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Spatial Distribution Pattern and Risk Assessment of Invasive Alien Plants on Southern Side of the Daba Mountain Area

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Abstract: The southern side of the Daba Mountain area is a hotspot of global biodiversity and an essential barrier promoting ecological security. However, knowledge about the distribution status and transmission pathways of invasive alien species (IAS) in this area is limited. We counted the IAS on the southern side of the Daba Mountain area through sample transects and analyzed the factors affecting their spatial distribution. We also assessed IAS risk using the analytic hierarchy process (AHP), which found 64 IAS belonging to 23 families and 53 genera. Around rivers and roads, the results showed a vertical two-way dispersal pattern. Human and environmental factors, such as a very dense transportation network, can affect the distribution pattern of IAS. AHP assessed 43 IAS (67.19%), primarily distributed in villages and towns, as being of high or medium risk. High- and medium-risk IAS should be the focus of invasion prevention and control, and priority should be given to controlling the spread of IAS around rivers and roads.

Keywords: Daba Mountain; invasive alien plants; distribution pattern; invasion risk assessment; biodiversity

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1. Introduction

Invasive alien species (IAS) are a major threat to global biodiversity. They have caused significant harm to biodiversity, the environment, the economy, and human health on regional and global scales and have aroused widespread concern and attention [1–6]. Hence, the threat from IAS should not be underestimated, and IAS control and management have become a primary focus of restoration projects. The spatial distribution and spread of invasive plants are research hotspots, and large-scale observations combined with models have been used to predict the spatial dispersal dynamics of invasive plants, which has provided essential insights into the causes and consequences of local biodiversity impacts [7–10].

China is a vast country with diverse climates and environmental conditions, making it especially vulnerable to the establishment of IAS of foreign origin [11]. The mountains of southwestern China are known for their high species richness, and play a vital role in biodiversity conservation and eco-security maintenance [12,13]. The southern side of the Daba Mountain area is the core of southwestern China's mountainous areas. The environmental characteristics of the natural vertical zones determine the high diversity of vegetation types, making it a priority region for biodiversity protection [14,15]. It is one of the world's three largest contiguous regions with a fragile ecological environment [16,17]. It is also a high-risk region that is affected by IAS, acting as the main entrance for IAS from Southeast Asia into inland China. In southwestern China, IAS numbers are three to four times greater than in northwestern China [18–20]. For example, *Chromolaena odorata*, originating in Central America, is widely distributed in many mountainous areas of southwestern China and is currently dispersing northward at a fast pace. [21,22]. *Ageratina adenophora* is dispersing northward and eastward at an average speed of 20 km per year

from the Yunnan–Guizhou Plateau to inland China, indicating a high risk for a massive spread throughout China. This invasion situation suggests that *A. adenophora* may establish locations along the Yangtze River and its tributaries [19,23]. Hence, concerted efforts are urgently needed to conserve the biodiversity in southwestern China's mountainous area.

It is known that the construction of highways and roads may interfere with vegetation and soil conditions, create a habitat with significantly reduced competition, and increase the diffusion and invasion probability of IAS [5,24,25]. Roadsides are preferential migration corridors for IAS, acting as starting points for plant invasions into adjacent habitats [26,27]. High-yield weeds usually colonize the roadsides, spread to the surrounding natural habitats [28,29], and can attach to vehicles, permitting long-distance transportation and diffusion [30,31]. Routine long-distance dispersal by vehicles may also cause a rapid rate of IAS spread along roads. This may explain the frequent occurrence of isolated founder populations and discontinuous distributional patterns during roadside invasions [32]. As a result, long-distance transportation is regarded as one of the crucial factors in overcoming the geographical barrier and determining invasive success [33]. It is critical to study the distribution of roadside IAS, since this may contribute to a more efficient control of IAS invasion and improve their management [34].

