has developed the following applications, which demonstrate a high level of development [5]:

1) Multi-agent learning framework with the Neuralgia AI engine from Hydroclimate Information Service of Wageningen University.
2) A virtual tool for modelling the interaction of weather conditions and agricultural objects, forecasting environmental impacts based on climate information, Earth observations and socio-economic data.
3) Hydrological modelling platform "Agropogoda" of Delphi University of Technology's in the form of a chat-bot for obtaining seasonal forecast of the influence of weather on the water cycle.
4) Chat-bot Uliza-WI provides real-time weather and agricultural advice.
5) The Climate Atlas provides interactive maps and tools to explore climate impacts based on thresholds, supporting climate change adaptation planning.
6) LPJmL model of the Wageningen University is designed to assess hydroclimate impacts on crops and hydrology.
7) MicroStep Company provides “Thunderstorm Forecast” tool for issues accurate thunderstorm forecasts from 30 minutes to one-hour in advance using EUMETSAT satellite data and AI algorithms.

The results of a brief analysis of the information technologies used in agriculture in Russia and abroad allow us to draw the following conclusion. Modern technologies are used in agriculture - AI, modelling, decision support and other breakthrough information technologies. The fact that almost all proposed solutions mention the terms "reducing the impact of weather conditions", "providing advice, and recommendations for decision-making", "reducing damage from natural hazards" and other marketing slang, there are practically no decision support systems operating in real time for all natural hazards. Information on the impacts and recommendations for various natural hazards, levels of danger for agricultural facilities is not formalized in the form of a knowledge base. Possible damage and the cost of preventive actions before the natural hazard are not taken into account. Developments are carried out for individual natural hazards or objects.

Many scenarios for using observed, predicted, and climate data to make decisions in case of natural hazards require to use dashboards that show the past, current, and future state of the environment, interactive maps, DSS. To use HMI correctly, it is necessary to:

– know where the sources of the necessary data sets are, how this data can be obtained, and how best to use it;
– regularly interact with managers and specialists of agricultural enterprises;
– explore the capabilities of existing tools and data that can help predict the impacts of natural hazards on enterprises and the population;
– obtain current and predicted information and understand how this affect agricultural activities;
– accept, that the forecast has a probability and learn to take this into account when optimizing decisions;
– make the request to DSS, in order to issues forecast of impacts to take in case natural hazards and how to prepare for it;
– expand the capabilities of enterprise managers to apply various optimization models.

There are no studies conducted in the world related to the creation of a security system for any natural phenomenon. There are developments only for individual natural hazards.

3 Methodological foundations of adaptation

3.1 General approaches

The following phenomena’s (frosts during sowing, late fruit harvesting, soil freezing, winter crop freezing, droughts, extreme heat, damping off, over-wetting of the soil, dust storms, early snow cover, crust, hail, heavy precipitation) are dangerous for agriculture. Due to accidents on power lines caused by lightning strikes, wind loads on wires and poles, loads on wires due to ice, there is a cessation of electricity supply. These phenomena’s may cause a delay in the transmission of information over overhead communication lines. Harvesting work is affected by ice, strong wind, and precipitation.

Based on meteorological data - the amount of precipitation, air humidity, air and soil temperature, groundwater levels; it is possible to manage a farm using agricultural machinery and an irrigation system. Models help to find connections between specific environmental parameters and the results of activities related to increasing the yield and agricultural products. Continuous analysis of data is necessary, based on which it is possible to take appropriate actions and give instructions to workers to carry out preventive actions for the treatment of agricultural plants. Satellite images, soil data, local weather, weather forecasts provide an understanding of when to plant, fertilize, spray, irrigate and harvest grain crops.

A special feature of taking into account the impact of hydrometeorological conditions on agricultural objects is that hydrometeorological parameters are measured in physical units, and to assess the impact of natural hazards and climate change on enterprises, risk indicators are used. These indicators associated with the wind, moisture, and thermal resistance of objects, the severity or comfort of weather and climate, can be used to assess the level of danger for various objects.

Weather data accounting issues should include the selection of hazard indicators, characteristics of the operation of enterprises, equipment, and technological processes subject to impact of hydrometeorological conditions. In this case, the following tasks must be solved:

– to assess the damage to justify the need for preventive actions;
– to calculate the cost of implementing adaptation actions that increase the safety, reliability and service life of technical devices;
– to optimize adaptation actions according to various criteria - cost, economic feasibility, probability of extreme climatic events, etc.

