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An Impact Analysis and Prediction of Disaster on Forest Fire

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Abstract

This study aims to create a model for predicting the number of extinguishment manpower to put out forest fires by taking into account the climate, the situation, and the extent of the damage at the time of the forest fires. Past research has been approached to determine the cause of the forest fire or to predict the occurrence of a forest fire. How to deal with forest fires is also a very important part of how to deal with them, so predicting the number of extinguishment manpower is important. Therefore predicting the number of extinguishment manpower that have been put into the forest fire is something that can be presented as a new perspective. This study presents a model for predicting the number of extinguishment manpower inputs considering the scale of the damage with forest fire on a scale bigger than 0.1 ha as data based on the forest fire annual report(Korea Forest Service; KFS) from 2015 to 2018 using the moderated multiple regression analysis. As a result, weather factors and extinguished time considering the damage show that affect forest fire extinguishment manpower.

Keywords: Correlation Analysis, Damaged Amount, Damaged Area, Extinguishment Manpower, Forest Fire, Moderated Multiple Regression Analysis

1. Introduction

Not long ago, a large forest fire broke out in Australia. Many experts have mentioned that climate change is the cause of forest fires. This forest fire could not be extinguished for a long time due to climate change in Australia which has become warmer and drier than in the past. In Korea, as the temperature is increasing, spring and autumn are disappearing in four seasons, and climate is changing to a subtropical climate that is humid in summer and dry in winter. Besides, because of the high proportion of mountainous terrain in Korea, it can spread to large forest fires on dry, windy days[1].

A total of 2,202 forest fires occurred between 2015 and 2018 based on Korea Forest Service (KFS). The data does not show an increase in forest fires year after year, but as the climate changes, big forest fires such as the Gangneung forest fire on April, 2019 are not easily suppressed, so preparing climate change is necessary.

In the past study, a model was developed to estimate the causes of forest fires through various weather factors, the number of hikers, and monthly factors, and to predict the probability of forest fires through weather factors possible scenarios. And, past research has been approached to determine the cause of the forest fire or to predict the occurrence of a forest fire. How to deal with forest fires is also a very important part of how to deal with them, so predicting the number of extinguishment manpower is important. Therefore predicting the number of extinguishment manpower that have been put into the forest fire is something that can be presented as a new perspective. In this study, we approach the forest fire extinguishment manpower to minimize the scale of damage when a fire occurs, rather than the cause of occurrence or the prediction of forest fire occurrence.

Therefore, we make a model for predicting forest fire extinguishment manpower by considering the climate, situation, and damage scale at the time of the fire.

In this paper, Section 2 introduces the past research direction of forest fires. Section 3 provides an introduction to the data and the current state of forest fires between 2015 and 2018. Section 4 presents the results of correlation analysis and moderated multiple regression analysis, and Section 5 draws conclusions.

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2. Disaster Caused by Forest Fire

Forest fire is a fire that is caused by combustion of fallen leaves, branches, herb, and timber in the forest. It means the burning of combustibles in the forest by embers caused by human inattention or arson and lightning or other explosives[2]. Forest fires can be classified by the extent of the damage. Fires that are less than 5 ha damaged and can be extinguished within 8 hours are called 'small forest fire' and fires that are 5 to 30 ha damaged and cannot be extinguished within 8 hours are called 'medium forest fire', for the last fires that are more than 30 ha damaged and last more than 24 hours are called 'large forest fire'[3]. In this study, small, medium, and large forest fires are not distinguished, and the forest fires are analyzed expecting forest fires which damage is less than 0.1 ha.

Past researches to minimize the damage of forest fires had been conducted to calculate the possibility of forest fire occurrence or to determine what caused forest fire. These studies are being conducted worldwide.

As a study on the causes of forest fires overseas, Calcerrada[4] mentioned that forest fires are closely related to human access to natural landscapes. another study on the prediction of forest fires, Kourtz and Todd[5] developed a forest fire prediction model using weather conditions and a forest fire risk index.

Lee[6] used to conduct a study about status and distribution of forest fires Korea forest fire statistics from 1991 to 2007, and Lee[7] who used forest fire occurrence statistics from 1991 to 2004 as a variable and provided basic development data on forest fire risk index. After that, a study was conducted through the relationship with weather factors along with the existing forest fire statistics. Lee[8] used the statistical analysis to characterize various types of forest fire occurrences in order to investigate the relationship between forest fire causes and weather conditions in climate change and forest fire research. Jeon[9] conducted a forest fire prediction model using various models using weather factors in each city.

In this study, we approach the forest fire extinguishment manpower that can minimize the scale of damage when forest fires occur, rather than the cause of forest fire occurrence or the prediction of forest fire occurrence. In addition, we develop a model for predicting forest fire extinguishment manpower using regression analysis, which is a statistical analysis method, rather than the conventional approach to forest fire occurrence probability.

