Journal of Global Change Data & Discovery. 2026, 10(3): 344-361
www.geodoi.ac.cn

GIES Case Study on Fusong Lushuihe *Pinus Koraiensis* Nuts Forest Ecosystem

QI Wei[1,2*] ZHU Jianhua[3] WANG Gang[4] GAO Jiantang[5] DU Yuchuan[5] ZHAO Wenxu[6] WANG Xiuqin[7] LIU Huiqiang[7] JIN Xin[7] XU Yanguo[8] ZHANG Zenggui[9] CHEN Yongting[3] LIU Yan[3] LIU Yubo[3] NIU Ziming[3] ZHU Wenhao[1,2] LI Yu[1,2] FAN Kai[1,2] TANG Xinrui[1,2]

1. Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China; 2. University of Chinese Academy of Sciences, Beijing 100049, China; 3. Northeast Normal University, Changchun 130024, China; 4. People's Government of Fusong County, Baishan City, Jilin Province, Fusong County 134500, China; 5. Fusong County Market Supervision and Administration Bureau, Baishan City, Jilin Province, Fusong County 134500, China; 6. Lazihe Village, Lushuihe Town, Fusong County, Baishan City, Jilin Province, Fusong County 134500, China; 7. Jilin Changbai Mingzhu Forest Food Co., Ltd., Fusong County 134500, China; 8. Hongguang Forest Farm of Lushuihe Forestry Co., Ltd., Fusong County 134500, China; 9. Fusong County Lushuihe Hualong Chinese Herbal Medicine Planting Professional Cooperative, Fusong County 134500, China

Abstract: The GIES case of Fusong Lushuihe *Pinus koraiensis* nuts forest ecosystem is located in Lushuihe Town, Fusong County, Jilin Province, in the core area of the Changbai Mt. The town administers 6 communities and 5 administrative villages, with an area of 855.58 km^2 and a total registered population of 28,000 in 2025. Benefiting from its distinctive natural conditions, including medium-to-high elevation, high vegetation coverage, a cold-temperate humid mountain climate, and fertile volcanic ash soils, Lushuihe supports extensive and contiguous century-old *Pinus koraiensis* forests. These environmental conditions contribute to the distinctive quality of the pine nut kernels, which are plump, milky white in color, and rich in aroma, making them a natural food resource with high nutritional value. This study analyzes Lushuihe Town as the case area from the perspectives of the ecological environment of *Pinus koraiensis* forests, product characteristics, management practices, and socioeconomic development. It further summarizes the habitat conservation and sustainable development model of the Lushuihe pine nut production area. The case dataset mainly includes data on the spatial extent of the case area, physical geographical conditions, product characteristics of Lushuihe pine nuts, socioeconomic development, management practices, and cultural context. The dataset is archived in .shp, .tif, .xlsx, .docx, and .jpg formats, consisting of 82 data files, with a total size of 264 MB, and is compressed into one file of 77.3 MB.

Keywords: Changbai Mountain; Fusong; Lushuihe; *Pinus koraiensis* nuts; *Pinus koraiensis* Forest; GIES; Case 36

Received: 21-11-2025; **Accepted:** 17-05-2026; **Published:** 25-06-2026
Foundation: Jilin Provincial Administration for Market Regulation (2025)
***Corresponding Author:** Qi, W., Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, qiwei@igsnrr.ac.cn
Data Citation: [1] Qi, W., Zhu, J. H., Wang G., *et al*. GIES case study on Fusong Lushuihe *Pinus koraiensis* nuts forest ecosystem [J]. *Journal of Global Change Data & Discovery*, 2026, 10(3): 344–361. https://doi.org/10.3974/geodp.2026.03.09.
[2] Qi, W., Zhu, J. H., Wang G., *et al*. GIES case dataset on Fusong Lushuihe Korean pine seeds forest ecosystem [J/DB/OL]. *Digital Journal of Global Change Data Repository*, 2026. https://doi.org/10.3974/geodb.2026.04.01.V1.

DOI: https://doi.org/10.3974/geodp.2026.03.09

Dataset Availability Statement:

The dataset supporting this paper was published and is accessible through the *Digital Journal of Global Change Data Repository* at: https://doi.org/10.3974/geodb.2026.04.01.V1.

1 Introduction

Pinus koraiensis, also known as "fruit pine" in Chinese, is a tall tree species belonging to the Gymnospermae, Pinaceae, Pinus, and subgenus Strobus. It is a dominant constructive species of coniferous and broad-leaved mixed forests, one of the zonal vegetation types in the temperate region of Northeast China. The species is mainly distributed in the Changbai Mt., Wanda Mt., Zhangguangcai Range, and Lesser Khingan Mt. in Northeast China. The natural *Pinus koraiensis* mother forest in Lushuihe Town, Fusong County, Jilin Province, is the largest, best-preserved, and most genetically diverse natural *Pinus koraiensis* mother forest in China[1]. In this forest, century-old trees are common, and there is even an ancient tree known as the "King of *Pinus Koraiensis*", which is estimated to be approximately 550 years old. As a tall tree species, mature *Pinus koraiensis* generally reaches 20–30 m in height and may grow up to 50 m. Its crown is conical at the juvenile stage and gradually develops into an open umbrella-shaped or tower-shaped form after maturity. *Pinus koraiensis* is characterized by slow growth and a long natural regeneration cycle. With the implementation of the Natural Forest Protection Program by China's forestry authorities, wild *Pinus koraiensis* resources have been subject to conservation and restoration[2]. Wild *Pinus koraiensis* grows slowly and usually begins to bear cones only after approximately 50 years. During the full-yield period, a single tree can produce up to 600–800 cones per year, yielding approximately 40–60 kg of pine nuts.

The Fusong Lushuihe pine nut production area is located in Lushuihe Town, Fusong County, Jilin Province, in the hinterland of the Changbai Mountain[3]. Fusong Lushuihe pine nuts are regarded as a representative high-quality pine nut product in Asia (Figure 1)[4]. Their kernels are large and plump, with a natural milky-white color and a high kernel yield, and are of significantly higher quality than ordinary pine nut kernels. They are also an important representative of national geographical indication products from the Changbai Mt. region. The kernels contain omega-3 and omega-6 fatty acids, which may act synergistically in regulating cholesterol levels and help reduce the risk of arteriosclerosis. Vitamin E and anthocyanins provide dual antioxidant effects and help inhibit oxidative damage caused by free radicals. In addition, their high protein content and slow-release carbohydrates can provide a lasting sense of satiety, making them suitable for people with high cognitive demands. In traditional Chinese medicine, pine nuts are used to moisten dryness, relieve cough, alleviate constipation, and support recovery from postpartum weakness. Fusong Lushuihe pine nuts are not only an important component of the traditional dietary culture of the Changbai Mt. region, but also align well with the modern dietary concept of "natural, nutritious, and functional" foods. They have therefore become a representative premium ingredient in the high-end health food market[5].

Figure 1 Fusong Lushuihe pine nuts

Fusong Lushuihe pine nuts grow in a distinctive regional setting and a unique ecological environment. They are not only a concentrated reflection of local natural resource endowments and historical and cultural traditions, but also a core industry that supports regional economic development and contributes to local residents' income. Protecting the habitat of *Pinus koraiensis* forests that produce pine nuts is of great significance for maintaining ecological balance, promoting local economic development, and preserving cultural traditions[6]. This study systematically reviews and analyzes diverse information on

the region, including its physical geographical characteristics, ecological conditions, pine nut product characteristics, industrial development and management, socioeconomic development data, and historical and cultural context. On this basis, it explores coordinated pathways for habitat conservation and sustainable development of Fusong Lushuihe pine nuts. The findings are expected to provide scientific support for *Pinus koraiensis* forest conservation practices and the high-quality development of the pine nut industry.

