Fuel Type Classification and Fuel Loading in Central Interior, Korea: Uiseong-Gun

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Abstract*—The objective of this study is classification of fuel type and calculation of fuel loading to assess forest fire hazard by fuel characteristics at Uiseong-gun, Gyeongbuk located in the central interior of Korea. A database was constructed of eight factors such as forest type and topography using ArcGIS 9.1 GIS programs. An on-site survey was conducted for investigating vegetation and fuel loading. Forest distribution of Uiseong-gun is composed of mixed forest, about 43.7%, of coniferous trees such as* Pinus densiflora*, approximately 43.5%, and of broad-leaved trees like* Quercus variabilis*, 8.7%. In order of age class, trees are III-class (11~20 years) 57.6%, IV-class (21~30 years) 25.1% and II-class (1~10 years) 14.4%. By diameter at breast height (DBH) 82.5% are small diameter, 6~16 cm, and 14.9% of young trees are under 6 cm diameter. Most trees are are less than 16 cm DBH. Considering Korean forest characteristics this study led to a classification of ten fuel types. With the utilization of the data taken into account, this research, based on the existing forest type and forest soil map, categorized the 10 fire fuel types into three coniferous forests (C), one broadleaf forest (D), and one mixed forest (M), five fuel type forests in total. In shrub layers and below them, fuel load was found to be 7.64 t/ha in* Pinus densiflora *pure forest (C-1), 10.99 t/ha in the* Pinus densiflora*-middle stratum (C-2), 8.62 t/ha in the* Pinus densiflora*-substratum (C-3), 9.17 t/ha in the mixed forest (M), and 1.01 t/ha in the broadleaf forests (D). To categorize fuel types in drawing a forest fire fuel map, the research analyzed the relationship between the density of coniferous forests (C-1, C-2, and C-3), fuel load and forest soil conditions.*

Introduction

The USDA Forest Service developed a forest fire danger rating system consisting of two fuel models in 1964. The 1972 National Fire Danger Rating System (NFDRS) used nine fuel models (Deeming and others 1972). The 1978 NFDRS uses 20 fuel models (Deeming and others 1977). This research enables people to predict fire behavior in wildlife resources, thereby allowing one to evaluate and control potential forest fire damage. Rothermel's (1972) mathematical fire spread model enables quantitative prediction of fire behavior and forest fire danger rating. This mathematical model requires a description of fuel characteristics to calculate forest fire danger indices, namely, fire behavior potential. Data collection for fuel characteristics can be categorized as fuel models, which consist of four groups: grass, shrub, timber, and slash (from logging or fire or wind damage). Fire danger rating uses 20 fuel models. Thirteen fuel models are used in the fire behavior prediction and application (Albini 1976). Anderson (1982) provided photographs and descriptions of fuel models in particular areas, allowing users to use them

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with ease. Anderson also linked the fire behavior fuel models with fuel models in the National Fire Danger Rating System.

The Canadian Fire Behavior Prediction (FBP) system categorizes fuel types into five groups consisting of 16 types. The FBP system fuel types are quality-focused rather than quantity-focused, and are categorized into overstory layers (structure and composition of standing tree areas), shrub layers (surface and ladder fuel), and surface vegetation and duff layers.

This research seeks to use fuel management programs fit for Korean circumstances, taking into account geographical and ecological characteristics, and develop fuel models to be used in evaluating forest fire danger levels.

Methods

Study Area

Uiseong-gun belongs to North Gyeongsang Province, and is located in the middle inland area of Korea (Figure 1). The county's topography, except the area of Sinpyeong-myeon to the northwest, is not so rugged. The northwestern area is part of Taebaek Mountain Ridges, featuring overlapped mountainsides and forming highlands, but is in its old age stage and is relatively well-developed. The county is long east to west, and narrow north to south, forming a narrow rectangle. Major mountains include Mt. Geumseong (530 m), Mt. Seonam (879 m), and Mt. Bibong (672 m) to the southwest, as well as Mt. Bibong (579 m), Guksabong Peak (521 m) and Mt. Munam (460 m) to the Northeast. The county's forests consist of mixed forests, coniferous forests, and broadleaf forests. Pine tree forests represent over one-third of the forests. By forest type, mixed forests represent 43.7% of the total forests, coniferous forests 43.5%, and broadleaf forests 8.7%, thereby forming various forest types.

