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KO'P YILLIK DARAXTZORLARNING MONITORING QILISHNING ILMIY-NAZARIY ASOSLARI

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Ushbu maqolada ko'p yillik daraxtzorlarni monitoring qilishning hozirgi holati, usullari, texnologiyalari va metodologiyalarining samaradorligi tahlil qilinadi. Maqolada ekologik barqarorlikni ta'minlash va resurslarni tejashda monitoring tizimlarining muhim o'rni va zamonaviy texnologiyalarning qo'llanilishi yoritilgan. Ko'rsatilgan monitoring metodlari, jumladan, masofaviy monitoring, dronlar yordamida kuzatish, GIS texnologiyalari va sensorli tizimlar yordamida daraxtzorlarning ekologik holati aniqlanadi. Olingan ma'lumotlar orqali ekologik tizimlarning holati va o'zgarishlar tahlil qilinadi, shu bilan birga, yangi texnologiyalarning qo'llanishi ekologik va iqtisodiy samaradorlikni oshirishga yordam beradi.

Kalit so'zlar: Ko'p yillik daraxtzorlar, monitoring texnologiyalari, ekologik barqarorlik, GIS texnologiyalari, masofaviy monitoring, dronlar yordamida kuzatish, sun'iy yo'ldosh tasvirlari, ekologik boshqaruv, iqlim o'zgarishlari, barqaror rivojlanish.

В статье анализируется современное состояние мониторинга многолетних древостоев, эффективность методов, технологий и методик. В статье подчеркивается важная роль систем мониторинга и использования современных технологий в обеспечении экологической устойчивости и экономии ресурсов. Экологическое состояние рощ определяется с использованием указанных методов мониторинга, включая дистанционный мониторинг, наблюдение с помощью беспилотников, ГИС-технологий и сенсорных систем. Полученные данные позволят проанализировать состояние и изменения экологических систем, а использование новых технологий будет способствовать повышению экологической и экономической эффективности.

Ключевые слова: Многолетние леса, технологии мониторинга, экологическая устойчивость, ГИС-технологии, удаленный мониторинг, наблюдение с помощью беспилотников, спутниковые снимки, экологический менеджмент, изменение климата, устойчивое развитие.

This article analyzes the current state, methods, technologies and methodologies for monitoring perennial tree plantations. The article highlights the important role of monitoring systems and the use of modern technologies in ensuring ecological sustainability and saving resources. The ecological state of tree plantations is determined using the specified monitoring methods, including remote monitoring, drone monitoring, GIS technologies and sensor systems. The obtained data are used to analyze the state and changes in ecological systems, while the use of new technologies helps to increase ecological and economic efficiency.

Keywords: Perennial tree plantations, monitoring technologies, ecological sustainability, GIS technologies, remote monitoring, drone monitoring, satellite imagery, ecological management, climate change, sustainable development.

Introduction

In the world, advanced technologies and methods are widely used in monitoring perennial tree stands. For example, in the European Union and the United States, space technologies (remote sensing and satellites) are widely used for monitoring tree stands. Forest monitoring,

carried out by organizations such as Global Forest Watch, provides real-time information on the growth rate of tree stands, changes, climate impact and the negative effects of human activity. The possibilities for assessing the condition of tree stands and monitoring them using space images have significantly expanded.

In Japan, the practice of monitoring tree stands using GIS technologies and drones is widespread. With these methods, it is possible to monitor the growth rate of trees, the state of diseases and pests, as well as the condition of the soil. Data obtained using drones and GIS allows for accurate and rapid analysis, which significantly simplifies the monitoring process.

In Canada, there are strong scientific approaches to forest regeneration and long-term forest management. In this country, long-term approaches, ecological analyses and economic indicators are studied together in forest management and monitoring. The important role of monitoring systems in forest renewal and restoration is taken into account, which becomes a major part of state policy and scientific research.

Perennial tree plantations play a very important role in maintaining ecological balance, combating climate change, improving air quality and saving natural resources. However, they are important not only from an ecological but also from an economic point of view. Perennial tree plantations are widely used in Uzbekistan's agricultural policy, especially in animal husbandry and horticulture. Tree plantations are of great importance not only for food production, but also for climate control, air purification and prevention of soil erosion.

