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# Habitat preference of wild boar (*Sus scrofa*) for feeding in cool-temperate forests



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## Abstract

**Background:** The growing wild boar population has become a social issue and its feeding characteristics could affect the physical condition and the plant species composition in the South Korean forests. We aimed to reveal the preference of the wild boar on forest type and site condition as feeding grounds in two cool-temperate forested national parks, Odaesan and Seoraksan, in order to provide information to manage the growing population.

**Results:** The 75 plots (53.6%) out of 140 plots were used as feeding grounds by the wild boar, implying a considerably large population. Especially, the observation frequency as feeding ground was the highest in *Quercus* forests (73.3%), and it was significantly more preferred than deciduous forest type (44.2%) and coniferous forest type (32.4%) ( $\chi^2 = 17.591, p < 0.001$ ). Significantly more and deeper pits were found in *Quercus* forests. Moreover, high elevation and gentle slope ridge were relatively preferred regardless of forest distribution.

**Conclusions:** South Korean forests are growing qualitatively and quantitatively. Particularly, *Quercus* forest area has increased markedly, while coniferous forest area has decreased. Since the *Quercus* forest provides rich food sources for the wild boar, the enlargement of this forest type is expected to increase the wild boar population. The forests located at high elevations have high species diversity, and it is expected that these forests will be greatly affected by the increase in the wild boar population as preferred feeding grounds.

**Keywords:** Diet, Feeding ground, Forest type, Habitat selection, *Quercus* forest, Rooting

## Background

In South Korea, the population of the wild boar has been growing rapidly since the 2010s (NIBR 2017). The wild boar has damaged the agricultural product since 1970, but it now advances into the urban area and threatens urban living. Consequently, it has become a social issue, and the wild boar is now designated as a big game animal by the Ministry of Environment in South Korea (Ministry of Environment 2010).

The wild boar (*Sus scrofa*) is a mammal, which is widely distributed throughout the world and has a very wide range of habitats (IUCN 2008). It is distributed in mountainous and hilly areas throughout South Korea (NIBR 2017). It is classified into *scrofa*, *crisatus*, *leucomystax*, and *vittatus* subspecies groups depending on the size and shape of this species (Wilson

and Reeder 2005). The wild boar inhabiting in South Korea belongs to the *leucomystax* subspecies group. It is large and weighs about 80~300 kg (Ministry of Environment 2010).

The wild boar distributes globally because it can eat diverse food types encompassing leaves, roots, seeds, earthworms, insects, and mammals (Baubet et al. 2004; Irizar et al. 2004). Practically, it is an herbivore in that it mainly relies on plants, with a small portion of the animal diet (Baubet et al. 2004; Irizar et al. 2004; Ballari and Barrios-García 2014; Shin 2019).

The increased population size of the wild boar implies that its impact on the natural ecosystem is getting larger. In particular, since the wild boar mainly eats the plant, the larger population consumes more plant materials to maintain the large body size and weight. Consequently, the feeding activities would strongly influence the structure and function of the forested ecosystems (Focardi et al. 2000; Hone 2002). Moreover, boars have a habit of rooting through the forest floor seriously to find food (Lyang and Lee 2010). This causes physical damage to

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the floor as a feeding ground (Singer et al. 1984) and low species diversity (Bratton 1975; Hone 2002).

The feeding characteristics of the wild boar affect not only the physical condition of the forests but also, inevitably, the composition and abundance of plant species (Howe and Bratton 1976; Piroznikow 1998; Cuevas et al. 2010). The effect of the wild boar population on the forest will depend on the type of forest and plant species preferred by wild boars (Virgos 2002). It has been reported that the wild boar prefers certain plant species such as *Erythronium japonicum* (Lyang and Lee 2010), suitably humid soil providing high productivity, and deciduous forests producing larger seeds than coniferous forests (Bruinderink and Hazebroek 1996; Welander 2000; Fonseca 2008).

