Analyzing the 100-Year Frequency Wildfire Hazard Near the Hanul Site Using Monte Carlo Simulation

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*** *Keywords :*** Nuclear Power Plant, Wildfire, Hazard, Probabilistic hazard analysis, Wildfire Simulation

1. Introduction

The Korea Climate Change Assessment Report 2020, published by the Ministry of Environment, predicts that the frequency and intensity of wildfires will continue to increase compared to the past due to rising maximum temperatures and decreasing relative humidity caused by climate change[1]. Actual events occurred when the reactors of Hanul Units 1 and 2 were shut down due to East Coast wildfires in April 2000, and the emergency diesel generator of Hanul Unit 6 was activated due to the Uljin-Samcheok wildfires in March 2022[2]. Wildfires caused all three incidents to downed power lines. Therefore, nuclear power plants located near forests are affected by wildfires and need to be evaluated for safety. This study analyzed the 100-year frequency of wildfire hazards in the vicinity of the Hanul NPP site using a Monte Carlo Simulation(MCS).

2. Wildfire Hazard Mapping Methodology

FlamMap was employed to conduct wildfire spread simulations for wildfire hazard analysis. A specific area was chosen to simulate wildfires, and geographical data within the selected region, including elevation, slope, aspect, fuel models, and canopy cover, was inputted. In addition, various conditions were created for wildfire simulations by combining wildfire duration, wind direction and speed, and ignition source as input variables to the MCS.

2.1. Setting the area of Interest

The area of interest for wildfire hazard assessment was established using the product of wildfire duration and spread rate, resulting in the maximum spread distance. To determine the duration of wildfires, a distribution for wildfire duration was developed using wildfire data from 13 to 22 years of the Korea Forest Service. The value of $\mu+1\sigma$, which is 3.4 hours from the distribution of wildfire duration, was employed for the area of interest. The maximum spread speed of a wildfire is 15 km/h, so we set the maximum spread distance of a wildfire to about 50 km [3]. To encompass all wildfires within a 50 km radius around the Hanul NPP, a square area of 200 km x 200 km was defined with the Hanul NPP site as its center. The area of concern is presented in Fig. 1.

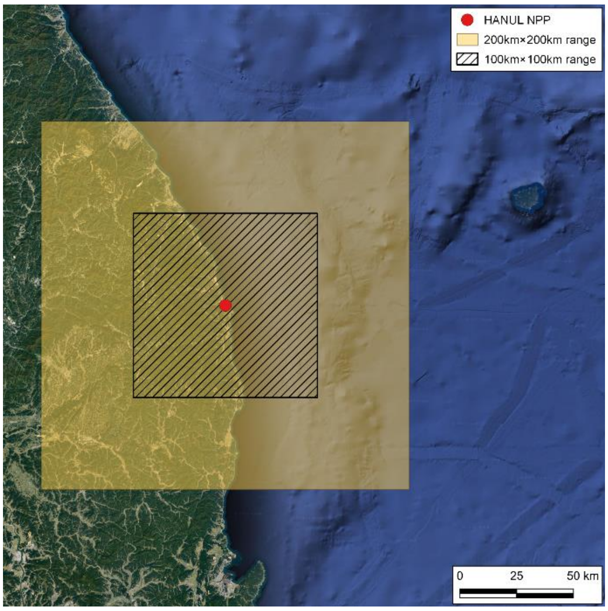
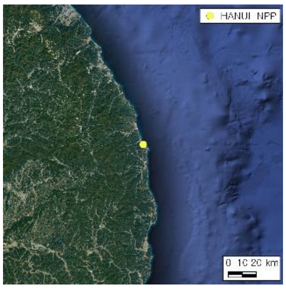


Fig. 1. Area of interest

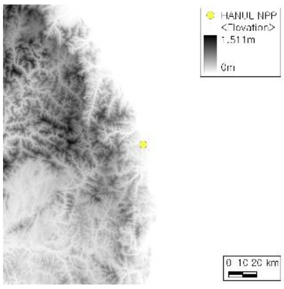
2.2. Creating FlamMap Input Data

2.2.1. Create Geographic Data for Wildfire Analysis.

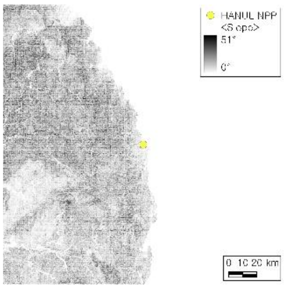
The elevation data from the 'Digital Elevation Model (DEM)_90M' provided by the National Spatial Data Infrastructure Portal was input into QGIS (Quantum Geographic Information System) to generate slope and aspect data. The fuel model utilized the 'Land Cover Medium Classification' provided by the Ministry of Environment. Referring to the 'Study on Sensitivities and Fire Area Errors in WRF-Fire Simulation to Different Resolution Data Set of Fuel and Terrain, and Surface Wind' appropriate fuel models for different terrains were input [4]. The canopy cover from the 'Digital Forest Type Map' provided by the Korea Forest Service is classified as A, B, and C. To use this in FlamMap, the midpoints of each category, which are 25%, 60%, and 85%, were input. The geographic data is presented in Fig. 2.