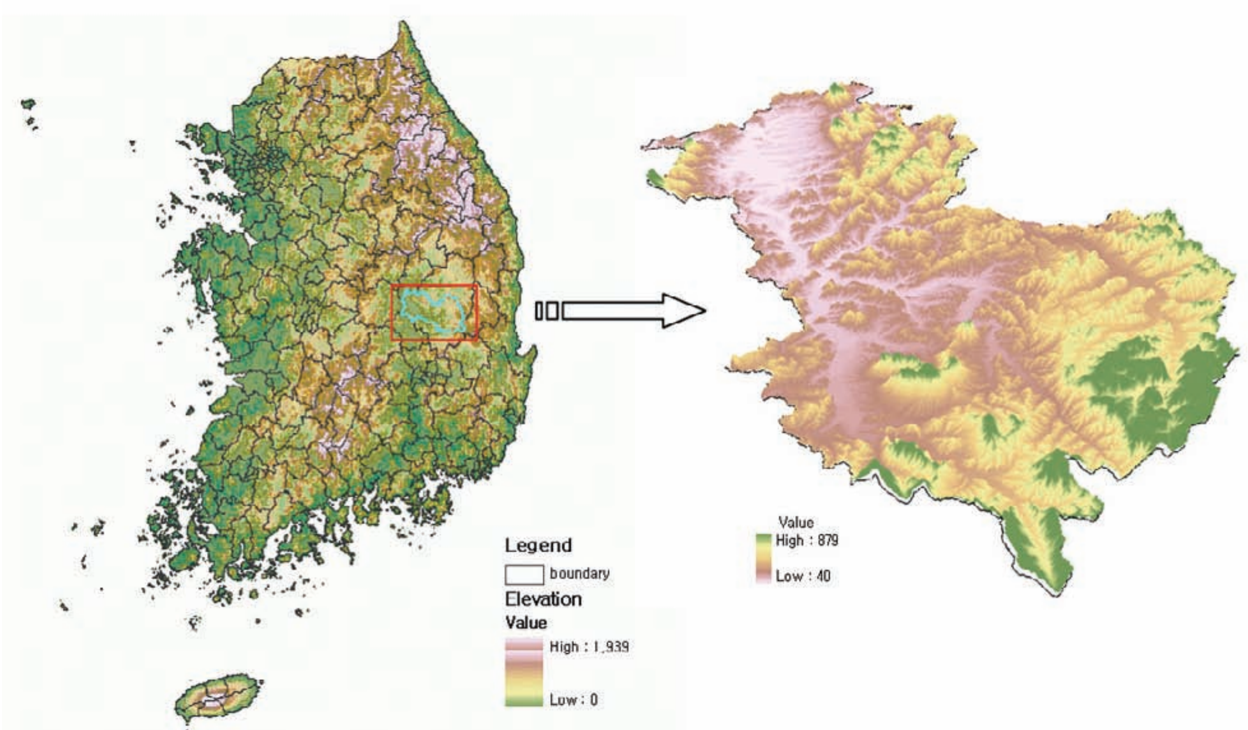


Figure 1—Site map of Uiseong-gun and on-site study area.

Field Methods

The recent-five-year (2001-2005) forest fire outbreak statistics by season indicates an annual average of 543 cases, and of these, in spring (March-May) alone, 364 cases broke out, representing 67% of the total. Thus, to accurately survey fuel load by forest fire type, on-site investigation was conducted in the spring, which is the driest season and has the greatest danger of forest fire.

To survey vegetation with the aim of categorizing forest fire fuel types, quadrates (10 m x 10 m) were installed in each vegetation community type classified by physiognomy and location conditions, and dominance and sociability by hierarchical level were measured using Braun-Blanquet (1964)'s phytosociological method, Z-M tradition. Regarding timbers and Korean dogwood existing in the installed quadrats, their species, tree height, crown base height, DBH, and crown diameter were measured. Also surveyed were each hierarchical level (timber, shrubs, and grass) and the thickness of fallen leaves that may influence forest fire ignition. Since fuel types within forest areas, even though the related trees are of the same kind, may have different structures according to topographical conditions, elevation, aspect, slopes and location coordinates were marked in the survey camp. To categorize Uiseong-gun's forest fire fuel types, live vegetation and dead fuel were surveyed in 46 survey zones. To estimate fuel load, fuel load in surface fuels in shrubs and litter were surveyed (Figure 2).

To survey fuel load, shrub forests were divided in a size of 2 m x 2 m, while grass, fallen leaves, fallen branches, and fruits were divided in a size of 1 m x 1 m. Also related fuels were collected on site and live load was measured. Each collected sample was dried in a drying oven, and dried load was measured again. On-site survey items are as follows (Figure 2).

- Vegetations survey: 10 m x 10 m quadrates
- Overstory: Tree height, crown base height, DBH, density
- Understory: Height of shrubs and grass layer, percent cover
- Fuel load: shrub, grass, fallen leaves, fallen branches
- Topographical conditions: elevation, slope, aspect

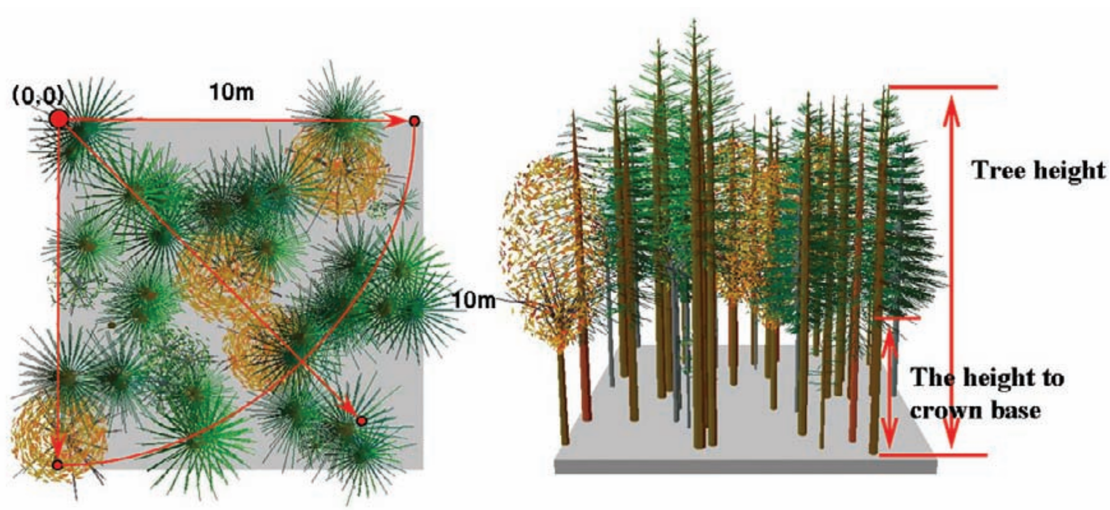


Figure 2—Field methods for fuel type classification.

Building of Database for Fuel Type Classification

To identify the distribution of Uiseong-gun's forest types, using a forest type map with a scale of 1:25,000 crafted by Korea Forest Research Institute and Korea Forest Service, maps by forest type and age class were developed. Using these forest type maps, survey points were selected to categorize forest fire fuel types, and taking account of the distribution ratios of forest types, the survey plan for the Uiseong-gun area was established. Also, to determine topographical features of Uiseong-gun, digital elevation models were crafted to manufacture a map featuring altitude, slopes and four directions (Figure 3). Also, since forest soil conditions have a great effect on the growth of trees and plants, (the map) reflected soil types to be used as reference data in categorizing forest fire fuel types. In this research, to distinguish the fuel type of pine tree forests, which have the highest danger of forest fire, soil types were extracted from the forest type map, and the relationship between the density and fuel load by soil type was analyzed.

