Information-measuring system for monitoring the sanitary condition of tree stands

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***Abstract**: The article presents the results of the development of an information-measuring system for monitoring the sanitary status of tree stands. The main purpose of such a system is to minimize the impact of the operator on the results of monitoring the sanitary status of tree stands by indirectly controlling the quality characteristics of the tree sap (by establishing the dependence of these characteristics on climatic factors) with the possibility of remote monitoring and control of the process of express control. The developed monitoring system allows to conduct a contactless (remote) survey of sensors, which are recorded in close proximity to the root system of selective trees from an array of tree plantations, and further, by mathematical treatment of climatic characteristics (acidity and salinity index, air temperature) zoning temperature health status. The system also allows you to predict the dynamics of extending the areas of tree planting. This enables those responsible for tree planting to take preventative measures to prevent such droughts. The main advantage of the developed information measurement system is its complete computerization, which eliminates a number of external subjective influences by the operator or the responsible person (necessity of visual inspection of the maximum number of trees in the array, erroneous perception of visual information, etc.). This, in turn, avoids systematic methodological errors, thereby improving the accuracy, speed and reliability of the monitoring and control results of this system.*

***Keywords**: INFORMATION-MEASURING SYSTEM, MONITORING, SANITARY CONDITION, TREE PLANTINGS, MEASUREMENT, CONTROL*

1. Introduction

Recent changes in climate change in the world have a negative impact on the health of the forest plantations. So, in 2019 alone, fires that have occurred around the world (the largest of them: Australia, October 2019 - January 2020; Amazon, January-August 2019; Russia, May-October 2019) have destroyed more than 20 million hectares of forest (about 0,5% of the total area of world forest plantations) [1]. The cause of forest fires, in addition to abnormally high temperatures and dry climate, is forest cover, lack of care for the sanitary condition of trees, and an anthropogenic factor [2].

In addition to forest fires, factors such as deterioration of soil composition (hydrogen index, salinity, etc.), pest propagation, etc. have a negative impact on the sanitary condition of trees [3, 4]. However, the study of the sanitary status of tree plantations and their further zoning for preventive and sanitary measures is still limited by the method of visual observation [5], as well as by a number of methods (resistographic, boroscopic and other) that do not allow to quickly and accurately determine the sanitary condition of trees on large lands [6-8]. Thus, studies of the sanitary condition conducted in the works [9-12] by scientists: Oliynyk V.S., Sklyar V.G., Antsiferov A., Meshkova V.L., Keeley J.E., Ciesla W.M., Ross R. and others, devoted mainly to the development of theoretical-experimental methods for individual trees.

At the same time, with the development of measuring methods and technical means for their implementation, there is an urgent need for prompt and high-precision monitoring of the sanitary status of tree stands.

Therefore, the purpose of this work is to develop and test an information-measuring system (IMS) for monitoring the sanitary status of tree stands by applying modern approaches and computer hardware, which allows to minimize the influence of subjective factors, to increase the accuracy, reliability and speed of monitoring results to predict the zoning of tree plantations by categories of their health status.

2. Development of information-measuring system of monitoring

Selection and justification of a complex of functional tasks for monitoring the sanitary condition of trees are one of the most important elements of creating information-measuring systems. The analysis of functional problems [13] indicates that their practical implementation in the conditions of information-measuring systems is multivariate. The same problem can be implemented by different methods, models and algorithms.

There are banks of models and algorithms, from which in the process of development of IMS choose the most effective for a specific object of management.

Virtually all data processing systems, regardless of their scope, contain the same set of components (components) - types of security. For the developed class of information and measurement systems, the following types of security should be noted: information (a set of methods and means for information placement and organization, methods for creating and placing an information database of the IMS measured data); methodological (a set of methods and means of their implementation - techniques, testing devices and stands, models, etc., which allow to monitor the determined parameters with minimal errors); software (computer implementation of the IMS architecture, which ensures its maintenance, optimization and protection of the received data, ensuring its integrity, as well as conducting error-free exchange of information between IMS units); technical (set of technical means: sensors, communication units, data storage and processing, etc.). The reliability and quality of the decisions made by the IMS in the process of zoning and forecasting of the sanitary status of tree plantations depend significantly on the quality of the developed provision.

Therefore, in order to observe the most rational structure of providing the developed IMS, minimize the impact of the operator on the results of monitoring, as well as to control the sanitary condition of tree stands with the possibility of remote monitoring and control of the process of express control, in the work it is proposed to automate the process of monitoring the quality characteristics of soil characteristics) survey of sensors that are introduced into the sample trees from the array of tree stands, and further, by mathematical arrays Blennes quality characteristics of wood juice (pH acidity, sugar content and viscosity) to conduct zoning tree plantations by category sanitary condition (fig.1).

