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GIES Case Study on Fusong Ginseng Facility Agriculture

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Abstract: Fusong County, Jilin Province, renowned as a prominent hometown of ginseng in China, is located in the hinterland of the Changbai Mt., the upper reaches of the Songhua River, and adjacent to Tianchi Lake of the Changbai Mt., with well-developed Cenozoic basaltic volcanic landforms. The case study on the geographical indication habitat of ginseng facility agriculture in Fusong covers 3 towns, namely Songjianghe, Quanyang and Donggang Towns in Fusong County, with a total area of 1,511.27 km^2 and a total permanent resident population of 79,371. In 2024, the reserved area of ginseng in the county was 720 ha. Guided by unified government coordination and resource integration, and relying on the market circulation advantages of a distribution hub, an industrial paradigm of "promoting production through aggregation and boosting aggregation via production" has been established. The soil quality in the case area is superior to the national

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standard for soil environmental quality, and the irrigation water quality is better than the national standard for farmland irrigation water quality. In addition, the complete vertical vegetation zonation, abundant litter from vegetation communities, volcanic clastic substrate, and unique climatic and topographic conditions, providing a highly suitable ecological environment for ginseng growth. The pesticide residue and heavy metal levels in Fusong ginseng are significantly lower than the national safety standards, and the total ginsenoside, Re+Rg1, and Rb1 levels exceed the standards for Jilin Changbai Mt. Ginseng, a geographical indication product. Through government-led formulation of industrial group standards, brand access and promotion, combined with improved variety breeding, green plant protection, and traceability by scientific research teams, as well as ginseng farmers' participation in production and information feedback, high-quality and sustainable development of the ginseng industry has been achieved under the premise of ecological environment protection. The dataset of this case includes the scope of the case area, physical ecosystem and environment data, product characteristic data, and data on economic development and management. The dataset is archived in .shp, .tif, .xlsx, .docx, .jpg and .txt formats, and consists of 108 data files with data size of 45.2 MB (compressed into one file with 19.7 MB).

Keywords: Changbai Mountain; Fusong ginseng; facility agriculture; GIES; Case 35

DOI: https://doi.org/10.3974/geodp.2026.03.08

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.2026.03.08.V1.

1 Introduction

A regionally favorable ecological environment is an inherent prerequisite for ginseng growth and development. High-quality ginseng also serves as an important indicator of superior regional habitats. Fusong County, located in the hinterland of the Changbai Mt. and the upper reaches of the Songhua River and adjacent to Tianchi Lake of the Changbai Mt., is the core production area of Changbai Mt. ginseng.

As the main raw material for medicinal and edible homologous products, the supply of high-quality ginseng directly affects the safety demand for ginseng products and the sound development of the ginseng ecological industrial economy[1]. According to the Pharmacopoeia of China, cultivated ginseng is commonly known as "garden ginseng", and artificially cultivated "garden ginseng" is collectively referred to as ginseng in the industry. In response to the need for sustainable development of the ginseng industry in Fusong County, this study focuses on artificially cultivated ginseng in facility agricultural land as the research object (Figure 1).

Figure 1 Fusong ginseng in Quanyang Town, Songjianghe Town, and Donggang Town

From the perspectives of the physical and geographical environment, product characteristics, economic development, and operation management, the GIES case dataset on Fusong ginseng facility agriculture was constructed. This study aims to provide data support for Fusong County to build a practical path of "ecology first, green development" with the ginseng industry as the core, and to promote ecological environment protection and sustainable development in the Changbai Mt. region.

2 Metadata of the Dataset

Information including the title, authors, geographical region, year of the data, dataset files, etc. of the GIES case dataset on Fusong ginseng facility agriculture[2] are listed in Table 1.

Table 1 Metadata summary of the GIES case dataset on Fusong ginseng facility agriculture

