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UNDERSTANDING WILDFIRES AND RISK IN ALBANIA: ANALYSIS OF FIVE YEARS' OBSERVATIONAL EXPERIENCE ON THE RISK AND ITS SPATIAL DISTRIBUTION

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ABSTRACT: Wildfire Risk Forecast (WRF) remains a regular procedure conducted by the National Centre for Forecast and Monitoring of Natural Hazards (NCFMNH), which is part of the Institute of GeoSciences of Albania (IGEO). WRF is generated daily by the country's administrative unit (prefecture) and disseminated to the National Civil Protection Agency (NCPA) in order to help the fire-fighting activities better coordinate in case of Fires caused or promoted by natural factors. The main purpose of this scientific work was to conduct a survey on forecast alerts and fire events during summer seasons in a period of 5 years (2017-2021). Analyses on Forecast Alert (FA), Prefecture Hit Probability (PHP) and Average Fires per Hit (AFH) were conducted on Risk-Level-bases in order to have a complete view of the topic of the study. Besides, the study put the findings on a Hazard Index Map (HIM) where Fire Risk on Prefecture basis was revealed. The calculations were made using the results of FA, PHP and AFH components in the High-Risk Level (FA_{High}, PHP_{High}, AFH_{High}) comprising wildfire Hazard Exposure Index (HI) for the first component and wildfire Vulnerability Index (VI) for the second and third component (VI-SA and VI-SB). The methodological approach was inspired by the one used to evaluate the risk in WorldRiskReport (WRR), but due to several restrictions in this study, components for the evaluation of risk were used. The final Hazard Index Map reveals the highest risk localised in Fier Prefecture, followed by Elbasan, Vlore and Diber Prefectures.

Keywords: Unhomogeneous forests, Natural disasters, Hazard index, Mediterranean forests, Climate change

1. INTRODUCTION

The main issue this scientific study is concerned with remains the presence of a high risk of wildfires in Albania, which necessitates studying the causes of such a situation to find objective ways to improve it. Albania is extremely subject to various natural disasters, both hydrological, geophysical, technological, climatological and meteorological. The annual WorldRiskReport (WRR) ranks Albania as the country with the highest risk index in Europe and 60th in the world. As it is noted in the "Albanian Disaster Historical Collection", the prevalence of meteorological disasters is 33% of the total quantity, climate change-related disasters – 22%, hydrological disasters – 21%, and landslides – 14%, while according to this study, floods have the major impact amongst natural disasters in Albania [1]. Nevertheless, the risk of wildfires is expected to increase according to modelled future climate forecasts. Massive wildfires of a high-intensity degree significantly damaged the forest cover of Albania, and completely destroyed individual ecosystems and livestock grazing areas. Fires of this magnitude were caused by abrupt summer temperature jumps, prolonged droughts, and earlier snowmelt on mountain peaks.

A research team of De Rigo et al., in a study of extreme parameters for the wildfires occurrence in Europe under climate change, modelled forecasts of future climate indicate the probability of an increase in the occurrence frequency of wildfires, as well as the severity of wildfires worldwide [2]. At the same time, there are expectations of an increase in the wildfire hazard, especially around the Mediterranean. The authors also forecast a decrease in humidity, which will lead to droughts in the region. In turn, Jaupaj and Zaimi, in a joint forecast study of the wildfires occurrence probability in Albania in the summer of 2020, note that the country's territory is often affected by wildfires, which annually cause significant economic and environmental losses [3]. At the same time, a number of wildfire forecasting alert systems have already been introduced in the country, one of which is the Fire Weather Index (FWI) system of the weather index for wildfires, the first supersystem of its kind developed in Canada.