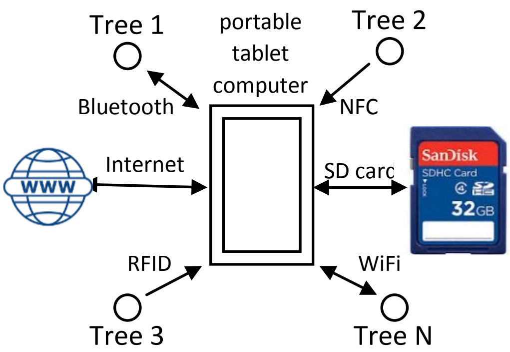

Fig. 1 *Scheme of remote survey of IMS gauges and their acquisition of soil status in close proximity to the root system of trees*

According to the scheme, Fig. 1, it is proposed to develop a set of equipment for the creation of IMS system for monitoring and control of the sanitary status of tree stands, which is a two-tier client-server multi-server model, where the server (portable tablet computer) acts as a server, and as clients that have the same priority in transmitting information.

As a result of this development, hardware and software and mathematics will be created for the IMS, which will improve the accuracy, reliability and speed of research results, fig.2.

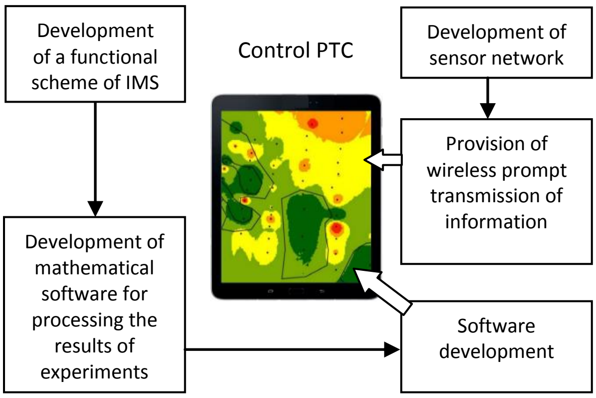

Fig. 2 *The sequence of development of the IMS monitoring the sanitary status of the plantations*

The monitoring process begins with the establishment and orientation of acidity and soil salinity sensors, as well as a precision temperature meter. This is the only process that cannot be performed without the involvement of the operator. After the sensors are installed, they are tested using test samples. Such samples shall be at least five in order to avoid the likelihood of subjective errors and unpredictable human factors (erroneous installation of a temperature sensor in a place subject to direct sunlight, or installation of pH / salinity sensors in a place with artificially disturbed soil). If the test results do not match with the visual assessment of the sanitary condition of the tree, a signal is issued to the system, requiring the operator to replace the location of the measuring sensors.

After a test check, the IMS allows you to start the monitoring process automatically in the following sequence.

The controller sends a request to the external sensors to obtain the necessary data.

The encoder accepts the request, processes it and sends to the control device the data on which it received the request.

The client-server two-tier model is optimal for tasks with a number of external sensors less than 100, since the server operating system will overload the server with a large number of client connections when servicing a large number of clients.

Such a client-server IMS has several advantages over other IMS architectures. First, network traffic when querying is reduced. Second, the client-server architecture becomes irreplaceable when the number of interrogated sensors exceeds 10-15. Another advantage of the client-server architecture is the extensive ability to manage user privileges and permissions to various database objects, backup and archive data, and optimize query execution.

Thus, the developed IMS allows not only to automate the process of monitoring the sanitary status, but also to predict changes in this state in the selected area of plantations.

Development of the functional scheme of the monitoring system. The electronic measurement unit is the link between the control panel and specially designed ion-selective measuring sensors [14]. It contains electronic circuits that receive and process the input data from sensors by the control panel commands, as well as transmitting the measurement data to the control program, Fig.3.