Items	Description
Dataset full name	GIES case dataset on Fusong ginseng facility agriculture
Dataset short name	FusongGinsengCase35
Authors	Wang, J. G., College of Earth Sciences, Jilin University, wang_jg@jlu.edu.cn Cheng, X. L., College of Earth Sciences, Jilin University, chengxl24@mails.jlu.edu.cn Wang, D., People's Government of Fusong County, 236147070@qq.com Wang, G., People's Government of Fusong County, 364899194@qq.com Gao, J. T., Fusong County Market Supervision and Administration Bureau, 84809029@qq.com Zhu, H. L., Ginseng Industry Development Center of Fusong County, 172953679@qq.com Du, Y. C., Fusong County Market Supervision and Administration Bureau, 84809029@qq.com Zhang, W. X., College of Earth Sciences, Jilin University, wxzhang24@mails.jlu.edu.cn Li, H., Ginseng Industry Development Center of Fusong County, lihao874@126.com Wang, X., Ginseng Industry Development Center of Fusong County, fsxwx01@163.com Li, Z. Y., People's Government of Songjianghe Town, Fusong County, 18943769000@163.com Jie, Z. Y., People's Government of Quanyang Town, Fusong County, 940676056@qq.com Yu, H. J., People's Government of Donggang Town, Fusong County, 410568085@qq.com Shi, L., People's Government of Wanliang Town, Fusong County, fsshilei@126.com Hou, Y. B., Fusong County Ginseng Association, 339559006@qq.com Liu, W. Y., Fusong Ginseng Agricultural Technology Co., Ltd., 13704490217@163.com Xu, H. Y., Jilin Shenwang Plant Protection Co., Ltd., cbsxu@126.com Ma, Y. D., Jilin Shenwang Plant Protection Co., Ltd., Baishan City Ginseng Industry Development Association, cbsma@126.com Guo, X. J., Fusong County Ginseng Quality Testing Center (Fusong County Ginseng Research Institute), gxj7578@126.com Qin, S. Z., Juqian Ginseng Breeding and Planting Professional Cooperative, Xiaoshan Village, Songjianghe Town, Fusong County, Yang, F., Ginseng Industry Development Center of Fusong County, 1175836669@qq.com Yan, H., Ginseng Industry Development Center of Fusong County, 609113920@qq.com Xu, X. W., Quality Supervision, Inspection and Testing Center of Ginseng and Antler Products, Ministry of Agriculture and Rural Affairs, Jilin Agricultural University, xuxuanwei83@126.com Wang, L., Jilin Institute of GF Remote Sensing Application Co., Ltd., wang_lei_1992@126.com Chen, S. B., College of Geo-Exploration Science and Technology, Jilin University, chensb@jlu.edu.cn Wang, Z. B., Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, wangzb@igsnrr.ac.cn
Geographical region	Quanyang, Songjianghe, and Donggang Town, Fusong County, Baishan City, Jilin Province
Year	2000–2024
Data format	.shp, .tif, .xlsx, .docx, .jpg
Data size	45.2 MB (19.7 MB after compressed)
Data files	Data on case study area scope, physical geography environment, product characteristics, economic development and operation management
Foundation	Jilin Provincial Administration for Market Regulation (2025)
Data publisher	Global Change Research Data Publishing & Repository, http://wwwgeodoi.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[3]
Communication and searchable system	DOI, CSTR, Crossref, DCI, CSCD, CNKI, SciEngine, WDS, GEOSS, PubScholar, CKRSC

3 Case Dataset Development

3.1 Case Area

Fusong County is situated in the southeastern part of Jilin Province, the northern part of

Baishan City, the upper reaches of the Songhua River, and the northwestern foothills of the Changbai Mt. It stretches 87 km from east to west and 125 km from north to south, located between 127°01′E–128°06′E and 41°42′N–42°49′N. To the north, it borders Huadian City and Dunhua City across the Second Songhua River; to the south, it is adjacent to Linjiang City and Changbai Korean Autonomous County; to the east, it shares boundaries with Antu County and the Democratic People's Republic of Korea; and to the west, it faces Jingyu County across the river and adjoins Jiangyuan District. The scope of this case area covers 3 towns in Fusong County, Jilin Province, namely Quanyang Town, Songjianghe Town, and Donggang Town (Figure 2), with a total area of 1,511.27 km^2, and a total permanent resident population of 79,371.

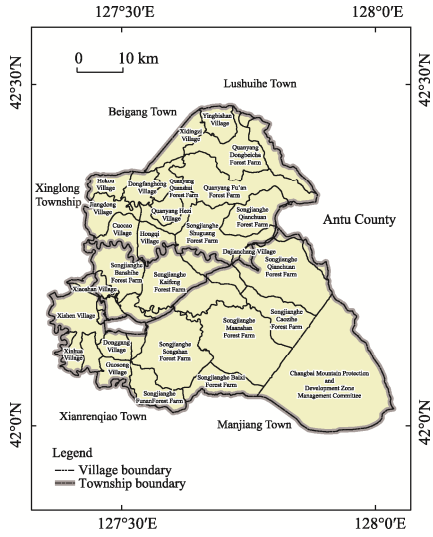

Figure 2 Geo-location map of the case area

3.2 Ecological and Environmental Data

3.2.1 Topography

Fusong County is located on the northeastern margin of the Sino-Korean Platform of the Eurasian Plate and has well-developed Quaternary volcanic lava landforms. Based on DEM data from the Resource and Environment Science and Data Center of China[1], the authors conducted topographic and geomorphic analyses. The results show that the average altitude of the case area is approximately 943.97 m, and the terrain is high in the southeast and low in the northwest (Figure 3), with an obvious elevation gradient. The overall spatial pattern is characterized by "steep eastern margin, gentle central and western parts". Slopes in the case area are dominated by gentle and moderate gradients. The 3–7° class accounts for the largest proportion (42.66%), followed by the 7–15° class (33.33%), with the two classes together exceeding 75%. Slopes steeper than 15° account for only 6.81%. This provides favorable slope conditions for ginseng rotation (Figure 4), facilitates irrigation, drainage, mechanical operation, and daily management of ginseng fields, and ensures large-scale production and stable quality of ginseng[4].

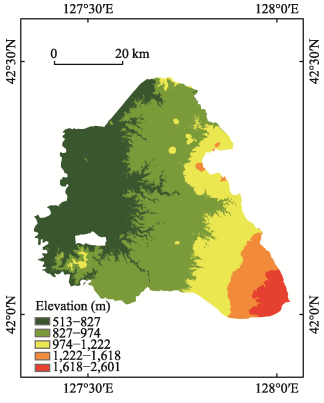

Figure 3 Elevation classification map of the case area

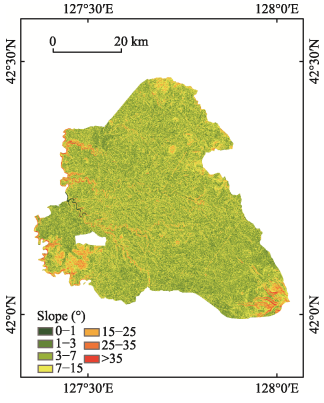

Figure 4 Slope classification map of the case area

[1] Resource and Environment Science and Data Center of China. https://www.resdc.cn/Default.aspx.