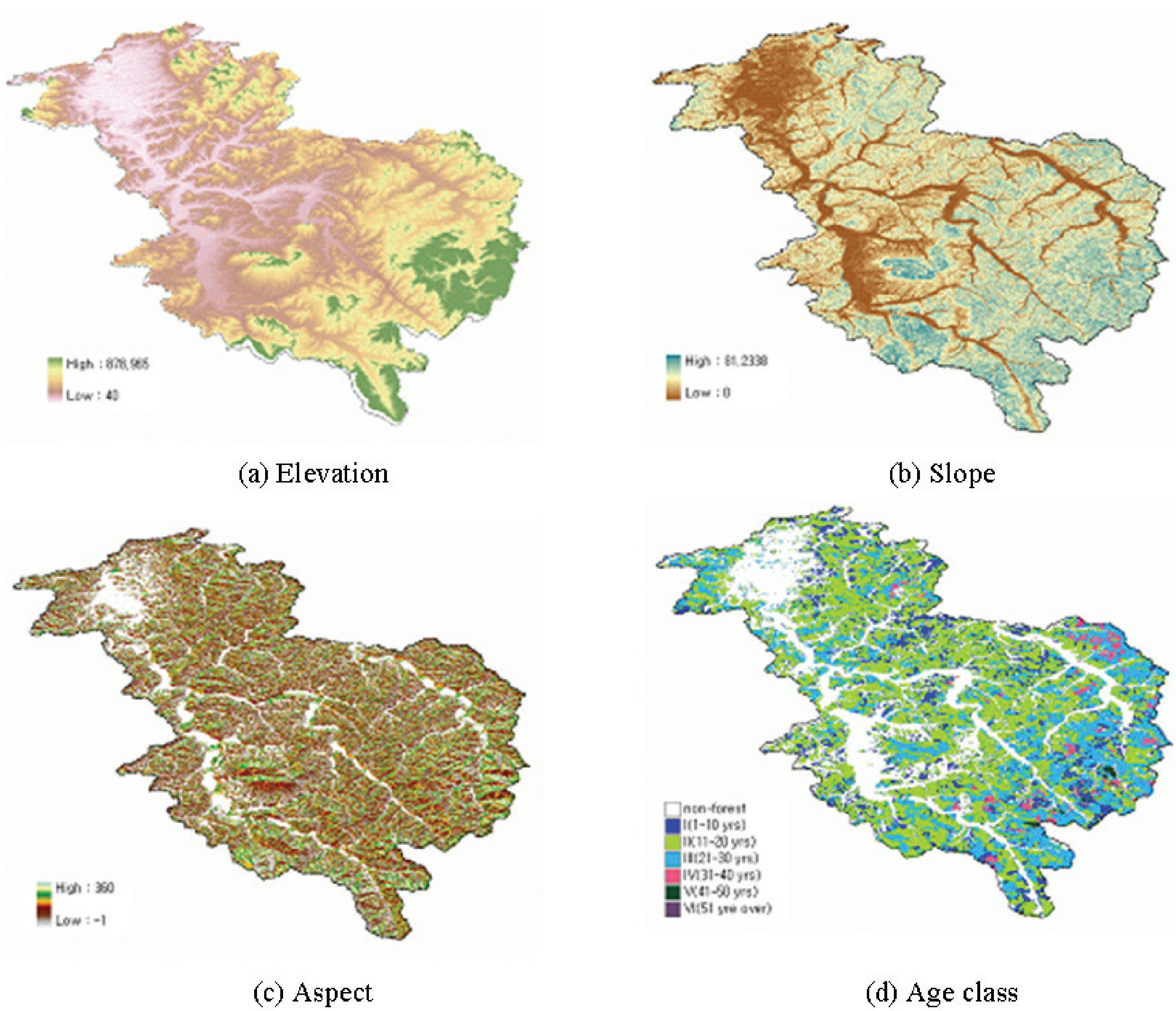


Figure 3—Topographical and forest conditions in Uiseong-gun.

Results and Discussion

Forest Type and Topographic Information

To structure databases designed for categorizing fuel types, using a forest digital map and a forest topographical map with a scale of 1:25,000, maps were crafted to reflect forest types, age class, forest type information by diameter class, DEM, slopes, aspect, and altitude, thereby determining the Uiseong-gun area's topographical information (Figure 4). In Uiseong-gun, mixed forests with coniferous and broadleaf forests represent the largest portion of the total at 43.7%, with pine tree forests accounting for 37.3%. Regarding distribution area by forest type, mixed forests represent 43.7% of the total, coniferous forests 43.5%, and broadleaf forests 8.7% (Table 1). By age class, the third-age class represents 57.6%, 4th-age class 25.1%, and 2nd-age class 14.4%, showing most of forests (72%) consist of forests under 30 years old (Table 2). Regarding distribution by diameter class, small-diameter trees account for 82.5%, thus making trees with the diameter of less than 16cm at the chest's height form the most of the forests (Table 3). Uiseong-gun's slopes are 20-25 degrees for 22.6% of the total area, 25-30 degrees for 40.3%, and over 30 degrees for 36.6%, showing most of the area has steep slopes.

