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DEVELOPMENT OF THE INFORMATION PORTAL "KAZGEOWARNING" FOR FORECASTING FIRES ON THE TERRITORY OF KAZAKHSTAN

Abstract. This article presents the development of an information system tailored for predicting and managing forest fires in Kazakhstan. The system's primary objective is to establish an information portal dedicated to fire forecasting, enhancing the accuracy of predictions and timely warnings. To achieve this, the system focuses on tasks such as predicting the likelihood of forest and steppe fires, monitoring environmental changes in real-time, and visualising the current situation on maps. It also generates comprehensive reports detailing fire risk, available resources, and necessary measures. Users will receive alerts about potential fire threats, facilitating rapid response. The system's data analysis incorporates geographical and climatic factors for precise forecasting. The ultimate goal is to significantly reduce the environmental and economic impact of forest fires in the country, emphasising the creation of a versatile platform for swift emergency response, integrating modern technologies into practical use. The practical significance encompasses improved fire warnings, enhanced safety for both the population and nature, and a reduction in economic losses. The accompanying website serves as a dynamic platform to collect, analyse, and visualise real-time data on disasters and crises, providing users with geographic information, maps, and reports crucial for making informed decisions during emergency situations.

Keywords. Forest fires, real-time tracking, data visualisation, user alerts, forecasting, emergency response, data collection.

Introduction.

With every passing year, climate change is becoming an increasingly noticeable adverse environmental factor. Environmental conditions in urban areas continue to deteriorate, making the environment not only unpleasant, but also posing a potential threat to the public. According to Kazhydromet observations, Kazakhstan's geographic features indicate that the country's climate is warming almost twice as fast as the global average [1]. Over the past century, the average annual temperature in the region has increased by 0.8-1.3 degrees Celsius. This warming trend is accompanied by a reduction in precipitation during the hot season, a factor that substantially influences the current climatic conditions. Such a process leads to a modification in the frequency of extreme weather conditions and an increase in the number of extreme events, including wildfires.

The Republic of Kazakhstan is characterised by a modest expanse of forested landscapes, constituting 4.57% (alternatively estimated at 4.2%) of the nation's total territory [2]. The region's sharply continental climate, coupled with regular strong winds and periodic droughts, fosters the development of extensive steppe fires, extending into forested areas, causing notable damage to the Republic's forestry.

Over the past two decades, the northern pine forests of Kazakhstan, the ribbon forests in the Irtysh region, as well as areas in Eastern Kazakhstan, Kostanay, Almaty, and various other regions have experienced significant and catastrophic forest fires. These incidents have not only led to the loss of extensive forest plantations but have also left an indelible impact. Notably, the

fire in the Abay region stands out as one of the largest in recent years, resulting in the devastation of 60 thousand hectares of forest and the unfortunate loss of 14 lives [3].

A large number of fires are caused by human activities, with additional influences from factors such as drought, wind, lightning strikes, and topography affecting both the initiation and spread of fires [4]. Improving wildfire management depends on gaining a deeper understanding of the scientific factors governing the occurrence, behaviour, and propagation of fires. The advancement of technology in wildfire prediction holds the promise to introduce novel tools and techniques, enhancing overall effectiveness.

Numerous contemporary AI technologies, like Big Data and Machine Learning find extensive application in the creation of advanced prediction systems. ML prediction is applied in healthcare, finance, retail, manufacturing, agriculture, and more, transforming decision-making processes across various sectors. This transformative technology not only revolutionises decision-making processes across various fields but also proves instrumental in enhancing wildfires monitoring.

In this context, the present study delves deeper into the outlined approach to address wildfires in Kazakhstan. The goal of this paper is to study and implement the monitoring and forecasting system for wildfires and demonstrate its practical significance in the long run. The article, following a structured outline, begins by providing a methodological overview for identifying wildfires. It then explores the application of ML algorithms, as outlined in Section 3, and delves into the system's development process and practical results in Section 4. And lastly, Section 5 engages in a thorough discussion and outlines the potential of the proposed approach.

Materials and methods.

Evaluation of wildfire predicting techniques.

To a large degree, the classification of wildfire prediction methods centres on three main approaches, each distinguished by its specific characteristics [5]:

1) Physics-Based Models.