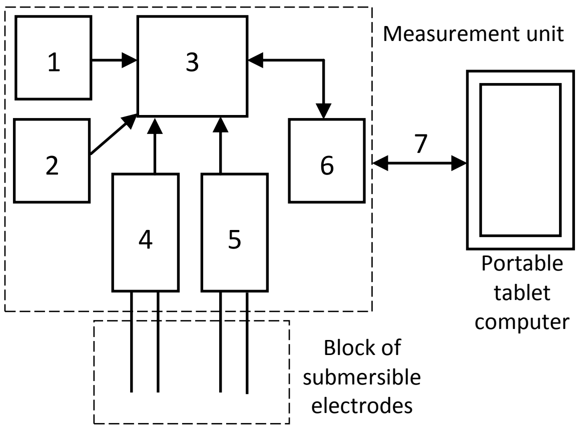

Fig. 3 *Structural diagram of the developed information-measuring system: 1 – portable power supply; 2 – tempera-ture sensor; 3 – module control unit of measuring sensors; 4 – pH sensor; 5 – salinity sensor; 6 – PTC remote control module; 7 – wireless data channel*

The electronic control unit consists of six functionally completed modules: portable power supply (1); sensors: temperature (2), acidity (4) and salinity (5); the sensor module control unit (3) and PTC remote control module (6).

The measurement unit communicates with the control unit (PTC) via the wireless data link (7). The electronic unit of measurement works as follows. Request commands from the PTC control program are sent via the wireless communication channel (depending on the schematic design of the unit of measurement – WiFi, Bluetooth, etc.) (7) to the module of wireless communication of the unit of measurement (6) and are transmitted over the common bus to the microcontroller module control of the sensor unit (3), which integrates all the unit's measuring modules. The common 16-bit bus contains a 3-bit address bus, a 10-bit data bus, and a 3-bit control bus. The portable power supply (1) is intended to supply the electronic elements of the unit of measurement and is selected from the condition of the longest possible conservation of electrical energy.

In the absence of a request from the control unit (PTC) in accordance with the set initial parameters, the control unit of the measuring sensor unit (3) is in "sleep" mode with minimum energy consumption, information from external sensors to the control module is not received.

In the case when a request for information about the status of the measuring sensors is received from the control unit (6) from the control unit, the module of control of the unit of measuring sensors (3) enters the operating mode of power consumption and begins to analyze the signals about the operating status from the temperature sensors (2), acidity (4) and salinity (5) and generates a signal describing the operating "x111" or emergency mode for all "x000" or for some sensors (e.g. emergency mode of the acidity sensor "x101") and via the remote module connection (6) transmits this information to the control device. According to such information, a database is formed on the coordinates of the location of the measuring sensors and their performance.

When a request for measurement information is received from the control unit (6) from the control unit, the control unit of the measuring sensor unit (3) starts to receive information from temperature sensors (2), acidity (4) at a time (at least nine cycles) and salinity (5) and, by the average value obtained, generates an 8-bit signal about the average value of each of the measured indicators (ninth and tenth bits – information indicating the parameter that is transmitted: x01 – temperature; x10 – acidity, x11 – salinity) which is transmitted through the data bus in module remote connection to the PTC (6) and then through a wireless data channel (7) – the control unit. According to the information obtained, the dependence of the distribution of tree plantations on the zones corresponding to different categories of sanitary status is being constructed.

In general, the developed IMS allows to control the processes of scanning the measuring blocks, obtaining and processing the measured information, as well as carrying out graphical zoning and further prediction of the sanitary state of tree stands without the participation of the operator and allows to solve the problem of insufficiently flexible communication between the control unit and the measuring channels ulcer. The functional scheme of the IMS of the sanitary status of the plantations is shown in Fig. 4.

