Regular Article
pISSN: 2288-9744, eISSN: 2288-9752
Journal of Forest and Environmental Science
Vol. 39, No. 4, pp. 235-245, December, 2023
https://doi.org/10.7747/JFES.2023.39.4.235

JFES
Journal of Forest and Environmental Science

The Change in Fuel Moisture Contents on the Forest Floor after Rainfall

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Abstract

Forest fuel moisture content is a crucial factor influencing the combustion rate and fuel consumption during forest fires, significantly impacting the occurrence and spread of wildfires. In this study, meteorological data were gathered using a meteorological measuring device (HOBO data logger) installed in the south and north slopes of Kangwon National University Forest, as well as on bare land outside the forest, from November 1, 2021, to October 31, 2022. The objective was to analyze the relationship between meteorological data and fuel moisture content. Fuel moisture content from the ground cover on the south and north slopes was collected. Fallen leaves on the ground were utilized, with a focus on broad-leaved trees (*Prunus serrulata*, *Quercus dentata*, *Quercus mongolica*, and *Castanea crenata*) and coniferous trees (*Pinus densiflora* and *Pinus koraiensis*), categorized by species. Additionally, correlation analysis with fuel moisture content was conducted using temperature (average, maximum, and minimum), humidity (average, minimum), illuminance (average, maximum, and minimum), and wind speed (average, maximum, and minimum) data collected by meteorological measuring devices in the study area. The results indicated a significant correlation between meteorological factors such as temperature, humidity, illuminance, and wind speed, and the moisture content of fuels. Notably, exceptions were observed for the moisture content of the on the north slope and that of the ground cover of *Prunus serrulata* and *Castanea crenata*.

Key Words: fuel moisture, slope (north, south), meteorological factors, forest fire management

Introduction

Dryness caused by climate change has led to large wildfires, resulting in damage in the U.S., Australia, Brazil, and Russia. Numerous factors have contributed to the recent increase in wildfires in the United States, but drier meteorological conditions driven by global warming have significantly increased fuel drying during the forest fire period, creating favorable conditions for wildfires across forested areas, and consequently more than double the areas have been affected (Goodwin et al. 2021). In 2019, Australia's average temperature was 1.3°C above the 1961-1990 average, and prolonged drought and dry weather led to widespread wildfires induced by lightning, affecting an area of 18.6 million ha, with 34 human casualties, and approximately 1 billion wildlife affected (World Wide Fund for Nature 2020). In California in 2021, the Dixie wildfire burned 374,000 ha of forest, and in southwestern Europe (e.g., Portugal, Spain, and France) in 2022, the area affected during the forest fire period was three times larger than the average from 2006 to 2021 (Taylor et al. 2022; Rodrigues et al. 2023). In the last four decades, wild-

Received: November 9, 2023. Revised: November 10, 2023. Accepted: November 17, 2023.

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fires have become more year-round and large-scale, with an increase in the average number of wildfire cases per year and the proportion of wildfires occurring in the non-forest fire precaution period (i.e., spring and fall) increasing along with temperatures (Kang et al. 2019). The form and intensity of forest fires are influenced by the fuel amount in the forest, tree species, terrain conditions such as forest floor, dip slopes, and elevation, as well as meteorological conditions such as wind direction, wind speed, and relative humidity. The spread patterns of wildfires can be classified as surface fire, crown fire, ground fire, and spotting fire. The characteristics of surface fire have the ground cover such as combustible substances, weeds, and fallen leaves, and the shrubs combusted on the surface in the forest; if there are many combustible materials on the surface, it may change from surface fire to crown fire (Park et al. 2007). Topography and weather are natural factors that are difficult to change , but fuels are important factors in terms of wildfire management because characteristics of them such as quantity of fuel can be changed (Korea Forest Service 2022). If the fuel becomes dry, a forest fire can spread rapidly and turn into a large wildfire, but if the fuel moisture content is high, it can reduce or inhibit flammability and forest fire spread, or even inhibit them (Nelson 2001; Wotton et al. 2005). Considering that, it is necessary to identify how meteorological factors (e.g., temperature, humidity, wind, and rainfall) affect the forest fuel moisture content (Lee et al. 2010). In other countries, forest fuel moisture content is measured in various manners, but fuel moisture measurement using a desiccator (dry oven) is the most commonly employed method (Matthews et al. 2010). Although it is possible to accurately measure fuel moisture by collecting samples in the field, it is difficult to predict precise forest fuel moisture on a daily basis since the samples are dried in the desiccator (dry oven) for 24 or 48 hours (Aguado et al. 2007). In other countries, models are used to estimate fuel moisture, analyzing the relationship between the observed fuel moisture content and meteorological data collected in the field (Matthews 2013). In the United States, the fuel moisture content is divided into four categories (i.e., 1 hour, 10 hours, 100 hours, and 1,000 hours) based on the diameters of live fuels (i.e., herbaceous plants and woody plants) and dead fuels (Carlson et al. 2007; White 2018). One-hour fuel moisture represents the moisture of herbaceous plants or dead fuel like logs that are less than 0.64 cm in diameter. Ten-hour fuels are those ranging from 0.64 to 2.54 cm in diameter; 100-hour fuels range from 2.54 to 7.62 cm in diameter, and 1000-hour fuels range from 7.62 to 20.32 cm in diameter (Carlson et al. 2007).