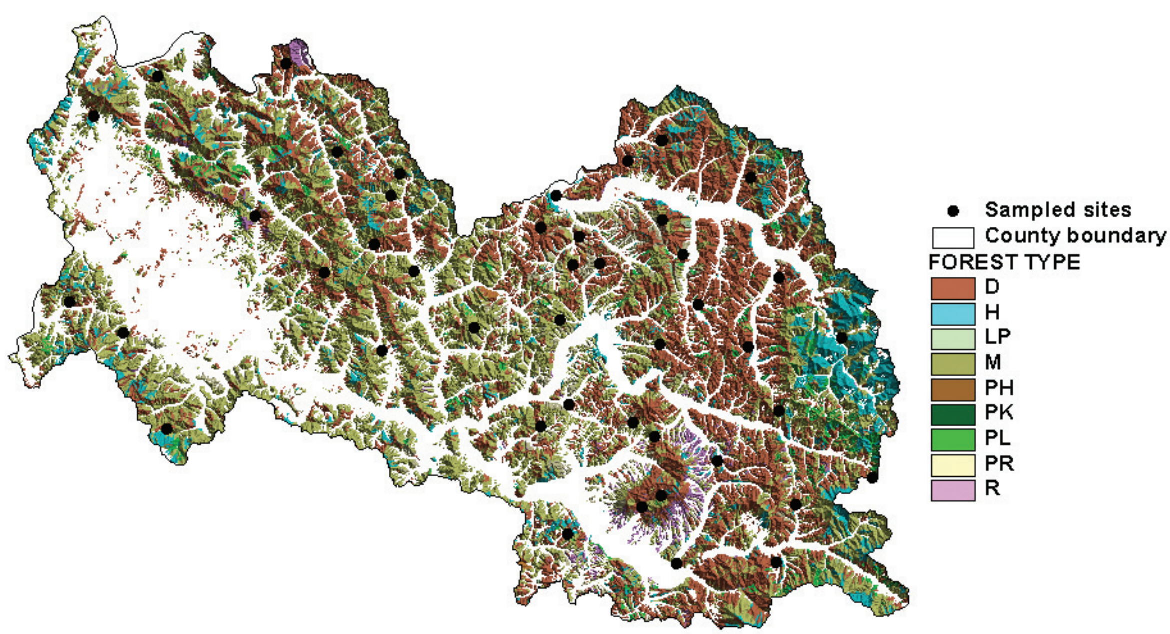


Figure 4—Forest type map in Uiseong-gun. D: *Pinus densiflora* Sieb. et Zucc; H: Deciduous forest; LP: Grass land; M: Mixed forest; PH: Unnatural deciduous forest; PK: *Pinus koraiensis* Sieb. et Zucc., Korean Pine; PL: *Larix leptolepis* (Sieb. et Zucc.) Gordon, Japanese Larch; PR: *Pinus rigida* Mill, Pitch Pine; R: Agricultural area within forest land.

Table 1—Forest distribution of Uiseong-gun by forest type map(1:25,000 scale).

Division	Code	Forest type	Area	Percentage	Total
			(ha)	- - - - - *(%)*	- - - - -
Coniferous Forest (C)	D,PD	*Pinus densiflora*	29,487.75	37.35	
	PK	*Pinus Koraiensis*	553.44	0.7	43.
	PL	*Larix leptolepis*	1,646.93	2.1	
	PR	*Pinus rigida*	2,713.03	3.4	
Deciduous Forest (D)	Q	*Quercus* sp. forest	108.72	0.1	
	PH	Unnatural deciduous forest	213.35	0.3	8.7
	H	Deciduous forest	6,543.59	8.3	
Mixed Forest (M)	M	Mixed forest	34,542.22	43.7	43.7
Open Land (O)	F	Cutover	7.32	0.0	
	O	Area of canopy cover 30% below	263.18	0.3	2.4
	E	Devastated region	2.95	0.0	
	LP	Pasture	52.6	0.1	
	L	Agricultural area	1,599.46	2.0	
Others	R	Agricultural area within forest land	1,372.57	1.7	1.7
	W	Stream	1.28	0.0	
	Others	—	0.62	0.0	
Total			**79,109.01**	**100**	**100**

Table 2—Distributed area by age class.

Age class	Area	Percentage
	(ha)	*(%)*
2 Class	10,944.95	14.4
3 Class	43,635.66	57.6
4 Class	19,007.94	25.1
5 Class	1,951.14	2.6
6 Class	243.39	0.4
Total	75,783.08	100.0

Table 3—Distributed area by diameter class.

Diameter class	Code	Area	Percentage
		(ha)	*(%)*
Sapling	0	11,314.75	14.9
Small	1	62,605.08	82.5
Medium	2	1,922.31	2.5
Large	3	55.70	0.1
Total	—	75,897.84	100.0

Forest Soil

As surveyed from the forest map, Uiseong-gun's forest soil area covers about 760,000ha, accounting for 65% of its total area. By soil attribute, dry brown forest soil accounts for 35.6%, slightly dry brown forest soil 31.2%, and moderately moist brown forest soil 15.9%, showing most of the forest area is brown forest soil (Table 4). Uiseong-gun's forest soil types are shown in Figure 5.

Table 4—Status of forest soil type in Uiseong-gun

Forest soil type	Percent of area
Dry brown forest soil (B1)	35.56
Slightly dry brown forest soil (B2)	31.18
Moderately moist brown forest soil (B3)	15.91
Slightly wet brown forest soil (B4)	0.34
Dry dark red brown forest soil (DRb1)	4.36
Slightly dry dark red brown forest soil (DRb2)	5.30
Slightly eroded soil (Er1)	3.22
Hardly eroded soil (Er2)	0.02
Lithosol (Li)	2.27
Red forest soil (R)	1.64
Dry reddish brown forest soil (rB1)	0.02
Slightly dry reddish brown forest soil (rB2)	0.19