3.2.2 Climatic Conditions

Fusong County, located in the mountainous terrain of Northeastern China, is characterized by a humid climate with cold-temperate conditions. Winter (November–March) is characterized by high air pressure, low temperature, low humidity, and low precipitation; summer (June–August) features low air pressure, high temperature, high humidity, and concentrated precipitation; and spring and autumn are transitional periods with significant fluctuations in meteorological elements (Figure 5).

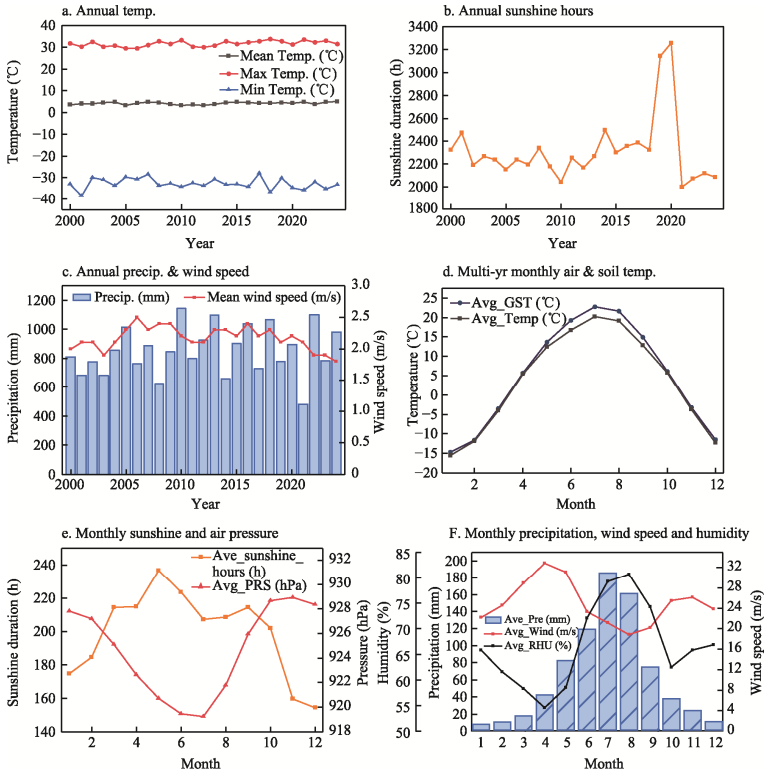

Figure 5 Statistical analysis of climate change in Fusong County

Meteorological data for Fusong County from 2000 to 2024 show that the annual average temperature ranges from 2.0 to 4.8 ℃, annual sunshine hours fluctuate between 2,000.1 and 3,257.8 h, annual average wind speed varies slightly from 1.8 to 2.5 m/s, and annual precipitation ranges from 480.3 to 1,143.6 mm. The county has a long snow cover period in winter, with a maximum snow depth of 540 mm.

With four distinct seasons, the county generally presents the characteristics of "long and severe winters, mild and short summers, and cool annual average conditions", which is conducive to the growth and development of ginseng and the accumulation of effective components such as ginsenosides[5].

3.2.3 Geological and Soil Conditions

The case area is located in the core zone of the Cenozoic basaltic volcanic rock region of the Changbai Mt., with significant geothermal anomalies and extensive outcrops of volcanic rocks and pyroclastics[6]. Loose pyroclastic particles are fine-grained, with rapid soil-forming rates, excellent water permeability, fertilizer retention, and aeration properties[7]. They are rich in mineral elements essential for plant growth, which

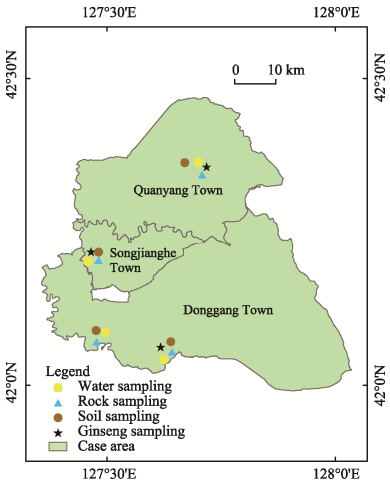

Figure 6 Distribution map of sampling sites

significantly promotes vegetation development and biological activity. Under hydrothermal processes, pyroclastics participate in soil formation, creating a unique soil physical structure, abundant mineral conditions[8], and suitable hibernation temperature conditions for ginseng[9] in Fusong County.

The authors collected samples from residual basalt blocks in the soil parent materials at 4 representative ginseng industrial parks (Figure 6). The samples were sent to the Key Laboratory of Mineral Resources Evaluation in Northeast Asia, Ministry of Natural Resources for analysis. The results show that in terms of major elements, the rocks are characterized by high iron and magnesium content and are rich in sodium, potassium and phosphorus (Table 2).

The soil parent rock is characterized by relative enrichment of light rare earth elements (LREE) and relative depletion of heavy rare earth elements (HREE), with significant enrichment of La, Rb, Nb, Sr, and Ba, and relative depletion of Ta. Heavy metal analysis showed that the contents of As, Pb, Cd, Cu, Hg, and Zn were significantly lower than their corresponding abundances in the continental crust, whereas Ni and Cr were comparable to crustal abundances. The nutrient element Se is notably higher than its crustal abundance.