In addition, the riverbank habitat is a fragile ecotone which is vulnerable to invasion [35–38] and is one of the habitat types with the most significant number of IAS [39,40]. Many IAS drive hydrological changes to form an easier-to-invade riparian environment by altering the nature of habitats [41–43]. They usually start along the watercourses and expand further inland [36]. For example, the invasion rate of *Alternanthera philoxeroides* is exceptionally high on both sides of river channels. An outward dispersion trend along the vertical river channel results in critical invasion conditions [44]. IAS distribution on riverbanks is often influenced by the distance from the river source [45], riverbank elevation gradient [45,46], riparian soil characteristics [47], human disturbance, and other factors [46,48]. It significantly impacts riparian vegetation structure and biodiversity [49,50]. Anthropogenic activities are known to promote the introduction, establishment, and persistence of IAS [51,52], either through environmental disturbance or by acting as a source of propagation. Potential human factors, such as trade and tourism, can significantly add to the explanatory power of environmental appropriateness as an index of invasivity [53]. Human trade and travel are breaking biogeographic barriers, resulting in shifts in the geographical distribution of organisms [54,55]. Increased visitor numbers are a vital factor promoting IAS introductions to tourist hotspots, making these the hardest-hit areas. Hence, a more comprehensive understanding of the spatial distribution of IAS around rivers, roads, and other transportation networks is essential to control human activity interference and optimize environmental management policies.

Continued investigation of the most noxious invaders and their impacts on nature is valuable for knowledge of invasive ecology and management. Previous studies have revealed that the damage caused by IAS might be determined by their invasive mechanisms, habitats to invade, and species traits [56,57]. These findings may aid us in drawing more attention to species presenting the greatest threats and in prioritizing the most hazardous invaders. However, the prerequisite is distinguishing various IAS from high to mild risk. The analytic hierarchy process (AHP) is a decision-making method which transforms decision-relevant elements into levels, then assigns weights to the levels, and performs qualitative and quantitative analysis based on them [58,59]. The main feature of this method is to convert complex decision-making problems into individual decision conditions, then to mathematize the process to prove its validity, and finally to provide an asymptotic decision strategy [60,61]. Therefore, conducting a risk assessment analysis on IAS is crucial, as this can help us to prioritize and control invasion efficiently.

In this study, we aimed to address two main questions: (1) What is the spatial pattern of IAS on the southern side of the Daba Mountain area? (2) Which species are the most hazardous, and to which should more attention be paid when considering invasion

control? Our findings will improve IAS management strategies in mountainous areas of southwestern China and promote the development of Chinese invasion ecology.

2. Materials and Methods

The southern side of the Daba Mountain area was selected as the sample area for inquiry. This area, known as a gene pool of biological species, has the most typical natural habitat and the most valuable biological species records [62,63]. The Daba Mountain area is the general term for the mountain at the crossroads of the Gansu, Sichuan, Chongqing, Shanxi, and Hubei Provinces in China, and it stretches for approximately 1000 km. It is a transition zone between the western plateau and east plain, belongs to the north subtropical monsoon climate, and has abundant biodiversity. Wuxi County, Wushan County, Chengkou County, and Kaizhou District are the core counties which are within the southern Daba Mountain area. They represent the geographical environment and biodiversity protection level and belong to the concentrated distribution areas of complete geomorphic units and nature reserves [64,65].

The following references were used for the floristic analysis of IAS information: *Flora Reipublicae Popularis Sinicae* [66], *Flora of Sichuan* [67], *Catalog of Higher Plants in Daba Mountain Area* [68], *Invasive Flora of China* [69], and websites (http://www.iplant.cn/frps, http://www.iplant.cn/ias/, http://www.cfh.ac.cn/, http://www.invasivespecies.org.cn/index, http://pe.ibcas.ac.cn, accessed on 19 November 2021).

Field surveys examined the status and distribution characteristics of IAS in the study area. We selected significant rivers, roads, forests, forest margins, wasteland, and other habitats for transect sampling in each township below the county level. The sample transects (121 total, 3 km/transect, 1 km apart) covered the entire area as evenly as possible. Once the IAS were identified, the sampling plots (372 total, 2 × 2 m) were set up around them for investigation. Along the nine major rivers, the vertical distance (0 m, 5 m, 10 m, 20 m, 40 m) was selected to set up sample plots on both riverbanks. River vertical distance was set according to the structure and class of the river system, the topography and geomorphology of the watershed, and the homogeneous characteristics of the river banks under human disturbance. As far as possible we placed sampling points in each secondary tributary classification unit and lake of the river. The purpose of reducing the survey distance for roads of smaller size and extent was to target the statistical impacts of the invasive plants, and avoid the appearance of intersecting roads which might have affected the survey results. Ten main roads were selected, and plots were sampled (vertical distance: 0 m, 2 m, 4 m, 6 m, 8 m).