2 Metadata of the Dataset

The metadata information of the GIES case dataset on Fusong Lushuihe Korean pine seeds forest ecosystem[7], including name, authors, geographical region, data period, data size, data format, and dataset files, is shown in Table 1.

Table 1 Metadata summary of the GIES case dataset on Fusong Lushuihe Korean pine seeds forest ecosystem

Items	Description
Dataset full name	GIES case dataset on Fusong Lushuihe Korean pine seeds forest ecosystem
Dataset short name	LushuiheKoreanPineSeedsCase36
Authors	Qi, W., Institute of Geographic Sciences and Resources, Chinese Academy of Sciences, qiwei@igsnrr.ac.cn Zhu, J. H., Northeast Normal University, zjh198827@163.com Wang, G., People's Government of Fusong County, Baishan City, Jilin Province, sjjbgs2024@163.com Gao, J. T., Fusong County Market Supervision and Administration Bureau, Baishan City, Jilin Province, sjjbgs2024@163.com Du, Y. C., Fusong County Market Supervision and Administration Bureau, Baishan City, Jilin Province, 84809029@qq.com Wang, X. Q., Jilin Changbai Mingzhu Forest Food Co., Ltd., bssonglin@163.com Liu, H. Q., Jilin Changbai Mingzhu Forest Food Co., Ltd., bssonglin@163.com Jin, X., Jilin Changbai Mingzhu Forest Food Co., Ltd., bssonglin@163.com Chen, Y. T., Northeast Normal University, 3118078674@qq.com Liu, Y., Northeast Normal University, liuyan0227@foxmail.com Liu, Y. B., Northeast Normal University, 2276359635@qq.com Niu, Z. M., Northeast Normal University, 13293223632@163.com Zhu, W. H., Institute of Geographic Sciences and Resources, Chinese Academy of Sciences, zhuwenhao18@mails.ucas.ac.cn Li, Y., Institute of Geographic Sciences and Resources, Chinese Academy of Sciences, liyu6917@igsnrr.ac.cn Fan, K., Institute of Geographic Sciences and Resources, Chinese Academy of Sciences, fankai0308@gmail.com Tang, X. R., Institute of Geographic Sciences and Resources, Chinese Academy of Sciences, tangxinrui20@mails.ucas.ac.cn
Geographical region	Lushuihe Town, Fusong County, Baishan City, Jilin Province
Year	2025
Data format	.xlsx, .shp, .tif, .jpg, .docx
Data size	246 MB (compressed into one file of 77.3 MB）
Data files	Spatial scope of the case area, physical geographical conditions, product characteristics of Fusong Lushuihe *Pinus koraiensis* nuts, and socioeconomic development, management and culture
Foundation	Jilin Provincial Administration for Market Regulation (2025)
Data publisher	Global Change Research Data Publishing & Repository, http://www.geodoi.ac.cn
Address	No. 11A, Datun Road, Chaoyang District, Beijing 100101, China
Data sharing policy	(1) *Data* are openly available and can be free downloaded via the Internet; (2) End users are encouraged to use *Data* subject to citation; (3) Users, who are by definition also value-added service providers, are welcome to redistribute *Data* subject to written permission from the GCdataPR Editorial Office and the issuance of a *Data* redistribution license; and (4) If *Data* are used to compile new datasets, the "ten percent principle" should be followed such that *Data* records utilized should not surpass 10% of the new dataset contents, while sources should be clearly noted in suitable places in the new dataset[8]
Communication and searchable system	DOI, CSTR, Crossref, DCI, CSCD, CNKI, SciEngine, WDS, GEOSS, PubScholar, CKRSC

3 Case Data Development

3.1 Case Area

Lushuihe Town is located in the southeastern part of Jilin Province, in the northern part of Fusong County, Baishan City. It lies in the hinterland of the Changbai Mt., within the vast forest region of the upper reaches of the Songhua River, between 127°25′E–128°05′E and 42°20′N–42°45′N (Figure 2). Lushuihe Town borders Liangjiang Town and Erdaobaihe Town of Antu County to the east, Quanyang Town to the south, Beigang Town to the west, and Yanjiang Township to the north. Lushuihe Town administers 6 communities: Zhanxi, Hebei, Dongshan, Beishan, Hongwei, and Xishan, as well as 5 administrative villages: Lazihe, Changsheng, Xinxing, Dongsheng, and Qingshuihe. In 2025, the town covered an administrative area of 855.58 km^2 and had a registered population of 28,000.

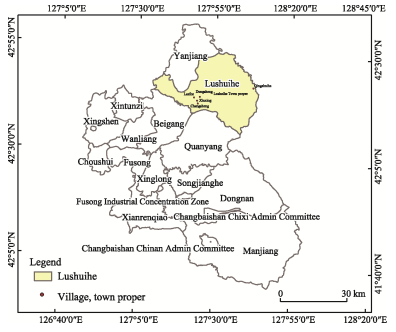

Figure 2 Geo-location map of Lushuihe Town

3.2 Ecological and Environmental Data

3.2.1 Topography

The overall topography of Lushuihe Town is characterized by higher elevations in the south and lower elevations in the north. Based on SRTM 30-m DEM data[1], the authors analyzed the topographic characteristics of the town and found that elevations are predominantly between 500 and 1,000 m (Figure 3). River valley lowlands below 500 m are mainly concentrated in the northern and northwestern parts of the town, while hilly areas at elevations of 500–700 m constitute the dominant topographic type. Low-mountain and hilly areas at elevations of 700–900 m, with some local areas exceeding 900 m, are mainly distributed in the central and southern parts. In terms of slope, flat areas with gradients of <3° extend in belt-like patterns along river valleys. Gentle hilly slopes of 3–15° are widely distributed across the central and eastern parts of the town, whereas low- to mid-mountain areas with slopes >15° are concentrated along the western margin. The moderate elevation of Lushuihe Town is suitable for the ecological preferences of *Pinus koraiensis*, and the extensive gentle slopes provide favorable conditions for its growth, drainage, and light availability.

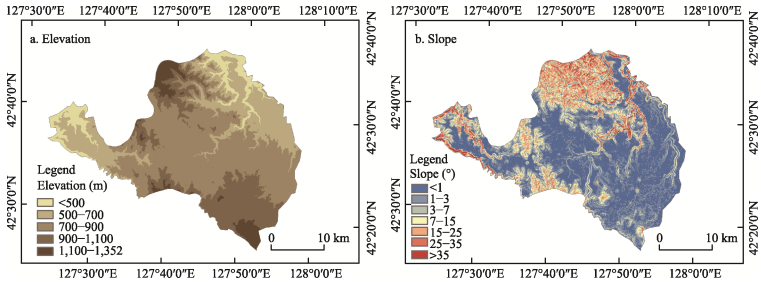

Figure 3 Elevation and slope classification map of Lushuihe Town

3.2.2 Climatic Conditions

Lushuihe Town has a middle-temperate humid monsoon climate, which is strongly influenced

[1] NASA. https://www.earthdata.nasa.gov/data/instruments/srtm.

by the topographic effects of the Changbai Mt. Areas with relatively high temperatures are mainly distributed in river valleys and lower-elevation zones. In contrast, the southern mountainous areas have relatively lower land surface temperatures due to their higher elevation and dense vegetation cover. The spatial patterns of precipitation and relative humidity are generally consistent, both showing higher values in the northwest and lower values in the southeast (Figure 4). The mean annual temperature in Lushuihe Town ranges from 0.9 ℃ to 1.5 ℃, with maximum temperatures of 29.5 ℃–32.2 ℃ and minimum temperatures of −44 ℃ to −39 ℃. The average annual frost-free period is approximately 105 d[4]. Overall, Lushuihe Town is characterized by a cool and humid climate, sufficient accumulated temperature, and large diurnal temperature variation, providing an ideal environment for the growth of *Pinus koraiensis* and the accumulation of nutrients in pine nuts.