Therefore, this study examines the relationship of variables that affect forest fire extinguishment manpower. It examines that the causes of the forest fire, evolutionary time, wind speed, relative humidity, temperature, damage, and damaged area affect forest fire extinguishment manpower. Then, we make a model for forecasting forest fire extinguishment manpower.

3. Data Introduction

This study used the data of forest fire document recorded in the forest fire annual report from 2015 to 2018. Variables such as the time, season, time required to extinguish forest fires, cause, and input extinguishment manpower were used. Also, Korea Meteorological Administration(KMA) record of the temperature, wind speed, and relative humidity, which are weather factor were added from time of the forest fire start and end. Since the dependent variable is used as forest fire extinguishment manpower, the analysis is conducted with a total of 1,029 cases. Table1 is the introduction to the

Table 1. Variable Name

Category	Variable Name	Unit	Collection
Forest Fire Information	Cause	-	KFS
	Extinguished Time	Minutes	
	Damaged Area(≥0.1Ha)	Ha	
	Damaged Amount	One million won	
	Extinguishment manpower	People	
Weather Factor	Wind Speed	m/s	KMA
	Temperature	℃	
	Relative Humidity	%	

Table 2. Current Status of Forest Fire

	2015	2016	2017	2018	Sum
Raw data	623	391	692	496	2,202
Over 0.1 ha	299	213	319	198	1,029

Table 3. Causes of Forest Fires

	2015	2016	2017	2018	Total
Arson	2	4	1	0	7
Spark	11	8	15	15	49
Inattention	123	75	125	76	399
Incineration	87	87	111	54	339
Facility Inattention	10	11	9	11	41
unknown cause	60	27	57	41	185
Natural cause	6	1	1	1	9
Sum	299	213	319	198	1,029

Table 4. Forest Fires for Season

	2015	2016	2017	2018	Total
Spring	178	129	210	80	597
Summer	49	23	36	31	139
Autumn	44	2	23	10	79
Winter	28	59	50	77	214
Sum	299	213	319	198	1,029

variables used in the forest fire extinguishment manpower model.

3.1 Current Status of Forest Fire

A total of 2,202 forest fires occurred between 2015 and 2018 based on KFS. Excluding forest fires with damaged area of less than 0.1 ha, a total of 1,029 cases occurred, with the largest number of forest fires in 2017. The data showed that forest fires do not show a trend of increasing over the years. Forest fires less than 0.1 ha require less forest fire extinguishment manpower, so, this study so this study is conducted with more than 0.1 ha forest fires. Table 2 is the status of forest fires from 2015 to 2018.

3.2 Causes of Forest Fires

The causes of forest fires are divided into natural occurrences such as lightning strikes and artificial occurrences such as fires of mountain occupants, incineration of paddy fields, incineration of garbage, fires of cigarettes, and fires of saints. Most of the forest fires recorded are caused by human rather than natural occurrences. The causes of the forest fire provided by the KFS were divided ourselves. Result of frequency analysis showed forest fire caused by inattention were the most frequent, with 399 cases, followed by fires with 339 incineration cases, such as trash and fallen leaves. Table 3 is the causes of forest fires from 2015 to 2018.

3.3 Forest Fires for Season

This is the result of frequency of forest fire occurrence according to season. In Korea, which has four seasons, the highest number of forest fires occurs 597 times in dry and windy spring. 139 cases in rainy and humid summer and 79 cases in autumn in the same condition. Table 4 is the seasonal forest fires from 2015 to 2018.

4. Analysis

4.1 Correlation Analysis

In this paper, we performed correlation analysis, a statistical method used to evaluate the strength of relationship between variables. Correlation refers to the

Table 5. Correlation Analysis Result

	Extinguished Time	Temperature	Wind Speed	Relative Humidity	Damaged Amount	Damaged Area	Extinguished Manpower
Extinguished Time		0.169**	0.072*	-0.039	0.749**	0.287**	0.332**
		0.000	0.021	0.213	0.000	0.000	0.000
Temperature			-0.165**	0.202**	0.013	0.007	-0.01
			0.000	0.000	0.671	0.81	0.747
Wind Speed				-0.199**	0.155**	0.151**	0.182**
				0.000	0.000	0.000	0.000
Relative Humidity					-0.187**	-0.119**	-0.146**
					0.000	0.000	0.000
Damaged Amount						0.435**	0.468**
						0.000	0.000
Damaged Area							0.920**
							0.000
Extinguished Manpower							

relationship between variables, which means looking at the direction and intensity of changes of another variable as one variable changes.