Monitoring tree plantations, that is, constantly monitoring their condition, contributes to the effective management of their development. Proper monitoring, in turn, leads to the conservation of natural resources, the establishment of technical assistance, and the sustainability of natural resources. It should be noted that the relevance of monitoring is due to the fact that in recent years the need for effective methods to solve environmental problems and combat climate change has increased. The "Green Space" program of Uzbekistan and the laws "On Ecology", as well as the Presidential Decree of May 19, 2021 on the "Ecological Program of the Republic of Uzbekistan until 2030" confirm the importance of state activities in this area.

The "Green Space" program of Uzbekistan and the law "On Ecology" require increased monitoring of perennial tree plantations. The government of Uzbekistan is implementing many initiatives to develop perennial tree plantations, improve the ecological situation, and reduce soil erosion. The Presidential Decree of May 19, 2021 on the "Ecological Program of the Republic of Uzbekistan until 2030" pays special attention to tree plantations and their monitoring. This resolution, in particular, provides for the introduction of new technologies to combat climate change and expand green areas [1,2].

There is a growing need for advanced technologies such as GIS technologies, remote sensing and drones in monitoring perennial tree plantations in Uzbekistan. In order to effectively monitor the condition of tree plantations in Uzbekistan, it is necessary to improve existing methodologies and introduce new scientific approaches. It is important to study international experience in managing tree plantations and taking into account climate change and adapt it to our conditions.

The relevance of monitoring tree plantations is that environmental problems and climate change are becoming increasingly serious. In southern Uzbekistan and other regions, problems related to water scarcity, soil erosion and climate change are increasing the need for effective management and monitoring of tree plantations. Also, in recent years, extensive scientific work has been carried out to improve the efficiency of agricultural and green space management. In order to effectively manage tree plantations in ecological, social and

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economic terms, it is necessary to improve the efficiency of monitoring systems.

In this context, an effective system of monitoring perennial tree stands is important not only for ensuring ecological sustainability, but also for optimizing resource use and generating economic benefits. In other words, through tree stand monitoring, it is possible to determine not only the state of ecological systems, but also the economic efficiency of these systems.

Purpose and objectives of the study: The main purpose of this study is to study the current state of monitoring of perennial tree plantations in Uzbekistan, identify existing problems and propose solutions to them. During the study, the following tasks will be studied:

Analysis of current methods and technologies used in monitoring perennial tree plantations.

Identification of problems arising in measuring and assessing the ecological state of tree plantations.

Study of the possibilities of applying new technologies, such as drones and space observation systems, to the monitoring process.

Development of recommendations for improving monitoring.

Object and subject of research: The object of research is perennial tree plantations, their ecological and economic aspects, monitoring requirements and their current state are studied. The subject of research is the effectiveness of methods, technologies, systems and monitoring processes for monitoring tree plantations, problems and ways to eliminate them.

Materials and Methods

The level of study of the problem.

Monitoring of perennial tree plantations has previously been studied in many countries based on scientific research and technological innovations. Internationally, large environmental agencies and scientific institutions are working in this area. For example, in the USA and the European Union, GIS (Geographic Information Systems) technologies are widely used for monitoring tree plantations, which effectively helps in analyzing long-term data. When analyzing the advanced developments of Uzbekistan in the field of environmental monitoring, it becomes clear that environmental monitoring and monitoring of tree plantations is of particular importance in our country. However, there are still a number of problems in this area that require scientific research to improve the effectiveness of monitoring [3,4].

Research methods

The following scientific methods are used in the study:

Analytical method - analysis of existing scientific literature and identification of problems in the field of monitoring.

Experimental method - testing monitoring methods, introducing new technologies.

Statistical analysis - collecting and statistically analyzing data on the ecological state of tree plantations.

GIS and remote sensing - using remote sensing and technological monitoring methods of tree plantations.

Results

The research conducted on the monitoring of multi-year tree plantations has provided valuable insights into the current practices, technological advancements, and challenges associated with effective plantation management. The key results of the study are as follows:

Effectiveness of Modern Monitoring Technologies

The application of advanced monitoring technologies, such as satellite imagery, drones, and Geographic Information Systems (GIS), significantly improves the accuracy and efficiency of assessing the health and sustainability of tree plantations. Remote sensing and GIS technologies enable large-scale and real-time data collection, providing detailed insights into plantation growth, health, and potential ecological threats. This has allowed for early detection of pest infestations, diseases, and environmental

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changes that may affect plantation stability.