The U.S. Wildland Fire Risk Prediction System initially consisted of nine fuel models, increasing to 20 models in 1978, which utilizing forest moist content (Anderson 1982). One to three fuel models are currently used depending on forest type (Gavazzi et al. 2013). Fuel moisture content, topographic factors, and daily weather observation data are used to generate a wildfire risk index for the day (Dimitrakopoulos et al. 2011).

In Canada, the fuel moisture content was divided into Fine Fuel Moisture Code (FFMC), Duff Moisture Code (DMC), and Drought Code (DC); FFMC indicates fuel a dry weight layer of approximately 0.25 kg/m^2; DMC represents fuel in a compacted organic layer of 5 kg/m^2 at a depth of 7 cm; DC represents seasonal drought effects in a deep organic layer of 25 kg/m^2 (Van Wagner 1987).

In South Korea, the following studies have been conducted: a study of modeling using indexing of 5 years' worth of meteorological data from the Gangwon province and Canada's Fine Fuel Moisture Code (FFMC) (Park et al. 2009); a study on the correlation of maximum temperature and relative humidity among meteorological factors, by collecting and drying fallen fuel to determine fuel moisture content in forests, as well as measuring changes in fuel moisture content after rainfall (Chae 2014); and a study on estimating forest fire probability and fuel moisture content by analyzing changes in moisture content after fuel collection (Lee et al. 2021). This study utilized meteorological factors, e.g., temperature, humidity, illuminance, soil moisture, wind direction, and wind speed, inside and outside a forest, identified the correlation between changes in fuel moisture content and meteorological factors in forests, and estimated fuel moisture content, in order to identify the relationship between meteorological factors and forest fire occurrence, which can be utilized to develop a modelling system for wildfire prediction.

Materials and Methods

Selection of the study site

The target site was Kangwon National University Forest located in Hyoja-dong, Chuncheon City, Gangwon Province. The elevation ranges from 95.00012 m to 135.2 m (N 37° 52' 01.47" E 127° 44' 40.79"). The area is approximately 11 ha. This target site was selected due to its easy accessibility considering the nature of the study, which requires daily fuel collections. The standard area for fuel collections was 20 m×20 m (0.4 ha), and we set up standard survey areas on the south and north slopes. The forest type is an artificial forest, and the forest floor distribution on the south slope is a mixed forest. The south slope is dominated by *Prunus serrulate*, and *Pinus densiflora*, with a forest age of Class Ⅲ, whereas the north slope is dominated by *Quercus dentata*, and *Pinus densiflora* with a forest age of Class Ⅴ (Table 1). The average annual temperature of Chuncheon obtained from the Chuncheon weather station is 11.4°C, and the maximum and minimum temperatures are 17.4°C, and 6.3°C, respectively; the average relative humidity is 70.7%, and the average annual precipitation is 3317 mm, and approximately 63% of the rainfall is concentrated in summer months.

Measurement methods

Meteorological data measurement

A HOBO data logger (u12-012) and a vane anemometer were installed in an exposed flat area and a forest inside Gangwon National University, to analyze meteorological factors inside and outside the forest, as well as the meteorological conditions affecting fuel moisture content (Fig. 1). An external sensor was connected to collect the following data at hourly intervals every day for one year from November 1, 2021 to October 31, 2022: daily average, minimum, and maximum temperature (°C), daily average, minimum, and maximum relative humidity (%), daily average, maximum, and minimum wind speed (m/s), daily average, minimum, and maximum soil moisture (%), and wind direction.