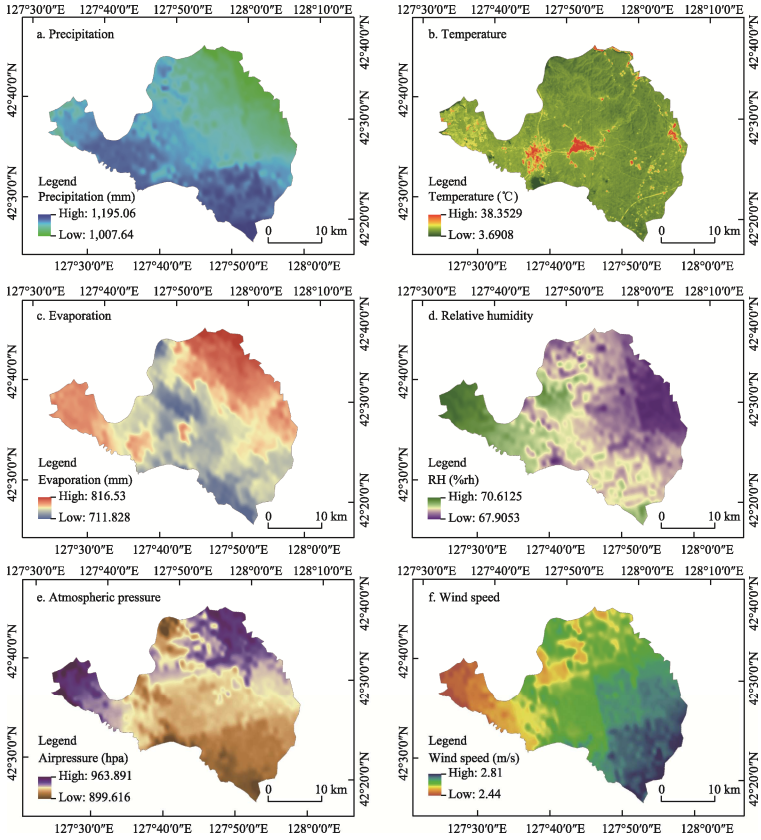

Figure 4 Analysis maps of climatic conditions in Lushuihe Town (2025)

3.2.3 Water Conditions

Lushuihe Town is rich in water resources. It is located in the upper reaches of the Songhua River system and serves as one of the headwater and water-conservation areas for important tributaries of the Songhua River[9]. Since the growth of *Pinus koraiensis* mainly depends on natural precipitation, a single sampling site was established at Dongsheng Forest Farm, where *Pinus koraiensis* is relatively densely distributed, for the collection of river water samples (Figure 5). The water samples

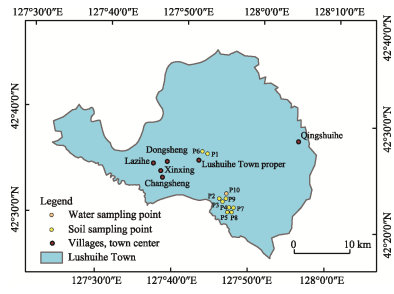

Figure 5 Distribution map of water and soil sampling sites in Lushuihe Town

were submitted to Earthworm Soil Testing Laboratory (Shandong) Co., Ltd. for analysis. The test indicators included 15 parameters: pH, total salt content, chloride, suspended solids, chemical oxygen demand (COD), five-day biochemical oxygen demand (BOD_5), total mercury, total arsenic, cadmium, lead, hexavalent chromium, fecal coliform count, Ascaris egg count, sulfide, and anionic surfactants. The results showed that all tested items were below the concentration limits specified in the National irrigation water quality standard[10] (Table2).

Table 2 Statistical testing result of surface water quality in Lushuihe Town

No.	Test item	Unit	Limits[10]	Testing result
1	pH	–	5.5–8.5	7.4
2	Total salt content	mg/L	≤1,000	65
3	Chlorides	mg/L	≤350	2.78
4	Suspended solids (SS)	mg/L	≤100	ND
5	COD	mg/L	≤200	22
6	BOD_5	mg/L	≤100	4.9
7	Hg	mg/L	≤0.001	ND
8	As	mg/L	≤0.1	ND
9	Cd	mg/L	≤0.001	ND
10	Pb	mg/L	≤0.2	ND
11	Cr^{6+}	mg/L	≤0.1	ND
12	Fecal coliform count	MPN/L	≤4,000	ND
13	Ascaris egg count	eggs/10L	≤20	ND
14	Sulfides	mg/L	≤1	0.0427
15	Anionic surfactants	mg/L	≤8	ND

Note: ND indicates not detected; – indicates no corresponding data.

3.2.4 Soil Conditions

The soil-forming parent materials in Lushuihe Town are mainly granite and basalt, with some sedimentary rocks. The dominant soil types are brown forest soil and albic soil, and the soil layer is generally more than 0.5 m thick. The soils in Lushuihe Town have developed through long-term weathering and pedogenesis of volcanic materials and forest litter. The surface layer is loose and porous, with a thick humus horizon, while volcanic sand and gravel deposits are often found in the lower layers. Overall, the soils are dark brown to brownish-black in color, with high organic matter content and strong water and nutrient retention capacities. These characteristics make them highly suitable for the growth of *Pinus koraiensis* and specialty understory crops.

In this study, 9 soil profile sampling sites were established in the case area (Figure 5). The sites were selected in forest farms with relatively dense *Pinus koraiensis* stands, taking into account factors such as elevation and slope aspect. In addition, to consider the potential influence of human activities, soil sampling sites were also established in areas with dense *Pinus koraiensis* stands around the built-up area of Lushuihe Town. Soil samples were collected by depth intervals of 0–20 cm, 20–40 cm, 40–60 cm, 60–80 cm, and 80–100 cm (Figure 6) to assess soil fertility and environmental quality in the case area. The tested indicators included pH, organic matter, cation exchange capacity, total nitrogen, available phosphorus, available potassium, lead, cadmium, chromium, arsenic, mercury, copper, zinc, nickel, and organochlorine pesticide residues.

(1) Soil fertility status

The test results of the soil profile samples showed that soil pH in the area ranged from 5.0

Figure 6 Profile diagram of soil sampling sites in Lushuihe Town

to 6.8, indicating that the soils were generally acidic to slightly acidic. This range is suitable for the growth of *Pinus koraiensis*. As a key indicator for evaluating soil nutrient retention capacity, soil cation exchange capacity (CEC) ranged from 8.98 to 31.84 cmol/kg, with an average value of 17.23 cmol/kg, suggesting good nutrient retention capacity in the case area. In particular, the CEC of the surface soil at sampling site P9 reached 31.84 cmol/kg, indicating excellent nutrient-holding capacity (Table 3). CEC showed only slight variation with soil depth, suggesting that all soil layers had relatively good nutrient retention performance. This favorable property provides suitable conditions for nutrient absorption by the deep root system of *Pinus koraiensis*, enabling the roots to acquire nutrients from the soil more effectively and thereby promoting the healthy growth and development of *Pinus koraiensis*.

