Relative importance analysis on deriving new forest fire extinguishing methods in preparation for climate change

Junha Park 01, Seongyoung Lee 02, Sangil Ryu 03

01 Department of Fire Administration and Disaster Management, Dong-eui University, Busan, Korea

02 Department of Fire Administration and Disaster Management, Dong-eui University, Busan, Korea

03 Department of Fire Administration and Disaster Management, Dong-eui University, Busan, Korea

Abstract

The amount of damage due to the simultaneous occurrence and expansion of large-scale forest fires due to climate change is increasing. This shows both the difficulties and limitations of current forest fire response methods, and it is analyzed that the relative importance of effectively using drone technology to suppress forest fires is gradually increasing. Considering the limitations of current forest fire suppression methods and the severity of damage caused by forest fires, we explore the possibility of applying the characteristics and advantages of drones to forest fire suppression. In addition, the development potential of drones and their impact on environmental conservation and life-saving when suppressing forest fires are analyzed to evaluate their relative importance, thereby suggesting future forest fire response strategies. As a result, experts recognized that system and policy improvement (53%) is needed first in order to quickly and effectively suppress forest fires using drones, followed by improvement in operational technology (31%) and improvement in public awareness (16%). It is recognized as being important.

Key words: Fire, Forest Fire Response, Drones, Climate Change

I. Introduction

Recently, due to climate change, forest fires have simultaneously become larger and the number of occurrences has rapidly increased. As a result, forest fires are called the most dangerous social disasters and are no longer discussed as a matter of interest in society as they have a high possibility of developing into large-scale disasters. Interest is increasing as it is not a disaster but a complex disaster. Prevention and response to this are also receiving attention as very important tasks.

Currently, manpower and equipment are used to extinguish forest fires in the event of a disaster. It is necessary to operate manpower and equipment to extinguish forest fires without being restricted by day or night time, but there are limits to operating equipment in mountainous environments without sidewalks and at night. Using helicopters to extinguish forest fires can be operated efficiently during the day, but is legally prohibited at night. Even if night flights are permitted for safety, there are many difficulties in responding to forest fires because there is a high probability that secondary accidents may occur due to the dangerous environment and weather. (Korea Forest Service, 2023)

Manpower will be deployed to preemptively build a cordon to prevent the spread of forest fires. The current strategy is to minimize the area that can be burned by removing trees to build a cordon. Therefore, removing trees using lawn mowers or logging tools takes an excessive amount of time and requires a lot of manpower. In order to secure a cordon, excessive time and effort is being spent to build a cordon in mountainous terrain where there are no roads or hiking trails.

In places where forest fires are extinguished or extinguished, the remaining flames are extinguished. To remove the remaining flames, people hike with a backpack pump on their backs, identify them with the naked eye, and do the extinguishing work. Removing residual fires also requires a lot of time and manpower, and there are times when residual fires cannot be found, leading to the possibility of additional forest fires occurring.

Division	Contents
Stem Fire	□ A fire that burns tree trunks and often combusts from surface fire. □ It is likely to occur in old-growth forests where dead trees or trunk cavities can be seen.
Crown Fire	□ Burning of tree leaves and branches □ It is considered a dangerous fire that originates from surface fire and spreads strongly from tree trunk to tree canopy.
Underground Fire	□ It is a phenomenon in which dry ground cover deposited in a forest or underground peat layer burns. □ Because fuel is piled up on the surface, oxygen supply is low and it is protected from wind, resulting in a continuous, slow-burning fire with a combustion speed of 4 to 5 kilometers per hour.
Surface Fire	□ It is the most common fire among forest fires. □ This refers to a fire in which fallen leaves, ground cover, ground shrubs, and new trees accumulated on the surface are burned. caused flooding □ Fires in forests, fields, or grasslands also fall into this category.