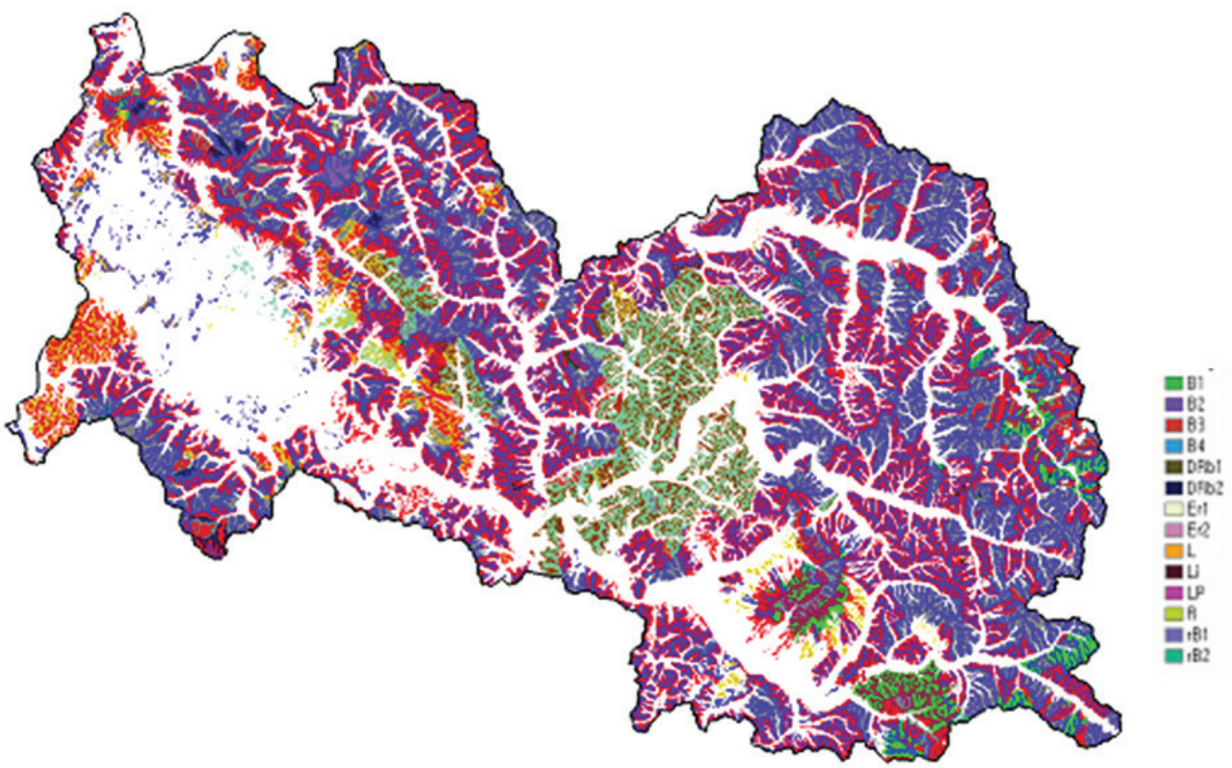


Figure 5—Forest soil type of Uiseong-gun.

Fuel Type Classification

Vegetation data gathered from on-site surveys were analyzed, thereby categorizing forest fire types by 10 items. To categorize forest fire types, based on the density of pine tree forests which are vulnerable to forest fire and have a wide distribution, dense and sparse areas were initially divided, and then four types were divided by the hierarchical level of pine trees. Also, one coniferous forest, one broadleaf forest and one mixed forest were divided. On-site-based forest fire types are divided as shown in Table 5. On the basis of Table 5 the results of vegetation survey classified by ten fuel types are shown in Table 6.

The ten forest fire types from on-site surveys are based on currently existing forest types, density of forest areas, and vegetation structures by hierarchical level, thus presenting limitations in using these forest fire types, categorizing fuel types in the whole survey areas, and crafting a fuel type map. Thus, to craft a fuel type map and put it to practical use, existing available forest type maps, forest soil maps, topographical data, satellite image data and others should first be used to categorize fuel types. This research first took account of cost and time in structuring databases as well as practical usage. A categorization of Uiseong-gun's forest fire types is based on forest type maps and forest soil maps, categorized as ten fuel types and reduced to five fuel types: three coniferous forest types (C), one broadleaf forest (D), and one mixed forest (M). Of these, pine tree forests which are the most vulnerable to forest fire are segmented into sub groups on the basis of forest types and hierarchical structures. The adjusted forest fire fuel types of Uiseong-gun are shown in Table 7.

Fuel Load Each Fuel Types

The type and strength of a forest fire may vary according to fuel load, size, and distribution, as well as depth of the fuel bed, fuel moisture, moisture of extinction and other conditions in the forest area. Thus, taking account of features of Korea's forests, pine tree forests which are the most vulnerable to forest fire were surveyed by hierarchical structure. As a result, in shrub levels, grass levels, fallen leaves, fallen branches, cones and other levels below the shrub levels, fuel load (ton/ha) of surface flammable materials was found to appear the most in broadleaf forests, *Pinus densiflora*-middle stratum,

Table 5—Ten fuel type classifications by field survey.

Forest type	Density	Fuel type
Coniferous forest	-*Pinus densiflora* (dense): 3,000 trees/ha and above	*Pinus densiflora* (dense) *Pinus densiflora* (dense)-shrub-grass *Pinus densiflora* (dense)-shrub
	-*Pinus densiflora* (sparse): 3,000 trees/ha and below	*Pinus densiflora* (dense)-grass *Pinus densiflora* (sparse) *Pinus densiflora* (sparse)-shrub-grass *Pinus densiflora* (sparse)-shrub *Pinus densiflora* (sparse)-grass
Deciduous forest		Deciduous forest
Mixed forest		Mixed forest

Table 6—Survey inventory classified by ten fuel types.

	Overstory (over 8m)				Middle story (2-8m)				Shrub		Grass		Fuel loading					
Fuel Type	TH	DBH	CBH	DEN	TH	DBH	CBH	DEN	SH	%C	GH	%C	shrub	grass	leaf	twig	cone	Total
	(m)	*(cm)*	*(m)*	*(trees/ha)*	*(m)*	*(cm)*	*(m)*	*(trees/ha)*	*(m)*	*(%)*	*(m)*	*(%)*	- - - - - - -	- - - -	- - *(ton/ha)* - -	- - - -	- - - -	- - - - - - -
1	8.9	9.9	4.6	17.0	6.0	5.8	3.6	27.0	1.5	21.3	0.5	21.3	0.4	0.3	5.7	1.5	0.3	8.0
2	—	—	—	—	4.8	6.9	2.2	42.0	1.8	30.0	0.7	65.0	0.7	1.4	6.5	1.8	0.3	10.7
3	9.4	12.4	4.7	15.0	6.1	7.0	3.9	23.0	1.5	70.0	1.0	20.0	1.1	0.1	8.0	2.2	0.3	11.7
4	9.1	13.3	3.7	6.5	5.3	6.4	2.7	41.0	1.8	20.8	0.9	62.9	0.3	0.7	6.1	1.6	0.4	9.0
5	11.3	20.1	6.2	14.0	6.4	10.3	3.8	7.0	1.7	23.3	0.4	20.8	1.3	0.3	5.0	1.2	0.5	8.2
6	9.7	29.7	6.4	9.0	2.8	2.3	—	12.0	1.5	60.0	0.7	50.0	4.2	1.0	4.2	1.2	0.3	10.9
7	9.9	16.8	4.6	12.0	5.5	7.2	2.6	16.8	1.8	50.0	0.6	13.8	0.8	0.4	7.1	1.7	0.2	10.0
8	9.3	14.2	3.7	10.3	5.8	9.4	2.7	13.4	1.6	18.1	0.9	70.0	0.4	1.1	4.5	2.0	0.5	8.3
9	11.3	15.0	3.9	8.4	4.8	8.4	2.2	8.8	1.9	29.0	0.8	13.0	1.4	0.2	5.8	3.7	0.2	11.0
10	10.5	13.5	3.5	8.9	5.1	6.5	2.4	17.0	1.7	22.5	0.4	35.0	0.3	0.2	7.0	1.7	0.1	9.2

TH: tree height, DBH: diameter at breast height, CBH: crown base height,
%C: percent cover, SH: shrub height

Table 7—Fuel type classification justified in Uiseong-gun.