Despite the increasing number of wild boars and the increasing threats of urban living, there is limited information to control them in cool-temperate zones like South Korea. Once the wild boar's preferred site conditions and forest types are known, it would be meaningful information to manage the growing wild boar population. Therefore, this study is aimed at examining the preference of the wild boar on forest type and site condition as feeding grounds in two national parks, Odaesan and Seoraksan, which are cool-temperate forests and known with a large wild boar population in South Korea (NIBR 2017).

## Methods

### Study area

This study was conducted at Odaesan National Park (N37°47'55.12", E128°32'34.50") and Jeombongsan (N38°02'57.20", E128°25'31.29"), a part of Seoraksan National Park. Odaesan National Park was composed of *Quercus* forests (58%), *Pinus-Quercus* mixed forests (10%), and other deciduous forests (9%) (Han et al. 2014), while *Quercus mongolica* stands were the most dominant forest type in Jeombongsan (KNA 2014). *Q. mongolica*, among species of genus *Quercus*, dominated both areas, but *Q. serrata* also occurred at valley-side and foothill areas, and *Q. variabilis* was found at dry foothill areas.

Odaesan National Park (data from Daegwallyeong weather station) and Jeombongsan (data from Inje weather station) are geographically close to each other, but they show different weather patterns due to the effects of the terrain and the ocean. Annual mean temperatures are 6.6 and 10.1 °C, and annual precipitation is 1898 and 1208 mm for Odaesan National Park and Jeombongsan, respectively (KMA 2017).

### Survey for feeding grounds

Fourteen regions were selected in order to include a large area and wide variations in site condition such as elevation in Odaesan National Park and Jeombongsan. Afterward, the feeding grounds (hereafter FG) of the

wild boar were surveyed (Table 1). One transect per region (1 km in length each) was established from low to high elevation. A total of 140 plots were obtained by installing 10 plots (20 m × 20 m) per transect with an interval of 100 m. The presence of FG in each plot was determined by the sign of rooting. Rooting was defined as visible signs of soil turnover. The number of pits and the depth of each pit were measured when the sign of rooting was found in a plot. This study only focused on FGs, estimated to be formed from the spring to summer of 2018. It was judged that the plants that emerged this year were either withered or that the soil was not covered with leaves fallen last year. The study was carried out from June to August 2018.

### Vegetation and site condition of feeding grounds

Each plot was classified into one of three forest types: *Q. mongolica*-dominated forest (hereafter *Quercus* forest), mixed-deciduous forest (hereafter deciduous forest), or coniferous forest. *Quercus* forest is defined as the forest where the canopy cover of genus *Quercus* is equal to or larger than 50%. In reality, the canopy layer is dominated with *Q. mongolica*. In the succession process, the other deciduous forest is the next succession stage of *Quercus* forest (Lee 2015). Although *Q. mongolica* is still dominant, it is not mono-stand; other species, such as *Tilia amurensis*, *A. pictum* var. *mono*, *Ulmus laciniata*, *A. pseudosieboldianum*, *Carpinus cordata*, and *Maackia amurensis*, are mixed. The coniferous forest was mostly pure *Pinus densiflora* stand, but a few stands were dominated by *Abies holophylla*, planted *Larix kaempferi* or *Pinus koraiensis*. *Q. mongolica*, *Q. variabilis*, *Q. serrata*, or *A. pseudosieboldianum* commonly occur in the sub-canopy layer.

Elevation, slope aspect, slope degree, and topography were measured as site variables. The first three variables were measured and topography was recorded as valley-side, slope, or ridge. Valley-side refers to the lower slope area adjacent to the valley. For analysis, elevation was divided into ≤ 500, 500–1000, and > 1000 m, and slope degree was divided into 15° intervals. Slope aspect was categorized into N (315–45°), E (45–135°), S (135–225°), and W (225–315°).