This study lasted 2 years, from 2020 to 2021. In each sample transect or plot, we recorded the species richness and abundance. For each species, we measured vegetative height, phenological period (vegetative or reproductive stages), life form, growth status, habitat, naturalization degree (naturalized or not), ability to occupy habitat, and geographic location. The distribution frequency of IAS was calculated by dividing the number of towns and streets where IAS appeared by the total number of towns and streets. The distribution, life forms, habitats, origin, and ways of introducing IAS were counted, and a list of IAS was compiled.

The risk assessment of IAS was evaluated through invasion history, environmental adaptability, growth status, biological characteristics, diffusion mode and ability, potential harm and influence, and the difficulty of prevention and quarantine [70]. The AHP was used to construct the judgment matrix. We calculated the product (Mi, $i = 1, 2, \ldots, n$) of each row of the judgment matrix and squared Mi to get wi ($Wi = \sqrt[n]{Mi}$, $wi = Wi / \sum_{i=1}^{n} Wi$). Then, we calculated the maximum characteristic root λ_{max} ($\lambda_{max} = \sum_{i=1}^{n} \frac{(AW)i}{nWi}$, $AW = \lambda_{max} W$) and tested the consistency of the matrix before utilizing AHP (CR = 0.074937 < 0.1) [58,59,61] (specific AHP steps are provided in Supplementary File S1). Finally, the risk category was divided according to the scores obtained from the comprehensive assessment. The risk assessment system comprised 7 first-class indices, 17 second-class indices and 55 third-class indices (Table 1). The total score (P score) is the sum of all indicator points (a maximum

of 100) and is positively related to the risk coefficient. According to previously reported research [71–74], the early warning system is divided into three grades according to the P score: 1) high risk ($p \geq 40$), suggesting strengthening control and the implementation of strict quarantining; 2) medium risk ($33 \leq p < 40$), suggesting taking corresponding preventive measures; and 3) low risk ($p < 33$), suggesting no intervention for the time being but paying attention to its possibility. The weight was revised to increase the proportion of environmental adaptation and spreading ability so these were closer to the actual invasion status, based on the *National Environmental Protection Standard of the People's Republic of China—Technical Guidelines for Environmental Risk Assessment of Alien Species*, *Risk Assessment of Introduced Plants and Their Harmful Organisms*, and the established literature [75–78].

Table 1. The levels of the risk assessment index system.

First-Level Index	Second-Level Index	Third-Level Index
Invasion history (6 points)	Invasion record in Chongqing (2 points)	Yes (2 points); no (0 points)
	Pathways of introduction (4 points)	Intentional introduction (2 points); unintentional introduction (1 point); natural introduction (0.5 point); unknown (0.5 point)
Acclimatization (17 points)	Origin (7 points)	America (3 points); other areas (2 points)
	Number of villages and towns distributed (10 points)	$1 \leq$ numbers ≤ 3 (2 points); $3 <$ numbers ≤ 6 (3 points); $6 <$ numbers ≤ 8 (5 points)
Growth condition (9 points)	Growth state (6 points)	Good (4 points); average (1.5 points); poor (0.5 points)
	Naturalized (3 points)	Yes (2 points); no (1 point)
Biological characteristics (19 points)	Life forms (10 points)	Annual herb (3 points); perennial herb (2 points); liana (1.5 points); shrub (1.5 points); arbor (1 point); hydrophyte (1 point)
	Reproduction modes (6 points)	Sexual reproduction (1.5 points); asexual reproduction (1.5 points); both (3 points)
	Habitats (3 points)	Specific habitat (0.5 points); minority habitat (1 point); multi-habitat (1.5 points)
Diffusion mode and ability (12 points)	Diffusion mode (3 points)	Wind propagation (0.5 points); flow propagation (0.5 points); self-propagation (0.5 points); animal carrying or feeding propagation (0.5 point); human active communication (1 point)
	Enemy (3 points)	Effective natural enemy (0 points); non-effective natural enemy (1 point); no natural enemy (2 points)
	Diffusion ability (6 points)	Powerful (3 points); general (2 points); poor (1 point)
Harm and influence (12 points)	Economic harm (4 points)	Serious influence (3 points); general influence (1 points); no influence (0 points)
	Ecological harm (4 points)	Serious influence (3 points); general influence (1 point); no influence (0 points)
	Allergic harm (4 points)	Allelopathic toxicity exists (2 points); other harm (2 points); no harm(0 points)
Control and quarantine difficulty (25 points)	Identification difficulty (10 points)	Great difficulty (5 points); intermediate difficulty (3 points); easy (2 points)
	Control difficulty (15 points)	Effective prevention and control measures exist (4 points); with feasible method and unknown effect (5 points); no feasible way yet (6 points)