The soil fertility indicators of different soil layers at each sampling site are shown in Table 3 and Figure 7. Soil organic matter content ranged from 5.29 to 89.3 g/kg, with an average value of 24.54 g/kg. Organic matter content decreased with increasing soil depth. The surface soil had a higher organic matter content than the other soil layers, showing obvious surface enrichment, whereas organic matter in the deeper layers tended to be more stable but remained at the lowest level. Total nitrogen content showed a similar pattern to organic matter, ranging from 0.047% to 0.498%, with an average value of 0.151%. The differences in total nitrogen content among deeper soil layers at different sampling sites were relatively small, and the values were generally low. Available phosphorus ranged from 0.1 to 26.8 mg/kg, with an average value of 6.27 mg/kg. At most sampling sites, available phosphorus content was relatively low in the surface soil but higher in deeper soil layers. This pattern may be associated with phosphorus activation promoted by the deep distribution of *Pinus koraiensis* roots. Available potassium ranged from 65 to 500 mg/kg, with an average value of 140 mg/kg. Overall, the soils in the case area showed good nutrient

retention capacity, providing a favorable nutrient environment for the development of the deep root system of *Pinus koraiensis*. These soil conditions effectively support the growth and development of *Pinus koraiensis* and provide an important basis for the high quality and high yield of pine nuts.

Table 3 Statistical testing result of soil fertility in Lushuihe Town

No.	Soil layer depth (cm)	pH	Organic matter (g/kg)	CEC/ (cmol(+)/kg)	Total nitrogen (g/kg)	Available phosphorus (mg/kg)	Available zinc (mg/kg)
P1	0–20	5.2	44.6	24.49	0.174	1.6	177
	20–40	5.0	24.9	25.60	0.113	4.6	109
	40–60	5.0	8.20	20.40	0.053	9.4	80
	60–80	5.3	5.55	23.92	0.047	25.8	99
	80–100	5.3	5.77	25.22	0.053	21.6	109
P2	0–20	5.6	89.3	12.35	0.498	2.7	129
	20–40	5.5	39.8	11.52	0.241	2.0	105
	40–60	5.6	18.7	10.66	0.121	3.8	75
	60–80	5.7	9.69	12.03	0.078	3.0	65
	80–100	5.3	11.2	17.50	0.056	7.4	75
P3	0–20	5.7	48.8	12.13	0.236	2.5	310
	20–40	5.7	32.5	14.10	0.207	2.5	249
	40–60	5.8	20.0	12.07	0.127	3.6	181
	60–80	5.7	17.2	13.69	0.115	4.9	225
	80–100	5.8	14.8	14.10	0.094	12.0	156
P4	0–20	5.2	29.4	15.38	0.133	2.5	136
	20–40	5.5	10.9	10.33	0.087	1.6	90
	40–60	5.4	6.72	12.49	0.051	2.9	87
	60–80	5.5	14.1	16.25	0.061	4.5	96
	80–100	5.6	9.10	16.15	0.055	6.8	92
P5	0–20	6.3	43.4	17.38	0.253	1.9	500
	20–40	6.5	34.6	13.53	0.192	1.6	440
	40–60	6.7	26.8	13.14	0.145	4.5	251
	60–80	6.8	12.0	10.76	0.073	8.2	100
	80–100	6.4	5.45	8.98	0.051	3.9	96
P6	0–20	5.1	30.7	18.84	0.190	0.1	66
	20–40	5.4	27.9	20.90	0.187	0.6	81
	40–60	5.3	17.6	19.72	0.107	0.4	68
	60–80	5.3	5.29	22.14	0.060	4.4	101
	80–100	5.3	5.45	27.24	0.058	10.2	133
P7	0–20	5.5	35.6	19.10	0.191	0.7	86
	20–40	5.7	21.2	14.57	0.168	1.4	77
	40–60	5.7	21.0	15.33	0.149	1.8	79
	60–80	5.8	10.5	9.07	0.080	2.6	66
	80–100	5.8	5.31	10.65	0.049	7.8	78
P8	0–20	5.4	63.2	26.20	0.381	2.1	160
	20–40	5.3	37.8	22.23	0.234	2.2	128
	40–60	5.4	18.6	12.21	0.136	4.5	91
	60–80	5.7	17.1	13.49	0.112	11.4	96
	80–100	5.8	10.2	14.06	0.077	18.0	92

(*To be continued on the next page*)

(*Continued*)

No.	Soil layer depth (cm)	pH	Organic matter (g/kg)	CEC/ (cmol (+)/kg)	Total nitrogen (g/kg)	Available phosphorus (mg/kg)	Available zinc (mg/kg)
P9	0–20	5.4	70.0	31.84	0.479	7.3	146
	20–40	5.4	53.6	26.38	0.370	8.0	129
	40–60	5.5	42.7	22.90	0.270	10.5	121
	60–80	5.6	19.5	21.13	0.128	15.6	164
	80–100	5.8	7.54	23.09	0.050	26.8	310

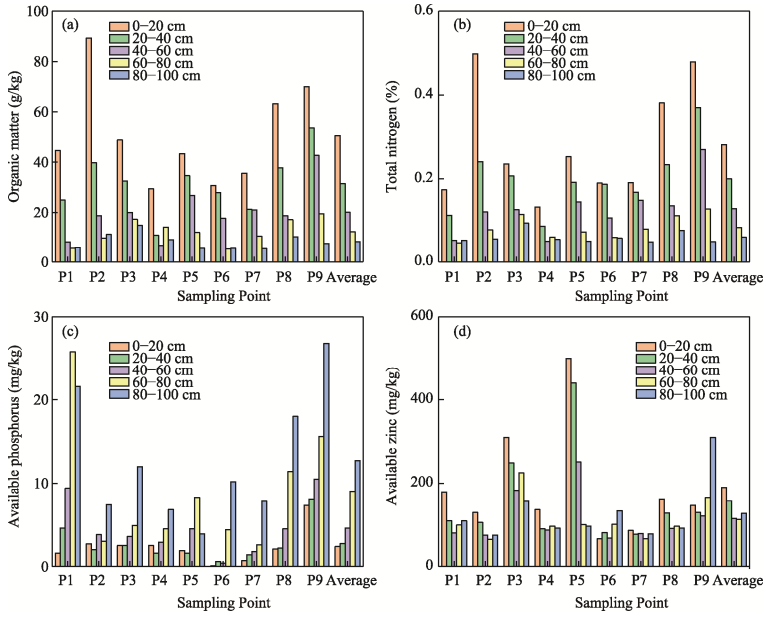

Figure 7 Soil organic matter, total nitrogen, available phosphorus, and readily available potassium contents in different soil layers

(2) Soil environmental quality

The soil environmental indicators were evaluated according to the national standard Soil environmental quality risk control standard for soil contamination of agricultural land (Trial) (GB 15618—2018)[11]. The results showed that the soil environmental quality of the *Pinus koraiensis* forest in Lushuihe Town was excellent. All tested indicators were below the national soil pollution risk screening values, and no pesticide residues were detected (Table 4). These results indicate that the soil environment fully meets the quality requirements for the growth and production of *Pinus koraiensis*[11]. The excellent soil environmental quality provides a safe foundation for the healthy growth of *Pinus koraiensis* and contributes to the production of high-quality and safe forest products.