Using fundamental physical laws and equations to model fire behaviour, such a model includes consideration of various factors such as the characteristics of combustible materials, wind conditions, terrain slope and moisture content. The physics-based methodology requires a large amount of input data, as well as significant computing resources to accurately recreate fire dynamics. As a result, they may face limitations in accounting for all the uncertainties inherent in real-world fire scenarios and may require additional calibration based on real-time observations.

2) Statistical Models.

The statistical approach to fire forecasting is based on the analysis of statistical data and historical patterns to identify trends and dependencies associated with the occurrence of fires. This method uses statistical models to predict the likelihood of fires based on previous events. To predict fires, statistical models take into account various variables such as climate conditions, vegetation types, and geographic characteristics. It is important to consider that statistical models may have difficulty accounting for complex interactions and nonlinear relationships in the data [6]. Examples of statistical models for fire forecasting include the Canadian Forest Fire Weather Index (FWI), Fire Potential Index (FPI), Keetch-Byram Drought Index (KBDI), and Palmer Drought Severity Index (PDSI).

3) Machine Learning Models.

When it comes to Machine Learning, this technique relies on the use of algorithms that can independently extract patterns from data. During the learning process, the model reveals complex relationships and patterns that may not be transparent to humans. Once training is completed, the model can be used to predict the likelihood of fires based on new input data. One of the advantages of machine learning methods is their ability to automatically adapt to changing

conditions and extract non-obvious patterns from data. However, like any method, there are limitations, such as the need for large amounts of training data [7].

Thus, physical models, although they provide high accuracy in describing the physical processes of a fire, place high demands on data and computing resources. Statistical models based on the analysis of historical data demonstrate the ability to take into account a variety of factors, but are limited in their predictive ability in complex scenarios. Machine learning methods, in turn, stand out for their ability to extract complex dependencies from data and adapt to changing conditions. Because of that, machine learning is emerging as a preferred forecasting method in the context of urgent fire prediction to strengthen vulnerable regions. Its ability to process large volumes of data and extract complex relationships provides a significant advantage in quickly analysing and predicting potential fires.

Machine Learning approach.

In the modern context of fire forecasting, machine learning is a branching field of computer science that focuses on creating algorithms and models that can learn from data and make predictions or decisions without explicit programming. This approach allows adaptive models to extract complex nonlinear dependencies over long intervals, due to which, as a rule, compared to models based on statistical approaches, they show better results when predicting time series for time periods quite far removed from the current moment.

Apart from being efficient, machine learning is highly appreciated for its versatility [8]. It's widely acknowledged that machine learning can enhance various processes, particularly those involving data. As the volume of big data and the need for automation continue to surge, machine learning emerges as a vital solution due to the inability of human resources to keep pace with market demands. The rapid adoption of machine learning comes as no surprise, given its array of benefits, which range from automating manual tasks to extracting valuable insights from data.

Results and Discussion.

Analysis of existing systems.

Embarking on an exploration of information systems tailored for monitoring and predicting forest fires in Kazakhstan, this analysis focuses on two key platforms - GDACS and Ambee.

Global Disaster Alert and Coordination System (GDACS) emerges as a crucial platform, offering real-time information and coordination to enhance global disaster response efforts [9]. The primary goal of this innovative system is to provide accurate and timely alerts about natural disasters worldwide, enabling authorities, organisations, and communities to respond swiftly and effectively to mitigate the impact of these events.

Ambee is a pioneering platform that specialises in environmental intelligence, providing real-time data and insights into various aspects of the environment [10]. The platform leverages advanced technologies such as artificial intelligence and data analytics to gather, analyse, and interpret environmental data.

Both platforms do share common functionalities that include:

1) Provides real-time data and insights into various environmental aspects.
2) Mapping tools for visualising disaster-affected areas.
3) Alerting system to notify users of changing environmental conditions.

GDACS and Ambee platforms for disaster monitoring and environmental data, exhibit some gaps in their coverage when it comes to certain aspects. One notable area where both platforms might fall short is in predicting natural hazards. While they excel in providing real-time alerts for various disasters, the ability to accurately predict and preemptively warn about potential forest fires seems to be an area of improvement. Additionally, the geographical coverage of data for Kazakhstan appears to be a shared limitation. Both GDACS and Ambee

may not provide comprehensive or detailed information for this specific region, possibly leaving a gap in the monitoring and early warning systems for environmental incidents in Kazakhstan.