The soil types in Fusong County are dominated by soils and dark brown soils. A large area of sandy loam with moderate bulk density has formed under the pyroclastic parent material. This is conducive to maintaining the normal morphological development of ginseng roots, ensuring good aeration, keeping the soil moist but not waterlogged, and preventing root rot caused by excessive moisture or growth inhibition due to drought[6]. Pyroclastic materials mixed with litter from coniferous and broad-leaved mixed forests participate in soil formation, resulting in abundant mineral content, strong nitrogen fixation capacity, and significant humus accumulation[10], making these soils highly favorable for large-scale cultivation of ginseng.

Soil samples were collected from ginseng beds at 4 representative ginseng industrial parks in the case area (Figure 6) at a depth of 40 cm. The samples were sent to the Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences for analysis. Tests of the basic physical and chemical properties showed that the soil was weakly acidic, highly fertile, and free of salinization risk (Table 3). According to the reference standard Green food-environmental quality for production area (NY/T 391—2021)[11], the contents of total nitrogen, available phosphorus and available potassium reach Grade Ⅰ soil fertility level. In terms of nutrients and beneficial elements, the average selenium content in the soil samples was 3.02 mg/kg, which is classified as green selenium-rich soil according to the Delimitation and identification of natural selenium-rich land (Trial) (DD 2019—10)[12] (Table 4). Regarding heavy metal pollution, the concentrations of Cd, Hg, As, Pd, Cr, Cu, Ni and Zn in the soil of the case area were all far below the risk screening values specified in the Soil environmental quality risk control standard for soil contamination of agricultural land (Trial) (GB 15618—2018)[13] (Table 5). For organic pollution, the total contents of benzene hexachloride (∑BHC), dichlorodiphenyltrichloroethane (∑DDT), and other indicators are also far below the control thresholds stipulated in the same national standard GB 15618—2018.

Table 2 Statistical testing results of major elements concentrations in rock samples Unit: g/100g

Test item	Si	Fe	Ca	Al	Mg	Na	Ti	K	P	Mn
R1-1	25.25	6.86	3.75	4.30	2.87	2.85	1.01	1.11	0.14	0.14
R2-1	23.39	8.90	5.39	4.17	2.77	2.24	1.40	0.62	0.20	0.21
R3-1	22.38	9.59	5.18	4.19	4.23	2.08	1.38	1.00	0.19	0.15
R4-1	26.25	5.79	5.02	3.98	3.24	1.76	0.55	1.52	0.13	0.12

Table 3 Statistical testing results of soil physical and chemical properties and nutrient content

Test item	pH	EC	CEC	TN	AN	AP	AK
Unit	–	μS/cm	cmol/kg	g/kg	mg/kg	mg/kg	mg/kg
S1-1	6.32	96.7	37.18	1.78	147.9	10.14	105.35
S1-2	5.03	101.8	37.59	1.10	180.4	22.00	112.46
S2-2	5.78	36.4	36.07	1.37	194.9	5.59	118.28
S2-3	5.59	76.6	52.87	3.83	389.7	10.13	165.26
S3-1	5.14	76.9	37.31	2.24	256.9	16.16	177.52
S3-2	5.26	58.6	36.07	2.00	280.0	18.18	153.71
S4-1	5.03	125.8	51.43	3.12	454.7	16.31	211.68
S4-2	5.02	102.1	39.57	1.50	281.5	20.54	172.01
NY/T 391—2021 limits[11]	/	/	/	Ⅰ (>1.0)	/	Ⅰ (>10)	Ⅰ (>100)

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

Table 4 Statistical testing results of soil nutrient and beneficial elements content in the case area

Test item	Se	Na	Mg	K	Ca	Fe	Mn
Unit	mg/kg	g/kg	g/kg	g/kg	g/kg	g/kg	g/kg
S1-1	3.21	12.94	7.40	17.60	4.36	26.52	0.381
S1-2	2.91	10.63	7.35	16.96	3.95	33.14	0.390
S2-2	2.62	13.45	11.04	16.89	4.59	35.13	0.449
S2-3	3.13	10.50	9.53	16.78	4.05	30.37	0.797
S3-1	3.29	10.46	6.67	15.13	3.26	25.51	0.300
S3-2	3.06	10.65	6.91	17.19	3.53	27.70	0.349
S4-1	3.27	8.46	7.54	14.51	5.60	39.70	0.626
S4-2	2.65	9.47	6.93	16.17	4.61	39.57	0.575

Table 5 Statistical testing results of soil heavy metal content in the case area Unit: mg/kg

Test item	Cd	Hg	As	Pb	Cr	Cu	Ni	Zn
S1-1	0.077	0.062	8.944	23.26	52.61	12.68	29.74	65.31
S1-2	0.038	0.071	10.268	13.38	86.56	10.52	37.39	45.20
S2-2	0.104	0.030	11.168	22.49	79.51	20.07	46.54	73.06
S2-3	0.178	0.073	10.575	18.60	79.30	14.19	36.07	80.37
S3-1	0.081	0.058	6.474	21.88	86.66	13.17	33.87	72.39
S3-2	0.082	0.096	8.575	21.09	83.70	13.97	37.60	75.69
S4-1	0.088	0.082	10.688	18.19	109.37	14.74	60.53	106.46
S4-2	0.085	0.093	9.193	16.91	75.79	19.54	63.20	76.47
GB 15618—2018 limits[13]	0.3	1.8	40	90	150	50	100	200