Improving the design of an object means increasing the safety of its operation when the values of the natural hazard indicators exceed the threshold values. The occurrence of dangerous and extreme phenomena is associated with both changes in climatic conditions and a decrease in the hazard level indicators of the object itself, associated with the aging of the object, severe operating conditions that reduce its safety.

To calculate the natural hazard indicators, the values of climate parameters on a multi-year scale are used, indicating the frequency and probability distribution of meeting certain weather conditions for each observation point. To calculate the hazard indicators before and during the natural hazard, local threshold values for the hazardous level - green, yellow, orange and red.

Adaptation to natural hazards and extreme climatic events consists of:

– clarification of the danger levels of natural hazards and extreme climatic events for various agricultural facilities;
– reducing the time spent in natural hazards, for example, prohibiting or restricting unmanned aerial vehicles flights;
– determining optimal periods of time – “weather windows” – for sowing or harvesting.

To increase the efficiency of using HMI, it is necessary to predict the possible impacts of natural hazards and climate change on enterprises. Knowing the impacts, the DSS make recommendations to on carrying out preventive actions. The amount of expenses on preventive actions should not exceed 30% of the possible damage. It is necessary to accept the possible damage, or improve the facility - increase the resistance of the facility to the impacts of natural hazards and climate change, or clarify the composition of preventive actions, for example, select actions that prevent or significantly reduce the greatest damage.

Existing approaches to assessing the effectiveness of hydrometeorological support include income from a forecast of weather that allows for the reduction of damage through a more accurate assessment of the impact of natural hazards and the implementation of only those actions that reduce the greatest damage.

3.2 Using models to assess damage

Economic losses from natural hazards and climate change depend on the technical and economic characteristics of the impact object:

– the cost of designing and building agricultural enterprises;
– the planned time of its operation;
– the annual profit brought by the enterprise;
– the cost of the facility;
– the probability of an accident from natural disasters;
– the amount of damage from the impact of natural hazards and climate change.

Agricultural insurance focuses on modelling the risk of crop damage due to natural hazards. Profit margins for insurance companies are becoming tighter over time, as insurers need to respond more quickly and accurately to volatility and advances in agriculture. Providing clients with advanced data and insights about agricultural fields is no longer a luxury, but an expectation that insurers will use risk management technologies. Satellite imagery combined with weather data sets and models can help improve operational efficiency, manage risk, and provide informed verification.

Satellite imagery provides a more complete picture of the impact of natural hazards on agriculture, so insurance companies can use such images to plan and manage financial risks. Satellite technologies, including remote sensing images, meteorological data, natural hazards warnings, and historical information from insurance companies, allow insurers to receive real-time information about what is happening in farmers' fields, providing the ability to monitor any weather conditions and properly manage cash flows for possible compensation. The insurance company needs to prioritize claims for their validity and calculate the actual damage. At this stage, it is necessary to track which areas are affected by natural hazards.

A key part of the crop insurance market is the procedures an insurance company takes for accurately assess risks. Crop insurance contracts involve many parameters, insure a wide range of objects - agricultural machinery, farm infrastructure; people - health, and be made for crop and orchard types for specific natural hazards and the overall risk. Using remote sensing data, surface weather data, and models combined with AI, it is possible to provide farmers with accurate and localized information about the potential impacts of specific natural hazards on their crops and what needs to be done to reduce or prevent these impacts. In many cases, damage assessments can be made to determine whether preventive actions are worth taking or whether it is better to pay out insurance to the farmer.

With the help of models it is possible calculate the insurance amount and damage from the loss of agricultural crops due to flooding, under flooding and unharvested crops, loss of net income due to the loss of agricultural products, and a decrease in crop yields due to under watering of irrigated lands. The calculation of the insurance amount and damage is given in [6, 7].