Development of the system.

Concerning the technical aspects, the platform integrated a suite of modern technologies to ensure peak performance and user satisfaction. Java was the natural choice for powering the system's backend, renowned for its scalability and widespread adoption in enterprise development. Complementing this choice, Angular was employed for its flexibility in crafting dynamic user interfaces, thereby shaping the frontend experience. Meanwhile, Python, supported by the scikit-learn and pandas' libraries, served as the cornerstone for model training. Together, these technologies harmonized to deliver stable performance and a seamless workflow, enhancing the system's effectiveness and user experience.

Coming to the broader functionality, the predictive fire system in Kazakhstan serves a dual purpose, catering to both users and employees. Primarily, users are endowed with the privilege of accessing the map functionality (Figure 1), which is subdivided into two essential categories: real-time fires and predictive fires. This dichotomy provides users with a comprehensive overview of ongoing incidents and forecasts. Notably, the maps are equipped with a sophisticated filtering mechanism, empowering users to pinpoint specific fire-related information.

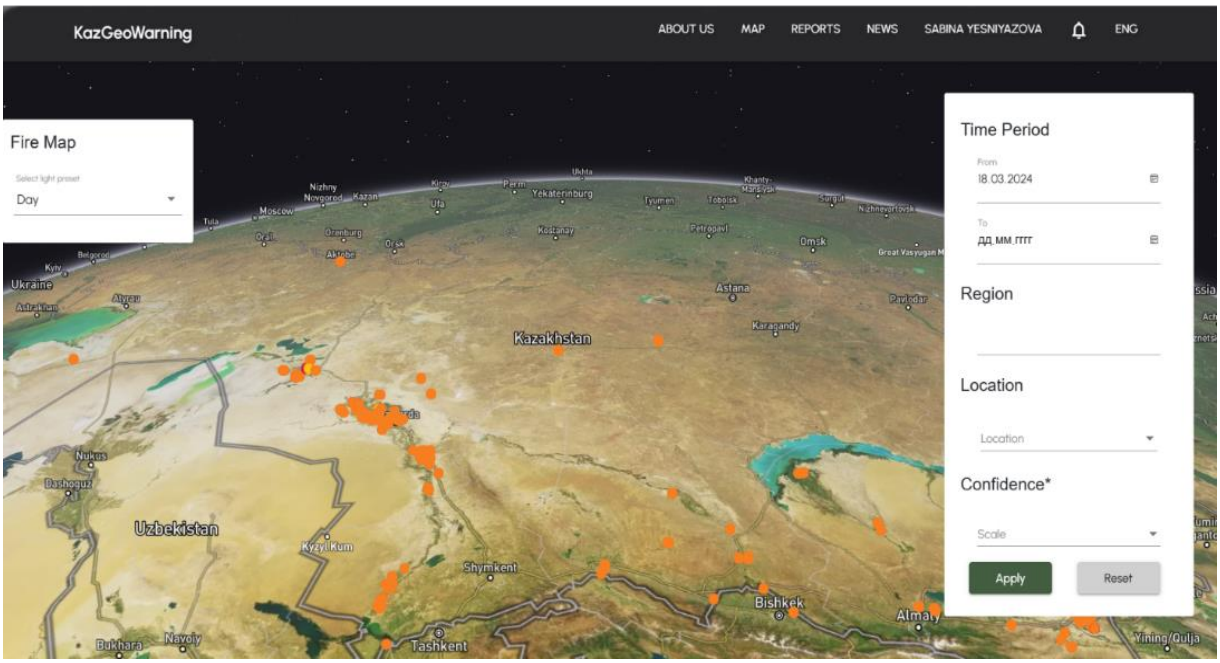

Figure 1 - Map Page

In the realm of user engagement, the system facilitates an alerting feature shown in Figure 2. To avail themselves of this service, users must undergo a sign-up process, subsequently customising their settings to configure the alert system within the platform. This customization allows users to receive notifications tailored to their preferences, disseminated through diverse channels such as email or phone. Furthermore, the notifications are seamlessly integrated into the system, ensuring a comprehensive and user-friendly experience. This multi-faceted approach to user interaction underscores the system's commitment to enhancing situational awareness and responsiveness in the face of fire-related challenges.