A team of authors, represented by Tsinko et al., in their study compared fire hazard indices with Canadian homogenised and raw weather data [4]. According to the authors, data on climate change should have a high homogeneity degree because this makes it possible to evaluate the real risk of wildfires in a particular geographical region. In turn, Pezzatti et al., in a joint scientific study, considered

the prospects for supplementing the daily evaluation to the fire metric, taking into account burnt areas [5]. According to scientists, fire hazard indices are a mathematical set of meteorological parameters that describe decision-making tools regarding the wildfire occurrence probability at a certain date. For their part, a group of scientists consisting of Zhao et al. jointly considered the principles of the bimodal and unimodal fire model changing under climate change [6]. According to the authors, it was climate change that caused the wildfires spread in a number of Mediterranean countries. At the same time, the changing dynamics of fire hazards have their own heterogeneity, which is characterised by the presence of peaks and recessions. The main purpose of this scientific study is to investigate the experience of 5 years on wildfires occurrence and forecasting in Albania.

2. RESEARCH SIGNIFICANCE

Wildfires pose a significant threat to the environment and human life globally, with Albania being no exception. Understanding the risk and spatial distribution of wildfires is crucial in developing effective prevention and mitigation strategies. The research on understanding wildfires and risk in Albania provides significant insights into the dynamics of wildfires, their patterns, and their impact on the environment. The study of five years of observational experience on the risk and its spatial distribution provides environmentalists, policymakers, and conservationists with important information to help design risk management strategies that minimize or prevent wildfires.

3. MATERIALS AND METHODS

The basis of the methodological approach in this scientific work is an empirical study based partially on the methodology that is used to evaluate the risk index in WRR. When making the reporting characteristics, special attention was paid to the evaluation of the threat level of natural hazards occurrence or exposure to them. From this point of view, the evaluation of social vulnerability in terms of the susceptibility of Albanian inhabitants to natural hazards and the population's ability to overcome them was made. Specifically, for Albania, the calculation was made by multiplying the wildfire hazard exposure index (HEI) and wildfire vulnerability index (VI). The study was carried out using the database of the Institute of GeoSciences, Polytechnic University of Tirana (Albania).

The HEI was assessed by evaluating the forecast alerts for high-risk exposure (FA_{High}) delivered by the National Center for Forecast and Monitoring of Natural Hazards (NCFMNH) generated on the country's administrative unit (prefecture) basis. Forecast alerts of the hazard exposure of each prefecture for the following day were analysed in the paper. They were calculated using the FWI, which was provided daily by European Forest Fire Information System [3]. The VI, on the other hand, was assessed by evaluating only susceptibility by means of two indicators: Susceptibility A (SA) and Susceptibility B (SB), where: SA relates to the assessment of the prefecture hit probability in high-risk exposure (PHP_{High}), while SB relates to the assessment of the average fires per hit in high-risk exposure (AFH_{High}). Data on fire occurrences that were provided daily by the National Agency of Civil Protection (NACP) as part of collaboration and memorandum of understanding with the Institute of Geosciences were used in order to calculate PHP_{High} and AFH_{High}. PHP_{High} was calculated using the following formula:

$$PHP_{High} = \sum_{i=0}^{n} \frac{n^0 Hits}{n^0 FA_{High}} * 100\%. \quad (1)$$

Where:

i - a summation index, which represents the individual prefectures being considered in the analysis; n - the total number of prefectures in the analysis; Σ - a summation operation, indicating that the values within the expression should be summed up. The PHP in equation (1) refers to the probability of high-risk exposure (PHP_{High}) in each prefecture, which is different from the PHP shown in Fig. 1.

For each index (HEI, VI-SA and VI-SB), three maps were generated using the results of FA_{High}, PHP_{High} and AFH_{High}. A final map was also created, combining the three indices into one using a factor 1 for the HEI and factor 1 for VI (where an index of 0.5 was used for SA and SB).

