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GIES Case Study on Ji'an Forest-Grown *Panax Ginseng* Temperate Conifer-Broadleaf Mixed Forest in Huadian Town

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Abstract: Forest-grown *Panax ginseng* refers to ginseng produced by manual sowing in forest environments that simulate wild habitats, followed by natural growth without human intervention. Ji'an City, situated at the southern foothills of the Laoling Mt. within the Changbai Mt. range. Huadian Town, under its jurisdiction, is one of the core production areas of forest-cultivated ginseng in Jilin Province. It covers a total area of 155.49 km^2, with a registered population of 9,414 and a permanent resident population of 6,174 as of 2024, and administers 1 community and 8 administrative villages. As a key township for ginseng distribution in Ji'an, Huadian Town offers favorable soil, hydrological and forest conditions. Ginseng cultivated in this environment fully exhibits the "Five forms and six bodies" morphological characteristics required under the national standard Identification and grade quality standards of wild ginseng (GB/T 18765—2015). Furthermore, its chemical composition—specifically total saponins, ginsenoside Rb_1, and ginsenosides $Re+Rg_1$—consistently exceeds the threshold values specified in the same standard. By 2024, the cultivation area of forest-grown *Panax ginseng* in Ji'an reached 9,733.33 ha, with the total output value of the ginseng industry chain reaching 16 billion CNY, making it the largest trading and distribution center for wild ginseng in China. This dataset compiles and analyzes habitat data from the temperate coniferous-broadleaf mixed forest case area in Huadian Town, Ji'an, resulting in the GIES case dataset on Ji'an forest-grown Panax ginseng temperate conifer-broadleaf mixed forest in Huadian Town. The case dataset includes: (1) case area boundary; (2) physical geography data; (3) product characteristic data of Ji'an forest-grown *Panax ginseng*; (4) socioeconomic data, etc. The dataset

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is archived in .xlsx, .shp, .tif, .jpg, .pdf and .docx formats, comprising 85 files with a total size of 36.5 MB (18.2 MB compressed).

Keywords: Changbai Mountain; Ji'an; forest-grown *Panax ginseng*; GIES; Case 31

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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.2026.02.06.V1.

1 Introduction

As one of the most valued herbs in Traditional Chinese Medicine (TCM), ginseng (*Panax ginseng* C. A. Meyer) has been utilized for thousands of years due to its diverse pharmacological effects, including promoting blood cell regeneration and regulating endocrine, metabolic, and the central nervous system functions[1,2]. Wild ginseng resources are now nearly depleted and have been designated as a Class I nationally protected species in China. As a result, current production mainly relies on field cultivation and forest-based conservation, producing "garden ginseng" and "forest-grown *Panax ginseng*", respectively. Forest-grown *Panax ginseng* (also known as "under-forest seeds" or "wild-simulated ginseng") is cultivated by sowing seeds in forest environments that mimic natural habitats, where the plants grow without further human intervention for at least 15 years[3,4]. Compared with garden ginseng, this cultivation method enables forest-grown *Panax ginseng* to develop morphological features—traditionally described as the "Five forms and six bodies"—and quality characteristics similar to those of wild ginseng[5,6]. Ji'an serves as the core production area for Changbai Mt. ginseng and has maintained a long-standing traditional of mountain harvesting since the Qing Dynasty[7]. Its superior product quality is attributed to several key environmental factors: the unique coniferous-broadleaf mixed forest ecosystem of the Laoling Mt. on the southern slopes of the Changbai Mt. range, a temperate continental monsoon climate with favorable hydrothermal conditions, and nutrient-rich volcanic soils (Figure 1).

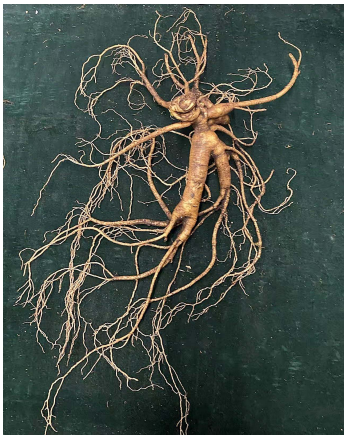

Figure 1 Forest-grown *Panax ginseng* of Huadian Town, Ji'an City

Based on the technical specifications of the Global Change Research Data Publishing & Repository (GCdataPR) World Data Center and the Geographical Indications Environment & Sustainability (GIES) Initiative, this study develops a comprehensive GIES dataset for the forest-grown *Panax ginseng* in the temperate coniferous-broadleaf mixed forest of Huadian Town, Ji'an, aiming to provide a scientific basis for ecological conservation and the sustainable development of forest-grown ginseng resources in Ji'an City[8–10].

2 Metadata of the Dataset

The metadata information of the GIES case dataset on Ji'an forest-grown *Panax ginseng* temperate conifer-broadleaf mixed forest in Huadian Town[11] including the title, author, geographical region, data size, data file, etc., is summarized in Table 1.

3 Case Dataset Development

3.1 Case Area

Ji'an is a county-level city of Tonghua City, Jilin Province, located in the southeastern part

Table 1 Metadata summary of GIES case dataset on Ji'an forest-grown *Panax ginseng* temperate conifer-broadleaf mixed forest in Huadian Town