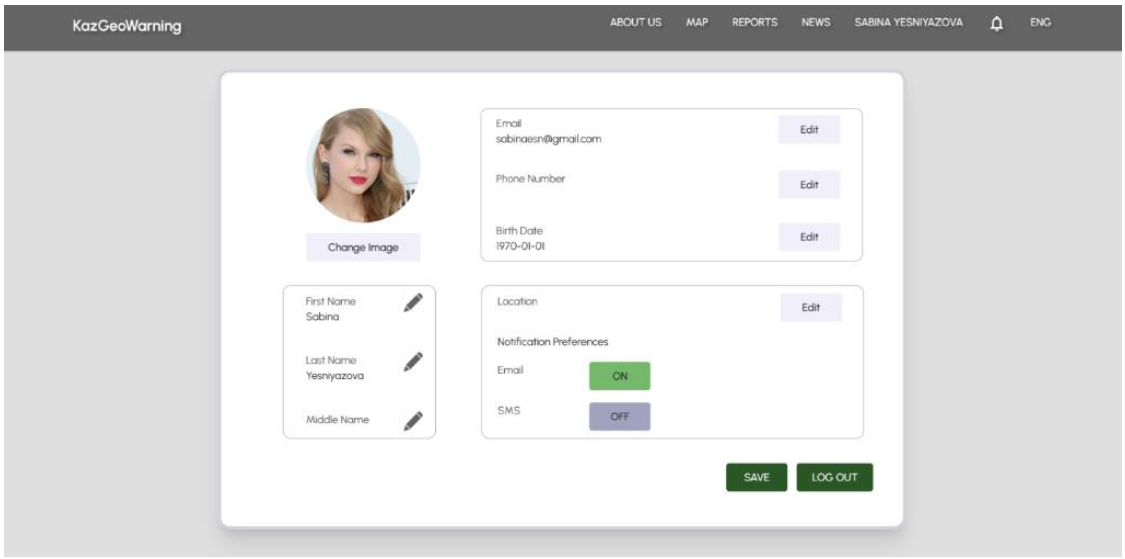

Figure 2 - Profile and Alerting Settings

On the employee part, the predictive fire system introduces a range of functionalities to optimise operational efficiency. Foremost among these is the capacity for employees to generate comprehensive reports utilising both real-time and predictive data. Figure 3 shows that these reports are systematically catalogued based on date and region, providing a structured repository of valuable insights. A distinctive feature of these reports lies in their collaborative nature, as each report is equipped with approval, signing, and editing functionalities. This collaborative workflow ensures that every report undergoes a thorough review process, involving designated editors and culminating with the endorsement of a top-level employee who signs off on the finalised report.