Table 1. Summary of the observation site statistics for the forest areas

Site	South	North
Location	N 37° 52' 2.11" E 127 °44' 45.56"	N 37° 52' 0.54" E 127° 44' 44.88"
Aspect	N	SW
Elevation (m)	126	126
Slope (°)	30	25
Age class	3	5
Tree density (tree/ha)	700	700
Crown density (%)	42.5	70.0
DBH (cm)	19.7	21.7
Height (m)	9.53	12.8

Forest fuels, soil

The fuel moisture content survey was conducted by collecting 10 g of fuel that fell on the campus forest at 15:00 every day from November 1, 2021, to October 31, 2022, which is the same as the meteorological measurement period, and the collections were repeated three times. Upper, middle, and lower ground cover and surface fuel samples were collected on both the south and north slopes. Ground cover included the fallen leaves and herbage on the forest surface, and the surface fuel included a layer of decayed organic matter such as fallen leaves and branches. For each of the dominant tree species in the forest, fallen leaves were collected from broad-leaved trees such as *Prunus serrulata* Lindl. f. spontanea (Maxim.) (Chin S. Chang), *Castanea crenata* Siebold & Zucc., *Quercus dentata* Thunb, and *Quercus mongolica* Fisch. ex Ledeb., and from coniferous trees such as *Pinus densiflora* Siebold & Zucc., and *Pinus koraiensis* Siebold & Zucc. (Korea National Arboretum 2021). After measuring the fresh weight of the collected fallen leaves and surface fuel, they were dried at 105°C for 48 h using a desiccator. By weighing the dried leaves, the fuel moisture content was calculated via Equation (1). To analyze the relationship between fuel moisture content and

Fig. 1. Meteorological equipment (HOBO data logger [u12-012]).

soil moisture, we monitored soil moisture through a HOBO data logger (u12-012) on the south and north slopes of Gangwon National University's campus forest. A soil moisture sensor was installed in the organic matter layer with a soil depth of 5-10 cm near the litter layer. The 10 HS sensor was employed as the soil moisture sensor, which is a Time Domain Reflector (TDR) sensor with a wide contact area that can measure the average volumetric water content of the measurement point, ranging from 0% to 57%, with a resolution of 0.08%.

$$FMC=\frac{(W_w-W_d)}{W_d}\times 100 \quad (1)$$

Results

Comparison of meteorological factors from the weather station and the forest

Meteorological factors affect the structure and function of forest ecosystems, and all components of forests are directly or indirectly influenced by climatic conditions, in this sense, collecting meteorological data is crucial when investigating forest vegetation (Choi and Chae 2019). To analyze the influence of meteorological factors on forest fuel moisture content, we measured temperature, relative humidity, wind direction, and illuminance at one-hour intervals every day from November 1, 2021, to October 31, 2022, using a meteorological measuring device (HOBO) installed in the forest of Gangwon National University. We also collected meteorological data from the Chuncheon weather station of the Gangwon Regional Meteorological Administration for comparison with the meteorological data from the forest. When comparing the data from the forest and the weather station from November 2021 to October 2022, there was no significant difference in the average and minimum temperatures, the maximum temperature from the forest was lower than that from the weather station for the entire period, by an average of 1.34°C. As for humidity, similar results were found for the average humidity, and the lowest humidity in the forest was 8.78% higher on average than that from the weather station. As for wind speed, both the average and minimum values from the weather station were higher than those from the forest (Tables 2, 3).

Comparison of soil moisture content in the forest

Precipitation was one of the meteorological factors examined when drawing correlations with soil moisture content within the forest (south-north slope). The annual average soil moisture on the south slope was 12.64%, and that on the north slope was 15.47%. The average precipitation was 142.19 mm per month. The months with the highest soil moisture on the south slope were July (22.62%) and August

Table 2. Observation of meteorological factors in the forest (2021.11.-2022.10.)

Study area		Temperature (°C)			Relative humidity (%)		Wind speed (m/s)			Light intensity (lx)		
Year	Month	T.	T. Max	T. Min	R.H.	R.H. Min	W.S.	W.S. Min	W.S. Max	L.I.	L.I. Min	L.I. Max
2021	11	4.54	0.18	9.94	69.47	48.61	0.03	0.00	0.30	5.51	1.10	25.80
	12	-1.32	-5.13	3.31	69.28	50.26	0.05	0.00	0.29	4.77	0.87	22.76
2022	1	-3.91	-8.84	1.44	63.31	42.88	0.02	0.00	0.10	6.27	0.65	30.25
	2	-2.33	-7.55	3.51	53.43	34.20	0.18	0.00	0.98	9.95	0.58	68.05
	3	6.58	1.32	12.37	63.08	43.15	0.23	0.00	0.98	11.34	0.96	58.45
	4	13.92	7.35	20.84	52.61	31.90	0.16	0.00	0.94	12.60	1.05	53.55
	5	17.77	11.22	24.38	56.56	35.18	0.04	0.00	0.45	7.37	1.10	29.59
	6	21.72	17.80	26.21	76.93	60.02	0.02	0.00	0.19	4.82	1.03	21.07
	7	25.45	22.04	29.69	86.37	68.85	0.00	0.00	0.07	4.27	0.99	17.07
	8	24.20	21.87	27.18	88.72	76.23	0.00	0.00	0.04	2.86	1.22	11.45
	9	19.91	16.15	24.94	79.27	58.31	0.00	0.00	0.00	2.91	1.10	11.23
	10	11.36	6.47	17.24	80.52	56.20	0.00	0.20	0.00	2.31	1.10	7.20
Average		11.49	6.91	16.75	69.96	50.48	0.06	0.02	0.31	6.25	0.98	29.71

Table 3. Observation of meteorological factors in chuncheon weather station (2021.11.-2022.10.)