Data processing was completed in Excel 2016. SPSS version 22.0 was used to perform linear regression and correlation analysis. Origin version 2018 and ArcGIS Desktop 10.2 software were used to map the results. Three data types were used in this study: land use, road, and river. All vector data used in this study were derived from the Resources and Environment Science and Data Center of the Chinese Academy of Sciences and the geospatial cloud data [15,79]. We geo-referenced field observations to spatialize the IAS distribution. The road data were collected from national highways and railways. The map (Figure 1) contains the first-order stream to the fifth-order steam.

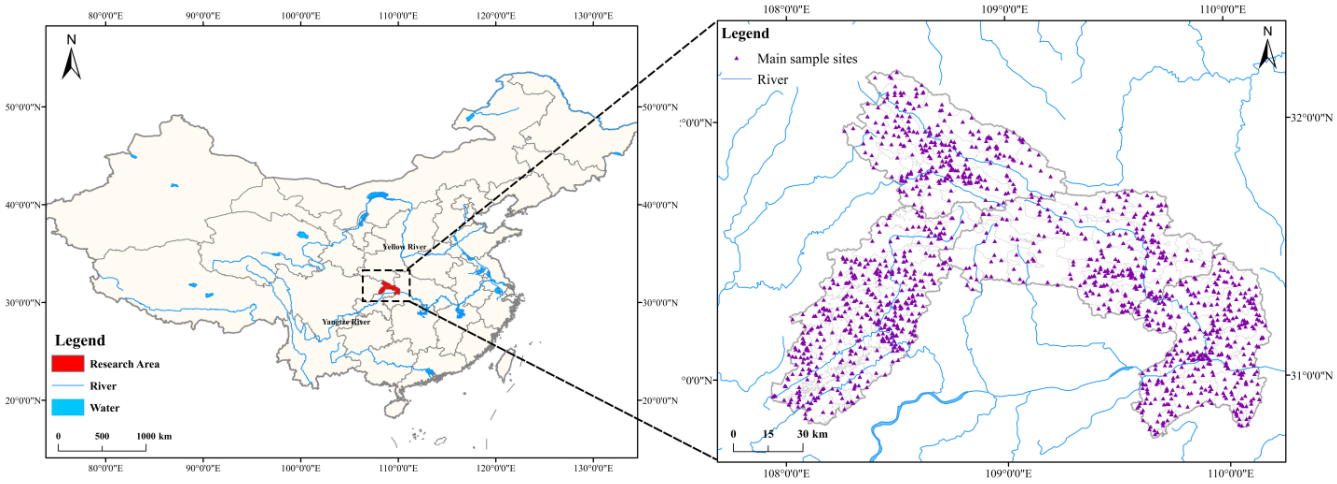


Figure 1. Distribution of invasive alien species (IAS) of the southern side of the Daba Mountain area, China. The geographic coordinate system used in maps is the China Geodetic Coordinate System 2000.

3. Results

3.1. Taxonomic Composition

A total of 64 IAS, representing 53 genera and 23 families, was recorded in the study: Asteraceae (17 species, 26.56%), Fabaceae (10 species, 15.63%), Amaranthaceae (8 species, 12.50%), Gramineae (4 species, 6.25%), and other families with only 1 or 2 species. The richest IAS genera were *Amaranthus* (5 species, 7.81%), followed by *Erigeron* (5 species, 6.25%).