3.2.5 Vegetation Cover and Land Use

The Normalized Difference Vegetation Index (NDVI) is an important indicator for characterizing vegetation growth and surface vegetation cover. In this dataset, 10-m Sentinel imagery[2] of 2025 was selected as the data source to enhance the spectral response of vegetation and reduce interference from non-vegetation factors. Based on these data, an NDVI map of Lushuihe Town was generated (Figure 8).

[2] European Space Agency (ESA). https://scihub.copernicus.eu/.

Table 4 Statistical testing result of soil environmental indicators in Lushuihe Town

Test item	Limits[11]	Unit	Testing result								
			P1	P2	P3	P4	P5	P6	P7	P8	P9
Pb	90	mg/kg	26	26	25	22	19	23	24	25	23
Cd	0.3	mg/kg	0.20	0.28	0.25	0.22	0.22	0.14	0.18	0.19	0.20
Cr	150	mg/kg	75	67	73	92	87	80	61	75	69
As	140	mg/kg	10.1	8.99	9.08	8.77	8.20	8.97	8.56	8.2	8.22
Hg	1.8	mg/kg	0.064	0.070	0.059	0.052	0.052	0.056	0.054	0.058	0.063
Cu	50	mg/kg	25	19	19	26	28	15	15	17	20
Zn	200	mg/kg	89	97	112	73	75	82	85	97	100
Ni	70	mg/kg	27	27	32	32	35	26	22	25	28
HCHs (Total)	ND	μg/kg	ND	ND	ND	ND	ND	ND	ND	ND	ND
DDTs (Total)	ND	μg/kg	ND	ND	ND	ND	ND	ND	ND	ND	ND

Note: ND indicates not detected.

Overall, NDVI values in Lushuihe Town are dominated by high-value areas, with most values above 0.6. This indicates high vegetation coverage and favorable ecological conditions in the region, reflecting the typical forest landscape characteristics of the Changbai Mt. forest region. In terms of spatial structure, NDVI exhibits a mosaic pattern consisting of a continuous high-value background interspersed with scattered low-value patches. The low-value areas are mainly distributed as point-like or clustered patches, mostly corresponding to areas with relatively intensive human activities, such as residential areas, logging sites, and open river valleys. Meanwhile, NDVI shows strong positive spatial autocorrelation, with high-value areas distributed contiguously and relatively weak overall heterogeneity. However, significant local differences occur in areas affected by human disturbance.

For land use classification, 10-m Sentinel remote sensing images from 2025 and cloud cover of less than 1% were selected as the data source. After image correction, sample extraction for different land use types, supervised classification, and stratified sampling-based accuracy assessment, the land use pattern of Lushuihe Town was obtained (Figure 9). The main land use types in Lushuihe Town include built-up land, forest land, cultivated land, and water bodies. Among them, forest land accounts for approximately 82.54%, cultivated land for approximately 10.04%, and built-up land for approximately 5.04%. Forest shade helps regulate the microclimate, fertile volcanic soils supply nutrients, and clean water sources support physiological metabolism. Together, these environmental

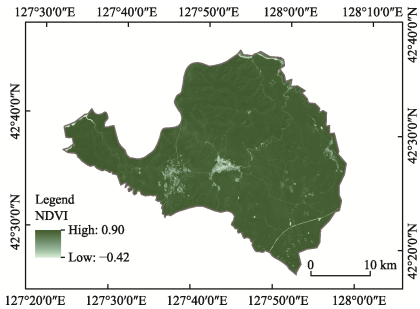

Figure 8 NDVI analysis map of Lushuihe Town

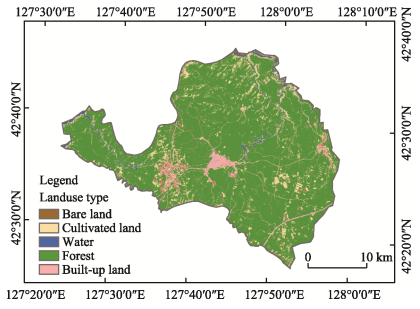

Figure 9 Land use map of Lushuihe Town (2025)

conditions contribute to the distinctive qualities of Lushuihe pine nuts, including their large and plump kernels, rich oil content, and excellent flavor.

3.2.6 Distribution of *Pinus Koraiensis* Forest

Forest lands in Lushuihe Town generally contain *Pinus koraiensis* stands, involving forest farms such as Dongsheng, Hongguang, Xinxing, Yongqing, Xilin, and Liming. Referring to the map of the protected geographical indication area for Lushuihe *Pinus Koraiensis* nuts, the forest zoning map of the Lushuihe Forestry Bureau of Jilin Province at a scale of 1:100,000, and the key pine nut harvesting areas, the authors delineated the main high-density distribution areas of *Pinus Koraiensis* (Figure 10). The main high-density distribution areas of *Pinus koraiensis* in Lushuihe are located around the built-up area of Lushuihe Town, in Hongguang in the west, and in Dongsheng Forest Farm in the south, covering nearly 20,000 ha.

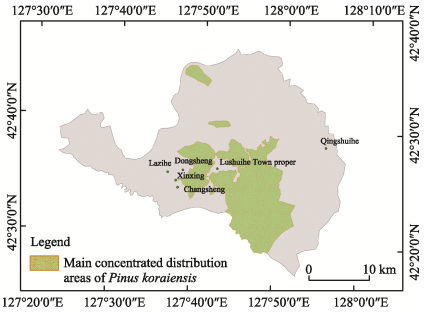

Figure 10 Distribution map of the main concentrated areas of *Pinus koraiensis* in Lushuihe Town

3.3 Product Characteristic Data

3.3.1 Characteristics of Fusong Lushuihe *Pinus Koraiensis* Nuts

Fusong Lushuihe *Pinus koraiensis* nuts require low-temperature stratification for more than 120 d before germination, and their natural germination rate is less than 5%. *Pinus koraiensis* generally needs to grow for more than 50 years before producing seeds, and its cones mature only once every two years, resulting in limited yields. The kernels are light yellow and oval-shaped, with uniform and plump grains and a thin light-brown seed coat on the surface. The kernel interior is milky white, with a fine, smooth, and oily texture. Fusong Lushuihe pine nuts have good storage stability and can maintain their flavor and quality for a long period under low-temperature and dry conditions. They also exhibit strong antioxidant properties and are not prone to rancidity, giving them high nutritional and health-promoting value as well as good suitability for food processing.

3.3.2 Fusong Lushuihe *Pinus Koraiensis* Nuts Quality Test and Analysis

To evaluate the quality of Fusong Lushuihe pine nuts, the authors collected samples harvested in 2025 and manually split open. The samples were mainly obtained from areas surrounding the built-up area of Lushuihe Town and from Dongsheng Forest Farm. They were submitted to the Jilin Provincial Institute of Quality Supervision and Inspection and Qingdao CTI Testing Technology Co., Ltd. for testing and analysis. With reference to the national standard Product of geographical indication—Lushuihe Korean pine seeds and kernel (GB/T 19505—2008)[12], the samples were tested in terms of sensory indicators, physicochemical indicators, and safety and sanitary indicators. The sensory indicators included 4 items: color, odor, appearance, and impurities. The physicochemical indicators included 16 items, such as fat content, acid value, peroxide value, protein, amino acids, vitamins, and minerals. The safety and sanitary indicators included 9 contaminants, such as arsenic, lead, mercury, cadmium, aflatoxin, and coliform bacteria.