Weather station		Temperature (°C)			Relative humidity (%)		Wind speed (m/s)		Precipitation (mm)
Year	Month	T.	T. Max	T. Min	R.H.	R.H. Min	W.S.	W.S. Max	Total
2021	11	4.49	-0.63	11.15	67.91	37.53	1.24	3.57	53
	12	-1.24	-6.18	4.47	67.56	39.26	1.23	3.49	5.1
2022	1	-4.19	-10.40	2.95	63.47	31.61	1.01	3.06	2.8
	2	-2.44	-9.53	4.85	52.45	24.93	1.63	4.10	6.6
	3	6.58	0.35	13.15	61.87	34.74	1.56	4.03	103
	4	13.97	6.55	21.58	52.19	26.10	1.74	4.49	28.5
	5	18.07	10.74	25.24	56.52	29.10	1.69	4.32	10.9
	6	22.60	18.25	27.41	73.56	51.70	1.66	3.85	402.5
	7	26.65	23.04	31.30	83.94	60.87	1.27	3.31	208.2
	8	25.15	22.12	29.00	86.92	66.32	1.24	1.24	491.7
	9	20.46	15.79	26.66	81.02	50.80	1.50	1.50	256.7
	10	12.69	7.91	19.37	80.28	47.42	1.11	1.11	137.3
Average		11.90	6.50	18.09	68.97	41.70	1.41	3.17	1,706.30

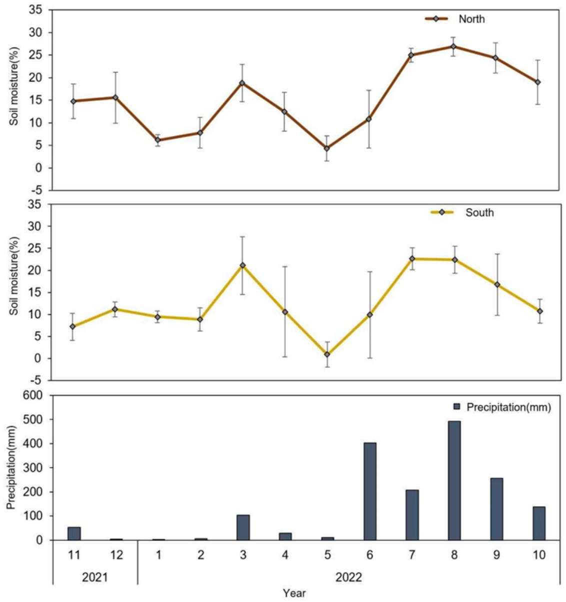

Fig. 2. Comparison of soil moisture content and precipitation in the forest (north and south).

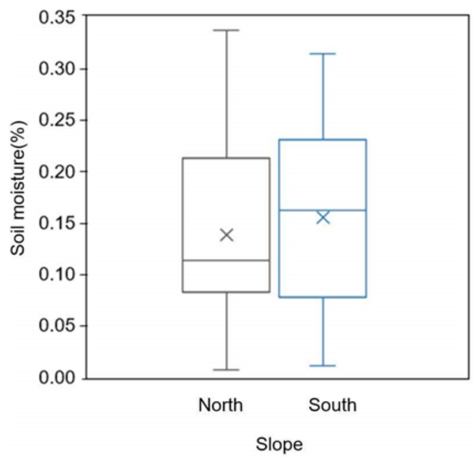

Fig. 3. Comparison of soil moisture on forest slopes.

(22.42%). Precipitation was concentrated in June-September with 402.5 mm in June, 208.2 mm in July, 491.7 mm in August, and 256.7 mm in September (Fig. 2). As a result of analyzing the soil moisture values per slope, the north slope showed 0.13% and the south slope showed 0.15%, which indicated similar values (Fig. 3).