Damage from the loss of agricultural crops due to flooding and unharvested crops, including berry fields, orchards, vineyards and other fruit-bearing plantings ($\mathbf{U_{sk}}$) is calculated using formula (1) [8]**:**

$$\mathbf{U}_{\text{ск}} = \text{C}_{\mathbf{p}} * \mathbf{S} + \boldsymbol{Z}_{\text{м}} - \text{C}_{\text{тр}} \quad (1)$$

where, the cost of completed agricultural work (plowing, harrowing, sowing, watering, fertilizing, pest control, post-irrigation treatment, rolling, etc.) for one ha ($\mathbf{C_p}$)**;** material costs (cost of seeds, fertilizers, pesticides, etc.), ($\mathbf{Z_м}$); crop area (**S**); State Insurance payments ($\mathbf{C_{тр}}$)**.**

Lost net income due to the loss of agricultural products – grain, berries ($\mathbf{D_{sk}}$) is calculated using formula (2):

$$\mathbf{D_{sk}} = \mathbf{D_{sr}} * \mathbf{V} \quad (2)$$

Where **V** is the volume of production, $\mathbf{D_{sr}}$ is the average total net income per unit of production for previous years.

In agricultural production, it is inevitable damage from natural hazards is determined by:

– the destruction of agricultural products - grain, grass, berry bushes, orchards, vineyards - due to flooding, under flooding;

– siltation of floodplain hayfields and pastures; washing away of the fertile layer of arable land;

– spoilage, loss of stocks of grain, seeds, hay and other harvested agricultural products in natural and processed form;

– loss of net income due to a decrease in crop yields due to under-irrigation of irrigated lands as a result of the destruction or damage of water intake structures;

– compaction of soils and grounds, deterioration of the melioration condition of arable lands of perennial plantings;

– additional work when growing agricultural crops located in the flood zone;

– loss of net income due to the loss of agricultural products - grain, berries;

– destruction of stocks of fertilizers, pesticides, and petroleum products;

– loss of produced grain, berry of agricultural enterprises;

– loss of land as a result of the construction of engineering protective structures in the landslide zone**;**

– withdrawal of agricultural land.

– Examples of formulas for calculating costs for preventive actions given in Table 1.

3.3 Cost calculation of preventive actions conducting

In order to make a decision, in addition to the possible damage, it is necessary to know the cost of preventive actions. To assess the economic contribution of preventive actions, it is necessary to calculate what damage will occur if the action is not taken. To assess the damage, it is necessary to evaluate the features of the impact of natural hazards on the object under various natural hazards and climate changes. The monograph [8] describes methods for assessing the economic efficiency of hydrometeorological support, taking into account the impact of meteorological factors and economic indicators. Immediately before natural hazards with use forecast are apply tactical preventive actions; during natural hazards based on observed data use operating actions; after natural hazards based on observed and forecast data apply operational and tactical actions; long before possible manifestation natural hazards based on climate data apply strategic actions.

For many natural hazards, existing forecasting methods do not always provide accurate results, and the manager faces a dilemma: to apply or not to apply protective actions when forecasting the occurrence of natural hazards. To assess the need for preventive actions, the manager requires information in the form of the cost of preventive actions to prevent damage. The solutions proposed by the DSS may not take into account many aspects of production activities. Depending on the chosen goal, the list of criteria for achieving the goal will vary.

Table 1 – Examples of formulas for calculating costs for preventive actions

Possible costs	Indicators for calculation	Formula
Evacuation costs (**Z_e**)	The cost of one passenger seat on different types of transport (**S_{pass}**), the number of people evacuated from the danger zone (**M_e**)	**Z_e=M_e*S_{pass}**
Costs of treating the wounded (**Z_1**)	Average cost of treatment (**S_l**), number of injured (**M_r**)	**Z_l=M_r*S_l**
Costs of operating equipment used to carry out preventive actions or emergency recovery operations (**Z_{et}**)	Cost of operating the involved equipment per machine shift (**S_{et}**), number of spent machine shifts (**Ch**); number of involved equipment (**K**)	**Z_{et}=Ch*K*S_{et}**
Costs for preventive actions for removal of property (**Z_p**)	Cost of removal of 1 ton of property (**S_{in}**), weight of removed (moved) equipment (**V**)	**Z_p =V*S_B**
Costs of covering materials (**Z_y**)	Cost of covering materials (**S_y**), area of covering (**S**)	**Z_y =S_y*S**
Costs of forced movement of material and technical resources (**Z_m**)	Cost of work on moving for one hour (**S_p**), number of hours spent on moving (**C_h**)	**Z_m=C_h*C_p**

4 How to organize the adaptation of agriculture?

The methodology for creating a DSS for assessing the impact of natural hazards on various types of activities is presented in the monograph [6]. With the help of geographic information systems, agricultural companies analyses data on precipitation in the winter period; snow reserves; soil temperature and other indicators.