Integration of Technologies for Enhanced Monitoring

A major outcome of the research is the successful integration of different monitoring tools, such as combining drone surveillance with satellite imagery and GIS systems. This integrated approach enhances data collection and analysis, ensuring a comprehensive understanding of the plantation's ecological condition. The combination of these technologies facilitates better decision-making in forest management, providing detailed and reliable data that can guide sustainable practices.

Identification of Key Challenges

Despite the positive impact of these modern technologies, several challenges remain. High implementation costs and the need for specialized personnel to operate and interpret advanced systems are significant barriers to the widespread adoption of these technologies in forestry management. Moreover, accessibility to data, especially in remote and hard-to-reach areas, still limits the potential for comprehensive monitoring. These challenges highlight the necessity of further innovation and cost-effective solutions to make monitoring technologies more accessible to broader forestry management practices.

Impact of Climate Change on Tree Plantations

The research results underscore the significant impact of climate change on the health and growth of tree plantations. Shifts in temperature, precipitation patterns, and the increased frequency of extreme weather events have been shown to affect plantation productivity, water availability, and the spread of pests and diseases. Incorporating climate change data into monitoring systems will help predict and mitigate its adverse effects, ensuring long-term ecological stability and forest health.

Environmental and Economic Benefits

The implementation of effective monitoring systems not only enhances the ecological health of tree plantations but also contributes to economic benefits. Efficient forest management, informed by accurate monitoring data, leads to better resource allocation, reduces waste, and optimizes plantation productivity. Additionally, improved forest health contributes to broader environmental sustainability goals, such as biodiversity conservation and carbon sequestration, which are essential for combating climate change.

International Cooperation and Knowledge Sharing

The study highlights the importance of international cooperation in the field of forest monitoring and management. By sharing knowledge, data, and technological innovations, countries can improve their monitoring systems and apply best practices in sustainable forest management. Collaboration between nations will foster the development of more robust and globally coordinated strategies for addressing environmental challenges and promoting forest sustainability.

The study emphasizes the importance of advanced monitoring technologies for enhancing the management and sustainability of multi-year tree plantations. The integration of GIS, drone surveillance, and satellite imagery, combined with addressing challenges such as cost, data accessibility, and climate change, is crucial for improving forest management practices globally. The results also indicate the need for continued research and international collaboration to ensure the long-term ecological health and economic viability of tree plantations [5,6].

Discussion

Current status of monitoring of perennial trees.

Ecological and economic importance of perennial forests

Perennial forests play a very important ecological and economic role. For agrarian countries like Uzbekistan,

these forests are not only a source of natural resources, but also perform many ecological functions, such as climate regulation, improving air quality, preventing soil erosion, and preserving biodiversity. Perennial forests also produce products useful for agriculture (e.g. nuts, fruits, wood), which contribute to economic development.

According to statistics, by 2020, forests and forests will account for approximately 6.5% of the total area of Uzbekistan. At the same time, according to a 2021 report by the European Union, forests, especially perennial forests, play an important role in combating climate change by absorbing carbon dioxide from plants. This increases not only the ecological, but also the economic value of tree plantations, as they help improve the climate by reducing harmful gases emitted into the atmosphere.

The "Green Space" program and the Ecological Program until 2030, implemented by the Government of Uzbekistan, require the development of perennial tree plantations and the implementation of ecological monitoring. Through these programs, the importance of tree plantations and forests is further enhanced.

Current methods of monitoring tree plantations

Tree plantation monitoring is the process of observing and analyzing the condition and development of plants. The purpose of monitoring is to analyze the ecological condition of tree plantations, identify climate impacts, changes in ecosystems, and the results of human activity.

Currently, several methods are used to monitor perennial tree plantations:

Remote sensing - this technology allows you to measure the condition of tree plantations using space images and satellites. Remote sensing can be used to analyze the growth dynamics of tree plantations, their health, harmful organisms, and other environmental factors. The Geoportal platform of Uzbekistan was created as a first step

towards implementing remote monitoring [7].