Actually, the study undertakes an entire analysis of the four levels of danger as forecast-alerted NCMNH, which was considered crucial mainly regarding the population response to the different types of forecast alerts distributed by NCMNH. For this reason, obviously, four levels of forecast alerts (FA), prefecture hit probability (PHP), and average fires per hit (AFH) were generated (FA_{High}, PHP_{High} and AFH_{High}; $FA_{Moderate}$, $PHP_{Moderate}$ and $AFH_{Moderate}$; FA_{Low}, PHP_{Low} and AFH_{Low}; FA_{NoRisk}, PHP_{NoRisk} and AFH_{NoRisk}). The four risk-level-based analysis aimed at obtaining a complete understanding of the spatial risk distribution for each risk level was introduced in the first part of the results. All identified results are shown in diagram form and followed by the risk maps generated using the data revealed for the High-Risk exposure as explained above.

4. RESULTS

4.1 Four-Level Hazard Exposure Analysis

This section conducts a study at the prefecture level, where the number of FA, PHP and AFH are

shown in diagram form for each risk-impact level. Fig. 1 graphically shows the results for the high-risk level analysis (by prefectures).

According to Fig. 1, FA_{High} has resulted in a very high number of fires in the Fier compared to other counties, making the prefecture the most fire-prone area in Albania (137). A lower fire hazard was noted in Berat, which is almost half the Fier's FA_{High} (70) in any case. But this is higher than that of Elbasan, Korca and Tirana, which are inferior to Berat. On the other hand, Diber was found to have the lowest fire risk due to very low FA_{High} values (10), followed by Kukes (12), Shkoder (14) and Vlore (20). Regarding the susceptibility components (PHP_{High} and AFH_{High}), it was noted that Diber, despite being recognised as the prefecture with the least fire hazard, on the other hand, it shows very high susceptibility values (PHP_{High} – 80%, the highest of all counties) and (AFH_{High} – 2.63, the second highest).

The same trend is observed in all other counties with low hazard exposure, with the exception of Kukes (74% and 68% of PHP_{High} in Vlore and Shkoder, and only 24% in Kukes). Actually, moderate to high correlations between FWI values and fires occurrence have been found in many studies [7-9]. These results contradict the abovementioned studies, but it can be concluded that vigilance and awareness in these communities appear to be low due to the low frequency of fires in these prefectures. Durres and Lezhe found FA_{High} values (35 and 30), but with susceptibility that varies from low PHP_{High} values (29% and 39%) to very high AFH_{High} values (3.21 and 2.19). Based on these data, it can be concluded that arsonists are a significant problem in these counties. Fig. 2 graphically shows the results for a moderate risk level analysis (by prefectures).

Following Fig. 2, $FA_{Moderate}$ in the Fier showed the lowest impact (242), followed by Diber (252). In any case, it should be noted that all counties showed a small difference in terms of moderate risk impact (from the 242 lowest $FA_{Moderate}$ in Fier to the 329 highest $FA_{Moderate}$ in Vlore). The level of $PHP_{Moderate}$ showed high values in Vlore (45%), Shkoder (42%) and Fier (39%). It should be noted that these prefectures also showed mostly the highest PHP_{High} values (74%, 68%, 65%), with the exception of Diber.

In Diber, $PHP_{Moderate}$ showed a huge decrease compared to PHP_{High}. On the other hand, $AFH_{Moderate}$ was found to have the highest value in Shkoder (1.97), which is even higher than AFH_{High} (1.8). Other prefectures showed small differences in $AFH_{Moderate}$ values. Fig. 3 and 4 show the results for low and no-risk level analysis (by prefectures).

Low risk and no risk are analysed together due to the low impact of these exposure levels on wildfire risk. In any case, a brief review of the facts is carried out to better understand specific prefecture-level indicators such as vigilance, awareness and response. Forecast alerts for these risk levels (FA_{Low} and FA_{NoRisk}) resulted in a very large number of Diber and Kukes (with corresponding 82 and 75, 100 and 91, respectively). Prefecture hit probability (PHP_{Low} and PHP_{NoRisk}) was highest in Shkoder for low-risk impact (25%) and Vlore and Gjirokastra for no-risk impact (24% and 25%, respectively).