Items	Description
Dataset full name	GIES case dataset on Ji'an forest-grown *Panax ginseng* temperate conifer-broadleaf mixed forest in Huadian Town
Dataset short name	Ji'anGinsengCase31
Authors	Zhu, W. B., Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, zhuwb@igsnrr.ac.cn Wang, F., Ji'an Municipal Administration for Market Regulation, 78530413@qq.com Zhao, Z. C., Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, University of Chinese Academy of Sciences, 2558253110@qq.com Cui, X. Y., People's Government of Huadian Town, Ji'an City, Jilin Province Xiang, L. F., Ji'an Municipal Administration for Market Regulation, 576325664@qq.com Wei, G. Y., People's Government of Ji'an City, Jilin Province Wang, M., Ji'an Ginseng Association, Jilin Province Hou, J., Ji'an Tianli Ecological Agriculture Co.，Ltd., Jilin Province, 15180396378@qq.com Li, Q., Ji'an Shenquantang Ginseng Planting Professional Cooperative, 18827935273@qq.com Liu, J. X., China University of Geosciences, Beijing, jinxiuliu@cugb.edu.cn Yao, Y., China University of Geosciences, Beijing, yaoying20010820@163.com Liu, H. B., China University of Geosciences, Beijing, 1937849173@qq.com Sun, J. C., Jilin Binde Participation Co., Ltd., lnsxbm@163.com Bai, H. G., Jilin Hongwuwei Biological Technology Co., Ltd., 1018030202@qq.com Hong, X., Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences Yang, X. Y., Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences
Geographic region	Huadian Town, Ji'an City
Year	2025
Data format	.xlsx, .shp, .tif, .jpg, .pdf, .docx
Data size	36.5 MB (18.2 MB compressed)
Dataset files	Case area boundary, physical geography data, product characteristic data, socioeconomic data, etc.
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[12]
Communication and searchable system	DOI, CSTR, Crossref, DCI, CSCD, CNKI, SciEngine, WDS, GEOSS, PubScholar, CKRSC

of the province. The city extends from 125°34′33″E to 126°32′48″E and 40°52′7″N to 41°35′18″N, encompassing a total administrative area of approximately 3,348.54 km^2. It comprises 11 towns and 4 subdistricts. Geologically, Ji'an lies on the southwestern foothills of the Changbai Mt., with the Laoling Mt. range traversing the territory from northeast to southwest. The case area, Huadian Town, is located on the western slopes of theLaoling Mt. in northwestern Ji'an (Figure 2). Huadian Town covers an area of 155.49 km^2 and, as of 2024, has a registered population of 9,414 and a permanent resident population of 6,174, distributed across 1 community and 8 administrative villages.

3.2 Ecological and Environmental Data

3.2.1 Topography

The optimal growth of forest-grown *Panax ginseng* requires well-drained soils and specific slope conditions, generally favoring gradients between 15° to 25°[13]. Situated at the southern foothills of the Changbai Mt., Ji'an is characterized by a mountainous landscape dominated by the Laoling Mt. range, with an overall topographical gradient descending from

northeast to southwest. Based on SRTM 30-m DEM data[1], slope reclassification and raster-based statistical analysis reveal that approximately 42.24% of the land area in Ji'an falls within the 15°–25° slope range. Huadian Town, a key cultivation area for forest-grown *Panax ginseng* located in northwestern Ji'an, features elevations ranging from 325 m to 944 m (Figure 2). The town is primarily composed of low mountains and gently undulating hills, with 47.61% of the area—nearly half—with the optimal slope range of 15°–25° (Figure 3). The hypsography is characterized by higher elevations in the north and south and lower elevations in the central region. The widespread distribution of suitable slopes provides natural drainage and geomorphological protection, creating favorable conditions for the cultivation of forest-grown *Panax ginseng*.

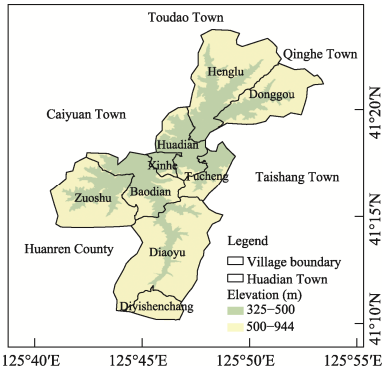

Figure 2 Geo-location and elevation classification map of Huadian Town

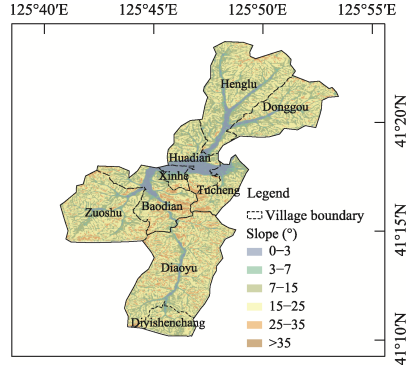

Figure 3 Slope classification map of Huadian Town

3.2.2 Vegetation Coverage and Land Use

Using Sentinel-2 satellite imagery with a spatial resolution of 10 m[2], the authors calculated the Normalized Difference Vegetation Index (NDVI) (Figure 4) and generated land-use/land-cover (LULC) map (Figure 5) for Ji'an City and Huadian Town. The NDVI results indicate dense vegetation cover across the region, reflecting a superior ecological baseline. Land-use types in the case area include forest, cropland, grassland, water bodies, and built-up land. Forestland is the dominant land-use type in both Ji'an and Huadian Town, accounting for approximately 81.46% and 83.17% of their total areas, respectively. These extensive forest resources provide primary ecological niches and physical environments for wild-simulated cultivation of forest-grown *Panax ginseng*, serving as the fundamental resource endowment for the development of the regional ginseng industry.

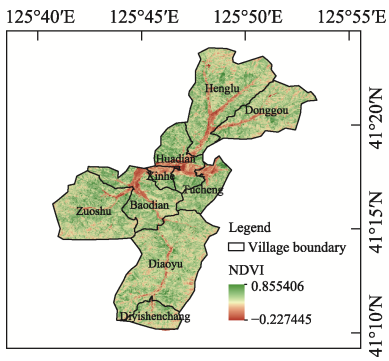

Figure 4 NDVI distribution map of Huadian Town

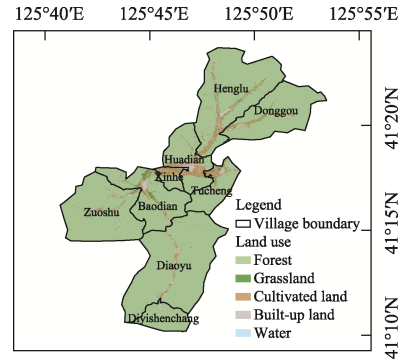

Figure 5 Land use map of Huadian Town

[1] NASA, NIMA. https://earthexplorer.usgs.gov/.