### Data analysis

The preference for forest type and site variables was analyzed by calculating the frequency of FG for each item and performing  $\chi^2$  independence analysis. Furthermore, to analyze whether the selection of FGs for forest type is independent of the distribution of forest in each location, we performed the  $\chi^2$  independence analysis between forest type and four site variables, respectively. We analyzed the significant difference among forest types by Kruskal-Wallis test for both variables. All

**Table 1** Fourteen investigated transects in Jeombongsan and Odaesan

Mountain	Transect <sup>a</sup>	GPS coordinates <sup>a</sup>	Elevation (m) <sup>a</sup>
Odaesan	Eulsugol~Horyeongbong	N 37° 47' 20.7" E 128° 30' 08.5"~N 37° 47' 34.7" E 128° 30' 63.1"	731~887
	Sangwonsa~Seodaesa	N 37° 47' 06.1" E 128° 33' 58.6"~N 37° 46' 74.4" E 128° 33' 39.7"	948~1203
	Somyeonggol~Sangwangbong	N 37° 47' 63.3" E 128° 33' 70.3"~N 37° 48' 09.1" E 128° 33' 55.1"	901~1108
	Bukdaesa~Sangwangbong	N 37° 48' 20.1" E 128° 33' 87.4"~N 37° 48' 50.3" E 128° 33' 48.4"	1354~1437
	Duroryeong~Durobong	N 37° 48' 66.6" E 128° 34' 36.0"~N 37° 49' 08.1" E 128° 34' 67.9"	1320~1330
	Jingogae Information Center~Noinbong	N 37° 46' 19.0" E 128° 37' 27.3"~N 37° 46' 37.1" E 128° 37' 79.9"	1138~1258
	Dongpigol~Horyeongbong	N 37° 45' 98.6" E 128° 34' 60.0"~N 37° 46' 15.2" E 128° 34' 08.0"	767~812
	Sogeumgang Ranger Station~Yeonhwadam	N 37° 48' 65.3" E 128° 42' 03.0"~N 37° 48' 39.0" E 128° 41' 57.8"	265~310
	Bonghwajae~Jatgogaegol	N 37° 50' 51.7" E 128° 42' 39.8"~N 37° 50' 13.6" E 128° 42' 60.5"	176~183
	Toegokri~Deoraenyigol	N 37° 50' 74.5" E 128° 44' 21.2"~N 37° 50' 35.7" E 128° 44' 39.4"	131~298
Jeombongsan	Ganeungol~Baekdudaegan	N 37° 02' 73.8" E 128° 27' 62.0"~N 38° 03' 06.8" E 128° 27' 19.2"	790~846
	Gangseon Village~Gombaeryeong	N 38° 01' 90.1" E 128° 27' 20.0"~N 38° 01' 71.5" E 128° 26' 72.7"	813~976
	Danmokryeong~Jeombong peak	N 38° 03' 35.3" E 128° 26' 33.8"~N 38° 03' 11.8" E 128° 25' 82.6"	1066~1262
	Danmokryeong~Bukamryeong	N 38° 02' 89.1" E 128° 28' 59.3"~N 38° 03' 20.7" E 128° 29' 02.0"	781~877

<sup>a</sup>At each transect, the former and the latter indicate the start and the end point, respectively

analyses were carried out using Statistical Package for Social Science (SPSS) (ver. 23, SPSS 2016).

**Results**

**Preference for feeding ground by forest type and site condition**

The 140 study plots were composed of 60 *Quercus* forest stands, 43 deciduous forest stands, and 37 coniferous forest stands. Among them, 75 plots were exploited as FG (53.6%). The frequency of FG (selected by the wild boar) was significantly different among forest types ( $\chi^2 = 17.591$ ,  $p < 0.001$ , Table 2). In addition, it was also significantly different among elevation, slope, and topography classes, respectively ( $p < 0.05$ ), except for the slope aspect classes which was not significant (Table 2).