It should be recalled that PHP values in the Shkoder turned out to be very high for other risk levels as well (68% of PHP_{High} and 42% of $PHP_{Moderate}$). The average fire hits (AFH_{Low} and AFH_{NoRisk}) showed high values in Lezhe for low risk (1.5), followed by Shkoder, Tirana, Elbasan and Lezhe (1.3) and high values in Tirana and Shkoder for impacts with no risk (1.7 and 1.5 AFH_{NoRisk}, respectively).

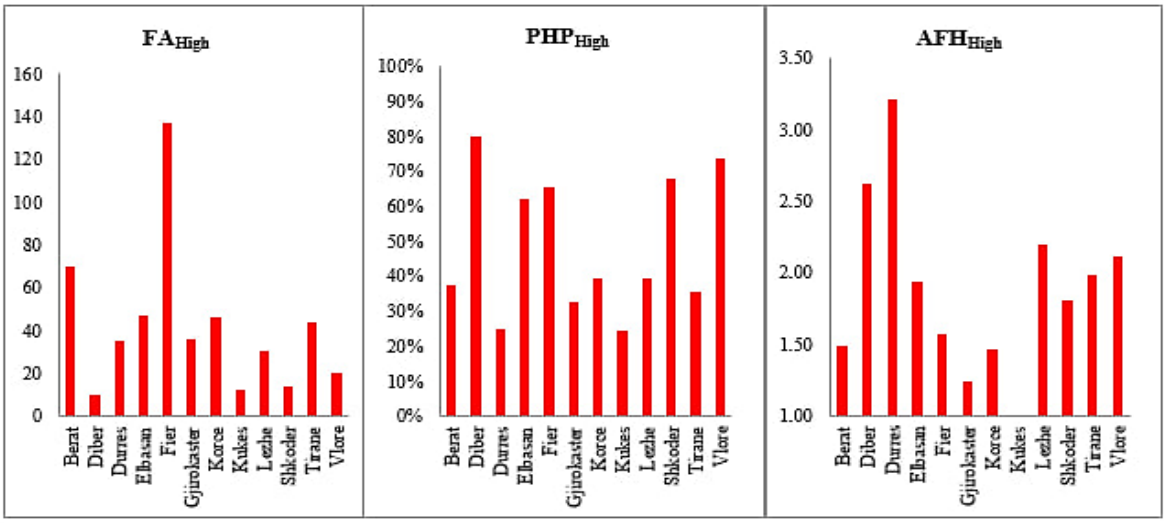

Fig. 1 High risk level analysis (2017-2021)

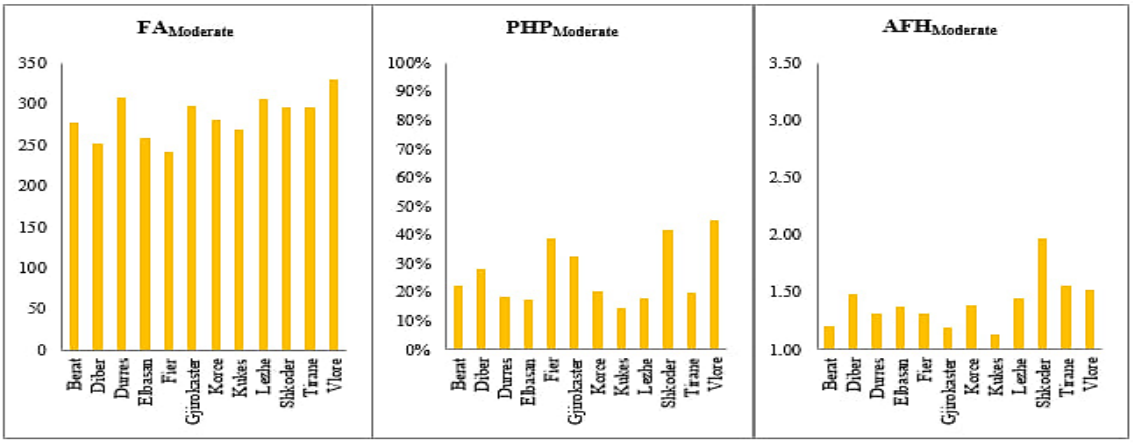

Fig. 2 Moderate risk level analysis (2017-2021)