Comparison of forest fuel moisture content

Comparison of the moisture content of the ground cover and the per slope

The fallen ground cover/was collected after dividing the areas into upper, middle, and lower slopes on the south and north slopes, and an analysis was performed using the Mann-Whitney U test, a non-parametric analysis, to verify the differences per slope. The collection interval was divided into four periods: autumn forest fire period (1 Nov.-1 Dec.), spring fire period (1 Feb.-15 May), non-forest fire period (1 Jan.-31 Jan., 16 May-31 Oct.), and the entire period of fuel collection (1 Nov. 2021-31 Oct. 2022). As for the ground cover and per slope in the fall forest fire precaution period, the fuel moisture content of the ground cover on the north slope was 18.75%, which was higher than that on the south slope, and the fuel moisture content of the surface fuel was 56.81%; results of the analysis indicated that the ground cover per slope showed significance, but the surface fuel per slope was not significant (Fig. 4). During the spring forest fire precaution period, the north slope had a higher moisture content than the south slope with a ground cover of 2.83% and a surface fuel of 9.01%; the ground cover and surface fuel both showed significance.

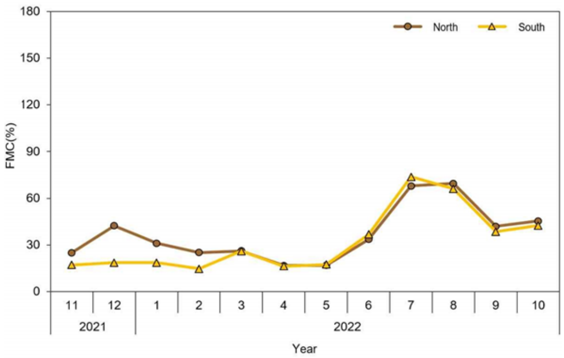

Fig. 4. Comparison of dead fuel moisture content by slope (2021.11-2022.10).

During the non-forest fire precaution period, the north slope had a higher moisture content than the south slope with 2.71% of ground cover and 0.92% of, and the significance was the same as the result in the spring forest fire precaution period. During the entire study period, the fuel moisture content on the north slope was higher than that on the south slope, with 4.47% of ground cover and 9.74% of the; the ground cover and showed significance. The moisture differences in the ground cover and during the spring forest fire precaution period, compared to the fall forest fire precaution period, was large due to the lack of precipitation and dryness in spring (Fig. 5).

Fuel moisture content comparison per tree species

The fuel moisture content of fallen leaves per tree species was analyzed using the following six tree species: broadeaved trees such as *Prunus serrulata*, *Quercus dentata*, *Quercus mongolica*, and *Castanea crenata*, and coniferous trees such as *Pinus densiflora*, and *Pinus koraiensis*. As a result, the order of fuel moisture content per tree species during the fall forest fire precaution period was as follows: *Prunus serrulata* > *Pinus densiflora* > *Castanea crenata* > *Pinus koraiensis* > *Quercus dentata* > *Quercus mongolica*. The significance analysis per tree species showed that *Quercus dentata*, *Quercus mongolica*, *Castanea crenata*,

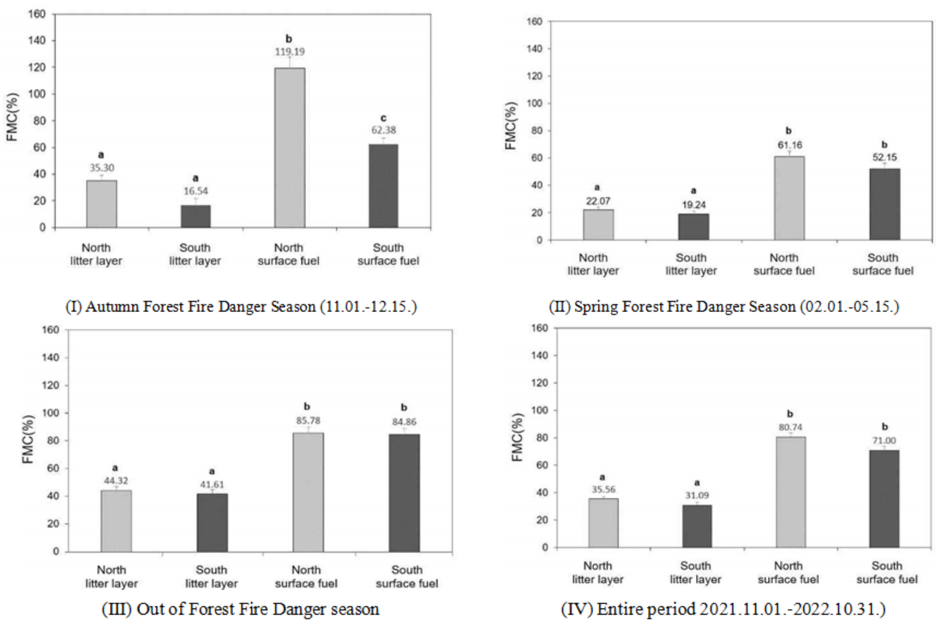

Fig. 5. Comparison of moisture content in litter layer and surface by period.