As a result of correlation analysis, Extinguished Time and Temperature(0.169), Wind Speed(0.072), Damaged Amount(0.749), Damaged Area(0.287) and Extinguished Manpower(0.332) have values with a significance probability of less than 0.05. The result is showing positive correlation(+) because correlation coefficient is positive number. Relative Humidity has a value bigger than 0.05, so the correlation coefficient can be said to be zero. In other words, there is no correlation. Temperature is positive correlation(+) with Relative Humidity(0.202) and negative correlation(−) with Wind Speed(-0.165). Wind Speed is positive correlation(+) with Damaged Amount(0.155), Damaged Area (0.151), Extinguishment manpower(0.182) and negative correlation(−) with Relative Humidity(-0.199). Relative Humidity is negative correlation(−) with Damaged Amount(-0.187), Damaged Area(-0.119), Extinguishment manpower(-0.146). Damaged Amount and Extinguishment manpower(0.468), Damaged Area(0.435) are showing positive correlation(+) as well as Damaged Area and Extinguishment manpower(0.920).

Extinguished Manpower is used as the dependent variable, it is judged that there is no problem of multicollinearity because the independent variables and moderator variables except the relation with Extinguishment manpower do not have a strong correlation coefficient relationship. Table 5 shows the correlation analysis between variables used in the regression analysis.

4.2 Moderated Multiple Regression Analysis

This study conducts multiple regression analysis to examine the effects of Extinguishment manpower following basic forest fire information and weather factor on forest fire. Additionally set the scale of damage as moderator variables, and the moderated multiple regression analysis is performed through hierarchical regression analysis. Moderated multiple regression analysis presented by Baron & Kenny[10] confirms the influence of the moderator variables on the relationship between the independent and dependent variables. Moderator variables are used to determine whether effect on dependent variables stronger or weaker. To see if there is a moderating effect, create an interaction term multiplying the independent and moderator variables. And then, If the interaction term shows a significant result, the influence of the moderator variable on the relationship between the independent and dependent variables are different. However, the interaction term itself consists of multiplying independent and moderator variables, which leads to multicollinearity problems. In order to solve the problem, this study creates and analyzes interaction terms using ‘mean centering’.

4.2.1 Damaged Area Moderator Variable

Figure out moderating effect of Damaged Area following Extinguishment Manpower in Extinguished Time and Weather Factor.

The first model shows only the relationship between independent and dependent variables. Significance probability of the F statistic is 0.000, which is less than 0.05, thus the first model is a significant model. Extinguished Time(β=348.6) and Wind Speed(β=110.786) have a positive relationship on Extinguishment Manpower and Relative Humidity(β=-6.249) has a negative relationship. Temperature is found to have no effect because the significance probability is greater than 0.05. The explanatory power of the first model is 14.3%.

The second model shows the relationship between the independent variable, the control variable and the dependent variable. Significance probability of the F statistic is 0.000, which is less than 0.05, thus the second model is a significant model. The independent variables Extinguished Time(β=82.516) and Wind Speed (β=27.274) and moderator variable damaged area(β= 26.847) are found to have a positive effect on the Extinguishment Manpower, Relative Humidity(β=-1.633) is found to have a negative relationship. The explanatory power of the second model with added Damaged Area, which is a moderator variable, is 85.3%.

The third model shows the relationship between independent variables, moderator variables, interaction terms and dependent variables. The significance probability of the F statistic of the third model is 0.000, which is less than 0.05, which is a significant model. Among the interaction terms, other interaction terms except Temperature x Damaged Area showed significant results because the significance probability was less than 0.05. The explanatory power of the third model reflected the moderator effect is 93.3%.

As a result of the above models, the Temperature is found to have no moderator effect. Since the Extinguished Time is positive(+) in first model and positive(+) in third model, it is found that the longer the Extinguished Time, the greater the impact on the Extinguishment Manpower by the Damaged Area, which is

Table 6. Moderated Multiple Regression Analysis Result – Damaged Area

	First Model		Second Model		Third Model	
	β	t	β	t	β	T
(Intercept)	-1438.298	-7.411**	-230.560	-2.806**	-370.902	-6.080**
Extinguished Time	348.600	10.931**	82.516	6.009**	147.291	14.702**
Temperature	-2.193	-0.719	-1.894	-1.499	-2.137	-2.483*
Wind Speed	110.786	4.520**	27.274	2.670**	9.893	1.417
Relative Humidity	-6.249	-3.407**	-1.633	-2.143*	-4.007	-7.325**
Damaged Area			26.847	70.374**	-24.269	-13.960**
Damaged Area*Extinguished Time					15.603	15.226**
Damaged Area*Temperature					0.057	0.792
Damaged Area*Wind Speed					-7.452	-14.950**
Damaged Area*Relative Humidity					-1.037	-10.746**
R^2	0.143		0.853		0.933	
ΔR^2			0.71		0.08	
ΔF	44.034		4952.535		306.955	
ΔF *p-value*	0.000		0.000		0.000	
F	44.034		1196.076		1595.84	
p-value	0.000		0.000		0.000	

the moderator variable. As the Wind Speed increased positively (+) in the first model and negatively(−) in the third model, the Wind Speed influenced the Extinguishment Manpower less significantly by the Damage Area. The Relative Humidity is negative(−) in the first model and negative(−) in the third model, and the lower the Relative Humidity is, the more affected by the Extinguishment Manpower by the Damaged Area. Table 6 shows the results of the moderated multiple regression analysis, in which the control variable was Damaged Area.