3.2. Life Forms and Habitats

Herbs (annual and perennial herbs) constituted 82.81% (53 species) of all aliens, followed by shrubs (9.38%, 6 species), and trees (4.69%, 3 species) (Figure 2). The IAS mainly involved eight habitat types: farmland, roadside, front and back of houses, flower bed, forest, forest edge, wasteland, and riverbank. We found 54 species distributed on the roadside, 46 in the wasteland, and 44 in the front and back of houses. Three species (4.69%) survived in up to seven habitats. Most IAS (60 species, 93.75%) lived in two or more habitats (Figure 3). For example, *Alternanthera philoxeroides* lived in five habitats, and *Trifolium repens*, *Bidens pilosa* and *Ageratum conyzoides* lived in four habitats.

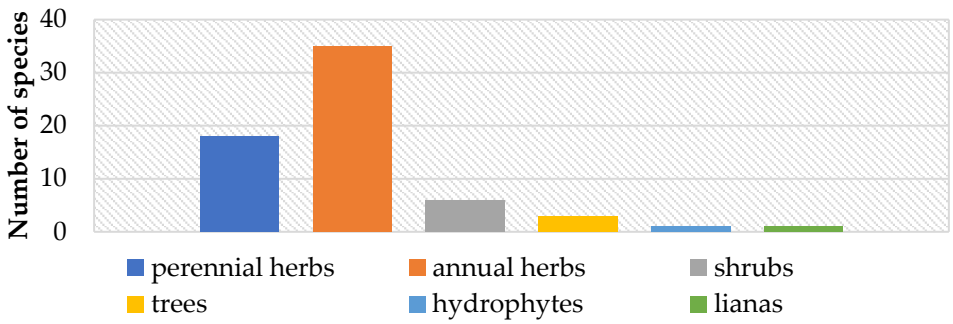


Figure 2. Life forms of IAS.

3.3. Origin and Pathways of Introduction

Most of the IAS originated from America (44 species, 68.75%), followed by Asia (7 species, 10.94%), Europe (6 species, 9.38%), and Africa (4 species, 6.25%) (Figure 4). The primary method of introduction was intentional introduction by people (42 species, 65.63%), followed by unintentional introduction (17 species, 26.56%), and natural introduction (3 species, 4.69%) (Figure 4).

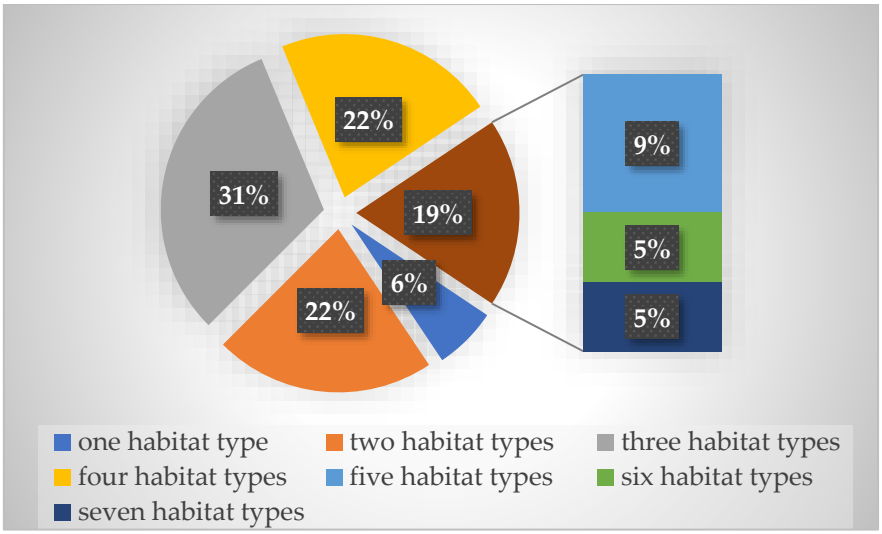


Figure 3. Habitat types of IAS.