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

3.2.3 Vegetation Conditions

Forest-grown *Panax ginseng* is a semi-shade-tolerant species that requires natural shading throughout its growth cycle. It is sensitive to direct sunlight and prefers diffuse light, making it well suited to broadleaf and coniferous-broadleaf mixed forests with good canopy cover[14]. In Ji'an, forest composition is dominated by Mongolian oak (*Quercus mongolica*), linden (*Tilia* spp.), and Korean pine (*Pinus koraiensis*)[15].

The forest exhibits a distinct vertical stratification. The canopy layer, dominated by oak and linden, has a crown closure ranging from 0.6 to 0.8 and provides primary shading. The shrub layer, mainly composed of hazel (*Corylus* spp.) and bush clover (*Lespedeza* spp.), forms a secondary shading layer. The herbaceous layer, consisting of ferns and mountain mugwort (*Artemisia* spp.), constitutes a tertiary protective layer[16].

This well-developed vertical structure not only provides natural shading but also contributes large amount of plant litter each year. The decomposition of this litter continuously enriches soil organic matter, creating an ideal habitat for ginseng growth.

3.2.4 Climatic Conditions

Ji'an has a temperate continental climate characterized by synchronized heat and precipitation and four distinct seasons. The Laoling Mt. range traverses the region, forming a natural barrier that moderates the climate on its southern slopes. This results in semi-maritime characteristics, including high humidity, abundant rainfall, and relatively low wind speeds, earning the region the nickname "Little Jiangnan of Jilin".

Consequently, Ji'an exhibits 4 climatic extremes within the province: the highest annual average precipitation (800–1,000 mm), the highest annual accumulated temperature (3,650 ℃), the longest frost-free period (approximately 150 d), and the lowest annual average wind speed (1.6 m/s). In Huadian Town, the mean annual temperature is 6.2 ℃ and the average annual precipitation is approximately 880 mm (Figure 6). This mild and humid environment, characterized by synchronized water and heat conditions and low climatic stress, provides an optimal foundation for the high-quality growth of forest-grown *Panax ginseng*.

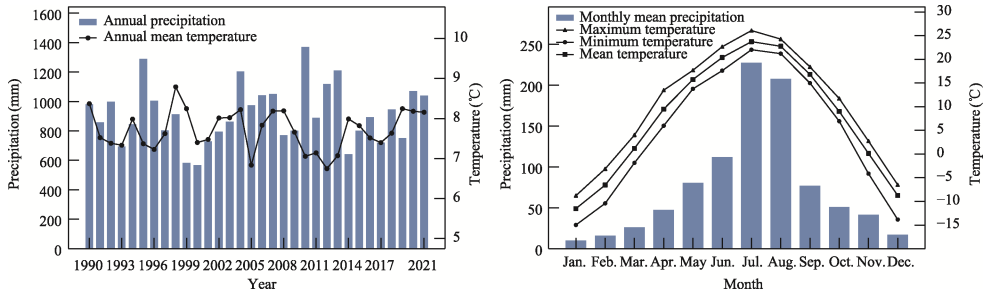

Figure 6 Statistical analysis of climatic characteristics in Ji'an City

3.2.5 Soil Conditions

The soil types in Ji'an transition from Phaeozems (black soil) to Luvisols (dark brown forest soil) along an altitudinal gradient ranging from 325 m to 944 m. These soils are typically weakly acidic and are rich in organic matter and available nutrients.

For this study, soil sampling and analysis were conducted within the Huadian Town case area. 3 topsoil sampling points were established at a depth of 0–20 cm. Additionally, a 1-m deep soil profile was excavated, and stratified samples were collected at 20 cm intervals (Figure 7a). During sampling, the profile surfaces were meticulously leveled, cleared of superficial impurities, and documented photographically.

The soil samples were analyzed for fertility and environmental quality at the Physical and Chemical Analysis Center of the Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences (IGSNRR, CAS). The assessment metrics included soil fertility indicators: total nitrogen (TN), total phosphorus (TP), total potassium (TK), organic carbon (TOC), and the carbon-to-nitrogen ratio (C/N), as well as environmental

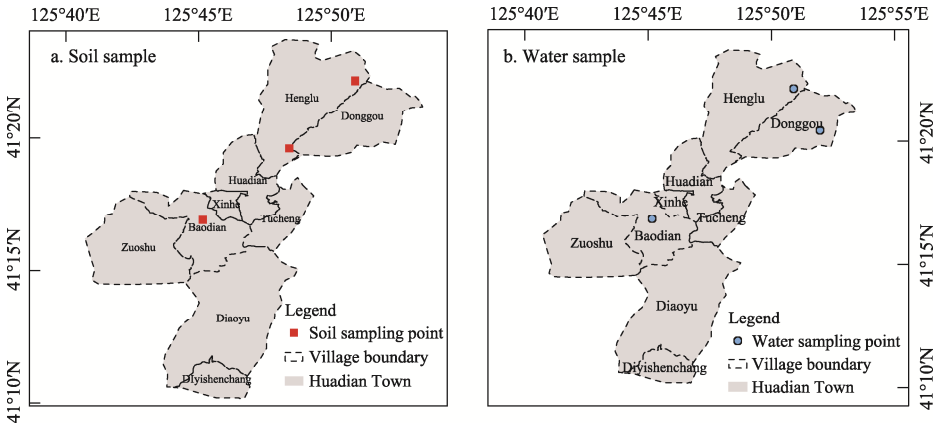

Figure 7 Distribution maps of soil and water sampling sites in Huadian Town

safety indicators, including pH and concentrations of cadmium (Cd), chromium (Cr), lead (Pb), copper (Cu), nickel (Ni), zinc (Zn), mercury (Hg), and arsenic (As).