Pinus densiflora, and *Pinus koraiensis* had significantly different fuel moisture contents, except for *Prunus serrulate*. *Pinus densiflora* had significance values with *Prunus serrulata* and other tree species. The average fuel moisture content of the tree species in the spring forest fire precaution period was 18.54%, which was 5.90% different from the average value in the fall forest fire precaution period. By tree species, the moisture content was high in the following order: *Prunus serrulata*> *Pinus koraiensis*> *Castanea crenata*> *Pinus densiflora*> *Quercus dentata*> *Quercus mongolica*. Like the fall forest fire precaution period, other tree species had significance, except for *Prunus serrulate*, and only *Pinus koraiensis* had significance with *Prunus serrulate* and other tree species. The average fuel moisture content of the six tree species in the non-forest fire precaution period was 34.14%, and the fuel moisture content was found to be high in the following order: *Prunus serrulata*> *Pinus koraiensis*> *Pinus densiflora*> *Quercus mongolica*> *Castanea crenata*> *Quercus dentata* (Fig. 6). During this period, all tree species had significance. The fuel moisture content for the entire year of fuel collection was found to be high in the following order: *Prunus serrulata*> *Pinus koraiensis*> *Pinus densiflora*> *Castanea crenata*> *Quercus mongolica*> *Quercus dentata*. *Quercus dentata*, *Quercus mongolica*, *Castanea crenata*, *Pinus densiflora*, and *Pinus koraiensis* showed significance, and also it was found that *Prunus serrulate* and *Pinus koraiensis* had significance. The fuel moisture content value was highest for *Prunus serrulata*, which may be attributable to the fact that *Prunus serrulata* is a tree species undergoing rapid moisture changes, and is dried quickly in the early stage, resulting in a different response to meteorological factors compared to other tree species (Chae and Lee 2003) (Table 4).

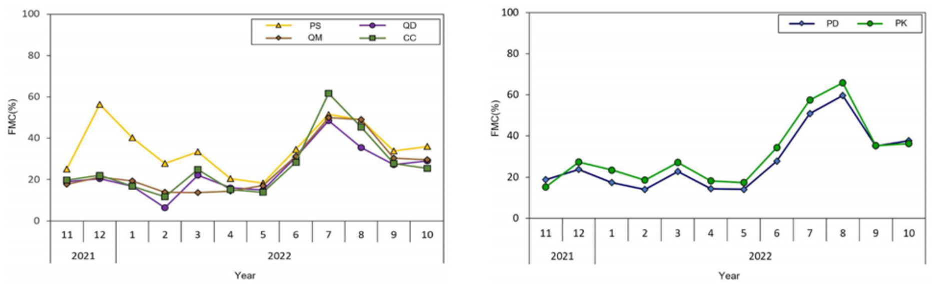

Fig. 6. Comparison of dead fuel moisture content by tree species (2021.11.-2022.10). PS, *Prunus serrulata*; QD, *Quercus dentata*; QM, *Quercus mongolica*; CC, *Castanea crenata*; PD, *Pinus densiflora*; PK, *Pinus koraiensis*.

Table 4. Fuel moisture content by tree species (2021.11.01.-2022.10.31.)

Year	Month	PS	QD	QM	CC	PD	PK
2021	11	25.05	18.95	17.70	19.78	18.68	15.13
	12	56.28	20.47	21.20	22.03	23.66	27.32
2022	1	40.24	16.78	19.37	16.85	17.37	23.42
	2	27.78	6.35	13.81	11.62	14.03	18.56
	3	33.42	22.17	13.72	24.85	22.66	27.05
	4	20.41	15.97	14.41	15.11	14.30	18.19
	5	18.33	14.89	17.07	13.89	14.06	17.34
	6	34.55	30.74	31.21	28.28	27.80	34.36
	7	51.50	48.59	49.88	61.76	50.92	57.49
	8	48.78	35.41	49.06	45.37	59.69	65.95
	9	33.86	27.31	30.35	27.73	35.11	35.25
	10	36.09	29.14	29.56	25.46	37.70	36.23
Average		35.52	25.44	25.98	26.34	28.00	31.36

PS, *Prunus serrulata*; QD, *Quercus dentata*; QM, *Quercus mongolica*; CC, *Castanea crenata*; PD, *Pinus densiflora*; PK, *Pinus koraiensis*.

