

## Geographic information system-based identification of suitable cultivation sites for wood-cultivated ginseng

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Wood-cultivated ginseng, including roots in its dried form, is produced in forest land without using artificial facilities such as light barriers. To identify suitable sites for the propagation of wood-cultivated ginseng, factor combination technique (FCT) and linear combination technique (LCT) were used with geographic information system and the results were superimposed onto an actual wood-cultivated ginseng plantation. The LCT more extensively searched for suitable sites of cultivation than that by the FCT; further, the LCT probed wide areas considering the predominance of precipitous mountains in Korea. In addition, the LCT showed the much higher degree of overlap with the actual cultivation sites; therefore, the LCT more comprehensively reflects the cultivator's intention for site selection. On the other hand, the inclusion of additional factors for the selection of suitable cultivation sites and experts' opinions may enhance the effectiveness and accuracy of the LCT for site application.

**Keywords:** *Panax ginseng*, Wood-cultivated ginseng, Geographic information system, Suitable site of cultivation

### INTRODUCTION

Wood-cultivated ginsengs are perennial plants that are semi-heliophobic and commonly used in Chinese medicine. Due to their extensive medicinal effects, they are widely cultivated in China, Korea, and Hong Kong; the cultivation area and production of ginseng are steadily increasing every year [1]. Historically, wild ginseng cultivation started in the period of the Three States, and continued during the Koryo Dynasty with wood-cultivation, followed by ginseng farming in the Chosun Dynasty [2].

Recently, the Korea Forest Service (KFS) defined wood-cultivated ginseng as ginseng (including dried ginseng) propagated in forest land without the use of any artificial facilities such as light barriers [3]. It is very difficult to search for suitable sites for wood-cultivation of

ginseng in forest land; the use of geographic information system (GIS) as an alternative to searching for suitable cultivation sites can thus serve as an effective solution.

Suitable cultivation sites for various crops such as ginseng [4], garlic [5], red pepper [6], *Rubus coreanus* (Korean black raspberry) [7], *Schisandra chinensis* [8], mulberry [9], and apple [10] have been recently identified using GIS. However, sites for wood-cultivated ginseng have not been conducted. In addition, most of the studies or searches for suitable plantations are limited to the use of the factor combination technique (FCT) on zonal overlaps or area analysis on the extracted suitable areas using the linear combination technique (LCT) [11].

This study embarked on employing the FCT and the

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**Fig. 1.** Research area of this study. Jinan-gun (green color) is located in the eastern mountain range of Jeollabuk-do (Jeonbuk).

LCT with GIS to search for the suitable sites for wood-cultivated ginseng in the forests, and the results were subjected to overlap analysis to provide a more effective way of identifying sites of propagation.

## MATERIALS AND METHODS

### Research area

This research was conducted by targeting the forests of Jinan-gun, Jeollabuk-do. Jinan-gun is located in the eastern mountain range of Jeollabuk-do, with geographical coordinates: N 35° 49'-N 36° 39', E 127° 16'-E 127° 37' (Fig. 1). Its area is 789.09 km<sup>2</sup>, the second largest region in Jeollabuk-do; 79.9% of the region consists of forests. As seen from its large forest area, Jinan-gun is one of the locations in South Korea that produces various forest products such as ginseng, Shiitake mushrooms, and the bellflower *Codonopsis lanceolata* [12].

### Factor selection for suitable cultivation site search

To search for suitable sites for wood-cultivated ginseng using GIS, several growth factors were selected based on the results of previous studies and a survey of farmhouses.

## Data processing

Data on suitable propagation sites for the propagation of wood-cultivated ginseng were processed using a topographic map (1:25,000) and the KFS's forest type map (5th ed.) and forest soil map. After generating triangulated, irregular network data through contour extraction, the altitude, aspect, and slope were processed as grid-shaped raster data (30×30 m) to create a topographic map. In addition, data regarding forest type (species), organic contents, effective soil depth, soil texture, humidity, and drainage were processed as raster data by using an attribute database of the forest type map and forest soil map.

The information on wood-cultivated ginseng cultivation locations (53 sites) obtained through a survey of farmhouses was used to produce a database.