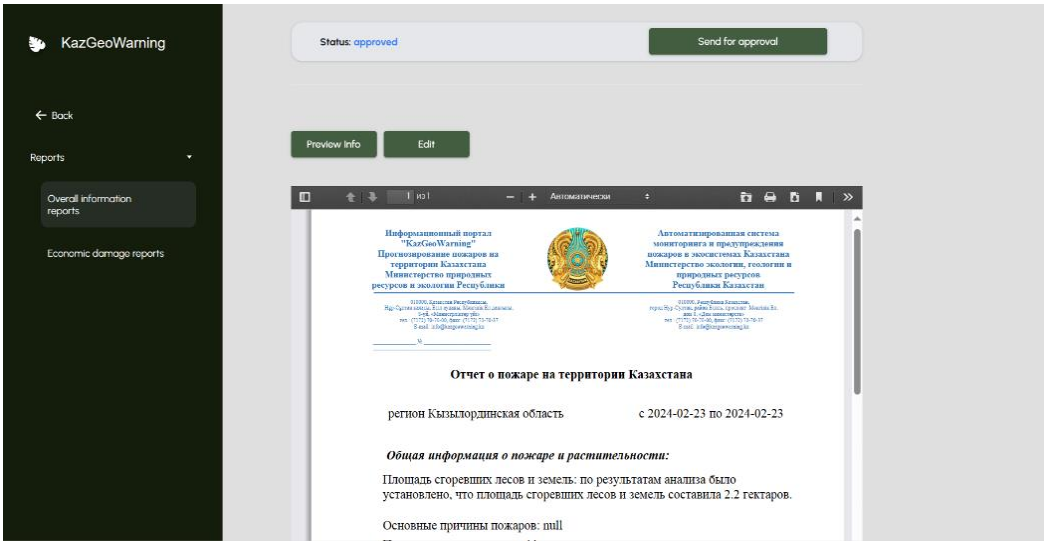

Figure 3 - Report Page

A separate page is reserved for an interactive map of vulnerable areas in the country (Figure 4). Receiving current data on weather conditions, the algorithm used returns an index describing how prone the area is to fires. In which 0-20 is low, 20-50 is medium, and 51 and more is high. Using a convenient filter, users can limit viewing by region, date, and danger level. The data is updated every hour.

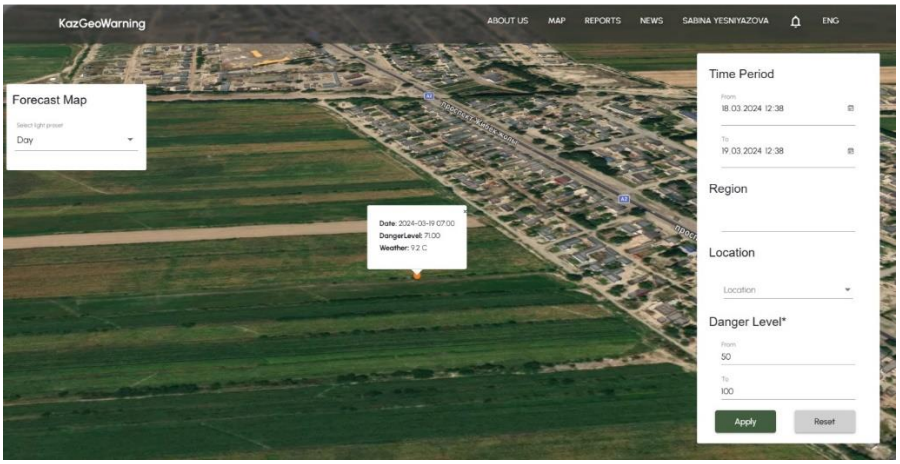

Figure 4 - Forecast Map

Practical results.

The chosen forecasting algorithm from which the data was derived was random forest. The use of the algorithm is driven by its ability to present excellent results in the face of limited data. Its ability to process a large volume of input parameters and identify complex relationships in the data allows it to produce accurate and reliable forecasts. By using a random forest with climate variables in mind, the algorithm can identify hidden patterns and adapt to changing climate dynamics, which is critical for effective fire forecasting. In addition, random forest is highly resistant to overfitting, which is especially valuable when working with limited data, where maintaining the generalisation ability of the model is a critical factor.

To train the model, a dataset was used that included historical data on fires from 2000 up to 2023, as well as climate conditions favourable to them (Figure 5). With that, the model demonstrated an accuracy rate of 82.56 percent (Figure 6). Given the constrained dataset available for the region, this algorithm demonstrated commendable predictive capabilities.

fire-data.csv (25.48 MB) 9 of 17 columns

# confidence	date	# time	# temp	# dwpt	# rhum	# wdir	# wspd	# pres
50.0	2019-12-04	6.0	5.0	-1.0	65.0	30.0	7.2	1021.0
50.0	2019-12-04	8.0	7.0	-0.9	57.0	350.0	7.2	1020.0
50.0	2019-12-04	20.0	1.3	-3.4	71.0	73.0	7.4	1023.2
50.0	2019-12-04	20.0	1.3	-3.4	71.0	73.0	7.4	1023.2
50.0	2019-12-04	20.0	1.3	-3.4	71.0	73.0	7.4	1023.2
50.0	2019-12-04	22.0	0.5	-4.0	72.0	70.0	7.4	1022.7
50.0	2019-12-05	8.0	14.0	-0.1	38.0	152.0	0.0	1020.9
50.0	2019-12-05	8.0	3.9	0.2	77.0	85.0	1.8	1023.1
50.0	2019-12-06	21.0	-6.5	-8.5	86.0	220.0	21.6	1034.4