FG frequency was highest in *Quercus* forest type (44 plots; 73.3%), while those were 44.2% and 32.4% in the deciduous forest and coniferous forest, respectively (Fig. 1). The frequency of FG was higher at a higher elevation (Fig. 2). In particular, that of FG was 81% when plots were located above 1000 m. Moreover, it tended to increase with a gentler slope, so it was 82.6% when the slope was equal to or less than 15°. The FG frequency in

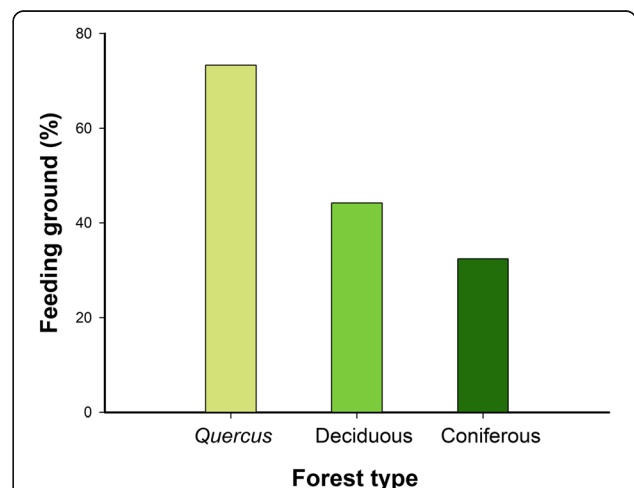
the ridge was as high as 72.2%. On the other hand, the FG frequency on the north aspect was higher than those on other aspects although it was not significantly different by slope aspect classes (Table 2).

In addition, we analyzed if the preference of the wild boar on the forest type and site condition was independent to or affected by the distribution of a specific forest type (Table 3). The selection of forest type and elevation was found to be independent ( $\chi^2 = 51.552$ ,  $p < 0.001$ ). The three forest types were distributed at different altitudinal ranges. In other words, *Quercus* forest, deciduous forest, and coniferous forest types tended to distribute at high, intermediate, and low elevation areas, respectively. Contrary to this, the frequency of FG

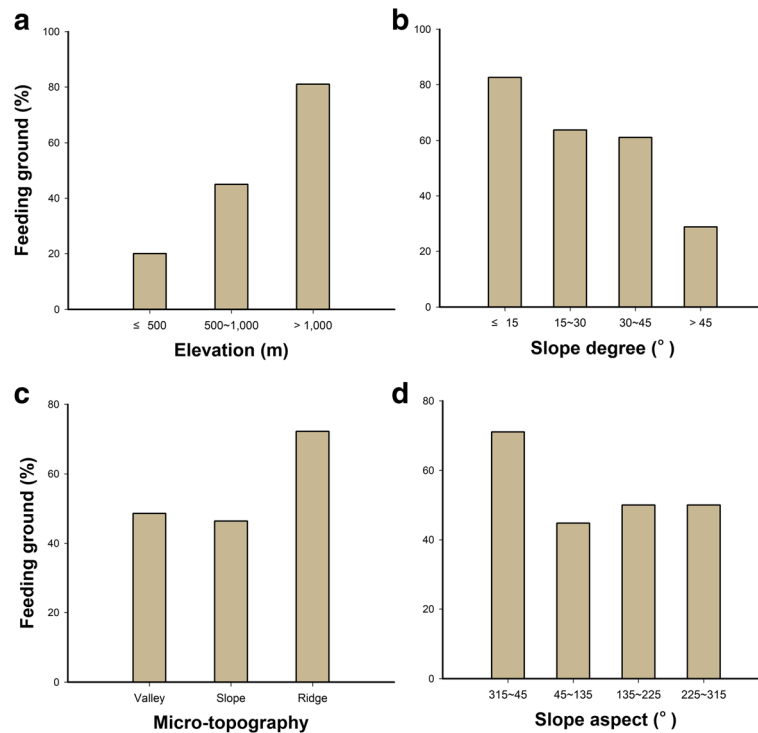
**Table 2**  $\chi^2$  independence analysis for the feeding ground preference according to forest type and site condition