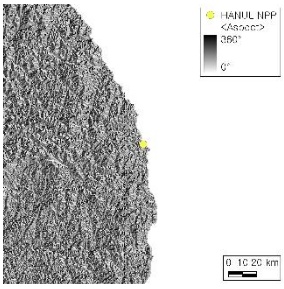
(a) Satellite photograph



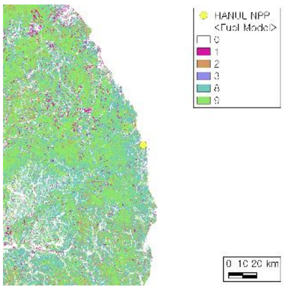
(b) Elevation



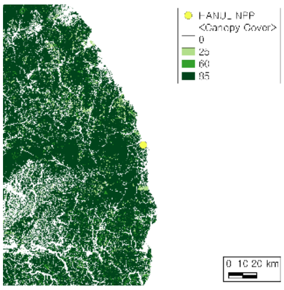
(c) Slope



(d) Aspect



(e) Fuel models

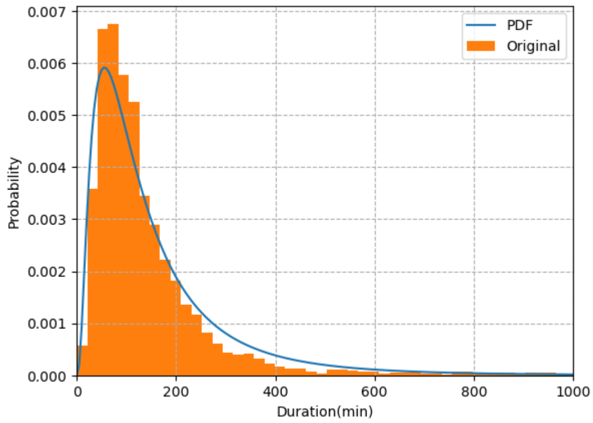


(f) Canopy cover

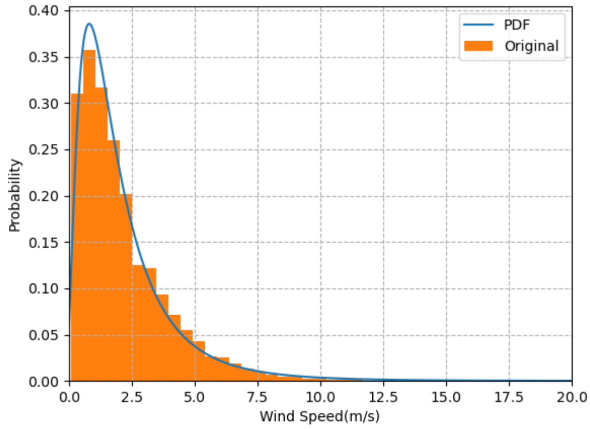
Fig. 2. Geographic data

2.2.2. Create Input Variables for MCS.

MCS input variables were generated using wildfire data from years 13 through 22. The wildfire duration was fitted with a lognormal distribution using the histogram to set the area of interest. The distribution of wildfire durations is presented in Fig. 3-(a). Wind direction was assumed to be uniformly distributed, and wind speed was fitted with a lognormal distribution using data from weather stations in the area of interest. The wind speed distribution is presented in Fig. 3-(b). Ignition source were randomized from forests within the area of interest.



(a) Distribution of wildfire durations



(b) Distribution of wind speed

Fig. 3. MCS input variable distributions

2.3. Derivation of Wildfire Frequency

The number of wildfires that occurred in Gangwon, Gyeongbuk, and Chungbuk from 13 to 22 years was divided by the forest area of the region and multiplied by the forest area in the area of interest to derive the frequency of wildfires in the area of interest. After summing the wildfire occurrence frequencies for each region, it was divided by 10 years, resulting in a Poisson distribution of 61.287 occurrences per year. In this study, 6,129 analyses were performed to produce a 100-year frequency wildfire hazard.

3. 100-Year Frequency Wildfire Hazard for the Hanul Site

Wildfire analysis was used to derive the 100-year frequency in the vicinity of the Hanul site. The Wildfire hazard of wind speed is presented in Fig. 4. The minimum probability of a wildfire is 0% and the maximum probability is 0.03%.

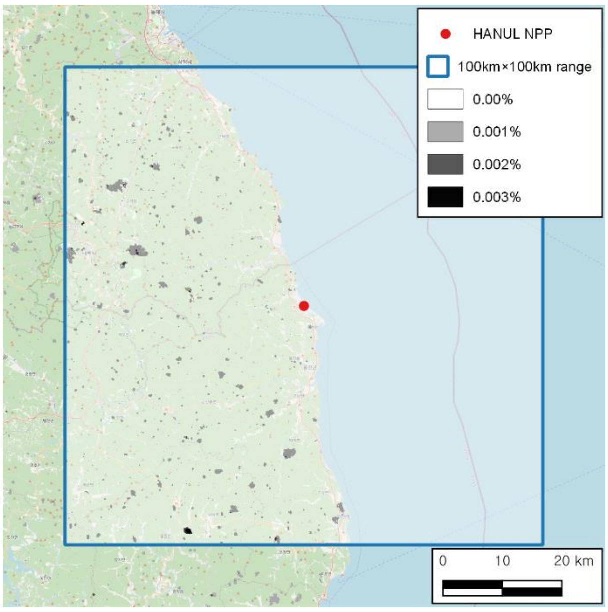


Fig. 4. Wildfire hazard near the Hanul site

4. Conclusions

Climate change is expected to increase the intensity and frequency of wildfires, affecting the operation and safety of NPP. In particular, the Hanul NPP is located near forests with a high proportion of coniferous trees vulnerable to wildfires. Therefore, in this study, wildfire analysis was performed for the Hanul site through fire data from 13 to 22 years, and a wildfire hazard at 100 years frequency was constructed. Wildfire hazard is expected to help assess the safety of marginalized power grids and power plant systems during wildfires.

5. Acknowledgement

This work was partly supported by Korea Institute of Energy Technology Evaluation and Planning(KETEP) grant funded by the Korea government(MOTIE)(No. 20224B10200050) and National Research Foundation of Korea (NRF) grant funded by the Korean government (Ministry of Science and ICT) (No. RS-2022-00154571)

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