The analytical results for nutrient indicators in surface soil samples are summarized in Table 2. Soil pH ranged from 5.33 to 5.38 (mean: 5.36), indicating weakly acidity consistent with the growth requirements of *Panax ginseng*. TN content ranged from 1.39 to 3.11 g/kg (mean: 2.64 g/kg). TOC concentrations were measured between 16.79 and 42.32 g/kg (mean: 32.78 g/kg); utilizing the standard conversion factor for organic carbon to organic matter, the resulting organic matter content ranged from 28.96 to 72.93 g/kg.

The C/N ratio fluctuated between 12.1 and 12.8 (mean: 12.4). Regarding macro-nutrients, TK concentrations ranged from 21.92 to 24.68 g/kg (mean: 23.40 g/kg), while TP ranged from 382 to 521 mg/kg (mean: 467 mg/kg). Both soil pH and organic matter content meet the requirements specified in the national standard for forest-grown *Panax ginseng*: Product of geographical indication—Jilin Changbai Mountain ginseng (GB/T 19506—2009)[17].

Table 2 Statistical testing results of surface soil fertility indicators in Huadian Town

Sample site	Elevation (m)	pH	Total nitrogen (g/kg)	Organic carbon (g/kg)	Carbon-to-nitrogen ratio	Total potassium (g/kg)	Total phosphorus (mg/kg)
Henglu	593.27	5.33	3.31	42.32	12.8	24.68	499
Donggou	398.10	5.38	3.21	39.22	12.2	23.60	521
Baodian	409.20	5.38	1.39	16.79	12.1	21.92	382
Maximum	593.27	5.38	3.31	42.32	12.8	24.68	521
Minimum	398.10	5.33	1.39	16.79	12.1	21.92	382
Mean	466.86	5.36	2.64	32.78	12.4	23.40	467
Limits[17]	/	5.5–6.5	/	1.74	/	/	/

Note: / indicates no corresponding standard limit.

The analytical results for heavy metal concentrations in surface soil samples are detailed in Table 3. Concentration ranges for Cd, Cr, Pb, Cu, Ni, and Zn were 0.09–0.18 mg/kg, 88.24–94.24 mg/kg, 16.37–23.23 mg/kg, 13.90–19.53 mg/kg, 26.01–33.48 mg/kg, and 74.90–77.20 mg/kg, respectively. Corresponding mean values were 0.14 mg/kg, 91.25 mg/kg, 19.88 mg/kg, 16.93 mg/kg, 28.96 mg/kg, and 76.20 mg/kg. Trace elements Hg and As were detected in ranges of 0.04 to 0.06 μg/kg (mean: 0.05 μg/kg) and 6.14 to 9.15 μg/kg (mean: 7.29 μg/kg). According to the Soil environmental quality risk control standard for soil contamination of agricultural land (Trial) (GB 15618—2018)[18], all measured values are well below the specified risk screening thresholds. These results indicate that no soil contamination risk in the study area.

Table 3 Statistical testing results of heavy metal content in the surface soil samples of Huadian Town

Sample site	Elevation (m)	Cd	Cr	Pb	Cu	Ni	Zn	Hg	As
		(mg/kg)						(μg/kg)	
Henglu	593.27	0.16	88.24	23.23	19.53	26.01	77.20	0.06	9.51
Donggou	398.10	0.18	91.28	20.03	13.90	27.38	74.90	0.05	6.21
Baodian	409.20	0.09	94.24	16.37	17.36	33.48	76.50	0.04	6.14
Maximum	593.27	0.18	94.24	23.23	19.53	33.48	77.20	0.06	9.51
Minimum	398.10	0.09	88.24	16.37	13.90	26.01	74.90	0.04	6.14
Mean	466.86	0.14	91.25	19.88	16.93	28.96	76.20	0.05	7.29
Limits[18]	/	≤0.3	≤150	≤90	≤50	≤70	≤200	≤1,800	≤40,000

Note: / indicates no corresponding standard limit.

The analytical results for deeper soil layers are presented in Table 4. Soil pH exhibited minor fluctuations with depth, maintaining a stable weakly acidic profile and demonstrating high vertical stability in soil acidity. Both TN and TOC concentrations peaked in the surface layer (0–20 cm), decreased significantly at 40 cm, and remained relatively stable in deeper layers. Notably, a slight increase in TOC was observed at 80–100 cm depth. TK content increased progressively with depth, while TP was highest in the surface layer and decreased markedly below it before stabilizing.

Overall, soil nutrients in the case area exhibit a pattern of surface accumulation and low vertical heterogeneity, indicating relatively uniform distribution throughout the profile. This vertical consistency facilitates downward root extension and supports sustained nutrient uptake by ginseng.

Table 4 Statistics testing results of nutrient content in soil profile of Huadian Town

Depth (cm)	pH	N (g/kg)	C (g/kg)	C/N ratio	K (g/kg)	P (mg/kg)
20	5.46	1.10	8.40	7.49	24.28	377
40	5.35	0.50	3.20	6.02	31.05	257
60	5.38	0.50	3.20	6.24	32.38	280
80	5.41	0.60	3.90	6.58	32.46	278
100	5.45	0.60	7.20	11.2	33.09	285

The concentrations of heavy metals—Hg, As, Cd, Pb, Cr, Cu, Ni, and Zn—across various soil depths remained well below national safety limits, indicating minimal environmental risk (Table 5). The concentrations of Hg, As, and Cd exhibited negligible fluctuations across the soil profile, demonstrating a highly uniform distribution. In contrast, the concentrations of Ni, Zn, Cr, Pb, and Cu showed a gradual increase with depth. Despite these variations, the absolute values of all heavy metal concentrations remained at low levels, consistently falling significantly below the risk screening thresholds defined in the Soil environmental quality risk control standard for soil contamination of agricultural land (Trial) (GB 15618— 2018)[18].