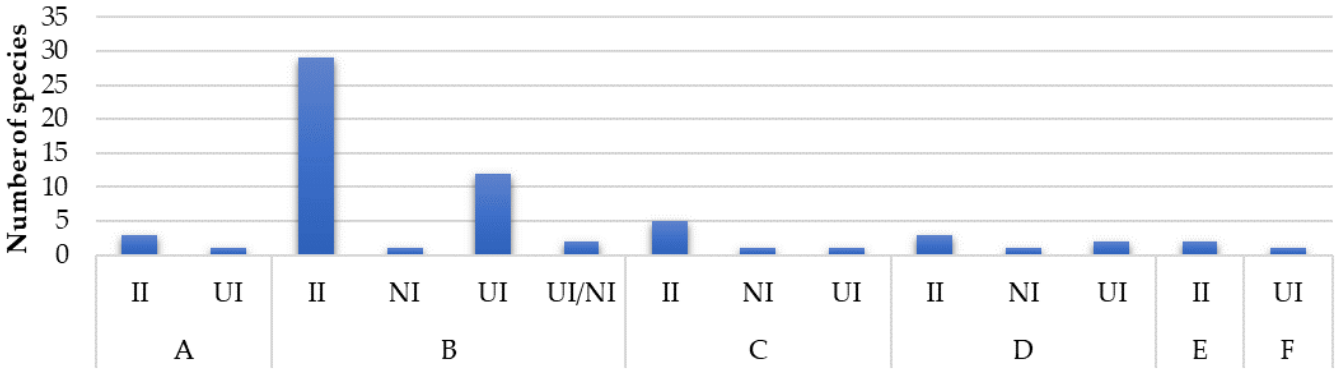


Figure 4. Origin and pathways of IAS. A, originated from Africa. B, originated from America. C, originated from Asia. D, originated from Europe. E, originated from Oceania. F, unclear origin. UI, unintentional introduction. II, intentional introduction. NI, natural introduction.

3.4. Spatial Distribution Pattern

There seems to be a positive correlation between IAS and regional population (R^2 = 0.22, $p < 0.01$; Figure 5). The species and quantity of IAS were the highest near rivers (0–5 m) and around roads (0–2 m) (Figures 6 and 7). As the outward distance from the vertical rivers and roads increased, the species and quantity of IAS gradually decreased. The vertical distance from rivers and roads was negatively correlated with the quantity and species of IAS. There were significant differences in the species and quantity of IAS of the Xiaojiang River, Jiangli River, Ren River, and Zhou River ($p < 0.05$). Among the eight major river systems, the worst invasion problem and the most abundant IAS were found in the Ren River and Xiaojiang River, followed by the Jiangli River. The level of plant invasion of the Meixi River was the lowest in this study, and at the time was in its early stages. Species and quantity of IAS on road 7 ($p < 0.01$), 8 ($p < 0.05$), and 9 ($p < 0.01$) all had significant differences. No significant differences were found for other roads and rivers.

IAS were widely distributed on the southern side of the Daba Mountain area (Figure 8). Most were in the northwestern and southwestern regions, whereas fewer kinds were found in the central region. The distribution locations of IAS were common to both sides of riverbanks along national and provincial trunk lines, and along entrances and exits of expressways. In areas with transportation networks along riverbanks, such as junctions with rural roads, the density of IAS distribution was greater. *Alternanthera philoxeroides*, *Erigeron sumatrensis*, *Bidens pilosa*, *Crassocephalum crepidioides*, *Oxalis corymbosa*, and *Setaria palmifolia* were widely distributed within all districts and counties (Figure 9).