(1) Sensory indicators

Fusong Lushuihe pine nut kernels have a strong pine aroma. The kernels are yellow with uniform coloration and no obvious color variation. They are plump and uniform in size. Minor damage was commonly observed, whereas severely damaged kernels accounted for less than 3%, and broken kernels accounted for less than 7%. The low proportions of

severely damaged and broken kernels indicate that effective measures were taken during harvesting, processing, storage, and transportation to ensure the overall appearance quality of the product. The kernels have a fine texture and contain no visible impurities. During processing, procedures such as impurity screening and cleaning were properly implemented, resulting in a clean and hygienic product (Table 5) that meets the requirements of the national standard[12].

Table 5 Statistical testing result of Fusong Lushuihe *Pinus koraiensis* nuts sensory indicators

No.	Test item	Standard indicator[12]	Test results	Judgment
1	Colour and lustre	Yellow	Yellow	Compliant
2	Smell	Strong pine scent	Strong pine scent	Compliant
3	Appearance	Minor damage<3%, broken kernels<7%	Minor damage<3%, broken kernels<7%	Compliant
4	Impurities	No visible impurities	No visible impurities	Compliant

(2) Physicochemical indicators

Pine nuts are widely recognized as nutrient-rich nuts, and Fusong Lushuihe pine nuts exhibit particularly prominent nutritional characteristics due to their unique growing environment. The test results (Table 6) showed that the crude fat content was 65.4%, while the dietary fiber content was 8.4 mg/100g. The relatively high fiber content provides a beneficial complement to the high fat content. The acid value was 0.6 mg/g, and the peroxide value was 0.0023 g/100g. These extremely low values indicate a low degree of oxidative deterioration, suggesting better flavor quality and nutritional value. Fusong Lushuihe pine nuts were also rich in protein and amino acids, with contents of 16.7 g/100g and 13.1 g/100g, respectively, making them a high-quality source of plant protein. The detected amino acids included 16 types: aspartic acid, threonine, serine, glutamic acid, glycine, alanine, valine, methionine, isoleucine, leucine, tyrosine, phenylalanine, lysine, histidine, arginine, and proline. The vitamin E content was relatively high, reaching 24.7 g/100g. Among the major elements, the calcium, potassium, and magnesium contents were 145 mg/100g, 594 mg/100g, and 2.58×10^3 mg/100g, respectively. Among the trace elements, the manganese, iron, and zinc contents were 56.1 mg/100g, 45.5 mg/100g, and 62.7 mg/100g, respectively.

Table 6 Statistical testing result of Fusong Lushuihe *Pinus koraiensis* nuts physicochemical indicators

No.	Test item	Unit	Limits[12]	Test results	Judgment
1	Fat	%	≥60	65.4	Compliant
3	Acid value	mg/g	≤4	0.60	Compliant
4	Peroxide value	g/100g	≤0.08	0.0023	Compliant
5	Protein	g/100g	/	16.7	–
6	Amino acids	g/100g	/	13.1	–
7	Vitamin E	g/100g	/	24.7	–
8	Vitamin B_1	g/100g	/	0.40	–
9	Vitamin B_2	g/100g	/	0.0551	–
10	Ca	mg/100g	/	145	–
11	K	mg/100g	/	594	–
12	Mg	mg/100g	/	2.58×10^3	–
13	Mn	mg/100g	/	56.1	–
14	Fe	mg/100g	/	45.5	–
15	Zn	mg/100g	/	62.7	–
16	Dietary fiber	mg/100g	/	8.4	–

Note: / indicates no corresponding standard limit; – indicates no corresponding data.

(3) Safety and hygiene indicators

The test results for Fusong Lushuihe pine nuts showed that heavy metals, including arsenic, lead, cadmium, and total mercury, were either not detected or were far below the limits specified in national standards. Aflatoxin B_1 was not detected, and the counts of coliform bacteria and other microorganisms were low, indicating excellent microbial safety indicators (Table 7). All test results complied with the requirements of the National food safety standard—maximum levels of contaminants in food (GB 2762—2022)[13] and National food safety standard—maximum levels of mycotoxins in food (GB 2761—2017)[14]. These results indicate that the food safety and sanitary indicators of Fusong Lushuihe pine nuts fully meet national standards. They also suggest that the cultivation and processing practices are conducted in accordance with safety requirements, thereby ensuring product safety.

Table 7 Statistical testing result of Fusong Lushuihe *Pinus koraiensis* nuts safety and hygiene indicators

No.	Test item	Unit	Limits[13,14]	Test results	Judgment
1	As	mg/kg	≤0.5	ND	Compliant
2	Pb	mg/kg	≤0.5	ND	Compliant
3	Cd	mg/kg	≤0.5	0.103	Compliant
4	Hg	mg/kg	/	ND	–
5	Aflatoxin B1	μg/kg	≤10	ND	Compliant
6	Coliform bacteria	CFU/g	/	<10	–
7	Mould and yeast	CFU/g	/	7.8×10^4	–
8	Salmonella	/25g	/	ND	–
9	Staphylococcus aureus	CFU/g	/	<10	–

Note: ND indicates not detected; / indicates no corresponding standard limit; – indicates no corresponding data.

4 Socioeconomic Development, Management, and Historical Traditions

4.1 Socioeconomic Development in Fusong and Lushuihe

The county economy of Fusong has maintained steady and rapid growth, providing a sound foundation for promoting green agricultural development across the county. In 2025, the GDP of Fusong County exceeded 15 billion CNY, and the total output value of agriculture, forestry, animal husbandry, and fishery increased by 5.0% year on year. The per capita disposable income of rural residents reached 22,008 CNY, higher than the average level of Jilin Province. Following the nationwide ban on commercial logging, Lushuihe Town underwent a profound industrial transformation. Its economy shifted from a reliance on forest logging and wood processing to a diversified industrial structure involving natural mineral water, ginseng, pine nuts, and other specialty industries. Meanwhile, the town has actively developed ecotourism based on resources such as national forest parks and hunting grounds, pursuing a green and sustainable development path[15–18]. Relying on more than one million century-old *Pinus koraiensis* mother trees and a well-established industrial chain integrating planting, harvesting, processing, and sales, the pine nut industry in Lushuihe Town has become a leading “one town, one specialty” industry in Fusong County. Its annual sales have exceeded 200 million CNY, with exports accounting for more than 60%. The industry has directly created employment opportunities for over 3,000 local forest farmers, achieving coordinated development among ecological resource protection, traditional skill inheritance, and industrial income growth. In 2025, the pine nut output of Lushuihe Town reached approximately 4,500 t, creating more than 200 regular jobs and over 400 seasonal jobs, with an average monthly wage of 4,500 CNY.

4.2 Protection and Development of *Pinus Koraiensis* Resources

Since the 1980s, with increasing awareness of natural forest protection, the Lushuihe Forestry Bureau has taken the lead in establishing a research group dedicated to the conservation and utilization of *Pinus koraiensis* resources. The group focused on systematic research related to the cultivation of *Pinus koraiensis* mother forests, improvement of cone-bearing rates, and optimization of kernel quality. Between 1990 and 1995, the research team successfully selected 3 superior mother-tree lines of *Pinus koraiensis* using a technical system integrating "plus-tree selection, artificial pollination, and seedling domestication". Subsequently, a large-scale mother forest improvement project was carried out in the core forest area of Lushuihe, expanding the protected area of ancient trees over 100 years old to 8,000 ha[19]. In 2003, "Lushuihe *Pinus Koraiensis* Nut Kernels" were officially approved as a National Geographical Indication Product, becoming the first nut product in Northeast China to receive this certification. Over the following two decades, through continuous scientific research and technological improvement, the product successively obtained Grade AA Green Food Certification, EU Organic Certification, and China Forest Certification (CFCC)[20]. In 2020, Lushuihe *Pinus koraiensis* nut kernels from mother forests were included in the second list under the China-EU Agreement on Geographical Indications. In 2021, the product was recognized as one of "China's Famous Agricultural Products", and the traditional *Pinus koraiensis* nut harvesting technique was included in the Jilin Provincial Intangible Cultural Heritage List. In 2023, the ancient *Pinus koraiensis* tree group in Lushuihe, Jilin Province, was selected as one of "China's Most Beautiful Ancient Tree Groups".