Table 5 Statistical testing results of heavy metal content in soil profile in Huadian Town

Testing item	Limits[18]	20 cm	40 cm	60 cm	80 cm	100 cm
Hg (μg/kg)	≤1,800	0.04	0.03	0.03	0.03	0.03
As (μg/kg)	≤40,000	5.27	4.18	4.53	4.39	3.89
Cd (mg/kg)	≤0.3	0.07	0.06	0.06	0.06	0.07
Pb (mg/kg)	≤90	20.95	21.65	25.13	27.69	24.99
Cr (mg/kg)	≤150	91.05	87.86	83.54	101.24	101.66
Cu (mg/kg)	≤50	19.70	23.23	21.81	24.46	24.63
Ni (mg/kg)	≤70	32.23	39.79	42.78	47.18	46.21
Zn (mg/kg)	≤250	74.91	81.51	90.70	93.18	93.44

3.2.6 Water Conditions

Ji'an is rich in water resources, with a total volume of 1.765 billion m^3, including 870 million m^3 of surface water resources. The river system in Huadian Town belongs to the Hunjiang River Basin, with a catchment area of 156.4 km^2. To correspond with the spatial distribution of the soil sampling points, 3 surface water sampling sites were established in the case area (Figure 7b). Samples were analyzed by the Physical and Chemical Analysis Center of the IGSNRR, CAS and Centre Testing International (Henan) Co., Ltd.

The analytical parameters included 8 environmental indicators: pH, suspended solids, biochemical oxygen demand (BOD), chemical oxygen demand (COD), anionic surfactants, chloride, sulfide, and total salt. Additionally, 8 heavy metal indicators were assessed: Cd, Cr, Zn, Pb, Cu, Ni, As, and Hg.

The analytical results for surface water samples are summarized in Table 6. The pH fluctuated within an extremely narrow range of 7.53 to 7.56, indicating high stability in alkalinity. Suspended solids ranged from 1 to 2 mg/L (mean: 1.67 mg/L), while BOD ranged from 2.4 to 2.6 mg/L (mean: 2.47 mg/L). COD was recorded at a constant 6 mg/L. Notably, anionic surfactants and sulfides were not detected (below the analytical method's detection limits). Chloride concentrations ranged from 2.20 to 2.91 mg/L (mean: 2.63 mg/L), and the total salt ranged from 60 to 63 mg/L (mean: 61.33 mg/L), both significantly below standard thresholds. Overall, all tested indicators were found to be well below the limits established in the Standard for irrigation water quality (GB 5084—2021)[19].

The detection results of heavy metal indicators in water samples from the case area are shown in Table 7. Hexavalent chromium, arsenic, and mercury were all below the detection limit in all samples. The concentrations of nickel, copper, zinc, cadmium, and lead ranged from 0.02–0.04 μg/L, 0.20–0.36 μg/L, 0.26–28.20 μg/L, below detection limit to 0.002 μg/L,

Table 6 Statistical testing results of water environmental indicators in Huadian Town

Sample site	Elevation (m)	pH	Suspended solids (mg/L)	BOD (mg/L)	COD (mg/L)	Anionic synthetic (mg/L)	Chloride (mg/L)	Sulfide (mg/L)	Total salt (mg/L)
Henglu	571.8	7.53	2	2.4	6	ND	2.77	ND	61
Donggou	389.4	7.56	1	2.4	6	ND	2.20	ND	60
Baodian	360.2	7.53	2	2.6	6	ND	2.91	ND	63
Maximum	571.8	7.56	2	2.6	6	ND	2.91	ND	63
Minimum	360.2	7.53	1	2.4	6	ND	2.20	ND	60
Mean	440.47	7.54	1.67	2.47	6	ND	2.63	ND	61.33
Limits[19]	/	5.5–8.5	100	100	200	8	350	1	1,000

Note: / indicates that no limit is specified in the standard; ND indicates not detected.

Table 7 Statistical results of water heavy metal indicators in Huadian Town

Sample site	Elevation (m)	Cr (μg/L)	Ni (μg/L)	Cu (μg/L)	Zn (μg /L)	Cd (μg/L)	Pb (μg/L)	As (μg/L)	Hg (μg/L)
Henglu	571.8	ND	0.03	0.20	0.26	ND	0.004	ND	ND
Donggou	389.4	ND	0.04	0.21	28.20	0.002	0.007	ND	ND
Baodian	360.2	ND	0.02	0.36	6.46	0.001	0.006	ND	ND
Maximum	571.8	ND	0.04	0.36	28.20	0.002	0.007	ND	ND
Minimum	360.2	ND	0.02	0.20	0.26	ND	0.004	ND	ND
Mean	440.47	ND	0.03	0.26	11.62	0.0015	0.0057	ND	ND
Limits[19]	/	≤100	≤200	≤1,000	≤2,000	≤10	≤100	≤100	≤1,000
Limits[20]	/	≤10	/	≤10	≤50	≤1	≤10	≤50	≤0.05

Note: / indicates that no limit is specified in the standard; ND indicates not detected.

and 0.004–0.007 μg/L, respectively; with mean values of 0.03 μg/L, 0.26 μg/L, 11.62 μg/L, 0.0015 μg/L, and 0.0057 μg/L, respectively. The heavy metal concentrations in the water samples were all far below the risk screening values of the standard GB 5084—2021[19], and the results also met the Class I water criteria of the Environmental quality standards for surface water (GB 3838—2002)[20], indicating that there is no risk of agricultural water pollution in the case area and the water quality is excellent.