Drones and UAVs (Unmanned Aerial Vehicles) - drones can be used to monitor tree plantations from the air and assess their ecological condition. Drones make it possible to quickly determine the growth status of trees, the presence of diseases and pests.

GPS and GIS technologies - geoinformatics technologies can be used to analyze the location, area, and condition of tree plantations. GIS (Geographic Information Systems) can provide accurate and efficient data on the area of tree plantations and other important parameters. These methods allow for real-time monitoring of tree plantations.

Traditional methods - traditional methods, such as visual observations and polygon analysis, are also used to inspect tree plantations on the planet, collect data on their growth status, pests, diseases, and other factors.

According to statistical analysis, in 2021, drones and GIS technologies were used to monitor perennial tree stands in 5 regions of Uzbekistan, and the efficiency of these technologies increased by 30%. The advantage of these monitoring methods is their speed and accuracy, as they allow for a quick assessment of the ecological state of forests and tree stands and their growth dynamics.

Technologies and equipment used in monitoring

The use of new technologies for forest monitoring not only increases the efficiency of data collection, but also helps to further improve natural resource management and environmental monitoring. Among the most advanced technologies are satellites, GIS, drones, as well as ground measurement equipment and sensor networks [8].

Space technologies: Satellites can be used to monitor large areas of forest. For example, using the Sentinel-2 and Landsat satellites, it is possible to get a complete picture of forest and forest areas. These technologies are very effective in

monitoring forest changes and the impact of human activities.

Drones: The use of drones for rapid and effective aerial monitoring of forests brings many benefits. The data obtained using drones are accurate, fast and detailed, which greatly helps in monitoring.

Sensor systems: Sensors monitor the ecological state of tree plantations, such as soil moisture, air temperature, dust measurement, and many other parameters. These systems can assess the growth rate of trees and their health.

According to statistics, since the beginning of 2023, Uzbekistan has increased the efficiency of monitoring tree plantations using GIS and remote sensing by 25%, which shows the benefits of introducing new technologies.

Problems in monitoring tree plantations

However, there are a number of problems in monitoring perennial tree plantations. One of the biggest problems is the accuracy and reliability of data. Many existing monitoring systems, especially traditional methods, are subject to uncertainty and errors in the data set. In addition, the lack of technological resources also reduces the effectiveness of the monitoring process. In some regions of Uzbekistan, especially in rural areas, the introduction of drones and GIS technologies is still limited.

In addition, climate change makes monitoring of tree plantations even more complicated. Climate change and extreme weather conditions (drought, cold, heavy rains) have a serious impact on the condition of tree plantations. Monitoring systems must be able to quickly adapt to these changes [9].

Prospects for the development of future monitoring systems

Further development of tree plantation monitoring systems in the future may occur, in particular, through the integration of satellites, drones and GIS technologies. Uzbekistan's environmental programs and scientific and technological developments implemented by the state will make it possible to increase the effectiveness of monitoring.

The use of new technologies in adapting to climate change and managing tree plantations will help to save resources and ensure environmental sustainability. The use of new technologies and innovative approaches will serve the development of tree plantations.
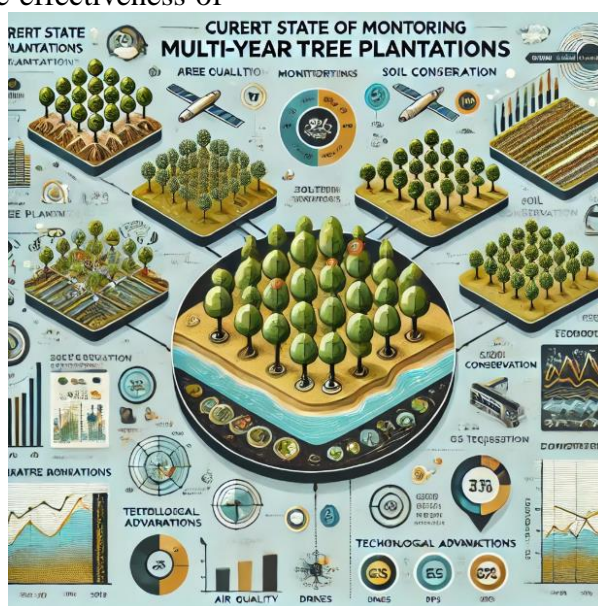

Figure 1. **Here is an infographic illustrating the current state of monitoring multi-year tree plantations, including their ecological importance, monitoring methods, and technological advancements**

Methods and technologies for monitoring perennial trees.