3.2.4 Water Conditions

Fusong County lies at the source of the Songhua and Yalu Rivers. The irrigation water for ginseng in the case area belongs to the Songhua River system. Donggang and Songjianghe Towns rely on the Toudao Songhua River and its tributary, the Songjiang River, whereas Quanyang Town depends on the Erdao Songhua River and its tributaries, the Lazi and Quanyang River. Irrigation water samples were collected from typical parks (Figure 6): well water in Songjianghe Town (WJ1-1), river water in Quanyang Town (WG3-1), well water (WJ2-1), and river water (WG2-1, WG4-1) in Donggang Town. All samples were tested at the Testing Center of the Northeast Institute of Geography and Agroecology, CAS. The results show that the irrigation water is high-quality low-salt soft water, rich in Ca, Mg, S, P and other macroelements (Table 6), which helps maintain soil cation balance and supports healthy ginseng growth.

Table 6 Statistical testing results of irrigation water conventional indicators in the case area

Test item	Unit	WG2-1	WG3-1	WG4-1	WJ1-1	WJ2-2
EC	us/cm	66.40	33.90	33.40	220.00	210.00
HCO_3^-	mg/L	18.69	14.28	16.10	125.13	121.50
TA	mg/L	15.33	11.71	13.20	102.65	99.67
Ca^{2+}	mg/L	7.96	2.92	2.93	31.09	31.12
SO_4^{2-}	mg/L	6.20	4.60	3.42	8.78	8.66
Na^+	mg/L	2.328	1.704	2.630	7.896	7.871
Mg^{2+}	mg/L	1.785	0.787	1.439	6.444	6.427
P	mg/L	0.02	0.01	0.03	0.02	0.01

The average pH was 6.92, within the suitable range of 5.5–8.5 specified in the Standard for irrigation water quality (GB 5084—2021)[14]. The mean values of suspended solids, five-day biochemical oxygen demand (BOD_5), chemical oxygen demand (CODcr), and anionic surfactants were 5.20 mg/L, 1.79 mg/L, 11.03 mg/L, and 0.030 mg/L, respectively, all at low levels. Chloride (8.95 mg/L), sulfide (0.006 mg/L), and total salt content (125.8 mg/L) met crop physiological requirements and are far below the standard limits, indicating no salinization risk (Table 7). Among the heavy metals and other indicators, hexavalent chromium was not detected. The total mercury (0.057 μg/L) and all other heavy metal indicators were well below standard limits. The total boron (0.134 mg/L) was suitable for crop growth, fluoride (0.616 mg/L) was at a safe low level, and cyanide showed no abnormality. All indicators met the irrigation requirements specified in the GB 5084—2021 (Table 7).

3.2.5 Vegetation Coverage

The case area is located in the hinterland of Changbai Mt. in Fusong County. It features a complete altitudinal vegetation zonation and mainly comprises two core communities: temperate deciduous broad-leaved forest and Korean pine cold-temperate mixed coniferous and broad-leaved forest. The dominant tree species in the deciduous broad-leaved forest are *Tilia amurensis*, *Fraxinus mandshurica*, and *Acer mono*; while the mixed forest is dominated by *Pinus koraiensis*, associated with *Picea jezoensis*, *Abies nephrolepis*, and *Betula costata*[15]. The NDVI was extracted and classified from 2024 Sentinel-2 images obtained from the Geospatial Data Cloud[2]. The average NDVI of the case area was 0.79 (Figure 7). The forest canopy density in the area is generally high. On the one hand, this creates a suitable microhabitat for ginseng, which prefers shade, moisture, and protection from direct sunlight[16]. On the other hand, the mixed litter from multiple tree species can

[2] Geospatial Data Cloud. https://www.gscloud.cn/search.

Table 7 Statistical testing results of limited items in irrigation water

Test item	Unit	WG2-1	WG3-1	WG4-1	WJ1-1	WJ2-2	GB 5084—2021 limits[14]
pH	–	6.4	6.34	6.43	7.71	7.72	5.5–8.5
SS	mg/L	8.00	7.00	3.00	4.00	4.00	100
BOD_5	mg/L	1.5	4.34	0.06	1.3	1.75	100
CODcr	mg/L	3.244	4.055	28.386	16.221	3.244	200
AS	mg/L	0.045	0.021	0.023	0.016	0.047	8
Cl^-	mg/L	7.1	5.68	5.964	10.65	15.336	350
S^{2-}	mg/L	0.009	0.007	0.011	0.003	0.002	1
TSC	mg/L	93	97	144	268	47	1,000
Pb	μg/L	2.46	3.30	3.05	3.24	2.75	200
Cd	μg/L	0.05	0.06	0.07	0.02	0.07	10
Cr^{6+}	mg/L	ND	ND	ND	ND	ND	0.1
Hg	μg/L	0.089	0.019	0.012	0.145	0.020	1
As	μg/L	1.685	2.851	2.723	2.214	2.780	100
Ni	μg/L	1.069	2.441	2.199	2.588	7.075	1,000
B	mg/L	0.104	0.123	0.167	0.113	0.164	1
Cu	μg/L	3.25	3.86	3.04	3.59	1.46	1,000
Zn	μg/L	37.25	15.83	15.82	59.60	39.77	2,000
Se	μg/L	0.05	0.04	0.09	0.06	0.04	20
F^-	mg/L	0.091	1.076	0.110	0.306	1.495	2
CN^-	μg/L	0.259	0.176	0.126	0.018	0.215	0.5

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

activate soil microorganisms, continuously releasing humic acids and mineral nutrients, thereby ensuring the nutrient cycling supply needed for ginseng root growth[17].