3.3 Product Quality Data

The primary cultivars of forest-grown *Panax ginseng* in Ji'an are "Changbo" and "Ermaya", which are characterized by vigorous growth and robust main roots, effectively balancing biomass yield with morphological aesthetics. Mature specimens exhibit a slender, curved rhizome (*lu-tou*), commonly known as the "swan-neck rhizome" (*yan-bo-lu*), with sparse stem scars (*lu-wan*). The main root is typically spindle-shaped, featuring mature epidermal texture with deep and continuous "iron-line" transverse rings. Fibrous roots are elongated and resilient, marked by prominent "pearl spots" (nodules) and occasional scars (Figure 8). These morphological characteristics meet the "Five forms and six bodies" criteria specified in the national standard Identification and grade quality standards of wild ginseng (GB/T 18765—2015)[3].

In this study, the chemical composition and heavy metal concentrations of forest-grown *Panax ginseng* from Ji'an were evaluated. Samples were analyzed by Ji'an Traceability Inspection, Testing, and Certification Co., Ltd. Measured parameters included moisture, total ash, acid-insoluble ash, total ginsenosides, ginsenoside Rb_1, and ginsenosides $Re+Rg_1$. Heavy metals analyzed included As, Pb, Cu, Cd, and Hg. The analytical results are summarized in Tables 8 and 9.

Figure 8 Growth habitat and growth process of forest-grown ginseng

Moisture content ranged from 6.67% to 11.70% (mean: 9.19%), total ash from 3.90% to 4.26% (mean: 4.08%), acid-insoluble ash at 0.63%, total ginsenosides from 6.11% to 6.33% (mean: 6.22%), ginsenoside Rb_1 from 0.68% to 2.90% (mean: 1.79%), and ginsenosides $Re+Rg_1$ from 0.93% to 3.10% (mean: 2.05%). All chemical constituents met the requirements stipulated in the national standard Identification and grade quality standards of wild ginseng[3]. Heavy metals As and Hg were not detected. Pb, Cu, and Cd concentrations were 0.37 mg/kg, 3.30 mg/kg, and 0.07 mg/kg, respectively, all well below the limits defined in the Pharmacopoeia of China[1].

Table 8 Statistical testing results of forest-grown *Panax ginseng* components in Huadian Town

Sample No.	Moisture (%)	Total ash (%)	Acid insoluble ash (%)	Total ginseng saponins (%)	Rb_1 (%)	$Re+Rg_1$ (%)
1	11.7	3.90	0.63	6.33	0.68	0.93
2	6.67	4.26	0.63	6.11	2.90	3.10
mean	9.19	4.08	0.63	6.22	1.79	2.05
Limits[3]	8.00	5.00	1.00	4.40	0.40	0.60

Table 9 Statistical testing results of heavy metal content of forest-grown *Panax ginseng* in Huadian Town

Sample No.	As (mg/kg)	Pb (mg/kg)	Cu (mg/kg)	Cd (mg/kg)	Hg (mg/kg)
1	ND	0.37	3.30	0.07	ND
Limits[1]	≤2.00	≤0.50	≤20.00	≤0.50	≤0.10

Note: ND indicates not detected.

4 Forest-Grown *Panax Ginseng* Industry Management

4.1 Socioeconomic Development

According to the Jilin Statistical Yearbook[21], Ji'an had a total population of 205,300 in 2022, including 119,900 rural residents. From 2019 to 2023, its Gross Domestic Product (GDP) increased from 5.5 billion CNY to 7.93 billion CNY, representing an average annual growth rate of 8.7% and reflecting a fluctuating yet upward trajectory. The primary industry accounted for approximately 12% of GDP (Figure 9).

The ginseng industry serves as a traditional competitive advantage and a pillar industry for Ji'an. In 2022, forest-grown *Panax ginseng* contributed 62.5% of the added value of the primary industry, with approximately 60% of farmers' income linked to ginseng production[22]. Leveraging its geographical advantage as a core production area of Changbai Mt. ginseng, Ji'an has developed an integrated model combing ginseng production, tourism and ecological conservation. The city has been designated as the "Hometown of Chinese Ginseng" and a "National Non-timber Forest Economy Demonstration Base", effectively stimulating industrial and agricultural production while significantly boosting rural incomes and providing vital support for local economic growth.

In Huadian Town, the registered population in 2024 was 9,414, with 6,174 permanent residents; In 2021, total ginseng cultivation area reached 318 ha, yielding an output value of 28.78 million CNY. By 2024, the cultivation area specifically dedicated to forest-grown *Panax ginseng* reached 169.13 ha, reflecting a substantial industrial scale.

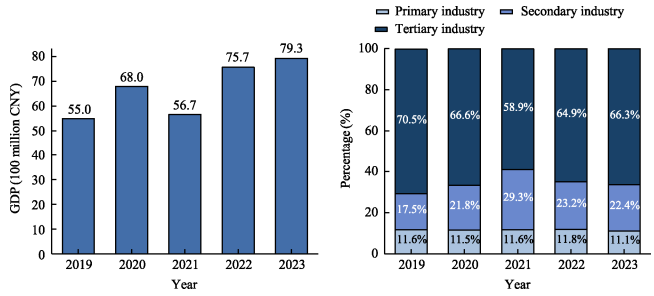

Figure 9 Statistical chart of economic development of Ji'an City

4.2 Cultivation History of Forest-Grown *Panax Ginseng*

Ginseng serves as the core industrial identity of Ji'an. Ji'an has a history of nearly 400 years of ginseng cultivation and is widely known as the "Hometown of Chinese Ginseng". In the 1990s, to address ecological damage caused by traditional deforestation-based cultivation, Ji'an pioneered under-forest seed sowing techniques that simulate natural growth conditions of wild ginseng. Following the nationwide ban on deforestation for ginseng cultivation in 2013, Ji'an actively responded by fully promoting under-forest sowing techniques. During this transition, Huadian Town emerged as a key pilot area due to its favorable forest conditions.