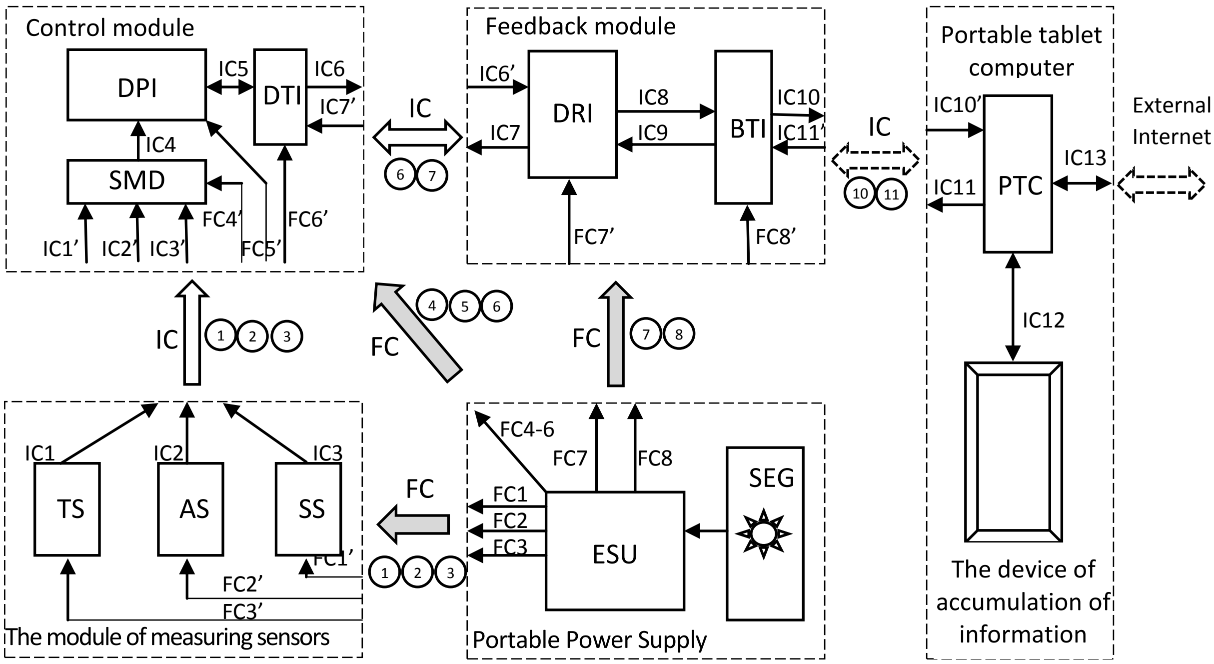

Fig. 4 *Functional diagram of the information-measuring system of sanitary state of tree stands:*
ESU – energy storage unit; TS – air temperature sensor; AS – soil acidity sensor; SS – soil salinity sensor; SEG is a source of energy generation (for example, a piezoelectric cell or a solar cell); BTI is a block of remote transmission of information; IC – information channel; FC – feed; DRI is a device for requesting information; DPI – the device of preliminary processing of information; DTI is a device for transmitting information; SMD is a signal matching device

The IMS functional circuit consists of five blocks, the main purpose of which is as follows:

1. Portable power is the primary IMS. It consists of two units – an optional (but one that significantly extends the reliable life of the measuring unit) – an energy source that can be used, for example, a piezoelectric element [15] or – a solar battery; and an optional battery pack (such as an electrolytic capacitor or battery). The device works to provide the required energy to the main modules of the measuring unit through the FC1-FC8 power supply channels. There is no information exchange channel between the power source and other system modules.

2. The module of measuring sensors is intended for prompt collection, digitization and transmission of information from sensors of air temperature (TS), acidity (AS) and salinity (SS) of the soil through information channels IC1-IC3 – to the control module. There is no feedback in this module (due to the requirements for simplifying circuit design and minimizing power consumption). The module's devices are powered through three low-voltage power supplies FC1-FC3.

3. Control module: intended for scanning of measuring sensors and preliminary processing of measured values. The main units of this unit are: an SMD signal matching device representing a switch of information signals coming from a module of measuring sensors; a DPI pre-processing device, in which the received information about the state of the sensors is checked for correctness and efficiency, as well as the average value of the measured parameter is determined and a 16-bit information signal is generated; The DTI is intended to transmit a previously generated signal through the IC6 communication channel to the feedback module. On the contrary, from the feedback module to the DTI via

the information channel IC7', a signal is sent to request information exchange between the measuring unit and the PTC.

Thus, this unit has seven communication channels, of which two channels for exchange with internal devices (one-way IC4 channel for transmitting a matched signal from the SMD matching device to the DPI processing device; two-way IC5 channel for exchanging information between the DPI and the transmission device DTI) and with external modules: four receive channels (IC1'-IC3' – from the sensor module, IC7' – request from the feedback module) and one transmission channel (IC6) per feedback module.

The devices of this module are powered through three low-voltage power supplies FC4-FC6.

4. The feedback module is designed to provide and ensure uninterrupted and reliable feedback between the measuring unit and the control unit. Thus, through the information channel IC11', the request for the provision of one or other information from the PTC is sent to the block BTI, in which the received radio signal is converted into an electrical pulse, which, via the information channel IC9 goes to the device request information. After processing the last received request, it is transmitted through the IC7 channel to the control module, as a set of data representing the request for information received. Back from the control module on the information channel IC6' formed information through the requesting device, and then, the channel IC8 enters the transmission unit BTI, in which the conversion of the wire signal to a wireless radio, and then transmit it to the control PTC. The module devices are powered by two low-voltage FC7-FC8 power supplies.