Source	$\chi^2$	p value
Forest type	17.591	< 0.001
Elevation	32.301	< 0.001
Slope degree	22.978	< 0.001
Micro-topography	6.823	< 0.05
Slope aspect	5.074	ns <sup>a</sup>

<sup>a</sup>Not significant



**Fig. 1** Preference for feeding ground among forest type. The feeding ground (%) was calculated as the percentage of the number of feeding plots to the total number of plots for each forest type



**Fig. 2** Preference for feeding ground according to **a** elevation, **b** slope degree, **c** micro-topography, and **d** slope aspect. The feeding ground (%) was calculated as the percentage of the number of feeding plots to the total number of plots for each class of the four site variables

increased with a higher elevation for all three forest types including coniferous forests which were mainly distributed at lower altitudes.

The selection of forest type and slope degree was found to be independent ( $\chi^2 = 22.397$ ,  $p < 0.001$ , Table 3). *Quercus* forest type was mainly found on slopes below 30°, while deciduous forest type and coniferous forest type mostly distributed on steep slopes ( $\geq 45$  degrees). Nevertheless, the FG frequency showed an opposite pattern, the highest on the gentle slope. Especially, the absolute FG frequency of the *Quercus* forests on a gentle slope ( $\leq 15$  degrees) was 91%. In the deciduous forest and coniferous forest types, FG frequency was higher on a gentle slope, compared to the distribution of actual stands.

The selection of forest type and micro-topography was also found to be independent ( $\chi^2 = 20.299$ ,  $p < 0.001$ , Table 3). *Quercus* forest was distributed on slope and ridge at a similar frequency. The deciduous forest was found most often at the valley-side, and the coniferous forest was most abundantly distributed on a slope area. In the *Quercus* forest, the frequency of FG was similar regardless of the topography type (except for the valley-side, which had a small number of sample plots). In the deciduous forest and coniferous forest, the FG frequency was higher on the ridge compared to the plot distribution. As a result, the frequency of FG was the highest on the ridge. Even though the FG frequency was relatively

high on the north aspect in three forest types, it was not significantly different (Table 3).

#### Pattern of feeding grounds

Among all FGs ( $n = 75$ ), the median number of pits per plot was 12.0 (ranging between 1 and 54) (Fig. 3). It was significantly different among forest types ( $\chi^2 = 9.739$ ,  $p < 0.01$ ). There were 19.0 pits per plot in the *Quercus* forest, while 6.0 and 5.0 pits per plot in the deciduous and coniferous forests, respectively.

The overall median pit depth was 8.7 cm (ranging between 2 and 22 cm) (Fig. 3). It was also significantly different among forest types ( $\chi^2 = 7.811$ ,  $p < 0.05$ ). Median pit depth was the deepest in the *Quercus* forest (10.8 cm), followed by the deciduous forest (7.3 cm) and the coniferous forest (6.5 cm). It has been reported that the mean pit depth of wild boar was 10.7 cm in Spain and 5~15 cm in California, USA, which agreed with the results of this study (Kotanen 1995; Bueno et al. 2013).

## Discussion

### Food source of wild boar

The energy demand, the type and amount of food resources, the seasonal resource availability, and the safe sites affect the FG selection of the wild boar (Abaigar et al. 1994; Welander 2000; Cahill et al. 2003; Baubet et al. 2004; Ballari and Barrios-García