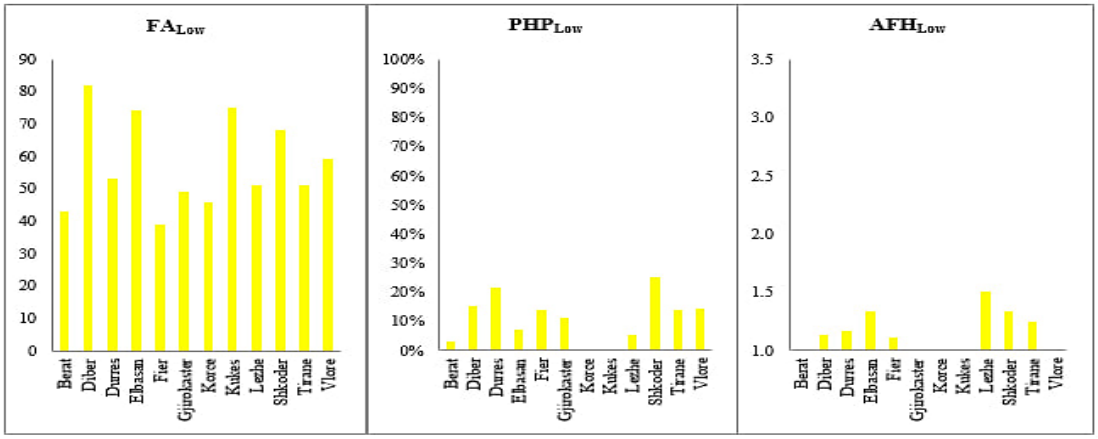

Fig. 3 Low risk level analysis (2017-2021)

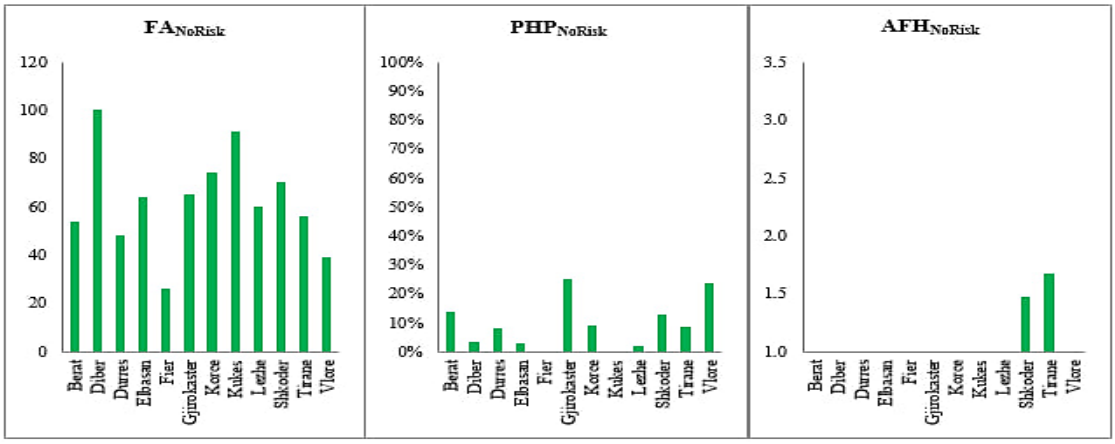

Fig. 4 No risk level analysis (2017-2021)

4.2 Fire Hazard Maps

Prefecture-level wildfires risk analyses are performed using maps designed to provide a complete picture of the risk components across the country in terms of spatial distribution. The maps are based on the results (FA_{High}, PHP_{High} and AFH_{High}) moderated over a 5-year study period. Thus, three maps are generated using the Quantum GIS system for each indicator, that is, Hazard Exposure Index (HEI or FA_{High}), Vulnerability-Index-SusceptibilityA (PHP_{High}) and Vulnerability-Index-SusceptibilityB (AFH_{High}), and one summary map for the final risk evaluation by Hazard Index

(HI). For this purpose, the three indices are combined into one, using a factor 1 for the fire hazard index and 0.5 for each of the susceptibility indices (Fig. 5-8).