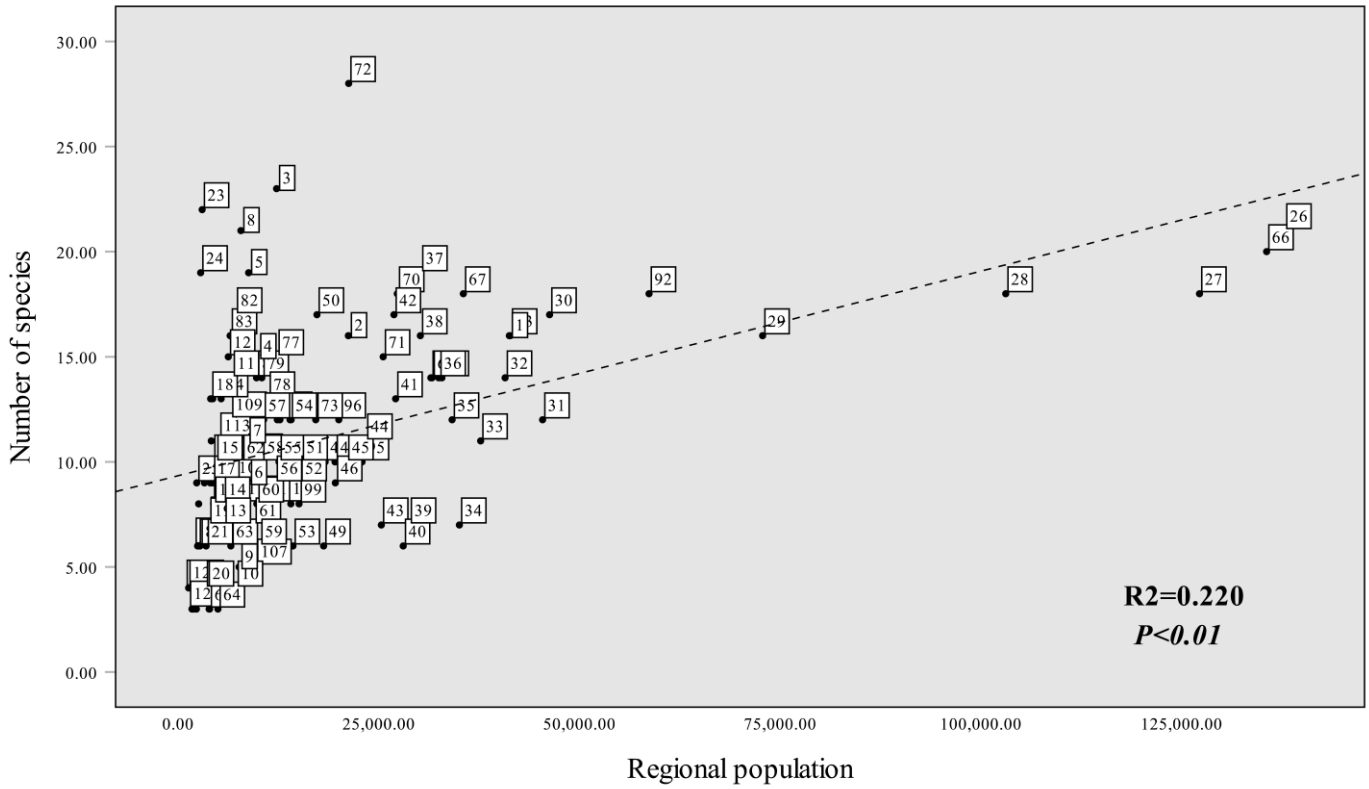


Figure 5. Correlation analysis between regional population (number of individuals) and IAS (number of species). Different positions represent different counties (e.g., position 3 represents Xiuqi town).