## Search for the suitable cultivation sites

A search for the suitable cultivation sites was conducted by using the FCT and LCT in combination with GIS. While the FCT is easy to apply and understand, its workload can increase if several factors are used. In terms of the LCT, depending on the relative importance of factors, inappropriate sites can be included in the search results [7,11].

This study analyzed suitable cultivation sites using 2 techniques: the sites were categorized into 4 grades; suitable, possible, contemplative, and unsuitable [9], based on the Jenks Natural Breaks Classification method [13]. In addition, the degree of overlap of each search technique was determined by comparing the raster data processed through extracting searched suitable areas with the data of wood-cultivated ginseng sites by using zonal statistics methods. ArcMap 10 by ESRI (Redlands, CA, USA) was used for suitable cultivation area search.

## RESULTS

### Factors for suitable cultivation sites

Previous reports have shown that altitude, aspect, slope, forest type (species), organic content, effective soil depth, soil texture, soil humidity, and drainage are important factors that affect the cultivation of wood-cultivated ginsengs [14-19]. Weighted values were assigned to the factors by subdividing specific conditions per suitable sites factor and applying these to the FCT and LCT (Table 1).

### Search of suitable sites for wood-cultivated ginseng

Suitable sites for cultivation were identified by ap-

**Table 1.** Factors and weighted values for searching suitable cultivation sites

Factor	Condition	Weighted value	
		FCT	LCT
Altitude	More than 300 m	1	1
	Others	0	0.5
Aspect	North	1	1
	East, northeast, northwest	0	0.67
	Others	0	0.33
Slope	Less than 30°	1	1
	Others	0	0.5
Forest type (species)	Hardwood forest, <i>Larix leptolepis</i>	1	1
	Mixed forest	0	0.67
	Others	0	0.33
Organic content	Between 2% and 9%	1	1
	Other	0	0.5
Effective soil depth	More than 15 cm	1	1
	Others	0	0.5
Soil texture	Sandy loam, loam, silty clay loam	1	1
	Others	0	0.5
Soil humidity	Suitable humidity	1	1
	Others	0	0.5
Drainage	Good condition	1	1
	Others	0	0.5

FCT, factor combination technique; LCT, linear combination technique.

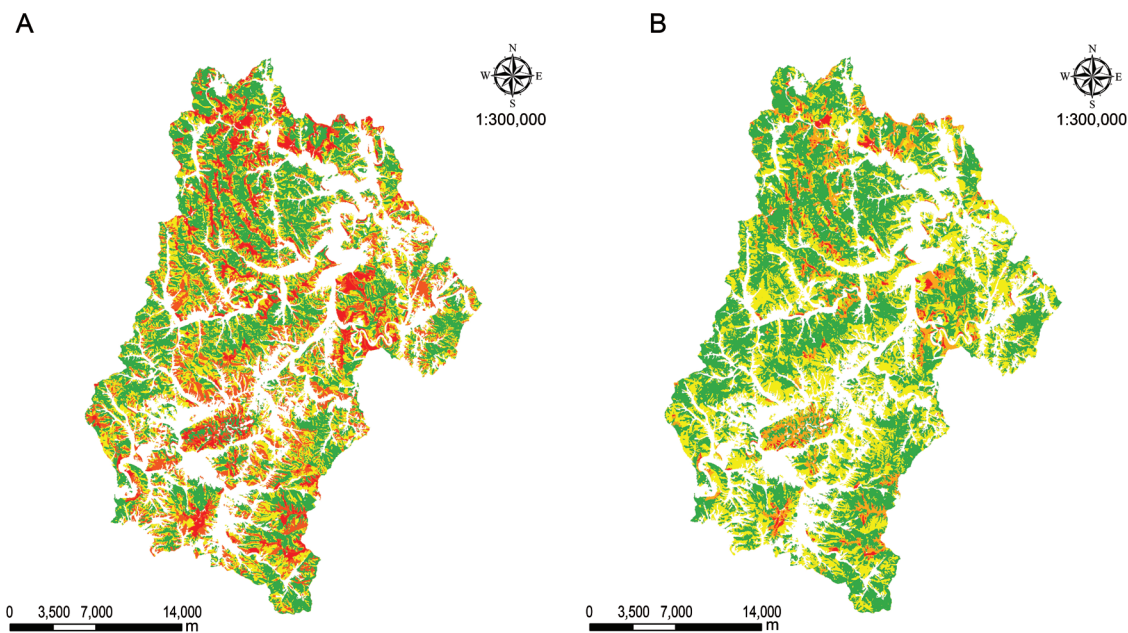
**Table 2.** Search results for suitable cultivation sites by using 2 techniques