From this difficult perspective of current forest fire response, if there is no mountain road, fire trucks cannot enter, and only helicopters can respond. However, there are limitations in operating helicopters at night. Additionally, there are restrictions on the operation of rotary wing aircraft when wind speeds exceed 5, visibility is less than 5,000 m, or ceiling height is less than 450 m. (Notice of the Ministry of Land, Infrastructure and Transport, 2015)

As an alternative to these restrictions, the use of drones is being discussed, and each year, the specifications of drones are gradually becoming larger and more advanced, reaching the level of replacing manned aircraft. Based on GPS, it is possible to respond to forest fires in an advanced manner at the exact location and altitude regardless of visibility and cloud cover.

Therefore, the purpose of this study is to conduct an analysis of the relative importance of AHP experts to determine which drones should be equipped with priority when using drones to suppress forest fires.

II. Theoretical Discussions

1. Significance and characteristics of forest fires

According to Article 2, Paragraph 7 of the Forest Protection Act, a forest fire is defined as the burning of trees, grass, fallen leaves, etc. in a forest or an area adjacent to a forest, caused artificially or naturally by fire (Article 2 (Definition), Article 7 of the Forest Protection Act) like)

Representative types of forest fires include stem fire, crown fire, underground fire, and surface fire. Surface fires burn fallen leaves accumulated in the forest and the fire progresses quickly, producing less heat. On the other hand, in the case of crown

flowering, heat generation is much higher than that of surface flowering due to the burning of trees and fallen leaves in the crown layer. Therefore, it can be said that most large forest fires are caused by crown fire (Jang Mi-na et al., 2011)

2. Significance and main use cases of drones

A drone refers to an aircraft that is controlled remotely using radio waves and a remote controller or flies a route according to a pre-entered program without a person directly riding in the cockpit (Article 125 of the Aviation Safety Act).

In Korea, drones are classified as "ultra-light flying devices," and if you look at the contents of Article 2, Paragraph 3 of the Aviation Safety Act, they are 'devices other than aircraft and light aircraft that can float by the reaction of the air, and their weight, number of seats, etc. are determined by Ordinance of the Ministry of Land, Infrastructure and Transport. 'Unmanned flying device specified in the list' and 'Standards for ultra-light flying devices', Article 5 of the Enforcement Rules of the Aviation Safety Act, 'Unmanned flying devices are flying devices without humans on board', Article 5, Paragraph 5 of the Enforcement Rules of the Aviation Safety Act. In the United States, it is classified as UAS because it includes all aircraft, mission equipment, ground control equipment, data links, and ground support systems. RPA (Remotely Piloted Aircraft) was defined by the International Civil Aviation Organization (ICAO) in 2010.), which implied that the remote operator could be held responsible, and is mainly used in Europe (Yong-ho Kim & Kyung-hyeon Lee. 2017).

Drones have continued to develop throughout the history of warfare. "Sperry Aerial Torpedo," developed in the United States in 1918 during World War I, carried a 300-pound bomb and flew horizontally, but was not deployed in combat due to its low success rate (Yong-ho Kim & Kyung-hyeon Lee. 2017).

"Firebird 2001," developed in Israel in the 1990s, has been developed for purposes other than military purposes, such as global positioning system technology, geographic information system mapping, and forest fire monitoring using forward surveillance cameras, and is being used in various fields as follows (Yong-ho Kim & Kyung-hyun Lee, 2017)

Metrics	Measurement element	Relative Importance	Priority of measurement elements by measurement area
Improving Systems and Policies	Overhaul of Laws	0.43(43%)	1st
	Reorganization of Related Departments	0.20(20%)	
	Prepare an Operation Manual	0.37(37%)	
Improved Operating Technology	Improved Fire Extinguisher performance	0.44(44%)	1st
	Development of fire scene application method	0.36(36%)	
	Promotion of Development Policy	0.21(21%)	
Improving Public Awareness	Need for Public Training	0.32(32%)	1st
	Formation of National Consensus	0.33(33%)	
	Strengthen publicity	0.36(36%)	

* CR(Consistency Ratio) < 0.2

3. Problems of drone operation

Drones have developed rapidly since the 2010s, and the world's leading IT companies such as Google and Amazon are actively entering the drone industry based on their judgment of the drone industry's positive potential for generating high profits, and the fields of use are very wide and diverse. It is expected to continue to develop (Yong-ho Kim & Kyung-hyeon Lee. 2017)

This global trend of drone development does not only have advantages. Unlike general aircraft, drones that communicate with the ground are vulnerable to external influences such as mechanical defects, communication disturbances such as radio interference, and hacking of the aircraft using communication, as well as problems in drone operation due to miniaturization and weight reduction of the aircraft, etc. Problems pointed out, such as casualties and property damage caused by poor handling, etc., are issues that need to be addressed in the future.