**Table 3** Relative frequencies of plots and feeding grounds according to forest type and site variables

Site	<i>Quercus</i> forest		Deciduous forest		Coniferous forest		Total	
	Plot (%)	Feeding ground (%)	Plot (%)	Feeding ground (%)	Plot (%)	Feeding ground (%)	Plot (%)	Feeding ground (%)
Elevation (m)	$\chi^2 = 51.552^a, p \text{ value} < 0.001$							
< 500	–	–	4.7	0.0	75.7	12.0	21.4	13.7
500~1000	35.0	29.2	65.1	50.1	18.9	32.0	40.0	30.6
> 1000	65.1	70.8	30.2	49.9	5.4	56.0	38.6	55.8
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Slope degree (°)	$\chi^2 = 22.397^a, p \text{ value} < 0.001$							
< 15	18.3	32.3	16.3	41.8	13.5	33.8	16.4	34.9
15~30	43.3	30.0	27.9	24.4	24.3	9.4	33.6	27.0
30~45	18.3	25.8	7.0	27.9	10.8	21.1	12.9	25.9
> 45	20.0	11.8	48.8	6.0	51.4	35.6	37.1	12.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Micro-topography	$\chi^2 = 20.299^a, p \text{ value} < 0.001$							
Valley-side	5.0	41.0	51.2	26.7	27.0	39.0	25.0	29.1
Slope	48.3	29.7	37.2	14.7	64.9	28.5	49.3	27.7
Ridge	46.7	29.3	11.6	58.7	8.1	32.5	25.7	43.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Slope aspect (°)	$\chi^2 = 4.185^a, p \text{ value ns}^b$							
315~45	20.0	30.6	25.6	35.6	21.6	32.5	22.1	32.9
45~135	18.3	18.2	30.2	17.2	13.5	38.9	20.7	20.8
135~225	38.3	20.3	27.9	23.3	29.7	23.6	32.9	23.2
225~315	23.3	31.0	16.3	24.0	35.1	5.0	24.3	23.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

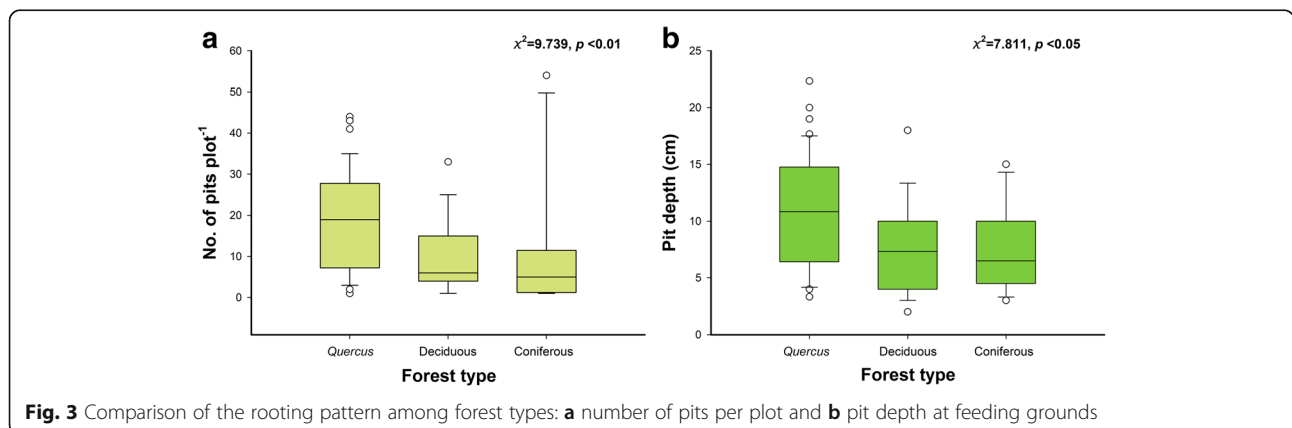
<sup>a</sup>Results of  $\chi^2$  independence analysis between forest type (FG%) and four site variables were added, respectively

<sup>b</sup>Not significant

2014; Gallo Orsi et al. 2014; Lee 2014). Bueno et al. (2009) argued that food is the most important factor for the wild boar to choose FG, followed by elevation, slope, the distance from a water system, and the distance from humans.