Figure 5 - Dataset

```
predictions = model.predict(X_test)
accuracy = accuracy_score(y_test, predictions)
print(f"Model Accuracy: {accuracy * 100:.2f}%")
```

```
Model Accuracy: 82.56%
```

Figure 6 - Accuracy Rate

In order to validate the efficacy of the algorithm, a small-scale investigation was executed, employing a real fire incident in the Abay region as an illustrative example. Through an analysis of the climatic conditions leading up to the fire event, the model substantiated its forecasting capabilities by generating a hazard level index of 50 which borders on a high level (Figure 7).

```
Climatic Conditions For 8 June 2023 23:00 in Semey:
Temperature: 21.0
Dew Point: 11.1
Relative Humidity: 1008.0
Wind (From) Direction: 7.0
Average Wind Speed: 53.0
Sea-Level Air Pressure: 240.0

127.0.0.1 - - [20/Mar/2024 09:42:08] "POST /predict_by_station_id HTTP/1.1" 200 -
Danger Level: 50.0
```

Figure 7 - Danger Level in Semey Before Fire Occurrence

The model's performance, while not perfect, demonstrated a reasonable level of accuracy in forecasting. If additional factors, currently unavailable in open sources, were incorporated, the algorithms could potentially enhance their efficiency, providing a more nuanced and precise prediction of fire incidents. This underscores the importance of continuous data acquisition and the potential for further refinement to elevate the predictive capacity of the model.

Conclusion.

In conclusion, the development of an information system for forecasting and managing forest fires in Kazakhstan, incorporating the robust random forest algorithm, signifies a significant step toward enhancing fire forecasting capabilities in the region. The architecture of the system makes it possible for the selected forecasting method to be seamlessly integrated, offering a flexible and dynamic framework. The system demonstrated its efficacy in predicting possible fire outbreaks by achieving an amazing accuracy rate of 82.56% by utilising historical fire and climatic data spanning from 2000 to 2023. The system's practical significance in enhancing fire alerts, guaranteeing the safety of both the populace and the environment, and minimising financial losses is enhanced by its real-time tracking, data visualisation, and complete report creation features.

REFERENCES*

[1] Kazhydromet. Dolgikh, S.A. Smirnova, E.Yu. Beldeubaev, E.E. Kurmanova, M. Turumova, G. Karatay, M. (2023). Review of Climate Features in the Territory of Kazakhstan 2022. Chapter 1 (pp. 10).

[2] Arkhipov, E.V. Zalesov, S.V. (2017). Dynamics of forest fires in the Republic of Kazakhstan and their environmental consequences. Agriculture, forestry, fisheries, no. 4 (158), (pp. 10-15).

[3] Prilepskaya, A. (2023, November 9). Forest fire in the Abay region: Was there arson. Zakon.kz. https://www.zakon.kz/proisshestviia/6413340-lesnoy-pozhar-v-abayskoy-oblasti-byl-li-podzhog.html

[4] Oulad Sayad, Y. Mousannif, H. Al Moatassime, H. (2019). Predictive modelling of wildfires: A new dataset and machine learning approach. Fire Safety Journal, 104, 130-146.

[5] Zaidi, A. (2023). Predicting wildfires in Algerian forests using machine learning models. Heliyon, Volume 9, Issue 7.

[6] Lin, X., Li, Z., Chen, W., Sun, X., Gao, D. (2023). Forest fire prediction based on long- and short-term time-series network. Forests, 14 (4).

[7] Jain, P., Coogan, S.C., Subramanian, S.G., Crowley, M., Taylor, S., Flannigan, M.D. (2020). A review of machine learning applications in wildfire science and management. Environ. Rev., 28 (4).

[8] Klyueva, I.A. (2021). Modern opportunities and examples of machine learning implementation. Scientific and practical electronic journal Original Research (ORIS), pp. 28.

[9] GDACS. (N.D.). About GDACS. Retrieved from https://www.gdacs.org/about.

[10] Ambee. (N.D.). About Ambee. Retrieved from https://www.getambee.com/.