Changes in forest fuel moisture content per tree species after rainfall

Precipitation is a meteorological factor influencing wildfire risk, increasing forest fuel moisture content and reducing wildfire risk in the event of forest fire. To predict forest fuel moisture, it is important to estimate the increase in forest fuel moisture content in connection with precipitation, and thus help predict moisture loss and the duration of wildfire risk (Lopes et al. 2014). Pearson correlation analysis was performed to confirm the correlations between daily precipitation and fuel moisture content by utilizing moisture content of ground cover and per slope (north-south), and average moisture content values of tree species, *Prunus serrulata*, *Quercus dentata*, *Quercus mongolica*, *Castanea crenata*, *Pinus densiflora*, and *Pinus koraiensis*, from November 2021 to October 2022. Results from the analysis indicated there was a significant correlation ($p < 0.001$) between the precipitation, and ground cover and per slope (south and north), and broad-leaved trees and coniferous trees (Table 5). Forest fuel moisture content can increase or decrease along with precipitation, as the intensity and amount of precipitation determines the amount of moisture content in the fuel (Chae 2014; Lopes et al. 2014). Based on previous studies indicating that fuel moisture content is maintained for 1-2 days after 10 mm of precipitation, and wildfire risk is low for a minimum of 3 days after more than 10 mm of precipitation (Lopes et al. 2014), we set the precipitation criterion as 10 mm, and compared changes in fuel moisture content up to five days after rainfall. Precipitation was classified into four bands: 1-10 mm, 11-20 mm, 21-30 mm, and 31-40 mm. When comparing fuel moisture content after rainfall per tree species, the moisture content of *Prunus serrulata* was found to be high except in the case of the 11-20 mm band. When precipitation is 1-10 mm, the moisture content was 11-13% higher for two days after the rainfall, and then decreased. In the case of 11-20 mm, the moisture content was 34-81% higher per tree species one day after rainfall; *Prunus serrulate* had the highest moisture content of 81.61%, and *Pinus densiflora* had the lowest moisture content of 34.92%. Two days after rainfall, the moisture content decreased. In the case of 21-30 mm precipitation band, the moisture content increased up to 30-66% one or two days after the rainfall, and the moisture content of *Quercus mongolica* had a 30% decrease two days after the rainfall. In the case of 31-40 mm of precipitation, the fuel moisture content per tree species increased over a wide range of 7-59% one day after the rainfall, but it decreased to 13-70% two days after the rainfall (Fig. 7).

A previous study of rainfall and fuel moisture content changes demonstrated that fuel moisture content changed within a range of 20% between one and two days after rainfall, but this study showed various results depending on the ground cover, tree species, and rainfall bands (Chae 2014).

Conclusion

In order to analyze the effect of metrological factors on fuel moisture content in forests, we collected the fallen ground cover and in the Kangwon National University forest, from November 2021 to October 2022, measured the dry weight and collected metrological data in the study target area, and then analyzed the correlation between the metrological data and fuel moisture.

As a result of analyzing the data on fuel moisture content in the forest, the moisture content of the on the north slope was 56.81% higher than that of the south slope. This is because the insolation distribution is highest on the south side and lowest on the north side. Therefore, even in the same forest, the fuel moisture content is different depending on

Table 5. Pearson correlation between precipitation and north-south slopes litter layer, surface fuel, broadleaved, and coniferous

Correlation	North litter layer	South litter layer	North surface fuel	South surface fuel	Broad-lea ved	Conifero us
	0.336**	0.391**	0.239**	0.330**	0.412**	0.398**
p	0.001					