Even when planning vegetable plantings in greenhouses, climatic conditions and the forecast of air temperature and the number of hours or days with sunshine are taken into account. The available data allow choosing the most favorable weather option for planting, taking into account the plant's requirements for degree-days of heat, the number of sunny days, and possible heat costs for heating greenhouses. After deciding to grow a crop in a given area, it is necessary to compile a list of detailed instructions for greenhouse employees responsible for planting, indicating forecasts of possible environmental impacts. In this case, a short-term weather forecast is taken into account for the planting date and the first week after planting, so that there are no abnormal temperatures during this time, a short-term weather forecast for 7-10 days for the implementation of agricultural actions and a long-term forecast for a month for planning such actions. Monitoring environmental indicators inside the greenhouse - microclimate and outside it - humidity, illumination, air and soil temperature, wind speed allows you to automatically monitor the dynamics of indicators and highlight deviations from specified threshold values. The latter shows information on the possible impacts of these deviations and provides recommendations for decision-making - choosing the most effective methods of applying fertilizers and plant protection products, optimizing the timing of agricultural work.

The DSS uses operational observed data; forecast data in regular grid nodes integrated into the ESIMO from the Hydrometeorological Center of Russia; climate data (norms, extremes, repeatability, probabilities, etc.). The data comes from the ESIMO integrated database in the form of hazardous levels for each natural hazard, different activities type. Hazardous levels are determined based on a knowledge base of local threshold values for typical objects and activities.

The hydrometeorological support uses such means of disseminating data and information products as the Global Telecommunications Network, subscription to data delivery, web-services, REST-services, WMS-services, E-mail, FTP-server for receiving operational and forecast data. The following services are created, to improve the efficiency of the hydrometeorological support:

–automatic identification of situations dangerous to plants based on local threshold values of indicators;

–automatic delivery of messages about natural hazards to consumers for specific agricultural enterprises;

–providing information on the state of the meteorological situation in the form of an dashboard with indication of the main parameters in the form of a danger level - yellow, orange, red and graphs of their change over time;

–obtaining more detailed information about the current and forecasted situation in the region using the MeteoMonitor application;

–automatic delivery of data to enterprise information systems;

–providing forecasts of possible impacts and obtaining recommendations for decision-making;

–optimization of decisions based on the “ratio of the cost of preventive actions to the amount of damage”, which should be less than 30%.

Based on the observed and forecast data, stations are identified where natural hazards affecting specific agricultural facilities are occurring or will occur. It is necessary to use both storm warnings sent by synoptic groups and observers at stations and the detected deviations of environmental parameters from climatic values or local threshold values. Information about natural hazards is automatically sent via SMS messages indicating the name of the facility, type of activity, name of the indicator, value and level of its danger. The message contains links to the dashboard, Information Panel, MeteoMonitor services for more detailed information on the current situation and to the DSS for information on impacts and recommendations. The information panel includes data for a point or area, the information is displayed on the screen in a compact form. The MeteoMonitor application is designed for a more detailed familiarization with the hydrometeorological situation at a point or in space in the form of natural hazards distribution map. In addition to the map, MeteoMonitor application is a graph of the change in the natural hazard indicators over time, tables of values of environmental parameters at the observation point or at the point of the regular grid closest to the object with an indication of their values. The level of danger is indicated in messages and warnings about natural hazards using color and sound.

An example of information from the description of the natural hazard “Damping off” is presented below:

Information type: forecast.

Indicators: height of snow =>30 cm; soil temperature = -0.5 … 0.5 C.

Impact:

Plants:

Snow will remain on unfrozen soil all winter.

A delicate greyish-whitish cobwebby coating of the fungus can be seen on winter wheat and rye plants after the snow melts [9].

Water splashing may cause soil to move from diseased to healthy plants, thus facilitating the spread of the disease [9].

Plants may become weakened and die from damping off.

The nutrient utilization rate of crop plants during the summer period will be lower than planned.

Root system damping off may occur if the soil is too moist.

No increase in yield is expected past warm winter.

Recommendations:

Heads of agricultural enterprises:

Choose the right place for planting.

Pinch the tops of the shoots to stop growth and speed up tissue maturation in young, rapidly growing plants in the second half of August.

Set aside additional funds for feeding plants with nutrients.

You should not delay applying nitrogen fertilizers, which delay growth.

Fertilize in early spring.

Do not water the plum tree at all in a year with normal moisture after harvesting.