Technique	Suitable site	Possible site	Contemplative site	Unsuitable site
FCT	22,337 (40.2)	17,907 (32.3)	11,061 (19.9)	4,196 (7.6)
LCT	28,328 (51.1)	21,408 (38.6)	4,323 (7.8)	1,429 (2.6)

Values are presented as ha (%).  
FCT, factor combination technique; LCT, linear combination technique.

plying weighted values that correspond to the specific conditions of each factor to the respective raster database (Fig. 2). Using the FCT, the search results were as follows: a suitable area of 22,337 ha (40.2%), possible area of 17,907 ha (32.3%), contemplative area of 11,061 ha (19.9%), and unsuitable area of 4,196 ha (7.6%). On the other hand, according to the LCT, the results were as follows: a suitable area of 28,328 ha (51.1%), possible area of 21,408 ha (38.6%), contemplative area of 4,323 ha (7.8%), and unsuitable area of 1,429 ha (2.6%) (Table 2).

The results of the 2 techniques were layer-extracted and the data were analyzed through zonal statistics. Among the suitable areas detected by the FCT, the overlapped area with wood-cultivated ginseng plantation data was 263.88 ha; and among suitable areas by the LCT, the overlapped area with wood-cultivated ginseng plantation data was 328.23 ha. The degree of overlap (b/a) of real cultivation area (a) with the results (b) of the FCT and LCT was 44.1% and 54.8%, respectively; the results of



**Fig. 2.** Suitable cultivation sites searched by using factor combination technique (A) and linear combination technique (B). Green color, yellow color, orange color, and red color show suitable site, possible site, contemplative site, and unsuitable site, respectively.

**Table 3.** Zonal statistical analysis result

Technique	Real area (a, ha)	Overlapped Area (b, ha)	Overlap ratio (b/a, %)
FCT	599.03	263.88	44.1
LCT	599.03	328.23	54.8

FCT, factor combination technique; LCT, linear combination technique.

the LCT showed a higher degree of overlap (10.7%) than that generated by the FCT (Table 3).

## DISCUSSION

Search analysis of suitable wood-cultivated ginseng plantations by utilizing GIS with FCT and LCT showed that wider areas were detected by the LCT than the FCT. This result may be attributable to the fact that more forest lands were selected as suitable sites according to the relative importance of the factors [7,11].

Comparison of the actual cultivation area and the suitable area detected by the 2 techniques showed that the LCT generated a greater area of overlap compared to that using FCT. This was not only because the LCT detected wide areas as suitable but also because it can be interpreted in terms of suitable site selection. Further, the LCT data comprehensively reflected the wood-cultivated ginseng growers' opinions on the propagation of wood-cultivated ginseng.

In the case of Korea, where forest lands are steep and rough and accessibility is poor, it will be ideal to use LCT to search for suitable wood-cultivated ginseng plantations so that wider areas can be detected; full consideration can be given to environmental and natural characteristics to identify a specific cultivation area.

On the other hand, a major merit of this study compared with recent studies [20,21], which identified the factors for suitable cultivation sites as quantitative indicators by analyzing the sites for wood-cultivated ginseng, lies in the fact that it presented a method for searching suitable sites for wood-cultivated ginseng applicable to the geographical conditions of Korean forest land using GIS as well as the quantitative factors for suitable cultivation sites. However, despite the advantages of this convenient GIS-based scientific method for identifying suitable sites, the accuracy of the site detection results should be cited as a limitation. Thus, there may be a need to include additional factors for the selection of suitable cultivation sites such as location, soil, and climate to raise the accuracy of the search using GIS. Hence, a system should be structured to easily utilize various GIS data-

bases at the national level. Also, the input of field experts such as researchers and farmers may also be integrated in the search for suitable sites by applying an analytic hierarchy process that reasonably assesses weighted values of each factor and maximizes the accuracy of the search [7,9].

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