Building upon these achievements in ecological transformation, the Ji'an Modern Agricultural Industrial Park was recognized in 2017 as one of China's first national-level modern agricultural industrial parks and remains the only one dedicated specifically to ginseng, thereby laying a solid foundation for industrial intensification. In 2018, Ji'an developed a high-standard development plan for the ginseng industrial park, establishing an industrial layout characterized by "one core, one center, and seven bases"[22]. By 2022, 5 major technological production demonstration bases had been completed. This was followed by the launch of operations at the National Inspection and Testing Center for Ginseng and Local Chinese Medicinal Materials in 2023, and the establishment in 2024 of the inaugural Ginseng Market Legal Service Center, aimed at combating counterfeit products and

standardizing trade practices.

Currently, Huadian Town has completed a fundamental transformation in its ginseng cultivation model, shifting from traditional forest-land utilization to wild-simulated under-forest systems, and from extensive to standardized management. Building on these advancements, the locality has prioritized the development of a comprehensive industrial chain and successfully explored an innovative "Ecology+" development model. This approach has paved a sustainable pathway for green development characterized by overall improvements in quality, efficiency, and industrial structure.

4.3 Cultivation Management of Forest-Grown *Panax Ginseng*

4.3.1 Site Selection and Preparation

Forest-grown *Panax ginseng* has highly specific environmental requirements for optimal growth. Cultivation sites should be located within broadleaf mixed forests with a canopy closure of 0.6 to 0.8, ensuring protection from direct solar radiation. Topographically, the slope gradient of 10°–25° are preferred to facilitate natural drainage and prevent waterlogging[23]. The forest soil should be loose in texture, rich in humus, and possess good water retention and aeration capacity. Suitable soil types include black sandy humus soil, sandy loam, and standard loam[13].

To ensure seedling survival, appropriate site preparation and clearing are required prior to planting. This involves selectively thinning overly dense trees, removing weeds, and underbrush below 1 m in height, and clearing excessive forest litter. However, where the litter layer is thin, it should be retained as a natural mulch to decompose and supply nutrients for ginseng growth[24].

4.3.2 Seed Preparation and Field Management

Panax ginseng seeds encompass several cultivated varieties, notably *Ermaya*, *Changbo*, and *Yuanbang Yuanlu*, each with distinct morphological and biochemical characteristics. Among these, the *Ermaya* cultivar is highly favored due to its elongated rhizome, tapered shoulder, prominent main root, and distinct lateral roots. It is also characterized by higher concentrations of active saponins, such as ginsenosides Rb_1 and Re[25]. Accordingly, *Ermaya* is predominantly cultivated in forest stands dominated by Mongolian oak (*Quercus mongolica*), linden (*Tilia* spp.), and hazel (*Corylus* spp.)[26]. Prior to planting, seeds undergo artificial stratification to stimulate germination. Once the seed coat softens and turns deep red, the fruits are harvested, depulped to remove the exocarp and mesocarp, and cleaned before sowing. Autumn sowing is commonly adopted, with seeds dibbled into furrows and covered with soil, after which they are left to grow naturally with minimal human intervention.

Management of forest-grown *Panax ginseng* in Ji'an strictly adheres to the "Five-No Principle"[26]: no transplanting, no soil disturbance, no artificial shading structures, no fertilization, and no weeding, representing a wild-simulated, low-intervention management approach. Specific protective measures include installing wire mesh fencing around cultivation sites to prevent disturbance by humans and livestock[27]. The application of chemical fertilizers and synthetic pesticides is strictly prohibited throughout the growth cycle. For the first three years after emergence, weeding is generally unnecessary; thereafter, only weeds taller than the ginseng plants are removed. For plants older than 5 years, periodic clearing of encroaching branches and shrubs is required to maintain suitable light conditions[28]. Furthermore, for plants older than 8 years, floral thinning and bud removal are practiced to reduce reproductive energy expenditure and promote root development.

4.3.3 Harvesting and Processing

The optimal harvest period for forest-grown *Panax ginseng* is after approximately 15 years of growth, specifically during September–October when the stems and leaves begin to senesce. After harvesting, farmers transport fresh roots—retaining adhering soil—to specialized cooperatives or local processing facilities for cleaning and primary treatment.

This process integrates traditional methods with modern standards: soil is gently removed using purified running water, damaged sections are meticulously trimmed, and preliminary sorting is conducted based on morphology, size, and integrity. Through this standardized processing, cooperatives ensure high levels of cleanliness and consistency in grading, establishing a solid quality foundation for subsequent desiccation, dehydration, and intensive processing.

As of 2024, Ji'an had more than 1,800 ginseng-related business entities covering the entire industrial chain, from cultivation and processing to marketing. This includes 126 processing enterprises, among which are 1 national-level key leading enterprise in agricultural industrialization, 4 provincial-level leading enterprises, and 16 enterprises above designated size. The city possesses an annual processing capacity of 9,000 t, with an actual annual throughput of approximately 6,000 t. Notably, 7 intensive processing enterprises each process over 600 t annually, representing about 10% of the total volume. Ji'an has achieved full utilization of the ginseng plant—including roots, stems, leaves, flowers, and fruits. Its range of deep-processed products ranks among the most diverse in China, with over 600 products developed across 4 major categories: food, pharmaceuticals, health supplements, and cosmetics[29,30].

4.4 Sustainable Development of the Forest-Grown *Panax Ginseng* Industry

4.4.1 Policy Support

Governmental policy support has played a critical role in promoting the development of the ginseng industry in Ji'an. By leveraging leading enterprises, the city has facilitated vertical integration across the industrial chain, connecting primary, secondary, and tertiary sectors. This development model is anchored in traditional cultivation, driven by advanced planting technologies, and supported by intensive product processing, and complemented by agritourism, ultimately promoting sustainable ecological agriculture[30].

Ji'an has formulated high-standard development plans for its ginseng industrial parks, defining a spatial layout of "one core, one center, and seven bases" and implementing a "company+production base" operational model to maximize land-use efficiency and resource integration[31]. By prioritizing full-chain development and high-end industrialization, the city is strategically positioning itself to build a 100-billion CNY ginseng industrial cluster[32,33]. In 2024, the ginseng industry contributed approximately 80% to local farmers' income, while the total output value of the entire ginseng industrial chain reached 16 billion CNY, indicating a rapid transition toward high-quality development.