Description	Fuel types	Fuel type code
Coniferous trees such as *Pinus densiflora*	*Pinus densiflora* pure forest	C-1
	Pinus densiflora-middle stratum	C-2
	Pinus densiflora-substratum	C-3
Deciduous trees such as *Quercus variabilis*	Deciduous forest	D
Coniferous and deciduous trees mixed	Mixed forest	M

mixed forests, and *Pinus densiflora*-substratum in this order, and the least fuel load was found in *Pinus densiflora* pure forest (Table 8). Fuel load, in the case of *Pinus densiflora* pure forest (C-1 type), was measured at 0.95 t/ha in shrubs, 0.22 t/ha in grass, 4.87 t/ha in fallen leaves, 1.27 t/ha in fallen branches, and 0.46 t/ha in cones, totaling 7.64 t/ha. In the case of *Pinus densiflora*-middle stratum (C-2 type), shrubs were measured at 0.88 t/ha, grass at 0.70 t/ha, fallen leaves at 7.34 t/ha, fallen branches at 1.89 t/ha, and cones at 0.28 t/ha, showing relatively a greater total amount of fuel load at 10.99 t/ha. Fuel load in *Pinus densiflora*-substratum (C-3 type) totaled 8.62 t/ha, with shrubs standing at 0.52 t/ha, grass at 0.89 t/ha, fallen leaves at 5.16 t/ha, fallen branches at 1.73 t/ha, and cones at 0.37 t/ha, showing a relatively greater grass fuel load, compared with other fuel load types. On the other hand, mixed forests (M type) where pine trees and oak trees were evenly distributed showed 0.29 t/ha, 0.16 t/ha, 6.98 t/ha, 1.67 t/ha, and 0.15 t/ha for a total of 9.17 t/ha of fuel load, in shrubs, grass, fallen leaves, fallen branches, and cones, respectively. Furthermore, fuel load in broadleaf forests (D type) totaled 11.01 t/ha, with fallen leaves and fallen branches standing at 5.78 t/ha and 3.68 t/ha, respectively, thus showing the greatest fuel load (Table 8).

Tree Density and Fuel Loading

To determine fuel features of C-1, C-2, and C-3, equivalent to 33 coniferous forests among 46 survey places, the relations between the density, fuel load below the shrub hierarchical level, tree height and diameter at the chest height were analyzed. The density of individual trees and fuel load in pine tree forests are displayed in a scatter plot in figure 6, which shows a distinctive “U” type on the basis of 3,000-4,000 trees per ha. In zones below 3,000 trees per ha, the more the density increased, the more the fuel load decreased. This is presumably because, in areas with a low density of pine trees, the age of pine trees was advanced at 3rd-4th age class (30-40 years), and biomass increased in forest areas as tree height was in proportion to diameter at the breast height. Also it is deemed that there was relatively greater volume and distribution ratio of thick branches in forest areas, thus increasing fuel load. And, fuel load decreased as the density of forests increased, presumably because competition between individual trees shortened tree height and diameter at the breast height, thus reducing biomass as well. In addition, artificial density management presumably decreased fuel load gradually. However, pine tree forests with 3,000 trees per ha showed trends that fuel load increased as density rose. These fuel features are characterized by low tree height and diameter at the breast height, and a high distribution ratio of small branches with small volume within forest areas. Mainly 2nd-3rd age class (20-30 years old) pine trees were packed closely, and the low hierarchical area had grass well developed, presumably providing a very high fuel load. These areas have not received density management and have been left abandoned, thus having great absolute amounts of fuel load. Thus, fuel load density management beginning with these areas should be conducted to reduce forest fire damage.

Fuel Types Classification by Forest Soil Types

Forest soil conditions have great impact on growth of trees and plants. According to soil moisture conditions, soil is categorized into dry soil, slightly dry soil and moderately moist soil. Dry soil includes B1 and Er1, slightly dry soil B2 and DRb2, and moderately moist soil B3. Thus, criteria for categorizing

Table 8—Survey inventory by fuel type in Uiseong-gun.

Fuel Type	Overstory (8m and over)					Middle story (2-8m)					Shrub		Grass		Fuel loading					
	TH	DBH	CBH	DEN	%C	TH	DBH	CBH	DEN	%C	SH	%C	GH	%C	shrub	grass	leaf	twig	cone	Total
	(m)	*(cm)*	*(m)*	*(trees/ha)*	*(%)*	*(m)*	*(cm)*	*(m)*	*(trees/ha)*	*(%)*	*(m)*	*(%)*	*(m)*	*(%)*	- - - - - - - - - - - - *(ton/ha)* - - - - - - - - - - - -					
C-1	10.1	16.1	5.7	1500	67	6.2	8.1	3.7	1700	37	1.6	18	0.4	18	0.95	0.22	4.87	1.27	0.46	7.65
C-2	9.9	17.4	4.6	1200	66	5.2	6.9	2.8	2000	52	1.7	49	0.7	35	0.88	0.70	7.34	1.89	0.28	10.99
C-3	9.2	13.7	3.8	800	55	5.4	7.6	2.7	2800	51	1.6	22	0.9	64	0.52	0.89	5.16	1.73	0.37	8.62
M	10.5	13.5	3.5	900	54	5.1	6.5	2.4	1700	45	1.7	22	0.4	35	0.29	0.16	6.98	1.67	0.15	9.17
D	11.3	15.0	3.9	800	63	4.8	8.4	2.2	900	27	1.9	29	0.8	13	1.36	0.21	5.78	3.68	0.26	11.01

TH: tree height, DBH: diameter at breast height, CBH: crown base height,
%C: percent cover, SH: shrub height