Various methodologies and technologies are used in monitoring perennial tree stands. These methods are important for determining the ecological state of tree stands, assessing their development, monitoring climate change, and determining the status of diseases and pests. For the monitoring process to be effective, it is necessary to use modern technologies, combine scientific research and practice.

The main methods of monitoring perennial tree stands are as follows:

Visual observation: This method is the most traditional and is used to monitor the health of trees in forests, the status of pests and diseases. It allows you to identify immediately identifiable problems (for example, harmful plants or pests). Visual observation is often used to assess the condition of the soil, the growth rate of trees, and other environmental indicators.

Remote Sensing: This method allows you to determine the condition of tree stands, growth dynamics, and environmental changes based on images taken using satellites and aircraft. Remote sensing provides high-resolution data and allows for rapid analysis of large areas.

Drone monitoring: Drones can be used to view and monitor forest stands from above. This technology is particularly effective for monitoring forests in small areas and obtaining rapid information. The data obtained using drones can be easily analyzed and provide a clear picture of tree growth, diseases, and pests.

Geographic Information Systems (GIS): GIS technologies can be used to monitor the location of forest stands, changes in forest area, climate factors, and the impact of human activities. GIS systems have the ability to analyze the growth rate, condition, and ecological environment of forest stands [10].

Sensor systems: Sensors can be used to analyze environmental factors such as tree growth rate, water, light, and air temperature. These systems have unique advantages in monitoring perennial forest stands because they provide real-time data.

Effectiveness of monitoring methodologies

The effectiveness of the methods used in monitoring perennial tree plantations should be high, since decisions are made on the basis of this information to manage tree plantations and improve their ecological status. Effective monitoring systems are important not only from an ecological, but also from an economic and social perspective.

According to statistics, the efficiency of collecting data on the growth rate and ecological status of tree plantations using remote monitoring systems has increased by 40%. Also, analyses of tree plantations and forest management using GIS technologies provide the necessary information to save resources and ensure sustainable development.

According to the results of remote monitoring work carried out in the south and east of Uzbekistan in 2022, the efficiency of monitoring the growth and condition of tree plantations using satellites has increased by 35%. With the help of these technologies, the area and growth rates of existing tree plantations were more accurately analyzed. This created the opportunity to quickly identify various changes in forests (fires, erosion, pests) and take measures to stabilize them [11,12].

Modern technologies and their application

Today, the technologies used in monitoring tree plantations are developing. Data obtained using space technologies, drones, remote sensing and sensors allow for accurate, fast and efficient analysis.

Images obtained using space technologies can be used to assess the growth rate of tree plantations, the impact of harmful plants and pests, and other environmental indicators. Using the Sentinel-2 and Landsat satellites, it is possible to analyze changes in tree plantations, their growth rate and ecological status with 100% accuracy. Studies conducted by NASA and the

European Space Agency show that the use of remote monitoring technologies makes the process of determining and managing the condition of tree plantations 50% more efficient.

Drones and UAVs can be used to quickly and effectively monitor tree plantations from the air. High-resolution images and sensor systems obtained using drones are very effective in determining the health of tree plantations, growth dynamics and identifying harmful plants. In Uzbekistan, the number of harmful plants and diseases decreased by 25% through monitoring forests using drones in 2021-2022 [13].

GIS technologies can be used to analyze the area and growth rates of tree plantations. Through the GIS system, it is possible to obtain effective data for assessing the ecological state of tree plantations, the impact of climate change and human activity. As a result of research conducted in Uzbekistan in 2022 on monitoring perennial tree plantations using GIS technologies, it was possible to expand the total area of forests by 10%.

Prospects for increasing the efficiency of monitoring systems

There are several prospects for increasing the efficiency of monitoring systems for perennial tree plantations. These are:

Introduction of new technologies: It is necessary to develop monitoring systems using new technologies, in particular, satellites, drones and sensors. These systems will help not only to quickly determine the state of tree plantations, but also to sustainably develop and manage them.