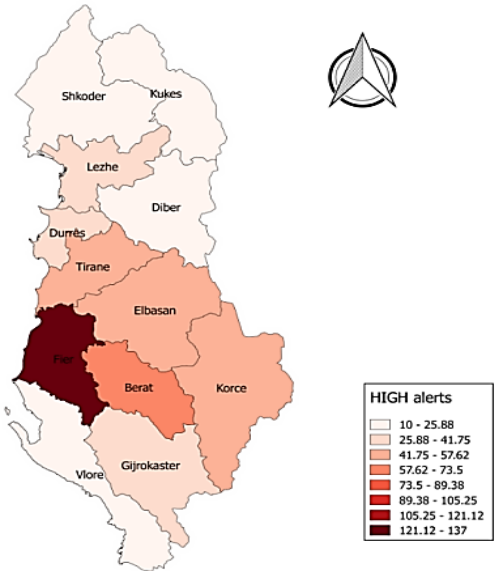

Fig. 5 The map for Hazard exposure (FA_{High}) risk component

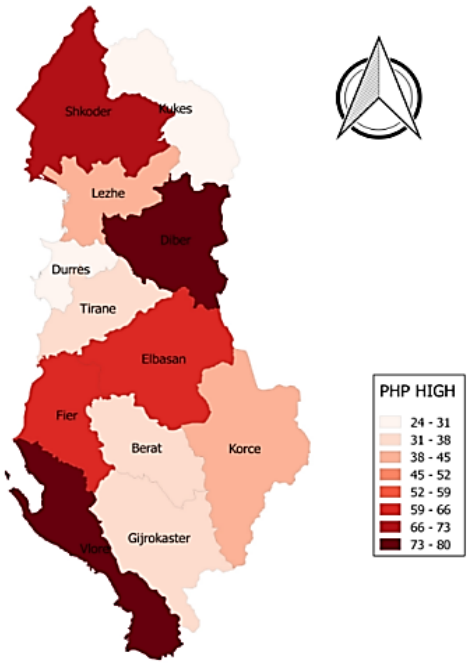

Fig. 6 The map for Susceptibility A (PHP_{High}) risk component

The hazard exposure map component shows that the highest FA_{High} is in Fier, speaking of the prefecture-level, while the increase in spatial distribution/level shows that the highest risk is localised in the middle and southern part of the country, as shown on the map. The two susceptibility maps, which take into account the communities' vulnerability to hazards, show the highest level in Vlore and Diber in terms of the SA component (PHP_{High}) and the highest in Durres in terms of the SB component (AFH_{High}). The summary map, created by combining the three indices into one, using a coefficient of 1 for the fire hazard index and 0.5 for each of the vulnerability indices (SA and SB), shows that the highest risk is in the Fier, followed by Elbasan, Vlore and Diber.