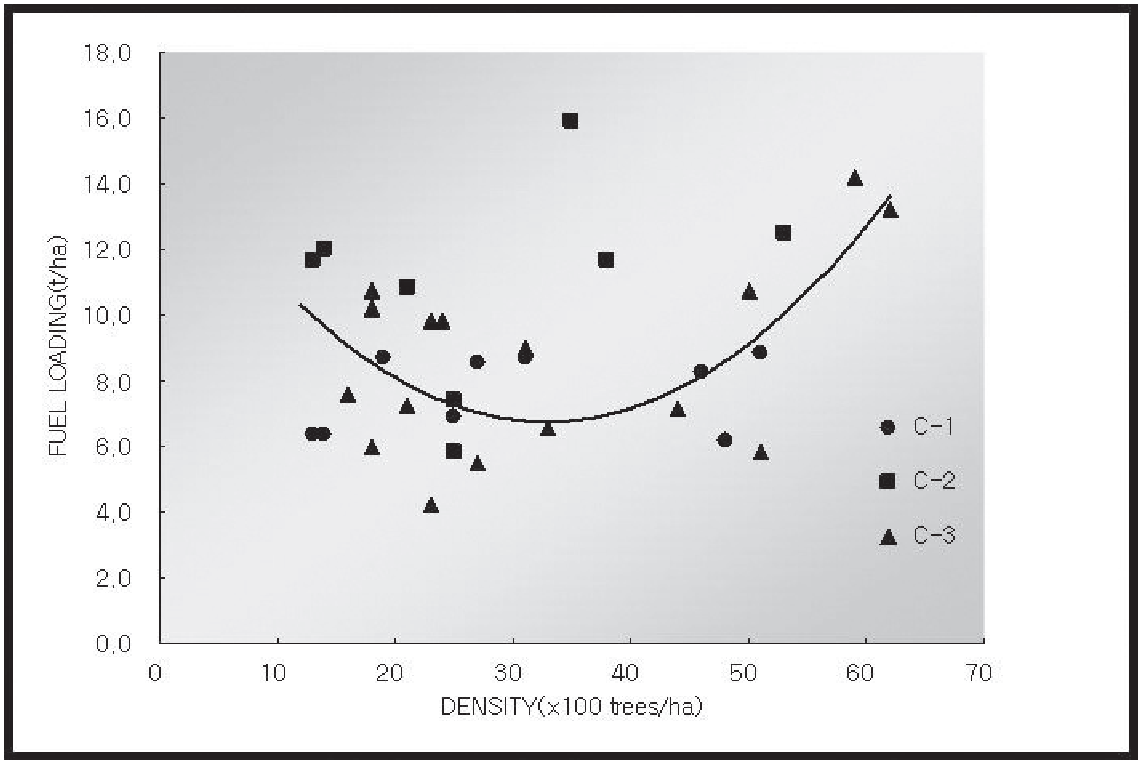


Figure 6—Density and fuel loading of the coniferous forest.

forest fire fuel types for coniferous forests (C-1, C-2, and C-3 types) can be established by utilizing soil types with soil moisture conditions reflected.

The dry soil B1, which is distributed chiefly in areas near ridgelines at the summit, upper areas of mountain slopes and other dry areas, accounts for about 70% of *Pinus densiflora* pure forest (C-1). In Figure 7, B1 soil maintains an average fuel load of 8.0 ton/ha, and the smaller the density is, the bigger the tree height and the diameter at the breast height are, thereby increasing the volume of fallen branches and amounts of fallen leaves and consequently presumably maintaining certain fuel load. With this type, the low hierarchical area usually remains a naked forest area, and thus, when a forest fire takes place, it will highly likely develop into surface fire.

Slightly dry soil B2, which is distributed chiefly at gentle-sloping summits and mountainsides in wind-hit areas, allows forest trees to have relatively good growth. Fuel load tends to decrease as the density of individual trees increases (Figure 7-B2). B2-soil areas saw mainly pine tree forests-low hierarchical type (C-3) distributed (60%), and the low hierarchical area was dominated by grasses, thereby boosting the ratio of grasses of fuel load. If a forest fire takes place in this case, grasses will play a role of ladder fuel, presumably creating danger of surface fire and crown fire in these areas.

Moderately moist soil B3 sees its fallen leaves decompose fast, mostly seeping into topsoil, and boosting the productivity of forest areas. Forest trees grow well in this soil. Fuel load of pine tree forests in B3 increases as density rises. C-1, C-2, and C-3 fuel types are evenly distributed, and the middle hierarchy has many broadleaf trees thus providing high possibility of developing into mixed forests. Pine tree forests-middle hierarchical type (C-2) are distributed at 50%.