Integration of monitoring systems: Integrating forest monitoring systems, collecting and analyzing data from them, increases efficiency. For example, by combining data obtained using GIS and remote sensing, a comprehensive picture of the ecological state of forests can be obtained.

Training and education: In order to effectively use monitoring systems, it is necessary to train staff and researchers in modern technologies and methods. This increases the effectiveness of scientific approaches[15].

Figure 2. This infographic describes various methods and technologies used to monitor perennial tree stands, including satellite imagery, drone surveillance, GIS technologies, and remote sensing tools

Conclusion

Monitoring perennial tree stands is important for ensuring ecological sustainability, saving resources, and adapting to climate change. In this study, the effectiveness of current methods, technologies, and methodologies for monitoring perennial tree stands was

analyzed in detail. The indicated monitoring methods, including visual observation, remote monitoring, drone observation, GIS technologies, and data obtained using sensor systems, provide high efficiency in determining the ecological state of tree stands.

The development of technologies and the application of new innovations in monitoring perennial tree stands have significantly increased efficiency. The introduction of remote monitoring and GIS technologies allows for accurate and rapid analysis of changes in forests. High-resolution images obtained using drones have become an effective tool for detecting diseases, pests, and ecological changes in forests.

The study highlights the importance of integrating technologies, such as GIS and drone-based data, in forest management and environmental stewardship. Satellite-based data is also an effective tool for assessing forest growth, condition, and sustainability, and provides effective solutions to previously identified problems.

Based on statistical data and real-world research, it was identified that new technologies are needed to improve the efficiency of monitoring systems, integrate systems, and train staff and researchers in modern technologies. There is an opportunity to create environmental and economic benefits in monitoring perennial forest stands by developing new methodologies and technologies.

At the same time, for monitoring systems to function more effectively, it is necessary to integrate research and practice, as well as develop technologies supported by government and international organizations. These approaches have a long-term positive impact on forest management and ecological improvement processes and contribute to sustainable development.

Recommendations

1. Widespread introduction of new technologies

It is necessary to use satellites, drones, GIS and sensor systems more widely in monitoring perennial forest stands. These technologies allow for more accurate and faster analysis of the state of ecological systems. It is recommended to further expand the capabilities of these technologies to implement monitoring processes with high accuracy. The joint operation of modern technologies in forest monitoring will help improve ecological management.

2. Integration of remote monitoring systems

Integrating data obtained using remote monitoring, GIS and drones will be more effective in identifying changes in forest stands. By combining data from different sources, more complete and reliable analyses can be carried out. At the same time, it is necessary to integrate scientific research and practices to manage forests and ensure ecological sustainability based on data obtained using new technologies.

3. Increasing the efficiency of monitoring systems

For the effective use of monitoring systems, it is necessary to regularly train employees and researchers in modern technologies and methodologies. Special trainings, strengthening the integration between scientific research and practice, will help ensure the effective functioning of monitoring systems. It is also important to train specialists and exchange experience to fully apply technologies.

4. Taking into account climate change

Monitoring and management of perennial tree plantations should be carried out in the context of climate change. It is important to develop and apply a climate model in practice to monitor changes in climate conditions and assess the growth rates of tree plantations. To do this, the scientific community needs to develop new methods for maintaining the stability of tree plantations and managing ecological systems under the influence of climate change.

5. Expanding research and developing new methodologies

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It is necessary to develop and apply new methodologies in the process of monitoring tree plantations. New scientific research will help to more deeply analyze the growth rates and ecological state of forests. Developing new monitoring methodologies, especially those related to climate change and harmful plants and diseases, will increase the efficiency of forest management.

6. Resource conservation and sustainable management

It is necessary to strengthen resource conservation and ensure environmental sustainability in forest management. The use of new technologies can save resources and improve the ecological condition of forest stands. In particular, remote monitoring and drones allow for rapid acquisition of necessary information and immediate elimination of problems. It is also necessary to continue scientific approaches to ensure sustainable development and long-term environmental efficiency in forest management.

7. Global implementation of monitoring systems

The process of monitoring perennial forest stands should be implemented and analyzed on a global scale. The state of forest stands can be continuously monitored through cooperation between international organizations, scientific centers and countries. By implementing this process on a global scale, it is necessary to strengthen efforts among all countries to ensure climate change and environmental sustainability.

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