In addition, while videos are captured using high-performance camera devices mounted on drones, problems are also being raised that privacy may be unintentionally invaded or personal information may be leaked. In particular, if drones used by judicial or investigative agencies for investigative or official purposes cause an incident like the above, it could cause bigger legal and social problems than the present (Yong-ho Kim & Kyung-hyun Lee. 2017)

4. Domestic regulatory laws related to drones

Drones are regulated by the Aviation Act enacted in 1961, and are classified as unmanned flying devices among ultra-light flying devices. The law contains regulations related to aviation in general, and was enacted on March 29, 2016 by subdividing it into the Aviation Safety Act, the Aviation Business Act, and the Airport Facilities Act. In particular, ‘any person who owns or has the right to use an ultra-light aircraft must report it to the Minister of Land, Infrastructure and Transport, and if the maximum take-off weight is 25 kg or more, he/she must obtain safety certification from the Korea Transportation Safety Authority.’ Article 122 of the Aviation Safety Act. (Yongho Kim & Kyunghyun Lee. 2017).

In addition, it is stipulated that anyone who wishes to use an ultra-light unmanned aerial vehicle (drone) must obtain certification for use of an ultra-light unmanned aerial vehicle (drone) from the head of an organization or organization designated by the Ministry of Land, Infrastructure and Transport.

Article 127 of the same Act states that ‘any person who intends to use an ultra-light unmanned aerial vehicle (drone) must obtain approval from the Minister of Land, Infrastructure and Transport when using a restricted flight area.’ Article 129 stipulates that ‘users of ultra-light unmanned aerial vehicles (drones) must obtain approval from the Minister of Land, Infrastructure and Transport. It states that special compliance must be observed to prevent damage to life and property. In addition, Article 129 of the Aviation Safety Act stipulates caution regarding various accidents that may result in damage to life and property that may occur when operating a drone.

In particular, Article 129 “④ Personal information pursuant to Article 2, Paragraph 1 of the Personal Information Protection Act (hereinafter referred to as “personal information”) using an unmanned flying device or 「Act on the Protection and Use of Location Information, etc.” When collecting or transmitting personal location information (hereinafter referred to as “personal location information”) pursuant to Article 2, Paragraph 2, the protection of personal information and personal location information shall be

governed by the relevant laws." Regulations regarding personal information infringement are specified (Yong-ho Kim & Kyeong-hyeon Lee. 2017)

III. Research Design

1. AHP(Analytic Hierarchy Process) technique

AHP technique is a methodology used in many fields. In other words, in the decision-making process of deciding on the latest alternative for policy establishment, etc., considering multiple criteria rather than just one standard is called multi-criteria decision making (MCDM), and this technique is used for policy making. It can also be applied to priority selection (Kim Yu-ho, 2018)

The usefulness of AHP presented by Saaty (1980) is that, first, information in the decision-making process can be measured on a ratio scale through qualitative and quantitative standards, and second, complex problems that are not formal and multi-criteria can be measured by sub-criteria. It can be resolved through pairwise comparison by subdividing and stratifying, and thirdly, qualitative information can be expressed quantitatively in numerical terms (Saaty, 1982; Kim Yu-ho, 2018).

2. Survey subjects and survey

The subjects of this relative importance analysis were selected as follows: 9 experts in firefighting-related fields who fully understand this task.

Data collection was conducted through email and in-person survey methods from November 21 to November 30, 2023, and 9 out of 9 questionnaires (recovery rate 100%) were collected, which were subjected to hierarchical analysis. It was analyzed using the Analytic Hierarchy Process (AHP) technique, and among all 9 parts, 2 parts with a consistency ratio (CR) of 0.2 or more were rejected, and 7 parts with a consistency ratio of 0.2 or less were actually analyzed.