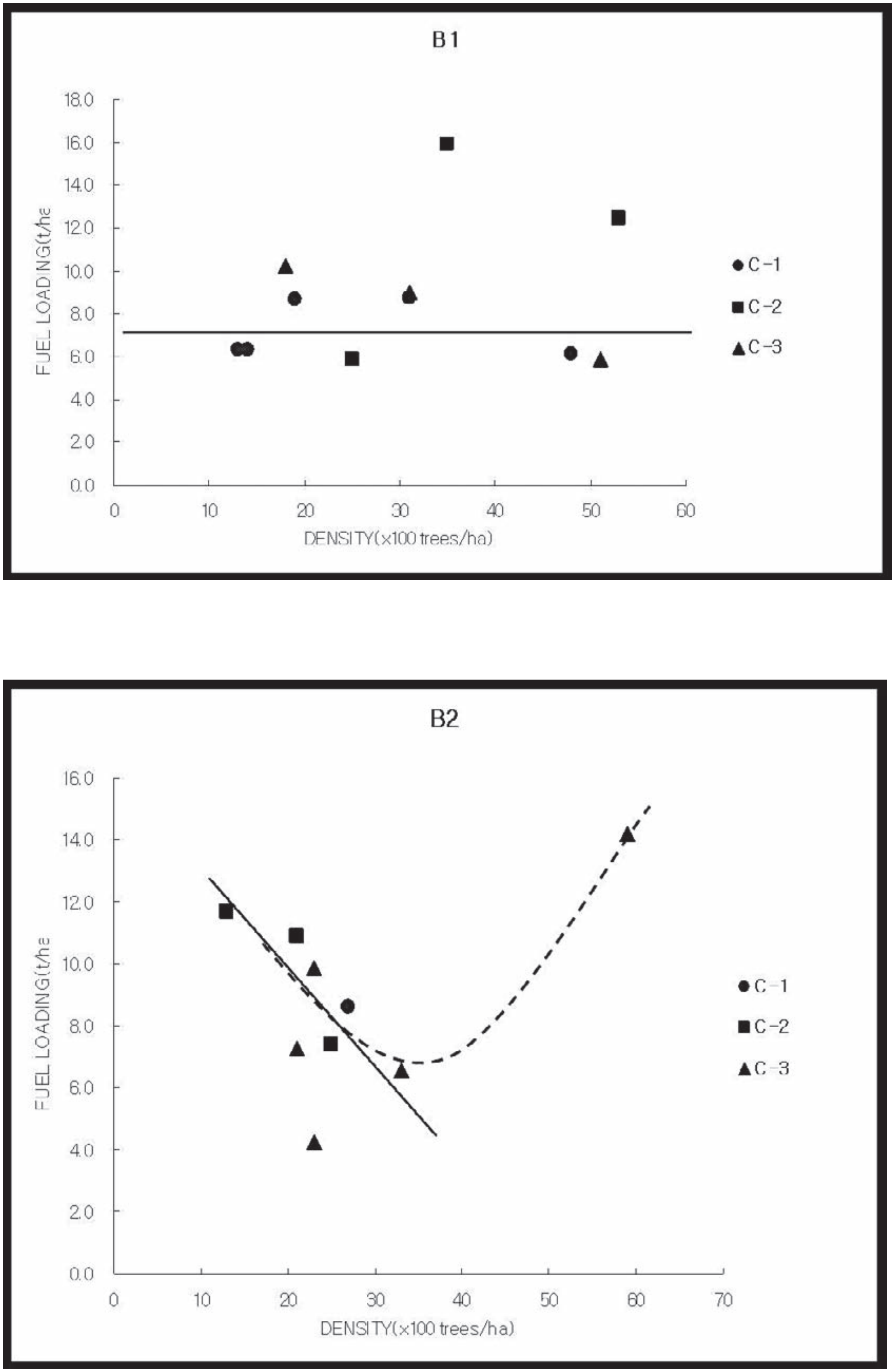
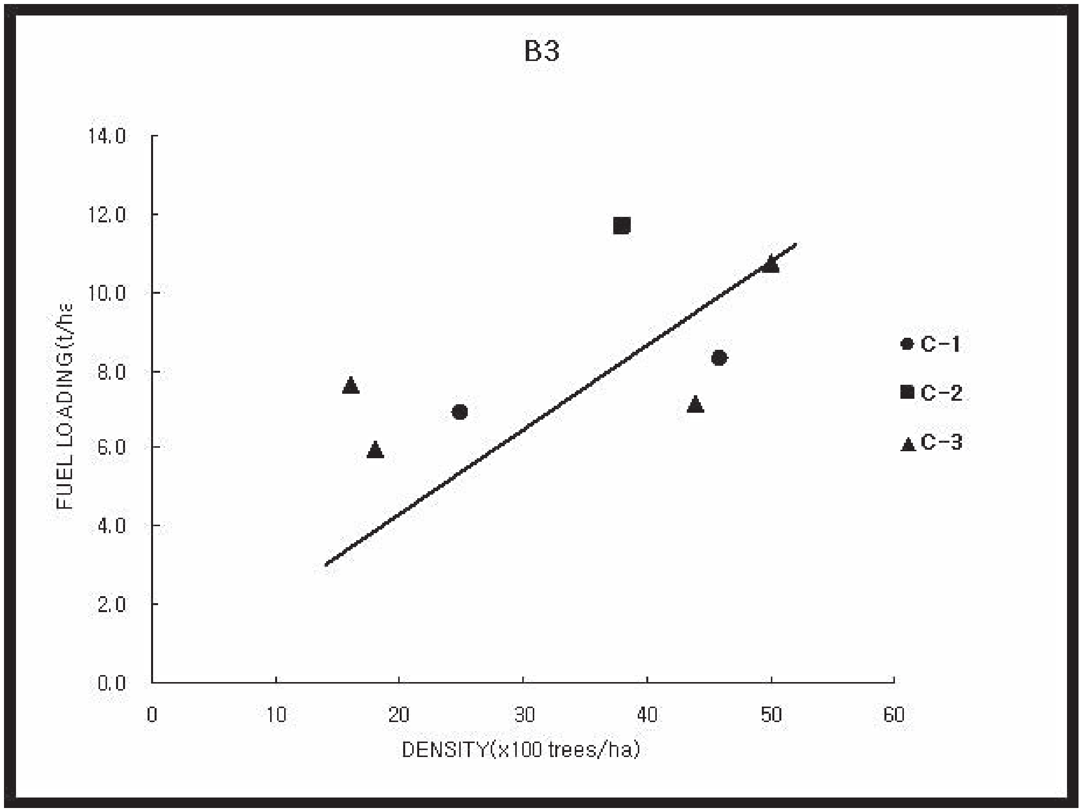


Figure 7—Density and fuel loading by forest soil of the coniferous forest. Dry Soil—B1, Er1; Slightly dry soil—B2, DRb2; Moderately moist soil—B3.



Conclusion

Forest fire occurrence probabilities and risk of fire spread in Korea are the greatest in coniferous forests. To ensure future efficient fuel management and make scientific and accurate prediction of forest fire occurrence and fire spread risk, basic surveys of fuel features of coniferous forests, particularly, pine tree forests, should be first conducted. Thus, to evaluate and quantify forest fire risk according to characteristics of forest fire fuel, fuel types should be categorized based on hierarchical structures by forest type, and the fire risk should be quantified on the basis of the survey of fuel load that allows one to estimate flammable amounts on topsoil. With the utilization of the data taken into account, this research streamlined forest fire fuel types from 10 to 5 (C-1, C-2, C-3, M, and H). In the future, nationwide-based forest fire fuel models will be developed by determining tree height and diameter at the breast height by density, and adding topographical factors such as mountain foot, mountainside, and summit in connection with fuel types.

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