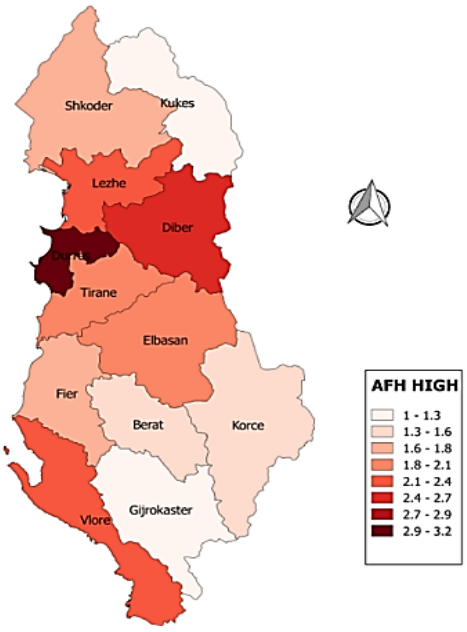

Fig. 7 The map for Susceptibility B (AFH_{High}) risk component

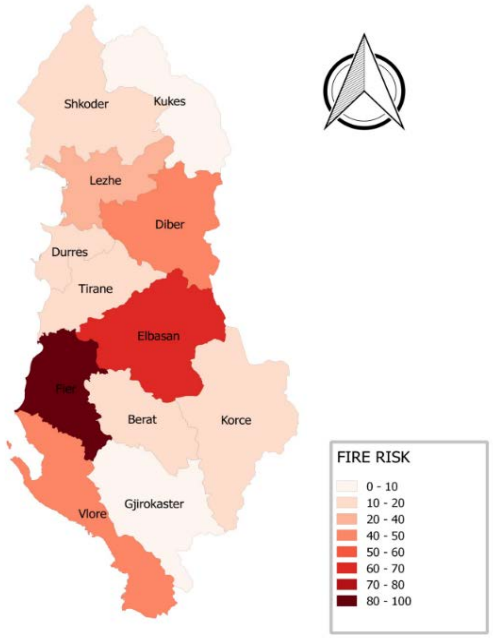

Fig. 8 Fire risk map in all three components together

5. DISCUSSION

A group of scientists represented by Zhao et al. in a joint scientific work aimed at studying the criteria for the area aridity, as one of the main indicators of the hazard of wildfires occurrence, note the fact that global climate change, leading to droughts, poses a significant threat to forestry [10]. The excessive dryness in forests often leads to wildfires, it was noted in a number of countries in East Asia and Europe. The conclusions of the researchers are fully confirmed by the results obtained in this scientific work. At the same time, the scientific team represented by Scarascia-Mugnozza et al. in a joint study of the climate change impact on the forests state of the Mediterranean region note that the forests of Central Europe are distinguished by a rich biological diversity of flora and fauna [11]. According to the authors, the survival of forest trees in Central Europe is directly connected to difficult natural conditions, their overexploitation and high fire hazards due to arid climate and sharp temperature jumps. The researchers' conclusions do not contradict the results of this scientific work, expanding them in terms of evaluating the impact of climate change on the fire hazard of a particular geographical region.

Dimitriakopulos et al. in a scientific paper studying the Canadian Forest Fire Index System in the Eastern Mediterranean environment, pay attention to the fact that the Fire Weather Index Module of the CFFDRS has been worked out over two fire seasons in Crete [12]. According to a group of authors, in the Mediterranean regions, one of which is Albania, wildfires lead to serious ecosystem disturbances, which determines the practicability of the practical introduction of wildfire forecasting systems. In the long term, this helps to avoid causing significant economic and environmental damage to forestry. The scientists' conclusions are fully consistent with the results obtained in this scientific work. The raised subject is developed by Bedia et al. in a joint scientific work aimed at studying the sensitivity of the fire weather index to various repeated analysis products in relation to the realities of the Iberian Peninsula [13]. It is noted that wildfires are a significant problem in the Pyrenees, which increases the importance of creating effective systems for early warning of their occurrence. According to the authors, the use of fire weather indices in many statistical studies is due to the presence of sufficiently large climatological time series over vast geographical areas, while the series is presented in a sufficiently high quality.

In turn, according to Lopez et al., when forming the evaluation of the wildfire risk, the interaction efficiency of all services involved in the forecasting process is of great importance [14]. It is also noted that the developed fire risk identification model effectively identifies areas of high fire risk, which emphasises the practicability of developing mathematical models for fire risk evaluation and fire prevention. San-Miguel-Ayanz et al., in a scientific study of the functioning principles of the European Forest Fire Information System, pay attention to the fact that natural wildfires are one of the component parts of the ecological systems of the Mediterranean region [15]. According to the group of scientists, the practice of using natural forest areas as recreation areas contributed to a significant increase in fires caused by human faults. This necessitates the need to create conditions for risks minimising wildfires through the use of available resources. The conclusions made by the researchers are fully consistent with the results of this scientific work in terms of evaluating the prospects for fire risk minimising.