3.3 Land use

The author classified and counted land use in Fusong County using the China Land CoverDataset (CLCD)[18]. The proportions of cropland, forestland, grassland, water bodies, and construction land are 2.05%, 96.43%, 0.51%, 0.04%, and 0.97%, of the total area, respectively (Figure 8). The overall land use structure presents a pattern of "large forestland

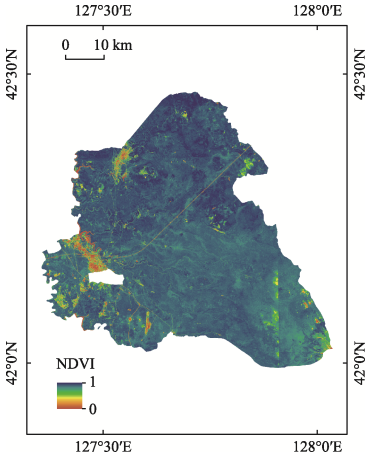

Figure 7 NDVI analysis map of the case area

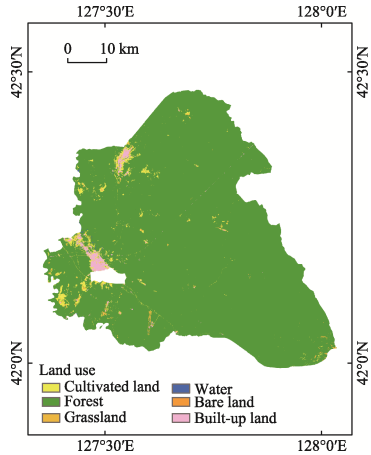

Figure 8 Land use map of the case area

patches interspersed with small scattered patches", highlighting a forest ecology-centered land use pattern with low human disturbance.

Fusong County has explored optimized land allocation models for ginseng cultivation. Combined with scattered logging and regeneration in forest areas, suitable sloped sites are selected for land preparation, shed covering, and cultivation. Broad-leaved tree species, such as Mongolian oak, are interplanted among ginseng beds[10], and forests are restored immediately after ginseng harvest. This approach makes full use of forest ecological conditions and effectively prevents soil erosion in the area. This study also lays a foundation for vegetation restoration and the sustainable use of ginseng gardens, actively promoting green ecological transformation.

3.4 Product Characteristics Data

Ginseng samples were randomly collected from representative plantations (Figure 6): 5-year ginseng from Songjianghe Town (Code G1-1), 6-year ginseng from Quanyang Town (Codes G3-1, G3-2), and 6-year ginseng from Donggang Town (Code G4-1). For the comparative analysis of ginseng products at different ages, additional samples were gathered: 4-year ginseng from Songjianghe Town (G5-1), 3-year ginseng from Donggang Town (G6-1), and 2-year ginseng from Songjianghe Town (G7-1). All samples were tested at the Sino-Vegetable and Animal Products Quality Supervision, Inspection, and Testing Center, Ministry of Agriculture and Rural Affairs, Jilin Agricultural University.

Ginseng products of different ages in Fusong County show excellent safety and quality levels. 6 organochlorine pesticide residues were detected in all samples, including HCH, DDT, quintozene, aldrin+dieldrin, and cyhalothrin. 6 organophosphorus pesticide residues, namely malathion, parathion, monocrotophos, dimethoate, methamidophos, and chlorpyrifos, were analyzed. 6 insecticide residues were detected: phorate, isofenphos-methyl, endosulfan, tetrachlorvinphos, methidathion, and acephate. 12 fungicide residues were tested: propiconazole, metalaxyl, cyprodinil, flusilazole, tebuconazole, difenoconazole, pyrimethanil, pyraclostrobin, fluazinam, kresoxim-methyl, propamocarb, and dimethomorph. The residues of 5 metals residues, including As, Pb, Cd, Cu, and Hg, were also measured. All residues were either not detected or were present at low levels. All results met the limit requirements specified in Geographical indication products—Jilin Changbaishan Ginseng (GB 19506—2009)[19].

In terms of medicinal ingredients, samples of different ages showed significant differences (Table 8). 6-year-old ginseng has the highest ginsenoside accumulation. Sample G4-1 from Donggang Town had a total ginsenoside content of 3.76%. Its Rb1 (0.80%) and Re+Rg1 (0.65%) contents were the highest. The 5-year-old sample G1-1 from Songjianghe Town had a total ginsenoside content of 2.89%. The total saponin content of 2–4-year-old samples ranged from 3.01% to 3.34%. All samples met the requirements for ginseng in GB 19506—2009 and the Pharmacopoeia of China (2020 Edition, Volume I)[20]. However, they are generally lower than those of 5–6-year-old samples. The saponin indices of all 5–6-year-old samples were significantly higher than the two standards. The Rb1 content was more than twice the standard value. This supports the traditional view that ginseng over 5-year-old has high medicinal value. Considering safety, active ingredients, and economic benefits, Fusong ginseng harvested at 6 years of age shows superior quality. However, all ginseng products have good medicinal value over 5 years. Mineral element analysis showed (Table 9) that Se was not detected. K, Mg, Ca, Fe, Zn and other essential elements were present at relatively high levels.