5. The PTC control is a core element of the IMS under consideration, which coordinates the operation of the software for defining tree areas by category of sanitary condition and measurement unit that generates the initial data of the monitoring process, allows to accumulate, process, analyze and store the results obtained.

The measurement unit requests information directly from the PTC (IC11 information channel) using wireless technologies (WiFi, Bluetooth, and more). On the other wireless channel IC10' receiving information received from the measurement unit. In addition to the command and control functions and functions of the information exchange from the unit of measurement, other functions are provided in the control unit. Thus, with the help of two-sided information channel IC12, received, processed and generated data can be stored on an external storage device (usually an SSD card). Another two-way IC13 information channel, the generated data set may be transmitted over the Internet to a remote ("cloud") medium where it will be stored and used from any Internet address that has access to this database.

The main advantage of using the proposed IMS scheme is the ability to remotely interrogate the sensors located in a sufficiently large area (modern high-frequency radio means allow you to connect and exchange information between devices from a distance of 150 meters to several kilometers), as well as full automation of the process of receiving, processing and visualization of information on the sanitary status of tree stands, which eliminates a number of external influences on the part of the operator (manual adjustment of measuring systems, entering false data, etc.). This, in turn, will avoid systematic methodological errors, which will increase the accuracy, speed and reliability of the results of operational control.

It is the application of the article developed by the authors of IMS monitoring that reduces the time of inquiry and feedback by 3 – 4 times, thus ensuring timely correction of the calculation equation and selection of the most rational modes of IMS operation. This increases the measurement accuracy by 12.5 – 15%, the research speed by 65 – 80% and provides high reliability of all blocks of the system (the probability of trouble-free operation increases from 0.89 – 0.93 to 0.95 – 0.97). To quickly save and accumulate the results with their further study and analysis, PTC has a remote Internet connection to an external storage server, which can be accessed quickly from any PC, such as "cloud" data exchange technologies.

Software of information-measuring system of monitoring. The developed IMS is a highly intelligent measurement and control tool whose development is correlated with the development of computer technology. Modern software expands the research capabilities of such a tool.

Specialized software developed on the basis of a special Java programming language specifically for the operating system of most modern Androide tablet computers, which can be used for scientific research on the health of tree plantations. It is a convenient tool for debugging, diagnosing, selecting optimal research modes and processing results.

A distinctive feature of this software implementation compared to existing software products today is the ability to conduct research in automatic mode. On the other hand, even if third-party interference with the monitoring system setup is required, the operator can manually select the study modes, try them out on the test samples and enter them in the database for future use. Another advantage of the developed software product is the ability to save the device configuration results and research results on a remote server, which allows you to retrieve this data from any PC connected to the Internet.

In general, using the developed software greatly simplifies the work of the IMS operator, both at the stage of its debugging and at the stage of scientific research.

Object-oriented programming (OOP) is based on the model of program construction as a set of objects of abstract data type. Object-oriented development defines the types that define the objects of the problem. Operations in object types, as well as functions in procedural programming, are abstract operations that solve programming problems. An object type can serve as a module that is used to solve another problem of the same type. Objects define both the structure of the data about the object and the operations that can be performed on the object. OOP is often used as a Java language, which combines several of the most important modern technologies: a high-performance compiler into machine code, an object-oriented component model, visual application building from software prototypes, scaling of database building tools.

Also, Java supports such low-level features as subclasses of Androide and Windows controls, overlapping of message processing cycle, use of the built-in assembler.

Due to the advantages described, IMS uses the Eclipse development environment as a writing tool for information processing software.

The operating instructions of the control program will help the user to master the work of IMS and make adjustments, choose the optimal modes, and also to establish the work in the remote-remote mode [16].

Thus, it can be concluded that the advantage of structure and software implementation of software based on object-oriented language "Java" to support the developed IMS is its relative simplicity, easy adaptation to different systems of interpretation ("Builder J", "Eclipse", etc.) in various versions of the Androide operating systems, as well as the possibility of further development of this software by adapting it to Web-technologies, which will greatly improve the reliability and adaptability of the software to modern virtual technologies (including "cloud").

4. Testing of the information-measuring system of monitoring

Monitoring using the developed IMS eliminates the operator's external influence (setting up and collecting data using the IMS), eliminates the need to connect to an external storage server, and minimizes the energy and time spent on data acquisition and storage. The operator only has to follow the established route with the IMS control unit included and further launch of specialized software that conducts zoning and forecasting of the distribution of tree plantations by categories of sanitary condition.