The wild boar mainly eats vegetable matter such as roots and fleshy fruits from spring to summer, forest

fruits (e.g., acorns, chestnuts, and beechnuts) during autumn, and roots during the winter (Genov 1981; Dardailon 1986; Taylor and Uvalde 1999; Schley and Roper 2003). Baubet et al. (2004) found that 91% of the food sources of the wild boar were the plant and 1% of them were the animal when the feces of the wild boar and gastric contents were analyzed in forests in southeastern



France. The plant root (39%) was the most common food source. Similarly to this, Irizar et al. (2004) found that 94% of the diet were also plant-origin food based on the gastric contents of the wild boar in the forests of northern Spain. Since the study was conducted from autumn to winter, acorns and chestnuts accounted for 85% of food. Shin (2019) analyzed the food sources of the wild boar at Jeombongsan, South Korea, and found that 61% of food sources was plant-origin from the feces mainly made from summer. The wild boar consumed Rosaceae the most followed by bryophyte and Fagaceae.

#### **Quercus forest preference of wild boar**

Wild boars selectively preferred the *Quercus* forest as FG, and they dug pit the most and deepest in this forest. Acorns, in particular, are the most important food resource for wild animals such as wild boars (Welander 2000; Fonseca 2008; Shin 2019) and the Asiatic black bear (SRTI 2012). It is a stable food source of supply due to the large area of *Quercus*-dominated forests. Singer et al. (1981) found that in mast year when acorn production is high, the wild boar's home range has expanded 3 to 5 times compared to the failure year. The mean acorn production of Odaesan and Seoraksan National Park were and 46.7 (max 164.1) and 17.3 (max 94.7) g m<sup>-2</sup> in 2018, respectively (Choung et al. 2018). That of Jirisan National Park peaked in 2009 reached 77.7 g m<sup>-2</sup> (SRTI 2012).

In addition, considering that the traces of FG found in this study were made from spring to summer, it may be the result of consuming favorite food sources as well as acorns. For example, the wild boar particularly likes the bulbs of *E. japonicum* and *Lilium* and the fruits of Rosaceae (Lyang and Lee 2010; Shin 2019). Therefore, large-scale excavation is commonly found in the *Quercus* forest where these species occur (Choung and Lee 2019). These species are more common in the *Quercus* forest (Choung and Lee 2019). The bulb of *E. japonicum* is buried about 12 cm below the ground surface (Lyang and Lee 2010), and it could be the reason why the wild boar dug deeper in the *Quercus* forest type than other forest types. The wild boar digs even *Sasa borealis* stands in the *Quercus* forest, which is dominated by *S. borealis* and has very low species diversity (Cho et al. 2018a, 2018b). The food sources such as acorns and insects for the wild boar are presumably between the packed roots or dense culms of *S. borealis*.

The wild boar less preferred other deciduous forest and coniferous forest types, mainly dominated by *P. densiflora*, because these forest types provide different food sources and they are located at relatively low elevations or at the bottom of steep mountains.

#### **Site preference of wild boar**

The results showed that the wild boar preferred ridge areas with a high altitude and a gentle slope. It was also analyzed that the site condition was associated with the distribution of the forest type to some extent. While *Quercus* forests tended to distribute at high elevations, deciduous forests and coniferous forests were mainly found at middle and low elevations, respectively. Nonetheless, the independence analysis confirmed that FG was selected independently between forest type and site variables except for slope aspect.

The wild boar showed feeding activities mostly at higher altitude because these areas had rich potential food sources due to maybe the high plant diversity (Choung and Lee 2019), and moreover they were safe sites due to access difficulty. Park and Lee (2003) reported that the wild boar preferred habitats far from forest roads that were frequently visited by a number of hikers. Similarly, Virgos (2002) suggested that the wild boar preferred large forest patches because they could avoid people and these patches had diverse food sources.