Mow the plants in advance so that the grass can get strong before the frost sets in.

Use crop rotation with grain crops and soil fumigation.

Irradiate the soil with sunlight.

Improve soil drainage by using raised seedbeds.

Improve sanitation conditions in greenhouses, including the use of sterilized seedling trays and proper soil sterilization.

Conduct good pre-sowing soil cultivation.

Apply the full rate of organic fertilizers, which ensures normal plant development and reduces crop infestation.

Conduct pre-sowing treatment.

6 Conclusions

A knowledge base of local threshold values of indicators of agricultural hazards and a database of information on the impact of natural hazards on the activities of agricultural enterprises and recommendations for decision-making before, at the time and after the natural hazard at three levels of danger have been created.

Notification of agricultural producers about agrometeorological conditions should be based on the identification of natural hazards for a particular type of activity or the state of grain growth. This ensures that current and forecast data are used for decision-making and the inclusion of forecasting models based with use an artificial intelligence. The legal significance of the provided information must be ensured, this is necessary, in particular, for interaction with insurance companies.

It is necessary to use:

– high-resolution spatial data taking into account industry specifics;

– ensure the possibility of selecting the best areas for introduction into agricultural circulation;

– provide interfaces for providing up-to-date information from the agricultural producer.

Because of the implementation of such hydrometeorological support technology, agricultural producers will increase the awareness of enterprise managers due to the rapid delivery of data, its compact visualization with an indication of the level of danger.

There are no studies in the world related to the creation of a DSS for any natural hazards. There are only developments for individual natural hazards. There is also no formalization of impacts and recommendations in the form of descriptions of situations for various levels of danger. To create a DSS, it is necessary to:

– collect information on the possible impacts of natural disasters on agricultural activities and recommendations for preventive actions;

– organize flows of operational HMI in the form of storm warnings or observed data;

– learn to identify natural hazards by dangerous levels based on the received operational and forecast data;

– obtain descriptions of the corresponding situation with possible impacts and recommendations.

The prospects for research in the field of creating a DSS in the agricultural sector are:

– development of software for autonomous detection of natural hazards;

– implementation of models for assessing the impact of natural hazards on agriculture to clarify their influence on various stages of crop growth, as well as models for optimizing decision-making taking into account the probability of natural hazards and their risk;

– use of artificial intelligence methods and tools to collect and formalize information on impacts and recommendations.

Information for climate change, used for impacts assessment, are delivering as ready-made statistical characteristics - climate norms, extreme values of parameters, their repeatability and the probability of occurrence of natural hazards.

Models for assessing impacts, calculating the cost of preventive measures and optimizing solutions are supposed to be used in further research on the development of DSS.

If agricultural managers treat environmental impact forecasts as weather forecasts, they will benefit.

Reference:

[1] Services of the Hydrometeorological Center of Russia. URL: http://meteoinfo.ru (Access date 24.02.2025)

[2] ESIlMO. Unified system of information about state World Ocean. URL: http://esimo.ru (Access date: 24.02.2025)

[3] Scientists from Skoltech and Sber have learned to predict droughts a year in advance. URL: https://new.skoltech.ru/news/ai-predicts-droughts-year-advance (Access date: 24.02.2025)

[4] Er-Telecom to monitor weather in Bashkortostan. 30.03.2022. https://www.cnews.ru/news/line/2022-03-30_er-telekom_prosledit_za (Access date: 24.02.2025)

[5] African Climate Atlases empower local practitioners for sustainable climate adaptation. https://www.safe4allafrica.eu/african-climate-atlases-empower-local-practitioners-for-sustainable-climate-adaptation (Access date: 24.02.2025)

[6] Viazilov E.D. *Digital transformation of hydrometeorological suppor*t. Obninsk: RIHMI-WDC, T. 1. 2021, 356 p.; 2022. T. 2, 2021, 355p.

[7] All-Russian Insurance Company “Insurance House”. https://www.vsk.ru/ (Access date: 24.02.2025)

[8] Khandozhko L.A. *Economic meteorology*. St. Petersburg, Gidrometeoizdat, 2005, 490 p.

[9] Tomato Disease. *Guide A Practical Guide for Seed Growers*, Vegetable Growers, and Agricultural Advisors. Edited by Brad Gabor, Seminis Vegetable Seeds, Inc., 1997, 81 p. https://semenashop.by/assets/images/pdf/Tomato.pdf