Table 8 Statistical testing results of ginseng physical and chemical index Unit: **%**

Test item	Rb1	Re+Rg1	TG	Rc	Rb2	Rf
G1-1	0.59	0.46	2.89	0.23	0.26	0.08
G3-1	0.66	0.50	3.55	0.27	0.36	0.08
G3-2	0.41	0.38	2.78	0.18	0.17	0.05
G4-1	0.80	0.65	3.76	0.31	0.39	0.10
G5-1	0.22	0.65	3.01	–	–	–
G6-1	0.27	0.77	3.34	–	–	–
G7-1	0.25	0.67	3.22	–	–	–
GB 19506—2009 limits[19]	≥0.20	≥0.30	≥2.50	/	/	/
Pharmacopoeia limits[20]	≥0.20	≥0.30	/	/	/	/
Judgment results	Qualified	Qualified	Qualified	/	/	/

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

Table 9 Statistical testing results of ginseng mineral elements Unit: mg/kg

Test item	K	Mg	Ca	Na	Fe	Zn	Se
G1-1	12,311.60	1,481.30	1,079.10	55.70	41.90	20.00	ND
G3-1	12,242.20	1,289.60	1,053.00	108.60	37.10	15.50	ND
G3-2	10,331.50	1,518.70	961.70	294.20	42.80	15.00	ND
G4-1	12,271.00	1,270.50	1,038.10	105.80	37.10	16.90	ND

Note: ND indicates not detected.

4 Socioeconomic Development and Industrial Management

4.1 Population, Economy and Ginseng Industry Development

In 2024, the registered population of Fusong County was 259,953, with an urbanization rate of 73.9% and a regional GDP of 14.477 billion CNY[21]. The permanent populations of Songjianghe Town was 56,046, Quanyang Town 21,637, and Donggang Town 1,688, totally 79,371. The three towns together accounted for 36.5% of the total population of the county.

As a core pillar industry of Fusong County, the ginseng industry has shown strong development. In terms of industrial scale, the reserved ginseng planting area in Fusong reached 720 ha in 2024, with an output value of 314 million CNY, accounting for 2.17% of the county's gross domestic product (GDP). There are more than 3,200 ginseng businesses, and the output value of the entire industrial chain reached 18.64 billion CNY. In variety breeding, Fusong has developed more than 20 high-quality new ginseng varieties, including Fuxing No.1 and Fuxing No.2, which feature high disease resistance and ginsenoside content. A ginseng germplasm resource nursery has been established, and eight high-quality varieties have been bred[22], supporting the upgrading of characteristic agriculture. In terms of product branding, Fusong successfully applied for the "Fusong Ginseng" geographical certification trademark in 2010 (Figure 9). On November 6, 2022, a new logo was approved by the China National Intellectual Property Administration. As the core production area for Changbai Mt. ginseng, it helped "Changbai Mt. Ginseng" enter the second batch of China-EU geographical indication protection list in July 2020. Fusong has become a representative core production area of national geographical indication protected products (Figure 10). As the largest core ginseng production area and distribution center in China, Fusong ginseng has established an important position in the industry with a stable supply

and standardized quality standards, becoming a key force driving industrial development.

Figure 9 Brand logo of Fusong ginseng

Figure 10 Geographical indication of Changbai Mt. ginseng

4.2 Cultivation Management

The ginseng studied in the case area was artificially cultivated garden ginseng. It is a perennial herb of the genus Panax in the family Araliaceae. Its growth cycle is 4 to 6 years, with distinct planting characteristics and strict management. Site selection requires a slope of less than 25° and good drainage. Dark brown or albic soil is suitable, avoiding previous rhizome crops. Land preparation should be completed in the year prior. Deep plowing is conducted to a depth of 30–40 cm, followed by disinfection and bed making. The bed height was 20–25 cm and the width was 100–120 cm. After the germination treatment, until the cracking rate exceeds 90%, seeds can be sown in autumn (after mid-October) or spring (late April to early May). Transplanting uses 2–3-year-old seedlings with oblique planting methods. The spacing was 10 cm×20 cm, with soil covering 5–8 cm. Field management is implemented carefully. Sheds were erected for shading with a light transmittance of 10%–20%. Organic fertilizers are applied, and the soil is loosened and weeded. Flower buds of 3–4-year-old ginseng plants are removed. Light and water are adjusted according to meteorological data, and pest and disease control are performed. Harvesting is conducted in September of the 4th to 6th year after planting. It also has obvious and distinguishable morphological characteristics. The main root was either fusiform or cylindrical. The plant height is 45–55 cm, with palmately compound leaves. The fibrous roots were dense and slender.

4.3 Fusong Ginseng Group Standards and Pesticide Control

Fusong County has focused on promoting group-standard development and pesticide control in the ginseng industry. Relying on the Ginseng Association, a series of group standards have been formulated covering seed germination, seedling breeding, variety breeding, land selection and preparation, sowing and transplanting, field management, harvesting, and processing. A closed-loop management mechanism for the group standards was established. An alliance of “group standards+enterprises+cooperatives+farmers” has been built, with a standardization coverage rate of 78%. Implementation has been strengthened through the dynamic revision of standards and cloud platform-based queries and training. A negative list of pesticides has also been issued. In accordance with relevant regulations, 46 high-residue pesticides including HCH, DDT, phorate, parathion and carbofuran, are banned. Twenty pesticides including methamidophos and omethoate, are restricted. Illegal use is strictly prohibited. Biological and physical control methods have been promoted. The safe interval period for pesticides was strictly implemented. No banned pesticides were detected in the tests. A win-win situation of clean production areas and ecological benefits was achieved.