4.2.2 Damaged Amount Moderator Variable

Figure out moderating effect of Damaged Amount following Extinguishment Manpower in Extinguished Time and Weather Factor.

In the first model, the same result as above.

In the second model, the significance probability of the F statistic is 0.000, which is less than 0.05. The independent variable Wind Speed(β=86.914) and the moderator variable Damaged Amount(β=320.106) are found to have a positive effect on the Extinguishment Manpower. The explanatory power of the second model with added Damaged Amount, which is a moderator variable, is 23.0%.

The significance probability of the F statistic of the third model is 0.000, which is less than 0.05, which is a significant model. All interaction terms are significant because the significance probability is less than 0.05. The explanatory power of the third model reflected the moderator effect is 65.6%.

Since the Extinguished Time is positive(+) in first model and positive(+) in third model, it is found that the longer the Extinguished Time, the greater the impact on the Extinguishment Manpower by the Damaged Amount, which is the moderator variable. The Wind Speed is positive(+) in the first model and positive(+) in the third model, it is found that the larger the Wind Speed, the greater the impact on the Extinguishment Manpower by the Damaged Amount, which is the moderator variable. The Relative Humidity is negative(−) in the first model and negative(−) in the third model, and the lower the

Table 7. Moderated Multiple Regression Analysis Result – Damaged Amount

	First Model		Second Model		Third Model	
	β	t	β	t	β	t
(Intercept)	-1438.298	-7.411**	-2839.915	-12.599**	-229.003	-1.322
Extinguished Time	348.600	10.931**	-28.979	-0.626	-34.733	-1.113
Temperature	-2.193	-0.719	1.427	0.490	4.158	2.123*
Wind Speed	110.786	4.520**	86.914	3.723**	52.970	3.382**
Relative Humidity	-6.249	-3.407**	-2.562	-1.445	-1.030	-0.865
Damaged Amount			320.106	10.770**	33.138	1.524
Damaged Amount*Wind Speed					209.309	17.961**
Damaged Amount*Extinguished Time					184.892	16.575**
Damaged Amount*Temperature					8.415	6.341**
Damaged Amount*Relative Humidity					-4.106	-4.115**
R^2	0.143		0.23		0.656	
ΔR^2			0.087		0.426	
ΔF	44.034		115.982		317.335	
ΔF *p-value*	0.000		0.000		0.000	
F	44.034		62.38		218.558	
p-value	0.000		0.000		0.000	

Relative Humidity is, the more affected by the Extinguishment Manpower by the Damaged Amount. Table 7 shows the results of the moderated multiple regression analysis, in which the control variable was Damaged Amount.

5. Conclusion and Remarks

In this study, Extinguishment Manpower is different as the Damaged Area or Damaged Amount changed as the moderator variable. The lower the Relative Humidity, the higher the Wind Speed, and the longer the Extinguished Time, the more Extinguishment Manpower are needed, and Temperature don't affect the Extinguishment Manpower. In the model that the moderator variable is Damaged Area, the larger Damaged Area and the lower Relative Humidity, the larger Damaged Area and the longer Extinguished Time and the larger Damaged Area and the stronger Wind Speed need the more Extinguishment Manpower. Therefore, when it is dry and windy, more Extinguishment Manpower will have to be queued, and other equipment need to extinguish forest fires.

In the model that the moderator variable is Damaged Amount, the larger Damaged Amount and the lower Relative Humidity and the larger Damaged Amount and the longer Extinguished Time need the more Extinguishment Manpower. The larger Damaged Amount and the stronger Wind Speed, Extinguishment Manpower increase slowly. Therefore, the high Damaged Amount and the stronger Wind Speed don't greater increase Extinguishment Manpower, so having a forest fire extinguishment center in the right place will help to minimize the damage to the forest fire and reduce the Extinguishment Manpower.

In this study, we used the information and weather data in the forest fire register. But more available variables such as soil moisture and forest area are not missing, and if it is provided, a model that reflects the phenomenon is likely to be created.

Since many forest fires originate from humans, we cannot eliminate the cause of forest fires from the beginning, It is likely that forest fires will need to be educated or promoted for deepening awareness of forest fires.

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