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ҚАЗАҚСТАН АУМАҒЫНДА ӨРТТЕРДІ БОЛЖАУДЫҢ «KAZGEOWARNING» АҚПАРАТТЫҚ ПОРТАЛЫН ҚҰРУ

Аңдатпа. Бұл мақалада Қазақстандағы орман өрттерін болжау мен басқаруға арналған ақпараттық жүйенің дамуы берілген. Жүйенің негізгі мақсаты – өртті болжауға, дер кезінде ескертулердің дәлдігін арттыруға арналған ақпараттық портал құру. Бұған қол жеткізу үшін жүйе орман және дала өрттерінің ықтималдығын болжау, нақты уақыт режимінде қоршаған ортаның өзгеруін бақылау және ағымдағы жағдайды карталарда визуализациялау сияқты тапсырмаларға назар аударады. Ол сондай-ақ өрт қаупін, қолда бар ресурстарды және қажетті шараларды егжей-тегжейлі сипаттайтын жан-жақты есептерді жасайды. Пайдаланушылар тез әрекет етуді жеңілдететін ықтимал өрт қаупі туралы ескертулер алады. Жүйенің деректерді талдауы дәл болжау үшін географиялық және климаттық факторларды қамтиды. Түпкілікті мақсат – қазіргі заманғы технологияларды тәжірибелік қолданысқа енгізе отырып, төтенше жағдайларға жедел ден қою үшін жан-жақты платформа құруға баса назар аудара отырып, еліміздегі орман өрттерінің экологиялық және экономикалық әсерін айтарлықтай азайту. Тәжірибелік маңыздылығы өртке қарсы ескертулерді жақсартуды, халық пен табиғаттың қауіпсіздігін арттыруды және экономикалық шығындарды азайтуды қамтиды. Ілеспе веб-сайт апаттар мен дағдарыстар туралы нақты уақыттағы деректерді жинау, талдау және визуализациялау үшін динамикалық платформа ретінде қызмет етеді, пайдаланушыларға төтенше жағдайлар кезінде негізделген шешімдер қабылдау үшін маңызды географиялық ақпаратты, карталарды және есептерді ұсынады.

Түйінді сөздер. Орман өрттері, нақты уақыт режимінде қадағалау, деректерді визуализациялау, пайдаланушы ескертулері, болжау, төтенше жағдайларға жауап беру, деректерді жинау.

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РАЗРАБОТКА ИНФОРМАЦИОННОГО ПОРТАЛА «KAZGEOWARNING» ПРОГНОЗИРОВАНИЯ ПОЖАРОВ НА ТЕРРИТОРИИ КАЗАХСТАНА

Аннотация. В данной статье представлена разработка информационной системы, предназначенной для прогнозирования и управления лесными пожарами в Казахстане. Основная цель системы — создание информационного портала, посвященного прогнозированию пожаров, повышающего точность прогнозов и своевременных предупреждений. Для этого система фокусируется на таких задачах, как прогнозирование вероятности лесных и степных пожаров, мониторинг изменений окружающей среды в режиме реального времени и визуализация текущей ситуации на картах. Платформа также генерирует подробные отчеты с подробным описанием пожарного риска, доступных ресурсов и необходимых мер. Пользователи будут получать оповещения о потенциальных угрозах пожара, что способствует быстрому реагированию. Анализ данных системы учитывает географические и климатические факторы для точного прогнозирования. Конечная цель – значительно снизить экологическое и экономическое воздействие лесных пожаров в стране, уделив особое внимание созданию универсальной платформы для быстрого реагирования на чрезвычайные ситуации, интеграции современных технологий в практическое использование. Практическая значимость заключается в улучшении пожарной сигнализации, повышении безопасности населения и природы, снижении экономических потерь. Сопутствующий веб-сайт служит динамической платформой для сбора, анализа и визуализации данных о стихийных бедствиях и кризисах в режиме реального времени, предоставляя пользователям географическую информацию, карты и отчеты, необходимые для принятия обоснованных решений во время чрезвычайных ситуаций.

Ключевые слова. Лесные пожары, отслеживание в реальном времени, визуализация данных, оповещения пользователей, прогнозирование, реагирование на чрезвычайные ситуации, сбор данных.

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