3. Trustworthiness of findings

Securing the reliability of the AHP technique is possible by measuring the consistency ratio (hereinafter 'CR'), which is a method of measuring the error in the judgment of individual experts when evaluating the relative importance of each evaluation element. Generally, the smaller the CR value, the smaller the CR. The higher the CR, the greater the consistency of the judgment. If the CR is less than 20% (0.2), the respondent can be considered to have performed the two-way comparison quite consistently (Saaty, 1982).

In this study, the consistency ratio (CR) was found to be less than 20% (0.2). The consistency ratio was measured in advance and respondents with a consistency ratio (CR) of 0.2 or higher were removed, thereby increasing the reliability of the response results. was able to secure it.

IV. Analysis results and implications

1. Relative importance analysis results for measurement items

The results of a 'relative importance analysis' on the effectiveness of drone use in forest fires targeting firefighting experts were

derived as follows.

In other words, experts recognized that in order to quickly and effectively suppress forest fires using drones, system and policy improvement (53%) must be implemented first. Next, it was confirmed that the priority or importance was recognized as improving operational technology (31%) and improving public awareness (16%).

Metrics	Improving systems and policies	Improved operating technology	Improving public awareness
Relative importance value	0.54% (54%)	0.30 (30%)	0.17 (17%)
First of all ranking	1st	2nd	3rd

* CR(Consistency Ratio) < 0.2

2. Relative importance analysis results for detailed items

As a result of conducting a relative importance analysis of detailed items on the effectiveness of using fire extinguishers in forest fires targeting firefighting experts, the following results were obtained.

First of all, it was confirmed that experts recognize that the overhaul of laws and regulations (43%) must be urgently done in terms of improving systems and policies, and that improving fire extinguisher performance (44%) is the most important in terms of improving operational technology. In terms of improving public awareness, it was confirmed that the importance of forming public consensus, the need for public training, and strengthening public relations were recognized at a similar level.

3. improvement direction

By using artificial intelligence technology to collect and analyze the data needed to respond to forest fires, there is no need to rely on human senses and experience (Deok-jin Kim et al., 2023).

Therefore, potential human errors can be reduced and accuracy and speed can be increased. In addition, forest fire response capabilities are strengthened by monitoring the forest fire suppression situation in real time, accurately analyzing the difficulty and cause of forest fire suppression, and establishing a rapid response strategy (Kim Deok-jin et al., 2023).

Through this, unnecessary waste of resources can be prevented by efficiently distributing and deploying resources such as necessary manpower and equipment. In the forest fire response stage, by accurately identifying the location of the fire and performing lifesaving work, human risks can be reduced and safety guaranteed. there is. Additionally, safety can be improved by preventing accidents that may occur during forest fire response using artificial intelligence (Deok-jin Kim et al., 2023).

1) Improving systems and policies

First, laws and regulations need to be overhauled. It is necessary to enact laws regarding the operation of unmanned aerial vehicles (drones) when suppressing forest fires, and infringement on private interests must also be reviewed.

Second, related departments need to be reorganized. The National Fire Agency and Fire Department Headquarters will need to revise the contents related to the operation of unmanned aerial vehicles and reorganize related organizations.

Third, it is necessary to prepare an operation manual. There is a need to develop a manual for smooth fire extinguisher operation when extinguishing forest fires. In particular, it is necessary to usenon toxic substances that are not harmful to the human body and the environment, ensure the safety of deployed personnel, and preserve the soil environment.

2) Improving systems and policies

First, drone performance needs to be improved. It is necessary to improve and secure drone specifications and performance to extinguish forest fires.

Second, it is necessary to develop a fire scene application method. There is a need to develop analysis methods and the feasibility of applying heavy-duty drones to forest fire sites.

Third, development policies need to be promoted. The development of unmanned aerial vehicles suitable for extinguishing fire extinguishers should be promoted through policy and upgraded.

3) Improving public awareness

First, public training is needed. Public evacuation training should be implemented that reflects drone operation and use scenarios.

Second, it is necessary to form a national consensus. When extinguishing fires using drones, it is necessary to form a consensus based on the pursuit of public interest, such as noise generation and personal information protection.