Huadian Town has actively implemented municipal-level policies by establishing standardized cultivation bases, strengthening benefit-sharing mechanisms between entrepreneurial leaders and demonstration bases, promoting industry-university-research collaborations, and exploring "Ecology+" industrial integration. These specific measures have effectively translated municipal strategic blueprint into tangible local practices.

4.4.2 Technological Empowerment

Ji'an hosts the only national-level modern agricultural industrial park in China dedicated to ginseng as its leading industry. In recent years, the city has fostered collaborative innovation through industry-university-research partnerships. By leveraging platforms such as the Jilin Ginseng Science and Technology Backyard (STB) cluster—the first national-level STB in China focused on ginseng processing—and through collaboration with research institutions including Jilin Agricultural University, the city has focused on frontier technologies including rare saponin transformation and probiotic fermentation. This dual-driven model of "expert think tanks+technology incubation" has accelerated the transition of the forest- grown *Panax ginseng* industry from traditional cultivation to high-value-added intensive processing.

To further ensure product quality, the "One Ginseng, One Code" traceability platform was officially launched in June 2024. By utilizing "QR code + blockchain" technologies, the platform establishes a three-tier traceability system that enables stakeholders to verify key

information such as geographical origin, cultivation age, and ginsenoside content, thereby achieving full lifecycle quality control. The China-Qinghe (Aoyang) Wild Ginseng International Trading Center, located in Qinghe Town, serves as the primary trading hub for forest-grown *Panax ginseng*. It has fully implemented this system, ensuring stringent quality supervision throughout the transaction process.

4.4.3 Cultural and Tourism Integration

Ji'an has strategically centered its industrial evolution on ginseng culture, fostering deep integration between the forest-grown *Panax ginseng* industry and cultural tourism. The development of the "Ji'an-Qinghe Wild Ginseng Town" serves as a primary platform for this synergy, hosting major events such as the "Chinese Farmers' Harvest Festival & Ji'an-Qinghe Wild Ginseng Festival". These festivals feature innovative activities including "Ginseng King" competitions, ginseng-themed banquets, and the release of digital collectibles. Furthermore, the development of the Jilin Xianshen Valley Tourism and Wellness Resort has introduced specialized programs such as ginseng-based medicinal cuisine and forest therapy (*Shinrin-yoku*).

Huadian Town has actively explored the "Ecology+" development pathway by leveraging its forest-grown *Panax ginseng* bases to develop forest tourism and experiential harvesting activities. By inviting tourists to participate in the full cultivation and harvesting cycle, the town has effectively advanced the integrated development of the ginseng and tourism sectors.

4.4.4 Ecological Environment Traceability for Forest-Grown *Panax Ginseng*

To enhance the real-time monitoring of forest-grown *Panax ginseng* growth, a GIES ground station has been established in Xianshen Valley, Ji'an (Figure 10). The monitoring suite integrates a comprehensive array of sensors to measure key environmental parameters, including air temperature, relative humidity, wind speed, atmospheric pressure, precipitation, and light intensity. Additionally, the system tracks ecological indicators such as negative oxygen ion concentration, alongside edaphic parameters including soil moisture and electrical conductivity. This integrated monitoring framework enables continuous, real-time observation of both the physiological growth status of forest-grown *Panax ginseng* and surrounding environmental conditions.

Figure 10 GIES ground station in Huadian Town

5 Conclusion

Huadian Town in Ji'an City possesses highly suitable and abundant habitat conditions for forest-grown *Panax ginseng*, enabling the production of high-quality specimens. Ji'an forest-grown *Panax ginseng* is characterized by a high concentration of total ginsenosides and is particularly rich in bioactive compounds such as ginsenoside Rb_1 and the Re+Rg_1 complex, conferring significant medicinal value. To further consolidate the leading position of the Ji'an forest-grown *Panax ginseng* in the national market, the following strategic recommendations are proposed: (1) Standardization and quality control. Efforts should be continued to refine and advance the standardized production of forest-grown *Panax ginseng* and its derivatives. This includes enhancing scientific research, manufacturing technologies, and quality management systems to ensure safety and consistency. (2) Innovation and R&D systems. It is essential to further strengthen the industrial innovation and R&D framework. Priority should be given to supporting specialized research projects and providing incentives for the development of new products, cutting-edge technologies, and advanced processing techniques. (3) Brand building and market positioning. Strengthening the brand identity of Ji'an forest-grown *Panax ginseng* is essential. This entails establishing a robust brand standard system and innovating marketing models to enhance market competitiveness and

consumer trust, thereby leveraging brand value to drive overall industrial upgrading. (4) Ecological integration. The "Ecology+" development trajectory in Huadian Town should be continuously advanced. Emphasis should be placed on the coordinated development of ecological conservation and industrial expansion, ensuring that ginseng cultivation remains aligned with environmental protection and long-term sustainability goals.

Author Contributions

Zhu, W. B. was responsible for the overall design and supervision of the manuscript. Zhao, Z. C. was responsible for manuscript writing and figure preparation. Zhu, W. B., Zhao, Z. C., Yao, Y., Liu, H. B., Wang, F. and Xiang, L. F. participated in field investigation and sample collection. Liu, J. X. provided detailed guidance for the completion of the work. Yao, Y. and Liu, H. B. conducted data curation. Wang, F. and Xiang, L. F. provided industry standards and data on the ginseng cultivation area. Hou, J., Sun, J. C. and Bai, H. G. provided economic data on the development of the forest-grown *Panax ginseng* industry in Ji'an. Cui, X. Y. and Wei, G. Y. provided industrial and social data for Huadian Town. Wang, M. and Li, Q. provided detailed guidance for identifying and evaluating forest-grown *Panax ginseng*.

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Conflicts of Interest

The authors declare no conflicts of interest.

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