4.4 Ecological Environment Traceability for Fusong Ginseng

The Jilin Shenwang Plant Protection Base of Fusong National Modern Agricultural Industrial Park is the only national-level regional Chinese herbal medicine seed breeding

base in the province. Relying on a seed resource bank, a ginseng traceability digital database covering the three northeastern provinces has been built. Together with the Changbai Mountain Ginseng Planting Alliance, a traceability management system was established. It has a comprehensive experimental demonstration base of nearly 200 ha, including a 30.06 ha green food certified base. Pesticide application records of all planting entities are integrated into the system, realizing the full traceability of ginseng from seeds to finished products. Meanwhile, a fully automatic GIES ground station was built at the Ginseng Industrial Park in Songjianghe Town, Fusong County. It can monitor real-time environmental data, such as temperature, humidity, wind speed, soil temperature and moisture. This supports precise traceability and park management (Figure 11).

Figure 11 GIES ground station in the case area (completed in 2025)

5 Fusong Ginseng Culture

Fusong County represents the cradle of mainstream ginseng culture in China and holds the distinguished designation of "Hometown of Chinese Ginseng Culture". The county boasts a cultivation heritage spanning over 400 years of artificial ginseng farming, grounded in profound cultural and industrial foundations. As early as the Han Dynasty, ginseng was regarded as an auspicious herb. Shennong Bencao Jing (Shennong's Classic of Materia Medica) listed it as a top-grade medicine, establishing its medicinal value as "mainly tonifying the five zang-organs"[23]. After the founding of China, the first state-owned ginseng farm was established locally. A complete system gradually took shape, covering improved variety breeding, standardized planting, and intensive processing. In 1985, Fusong was awarded the title of "Hometown of Chinese Ginseng". Currently, the ginseng planting area exceeds 6,666.67 ha, with an annual output of fresh ginseng reaching 10,000 tons, making it a benchmark in China's ginseng industry. Local legends such as the Ginseng Girl and Ginseng Doll[24] have been passed down and evolved into classic literary and artistic works, forming unique regional cultural symbols. Based on inheriting traditional ginseng cultivation techniques, Fusong integrates the experience of the older generation with scientific standards. It has transformed traditional cultivation proverbs into national standards, bred high-quality varieties, and formulated the technical code for Changbai Mt. ginseng cultivation, thereby establishing an industry benchmark. Since 1987, the China Fusong Changbai Mountain Ginseng Festival has been held for 39 sessions. Through cultural exhibitions, picking experiences, and 51 intangible cultural heritage items, it has continuously promoted ginseng culture at home and abroad, achieving an organic integration of traditional skill inheritance and modern cultural development[25].

6 Discussion and Conclusions

The ginseng industry in Fusong County has formed a collaborative development framework supported by natural ecology, driven by the social economy, and empowered by technology and culture. Through the precise utilization of natural endowments, standardized

construction of the industrial system, and in-depth exploration of cultural resources, the preliminary integration of ecological, economic, and social benefits has been achieved. This project successfully constructed a five-in-one collaborative innovation system of "government, industry, university, research, and application". An operational mechanism with the organic connection of "drive-support-implementation" has been formed. This system uses habitat landmarks and sustainable development as the innovation engine, driving the exploration of cutting-edge theories and breakthroughs in core technologies. Government agencies and scientific research institutions are the system hubs that provide policy guidance and resource support. Leading enterprises and industry associations are used as implementation terminals to promote technology transformation and market application, forming a complete closed loop from theory to practice. By connecting the innovation, industrial, and service chains, a sustainable development pattern with multi-party coordination and complementary advantages has been realized. Supported by this system, Fusong ginseng products not only have excellent quality but also highlight their regional characteristics. An industrial development framework based on natural ecology, driven by the social economy, and empowered by technology and culture has been established. This exploration not only provides a demonstration for regional characteristic industries to coordinate ecological protection and upgrading, but also contributes a Chinese solution of "ecology priority, brand leadership, and technology-driven quality improvement" to the global ginseng industry.

Author Contributions

Wang, J. G. was responsible for the overall research of this case study. Wang, D., Wang, G., Gao, J. T., Zhu, H. L., Li, H., Shi, L., Du, Y. C., Wang, X., Li, Z. Y., Jie, Z. Y., Yu, H. J., Yang, F., Yan, H. and Liu, W. Y. were responsible for project coordination and participated in the project design and research & development. Hou, Y. B. and Guo, X. J. provided constructive suggestions for project design and dataset collection. Xu, H. Y. and Ma, Y. D. provided technical support in enterprise management data and sample collection for the case study, and put forward comments on the revision of the paper. Cheng, X. L. and Zhang, W. X. were responsible for the collection of soil, rock, ginseng and water samples, and completed data processing and part of the paper writing. Xu, X. W. participated in the detection and analysis of ginseng samples. Wang, L. was responsible for the construction of the ecological environment monitoring station and technical support for dynamic data.

Conflicts of Interest

The authors declare no conflicts of interest.

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