Third, strengthening public relations is necessary. There should be a variety of publicity (YouTube, blogs, newspapers, SNS, etc.) about the necessity and benefits of using drones to suppress forest fires.

Ⅴ. Conclusion

In this study, we provided basic data for the use of drones for forest fire suppression in preparation for the 4th Industrial Revolution and analyzed the relative importance of drones that absolutely improve the capabilities of forest fire suppression organizations. Although research on the development of drones and presentation of policy areas is actively underway, there is a lack of research on ways to utilize drones specialized for forest fire suppression. This study is expected to be of appropriate help in suggesting directions for the use of drones by forest fire response organizations in a disaster environment that is changing due to rapid climate change.

We are currently facing a new technological revolution society called the 4th Industrial Revolution, and we are making progress with the development of cutting-edge technology. However, related laws are not keeping pace with the pace of technological development.

There is an opinion that legal regulations prevent the development of technology, but it is an appropriate procedure for the overall development of society and maintenance of order. This further highlights the advantage of ensuring and protecting technological advancement.

Therefore, the enactment of related laws will be an essential procedure to support the technological growth of forest fire

suppression drones within legal limits and minimize social side effects of new technologies (Yong-ho Kim & Kyung-hyun Lee, 2017)

Accordingly, this study would like to propose the enactment of a "Special Act on the Operation of Drones" to ensure the legal authority to use drones in protecting people's personal information and suppressing forest fires in accordance with the development of the 4th Industrial Revolution.

References

Korea Forest Service, 『2023 K-Comprehensive Forest Fire Prevention Measures』

Korea Forest Service, 「2021 Scientific Forest Fire Response Strategy Amid Climate Crisis」

Deokjin Kim, Minji Seo, & Gwangyoung Park. (2023). A plan to introduce an artificial intelligence system for forest fire response. *Proceedings of the Korean Information Processing Society Conference*, 30(1), 612-614.

Bang, Seonghyuk. (2023). A study on forest fire response systems by country. *Korean Fire Protection Society Conference Proceedings*, 2023(2), 160-160.-

Lee Min-jae, Shin Sang-gyun, Kim Ju-yeon, Jang Seung-soo, Han Sang-soo, Choi Chan-ho, ... & Kim Song-hyun. (2022). Artificial intelligence and image-based drone mission control system for effective suppression of forest fires. *Journal of the Korean Society of Information Technology*, 20(1), 75-85.

Beopheon Kim, & Jaehyun Kim. (2022). Research on the efficient operation of drones in public safety. *Humanities and Social Sciences* 21, 13(2), 1827-1836.

Junbeom Kwon. (2022). A study on ways to utilize drones in the event of a forest fire disaster. *Korean Disaster Information Society Conference*, 117-118.

Kang-Hoon Ha, Jae-Ho Kim, & Jae-Wook Choi. (2021). Analysis of research trends on drone utilization in the firefighting field. *Journal of the Korean Society of Industrial-Academic Technology*, 22(4), 321-330.

Jihyun Lee, Minsoo Park, Daekyo Jeong, & Seunghee Park. (2020). A study on forest fire disaster response based on cases of overseas disaster safety management systems. *Journal of the Korean Society of Civil Engineers*, 40(3), 345-352.

Jo Jung-yoon, Song Joo-il, Jang Cho-rok, & Jang Moon-yeop. (2020). A study on ways to utilize drone images for disaster management. *Journal of the Korean Society of Industrial-Academic Technology*, 21(10), 372-378.

Yongho Kim, & Kyunghyeon Lee. (2017). Legislative proposal to prevent privacy violations by drones and resolve operational issues. *Journal of Information Security Society*, 27(5), 1141-1147.

Lee Sang-chun, Yoon Byeong-cheol, Kim Dong-eok, & Chae Ji-in. (2016). Utilization of drones for public missions. *Journal of the Korean Society of Communications (Information and Communication),* 33(2), 100-106.

Nojun Kim, Seongseong Lee, & Hwangjin Kim. (2016). Basic research on laws and performance standards for the introduction of disaster safety drones. *Journal of the Korean Society of Safety*, 31(4), 150-155.