The ridge areas are drier and have fewer food resources than slope and valley-side areas in general. So it was known for the wild boar to prefer moist sites that are easy to dig (Vittoz and Hainard 2002). Nevertheless, the wild boar prefers the ridge relatively more than other topography probably because it secures a clearer view due to relatively less dense vegetation and provides a pathway to a higher elevation in an emergency situation. The ridge is the major corridor for wild animals (Lee et al. 2011; Woo 2014; Kim et al. 2018).

#### **Expansion of *Quercus* forest and projection of wild boar population**

It is highly likely that the size of the wild boar population will continue to increase. The NIBR (2017) has conducted a long-term monitoring on the wildlife of South Korea and reported that the wild boar inhabited mountainous areas throughout the country and the population size has increased since the 2010s. The estimated number of the wild boar in Inje, Pyeongchang, and Hongcheon areas including the study area was reported as 7.2 per 100 ha<sup>-1</sup> as of 2017, which was higher than the nationwide mean number (5.6).

Furthermore, the area and wood stock of the *Quercus* forest is rapidly increasing replacing the pioneer coniferous forest (KFRI 2010; Lee 2010). These changes mean the increase of the food sources and the potential refuge sites, resulting in the expansion of the potential carrying capacity for the wild boar. The home range of the wild boar was 1.5 km<sup>2</sup> on average in many national parks and the core feeding area is far smaller (0.3 km<sup>2</sup>) (Choi et al. 2006; KNPRI 2013, 2017).

Moreover, wild boars have the habit of rooting in a habitat for several months (KNPRI 2016). Also, the home range has expanded 3 to 5 times in a mast year (Singer et al. 1981). This feeding behavior could lead to a reduction in plant species richness and the diversity of *Quercus* forests with high species diversity at high elevations (Ickes et al. 2001; Siemann et al. 2009). High elevation regions are more vulnerable to change (Adhikari et al. 2018). Because of this, we are concerned that the increase in wild boar populations will have a greater impact on forests, especially *Quercus* forest.

## Conclusion

The feeding characteristics of the wild boar were examined in ten regions of cool-temperate Odaesan and Seoraksan National Parks. The results showed that 53.6% of the 140 plots were dug and used as a FG, implying that there is a considerably large wild boar population. Particularly, the frequency of FG was the highest in *Quercus* forests (73.3%). The results showed that the wild boar preferred *Quercus* forest to deciduous forests (44.2%) and coniferous forests (32.4%). In addition, the boar favored ridge areas at high elevations and with a gentle slope, independent to the distribution of forest type. This study confirmed that *Quercus* forests growing on ridges at high elevations were the most FG preferred by the wild boar.

Forests in South Korea are rapidly developing qualitatively and quantitatively. *Quercus* forest area has increased noticeably, replacing coniferous forest area. Since *Quercus* forests provide major food sources for wild boars, an increase of this forest type will lead to an increase in the size of the wild boar population. In South Korea, forests located at a high altitude have relatively high species diversity due to past disturbances of lowland forests. Therefore, it is expected that the increase in the wild boar population size will affect these forests greatly as preferred FGs.

## Abbreviations

IUCN: International Union for Conservation of Nature and Nature Resources; KFRI: Korea Forest Research Institute; KMA: Korea Meteorological Administration; KNA: Korea National Arboretum; KNPRI: Korea National Park Research Institute; NIBR: National Institute of Biological Resources; SPSS: Statistical Package for Social Science; SRTI: Species Restoration Technology Institute

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## Authors' contributions

YK and SC conducted field investigation, analyzed the data, and wrote the manuscript draft. YC planned, wrote, and revised the manuscript. All the authors approved the final manuscript.

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## Availability of data and materials

The datasets during and/or analyzed during the current study are available from the corresponding author on reasonable request.

## Ethics approval and consent to participate

Not applicable

## Consent for publication

Not applicable

## Competing interests

The authors declare that they have no competing interests.

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