4.3 Industry Development and Operational Management

4.3.1 Pine Nut Resource Control

Relying on Asia's largest natural *Pinus koraiensis* mother forest, Lushuihe Town implements fine-scale management of *Pinus koraiensis* resources. Based on the growth cycle and fruiting patterns of *Pinus koraiensis*, a strict quota-based harvesting system has been adopted. The annual harvest volume is determined according to monitoring data to ensure the sustainable growth of mother trees. Forestry authorities and forest farms have established a comprehensive monitoring system for *Pinus koraiensis* resources. By integrating satellite remote sensing, unmanned aerial vehicle (UAV) monitoring, and ground patrols, the system enables real-time monitoring of *Pinus koraiensis* growth, pest and disease occurrence, and changes in the forest ecological environment.

4.3.2 Business Management

Lushuihe Town has developed a management model characterized by government guidance, cooperation between research institutions and enterprises, and collaboration between cooperatives and local villagers. Research institutions and enterprises jointly carry out the selection and breeding of improved *Pinus koraiensis* varieties, optimization of shell-breaking and kernel-extraction processes, and studies on the functional components of pine nuts. Enterprises have introduced internationally advanced aseptic production lines and processing technologies. During primary processing, impurities and defective seeds are accurately removed, and low-temperature roasting is adopted to maximize the retention of nutrients and flavor in pine nut kernels. Cooperatives are responsible for organizing villagers to conduct standardized harvesting, drying, and preliminary sorting, thereby ensuring the purity and traceability of raw materials. By participating in harvesting, forest management, and transportation, villagers not only increase their income but also provide enterprises with a stable supply of high-quality raw materials.

Relying on the geographical-origin advantages of Lushuihe pine nuts, the government has promoted industrial clustering and industrial chain extension through policy guidance. A

modern industrial system has gradually taken shape, covering multiple links, including wild resource management, integrated mechanized harvesting, low-temperature shell breaking and kernel extraction, deep processing of pine nut oil, and the development of health food products. Meanwhile, with the support of leading enterprises such as Jilin Changbai Mingzhu Forest Food Co., Ltd., multiple stakeholders have jointly promoted the research and development of "pine nut +" product series. These efforts have led to the development of composite products combining pine nuts with ginseng, cocoa, crispy confectionery, and other ingredients, further extending the industrial chain.

4.3.3 Marketing and Brand Building

The government plays a leading role by using industrial policies to guide enterprises in better aligning their products with consumer demand and developing diversified products for different consumer groups. For the high-end consumer market, organically certified pine nut products with refined gift-box packaging have been introduced, emphasizing their ecological, healthy, and high-quality attributes. For ordinary consumers, affordable ready-to-eat pine nut kernels in small packages have been launched to meet daily consumption needs. Meanwhile, the government actively promotes investment attraction and introduces professional institutions specializing in e-commerce operations and brand planning. These efforts help enterprises use emerging marketing channels, such as social media and live streaming, to communicate the brand story and ecological value of Lushuihe pine nuts, thereby enhancing consumer awareness and purchase intention.

In terms of brand building, the government has led the formulation of regional public brand standards for "Lushuihe *Pinus Koraiensis* Nut Kernels" and has worked with industry associations to strengthen brand authorization and supervision. Brand promotion highlights the product's natural ecological attributes and high nutritional value. Through integrated online and offline communication, participation in exhibitions and promotional events, and culture–tourism integration projects, the brand's visibility and market share have been continuously improved. At the same time, market regulatory authorities, together with industry associations, have strengthened the protection of the "Lushuihe *Pinus Koraiensis* Nut Kernels" geographical indication brand. They regularly carry out targeted enforcement campaigns, strictly crack down on counterfeit and substandard products, and safeguard the reputation of the brand.

4.4 Inheritance and Promotion of Fusong Lushuihe Pine Nut Culture

The history of *Pinus koraiensis* in Lushuihe Town can be traced back to ancient times. Numerous forestry studies indicate that *Pinus koraiensis*, as an ancient tree species, existed in East Asia at least 10,000 years ago, with a distribution range broader than that of today. Local ethnic minorities in Fusong County, including the Manchu and Korean ethnic groups, have long lived in close association with *Pinus koraiensis*[21]. During the Qing Dynasty, Manchu nobles regarded *Pinus koraiensis* nuts as precious delicacies. They were not only consumed as part of the daily diet, but also played an important role in ritual ceremonies. Pine nut kernels were listed among the "Eight Delicacies" and were often used to make pastries and other offerings. Among local communities, pine nut kernels have also been an important component of traditional dietary culture. They have been made into characteristic foods such as pine nut porridge and pine nut cakes, with related practices passed down through generations. *Pinus koraiensis* holds a special position in local culture and is regarded as a symbol of longevity and resilience. In folk legends, *Pinus koraiensis* is considered an incarnation of the mountain deity, protecting the forests and the people who live there.

A variety of cultural activities have developed around *Pinus koraiensis*. The government plays a guiding and supportive role by coordinating forestry, culture and tourism, market regulation, and other departments throughout the processes of event planning, safety

management, and brand promotion, thereby creating the *Pinus koraiensis* Cultural Festival. During the festival, traditional pine nut processing techniques are demonstrated, characteristic foods are offered for tasting, and folk performances and knowledge competitions related to *Pinus koraiensis* are held. These activities help preserve and promote *Pinus koraiensis* culture, enhance local residents' awareness of resource conservation and cultural identity, and allow more people to understand the distinctive regional cultural charm of Lushuihe pine nuts[21]. Meanwhile, the integrated development of "*Pinus koraiensis* culture + ecotourism" has been actively promoted. Taking advantage of Lushuihe's proximity to Fusong County seat, Erdaobaihe Town, and the core scenic area of Changbai Mt., the town has integrated outdoor activities such as forest hunting culture experiences, wilderness hiking, mountain camping, and forest exploration, and has developed premium tourism routes in collaboration with surrounding scenic areas.

4.5 Ecological Environment Traceability for Fusong Lushuihe *Pinus Koraiensis* Nuts

Promoting the sustainable development of the Fusong Lushuihe pine nut industry requires strong support from modern technology. To this end, a geographical indication habitat ground station has been established in the forest farm of the case area (Figure11). The station is used for real-time, round-the-clock monitoring and traceability of the ecological environment of *Pinus koraiensis* forests. The monitored indicators mainly include negative oxygen ions, phenology, wind speed, wind direction, rainfall, air quality, temperature, relative humidity, soil temperature and moisture, atmospheric pressure, and soil electrical conductivity. These real-time monitoring data can be used to characterize the high-quality growing environment of Lushuihe pine nuts and provide scientific and precise data support for analyzing phenological changes and associated responses in *Pinus koraiensis* forests. This further promotes the transformation of the pine nut production model toward greater intelligence, scientific management, and sustainability.