The principle of the developed IMS is as follows: the operator, after arriving at the location of the information capture and pre-configuring the control device, downloads to it a developed software application, in which, selecting the necessary parameters, starts the monitoring process. After that, the program automatically generates a set of commands transmitted to the measurement unit. Further, the control device is decoding the received commands and generating data for calculation and simulation. Upon completion of the on-going monitoring process, the accumulated data is processed by specialized software, with the help of which visualization of sanitary areas of tree stands is rendered.

It is this configuration of the IMS that can significantly speed up the processing and transmission of data between the PTC and the unit of measurement (from 2.0 – 3.5 s to 0.5 – 1.2 s); avoid a number of hardware failures leading to monitoring errors, which will increase the accuracy of the results by 12.5 – 15%; automate and speed up the operation of the device by 65 – 80%, eliminating the influence of the operator on the monitoring process.

According to the selected topology, the PTC requests a measurement block, the latter receives and returns information to the PTC. At the same time, the PTC can process up to a hundred requests, so a control unit that is on the same network as the measuring unit allows it to be effectively administered and configured. As the measuring unit is constantly under information load (even in the case of "sleep" mode - information is constantly supplied to the control module from the measuring sensors), for example, a set of wireless standards is selected as a configuration that can simultaneously serve the maximum number of users. IEEE 802.11 Series (a, ac, b, g, n).

Thus, the implementation of the developed IMS monitoring was to create a measuring unit to determine the climatic factors (air temperature, soil acidity and salinity), the appearance of which is shown in Fig.5.

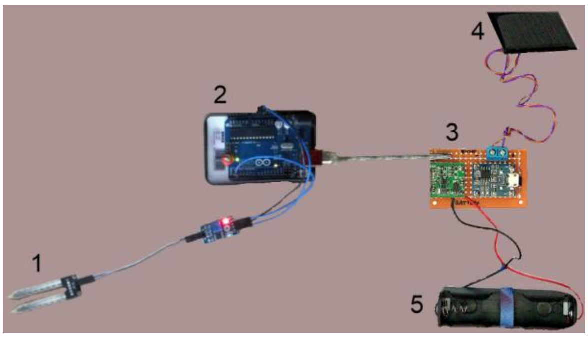

Fig. 5 *Appearance of the measuring block (without the case) of the information-measuring system for monitoring the sanitary condition of tree stands: 1 – measuring electrodes; 2 – control module; 3 – feedback module; 4 – solar battery; 5 – block of energy storage*

During the testing of the developed IMS monitoring, the site of the Park “Sportyvnii” (Cherkasy), approximately 0.1 hectare, was investigated. The results of this test, namely the zoning of tree plantations in this area by category of sanitary condition, are shown in Fig.6.

Fig.6 *The results of the zoning of tree plantations on the site of the Park “Sportyvnii” (Cherkasy) by sanitary status categories (from 1 category (completely healthy tree state) – green zone, to 6 categories (tree perished) – red zone; red crosses – checkpoints definition*

To confirm the adequacy of the obtained results, a control check of the sanitary condition of the trees in the studied area was carried out using the traditional – visual method. Such a control test showed a high convergence of observation results (the correlation coefficient for the monitoring results obtained by the above methods was 0.89), and the discrepancy in the points of establishment of the measurement unit according to the developed IMS monitoring did not exceed 5.1%.

Thus, the paper proposes a fundamentally new approach to the construction of information-measuring systems and monitoring and control systems, which may consist of equipment spaced territorially, and which can be integrated by wireless communication channels, which improve the speed of information retrieval by the measuring system, minimize the impact of subjective factors, increase the accuracy and reliability of results, in particular when dividing tree plantations by category of sanitary condition.

5. Conclusion

The article presents the results of development and testing of information-measuring system for monitoring the sanitary condition of tree stands, the main purpose of which is to improve the accuracy, reliability and efficiency of monitoring the sanitary condition of tree stands and minimize the impact of the operator on these results by controlling the quality characteristics of the tree and managing the express control process.

The information-measuring system allows to predict the dynamics of expansion of areas of drying of tree plantations, which enables the persons responsible for tree planting to apply preventive measures to prevent such drying.

Through experimental testing it is proved that the developed information-measuring system of monitoring and control allows to automate the process of control, which significantly increases the speed of the study (3 – 4 times) and the accuracy of the obtained results (by 12.5 – 15%), and also provides high reliability of all units of the system (the probability of failure-free operation with increases from 0.89 – 0.93 to 0.95 – 0.97).

6. Literature

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