**Signigicant at 1% levels respectively.

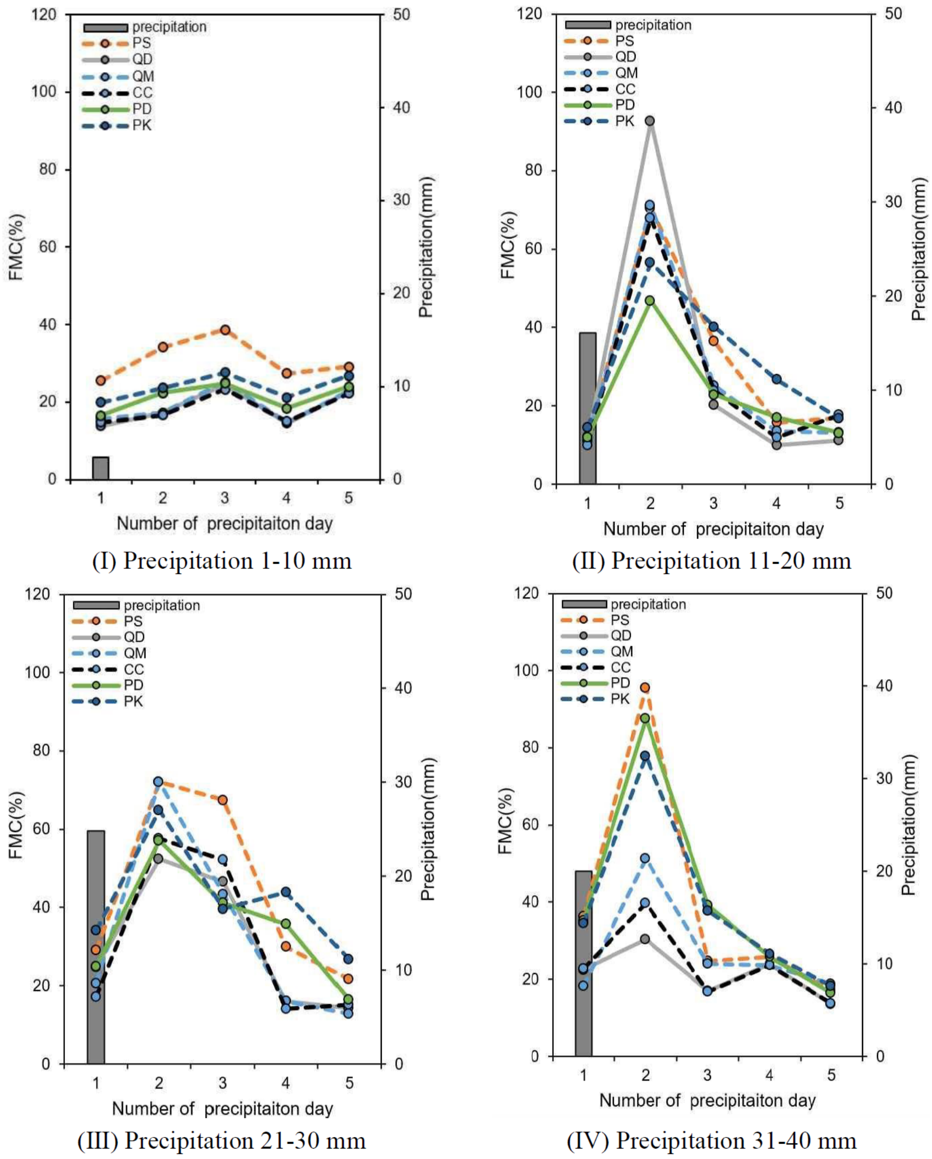

Fig. 7. Comparison of moisture content by tree species after rainfall. PS, *Prunus serrulata*; QD, *Quercus dentata*; QM, *Quercus mongolica*; CC, *Castanea crenata*; PD, *Pinus densiflora*; PK, *Pinus koraiensis*.

the slope. By tree species, *Prunus serrulate*, a broad-leaved tree species, had the highest fuel moisture content during the entire study period; other tree species, except for *Prunus serrulate*, had significance differences in the spring and fall forest fire precaution period, the non-forest fire precaution period, and the entire study period. When comparing the average values of the meteorological data from in the forest (south-north slope) and outside the forest (bare land) during the period of November 2021 to October 2022, the area outside the forest (bare land) showed the highest values with the average temperature of 1.24°C and the maximum temperature of 5.83°C. The average and minimum humidity of the area outside the forest (bare land) was 5.03% and 14.56% lower than the area inside the forest (south-north slope). As for wind speed, both average and maximum wind speeds in the area outside the forest (bare land) were 0.29 m/s and 0.92 m/s, respectively, which were higher than those inside the forest, and the minimum wind speeds were found to be the same outside the forest (bare land) and inside the forest (south-north slope). As for illuminance, its difference between inside and outside the forest was the highest, with an average illuminance of 71.77

lux and the highest illuminance of 283.14 lux outside the forest (bare land) which is higher than those inside the forest (south-north slope). However, the lowest illuminance was found to be high (0.30 lux) inside the forest (south-north slope). Even within the same forest, it is assumed that there are differences in metrological factors depending on the slope and vegetation distribution.

As a result of analyzing a regression equation through the meteorological factor with high significance levels, and fuel moisture content, except for *Prunus serrulate* and *Castanea crenata*, significance was found in ground cover, and per slope (north and south slopes), and tree species (*Quercus dentata*, *Quercus mongolica*, *Pinus densiflora*, *Pinus koraiensis*) with temperature (average, minimum, maximum), humidity (average), illuminance (average), and wind speed (average). Regression analysis between metrological factors and fuel moisture indicated that meteorological factors such as temperature, minimum temperature, maximum temperature, and average humidity had a significant effect on the moisture content of the on the south slope, and the analysis showed 25.4% explanatory power. The regression analysis of fuel moisture with meteorological factors on the north slope showed 26.8% explanatory power using the meteorological factor values such as the average temperature, minimum temperature, maximum temperature, average relative humidity, and illuminance of the on the north slope.

This study analyzed the relationship between forest fuel moisture content and meteorological factors, and the findings of this study are expected to contribute to building basic data capable of predicting changes in forest fuel moisture content per region. We analyzed the data by utilizing the results for one year, but it is necessary to conduct more systematic and effective research on fuel moisture content per season and period through long-term data collection in the future.

Acknowledgements

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (No. 2021344E10-2223-CD01).

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