Figure 11 GIES ground station

5 Conclusions

The GIES case of Fusong Lushuihe *Pinus koraiensis* nuts forest ecosystem is located in the core area of the Changbai Mt. in Fusong County, Jilin Province. The primary forest ecosystem, characterized by high elevation, a cold-temperate humid climate, and fertile volcanic ash soils, provides favorable habitat conditions for the growth of *Pinus koraiensis*. Lushuihe Town has excellent soil environmental quality, with no detectable pesticide residues,

and its clean water resources are conducive to the production of high-quality pine nuts. Lushuihe pine nuts are characterized by plump kernels, a milky-white kernel color, and a rich aroma. They are also rich in fat, protein, and essential trace elements required by the human body, indicating significant nutritional value. Through standardized management of wild pine nut harvesting and the establishment of an integrated management model involving industry, universities, research institutions, government, cooperatives, local residents, and traditional practices, the local area has achieved conservation-oriented development of rare *Pinus koraiensis* mother forest resources. In the future, it will be necessary to further deepen the integration of ecological conservation and industrial development. On the basis of ensuring the security and stability of *Pinus koraiensis* resources, efforts should be made to improve the quality and added value of *Pinus koraiensis* nuts, so as to achieve coordinated enhancement of ecological, economic, and social benefits.

Author contributions

Qi, W. designed the overall study, including the dataset structure, paper framework, technical route, and writing approach; organized field investigations and seminars; and contributed to paper writing. Wang, G., Gao, J. T., Du, Y. C., and Zhao, W. X. coordinated the case investigation and data collection. Qi, W., Zhu, W. H., Zhu, J. H., Chen, Y. T., Liu, Y., Liu, Y. B., and Niu, Z. M. participated in the field investigation of the case study. Wang, X. Q., Jin, X., and Qi, W. were responsible for the collection and analysis of soil and water samples. Chen, Y. T., Liu, Y., Liu, Y. B., Niu, Z. M., Li, Y., and Fan, K. were responsible for data collection, analysis, processing, and figure preparation. Tang, X. R. and Liu, H. Q. were responsible for coordinating support from relevant organizations at different levels and collecting local cultural data. Qi, W. was responsible for meteorological data collection and analysis. Zhu, J. H. was responsible for the collection and analysis of cultural information related to *Pinus koraiensis* nut kernels. Liu, H. Q., Xu, Y. G., and Zhang, Z. G. were responsible for collecting data on management practices, economic development, and product characteristics. Zhu, W. H., Zhu, J. H., Chen, Y. T., Liu, Y., Liu, Y. B., Niu, Z. M., Li, Y., Fan, K., and Tang, X. R. contributed to the writing of the paper.

Acknowledgements

We would like to express our sincere gratitude to Professors Liu, C., Song, X, F., and Wang, Z. B. from the Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, for their guidance and assistance during the preparation of this case dataset and manuscript. Our thanks are also extended to the local villagers who provided assistance during the collection and analysis of soil and water samples.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Liu, J. B. Management and protection measures of natural *Pinus koraiensis* mother forest in Lushuihe [J]. *Jilin Forestry Science and Technology*, 2012, 41(3): 44–45

[2] Zu, S. C. Resource evaluation and deep processing technology of *Pinus koraiensis* Sieb. et Zucc. seeds [D]. Harbin: Northeast Forestry University, 2020.

[3] Li, X. H. Study on the relationship between vegetation productivity and water use in the broad-leaved *Pinus koraiensis* forest region of Changbai Mountain [D]. Beijing: Beijing Forestry University, 2019.

[4] Liu, D. D. Research progress on selective breeding of *Pinus koraiensis* in China [J]. *Protection Forest Science and Technology*, 2017(3), 96–99+116.

[5] Zhang, H. N., Guo, J. Q., Zhao, Y. H. Research status on composition, nutritional value, development and

utilization of *Pinus koraiensis* seeds [J]. *Forest By-Product and Specialty in China*, 2022(2), 84–86.

[6] Song, W., Yan, P. Y., Liu, J., *et al*. GIES case study on Qin County millet Shangdang Basin [J]. *Journal of Global Change Data & Discovery*, 2024, 8(3): 267–285. https://doi.org/10.3974/geodp.2024.03.05.

[7] Qi, W., Zhu, J. H., Wang, G., *et al*. GIES case dataset on Fusong Lushuihe Korean pine seeds forest ecosystem [J/DB/OL]. *Digital Journal of Global Change Data Repository*, 2026. https://doi.org/10.3974/geodb.2026.04.01.V1.

[8] GCdataPR Editorial Office. GCdataPR data sharing policy [OL]. https://doi.org/10.3974/dp.policy.2014.05 (Updated 2017).

[9] Li, H. Y., Sun, Y. H., Lu, L. L., *et al*. Analysis of water resources characteristics in Fusong Drinking Water Source Protection Area [J]. *Jilin Geology*, 2013, 32(3), 80–85.

[10] State Administration for Market Regulation, Standardization Administration of China. Standard for irrigation water quality (GB 5084—2021) [S]. Beijing: China Planning Press, 2021.

[11] Ministry of Ecology and Environment of P. R. China, State Administration for Market Regulation. Soil environmental quality risk control standard for soil contamination of agricultural land (Trial) (GB 15618—2018) [S]. Beijing: China Environment Publishing Group, 2018.

[12] General Administration of Quality Supervision, Inspection and Quarantine of P. R. China, Standardization Administration of China. Product of geographical indication—Lushuihe Korean pine seeds and kernel (GB/T 19505—2008) [S]. Beijing: Standards Press of China, 2008.

[13] National Health Commission of P. R. China, State Administration for Market Regulation. National food safety standard—maximum levels of contaminants in food (GB 2762—2022) [S]. Beijing: Standards Press of China, 2022.

[14] National Health and Family Planning Commission of P. R. China, China Food and Drug Administration. National food safety standard—maximum levels of mycotoxins in food (GB 2761—2017) [S]. Beijing: Standards Press of China, 2017.

[15] Wang, X. H. Discussion on the construction technology of *Pinus koraiensis* fruit timber forest [J]. *Agriculture and Technology*, 2019, 39(3), 88–89.

[16] Wang, W., Li, P. X., Wang, G. X., *et al*. Effects of storage temperature on the physiology and quality of pine nut kernels under different states [J]. *Zhejiang Agricultural Science*, 2009(4), 743–746.

[17] Dong, S. N., Yu, Y. F., Fu, Y. C. Study on the spatiotemporal differentiation and influencing factors of the quality of under-forest economic growth in Changbai Mountain area of Jilin Province [J]. *Journal of Northeast Normal University* (*Philosophy and Social Sciences Edition*), 2023(1), 147–158+202.

[18] Liang, Y. F. Evaluation of development level and model effect analysis of agricultural green development pilot zone in Fusong County [D]. Changchun: Jilin University, 2024.

[19] Ren, Z. J., Shi, W. H. Exploration of forest resource protection and development under the background of sustainable development—a case study of Fusong County [J]. *Guangdong Sericulture*, 2024, 58(10), 24–26.

[20] Liu, L., Nie, H. Y. Analysis of the protection development status and countermeasures of national geographical indication products in Jilin Province [J]. *Science and Technology Innovation Herald*, 2018, 15(28), 152–153.

[21] Xu, W. “Shanlihong” forever red—the growth track of Shanlihong Troupe in Fusong County [J]. *Shenhua* (*Part* 2), 2019(7), 62–65.