At the same time, Di Giuseppe et al. in a joint scientific study of the potential predictability of fire hazard provided by weather forecasting, note that to provide early alerts information to the civil protection authorities of several countries in North America, a fire risk evaluation system was established, the principle of which is based on the modelling of potential atmospheric effects [16]. According to the group of authors, the use of such systems in the countries of Central Europe and the Mediterranean region will provide an opportunity to effectively forecast the occurrence of wildfires. The researchers' conclusions are fundamentally consistent with the results obtained in this scientific work. Papagiannaki et al., in a joint scientific work, studied the threshold values for the wildfire risk in the Mediterranean region [17]. According to the authors, effective forecasting of the wildfires probability requires the coordination of certain actions of ground services to obtain the optimal result. At the same time, objective results are of great importance for maintaining a high level of fire safety in the region as a whole.

The research team consisting of Trnka et al. in a joint scientific study aimed at studying the observed climate change for the fire hazard regime in the humid temperate climate of the Czech Republic paid attention to the fact that during the period from 2017 to 2022 in the countries of Central Europe and the Mediterranean there was a trend towards an increase in the number of years with wet, warm winters and dry, hot summers [18]. This has led to an increase in the overall level of fire hazard in forests and an increase in wildfires. The scientists' conclusions correlate with the results of this scientific study, expanding them in terms of evaluating the impact of weather conditions on the fire spreading probability in certain geographic regions. The topic was developed by Calheiros et al. in a joint scientific study of the spatial and temporal

patterns evolution of burned areas and the fire risk in the Iberian Peninsula [19]. Scientists note that weather changes, in particular temperature changes, are the most important factors in the fire's occurrence because they cause the hazard of forest flammability in the Mediterranean. According to scientists, the variability of weather characteristics in this region makes it possible to better understand the variability of statistical data on fire occurrence [20-24]. Thus, the discussion of the results obtained in this scientific study, in terms of their comparison with the results and conclusions of a number of researchers of problematic aspects understanding of wildfire risks, demonstrated their fundamental correspondence in key aspects [25-27]. This is evidence of the scientific reliability of this scientific work results, as well as the admissibility and practicability of their practical use in the practical development and introduction of forecasting and alert systems and wildfire probability.

6. CONCLUSION

Reducing the wildfire risk in Albania can be achieved by developing the ability of the country's society to minimize the negative impact of natural disasters on the fauna in general and forest plantations in particular. This means the need for the development and subsequent introduction of certain design and technological innovations in this direction, as well as the organisation of rational use of the state's available resources. Such innovations include an effective system for evaluating wildfire risks and preventing their occurrence. The functioning of this system is provided with the inclusion of indices for evaluating fire hazard risk levels (FA_{High}, PHP_{High} and AFH_{High}), which provide a quite high level of fire forecasting in each particular region of the country. The harmful impact of climate change, which causes wildfires, significantly harms the inhabitants of mainland Europe, as well as damages the biodiversity of species and the ecosystem. It can be minimised by improving the efficiency of risk reduction strategies. But improved risk reduction strategies are based on a detailed study of the hazard profile and how they affect space and time plans. Thus, in countries such as Albania, which are threatened by the occurrence of many natural disaster types, as well as high frequency, such studies are mandatory. The wide variety and frequency of hazards, if not properly understood and controlled, can lead to increased fire hazard risks over time. The prospect of further scientific study in the chosen direction is determined by the consistently high risks of wildfires in the forestry of the Mediterranean and the connected need to study the possibilities of minimising these risks and introducing alert systems about the presence of such hazards. There is also a need for further study to analyse the burnt forest space in individual prefectures at all levels of fire risk forecast. In this case, the emphasis should be made on specific damage that was noted in accordance with the forecast of a high hazard level.

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