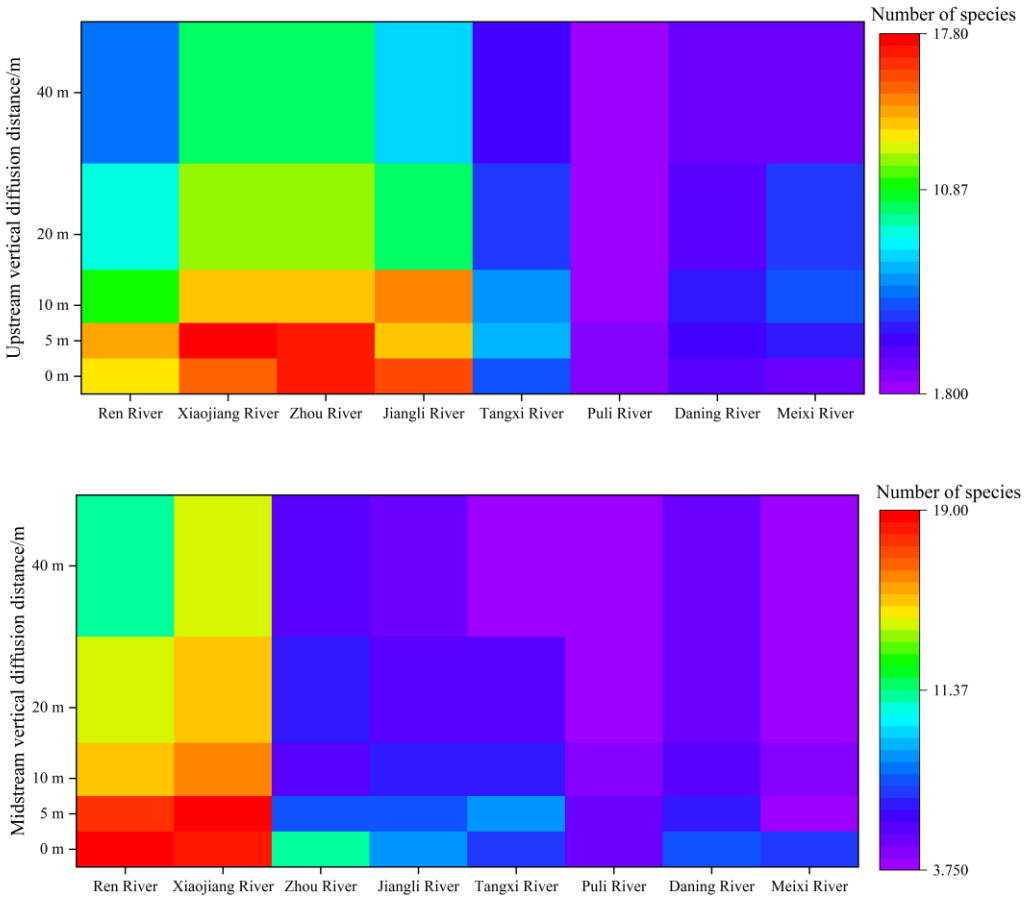


Figure 6. *Cont.*

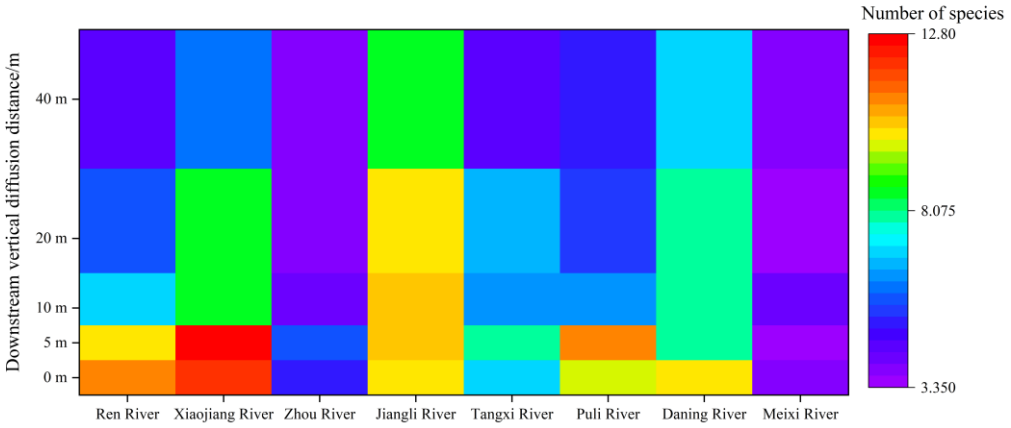


Figure 6. Heatmap of IAS close to and far from riverbanks.

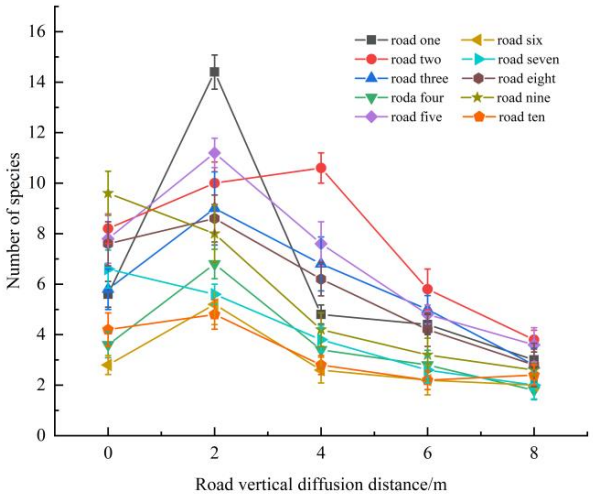


Figure 7. Diffusion pattern of IAS on both sides of roads.

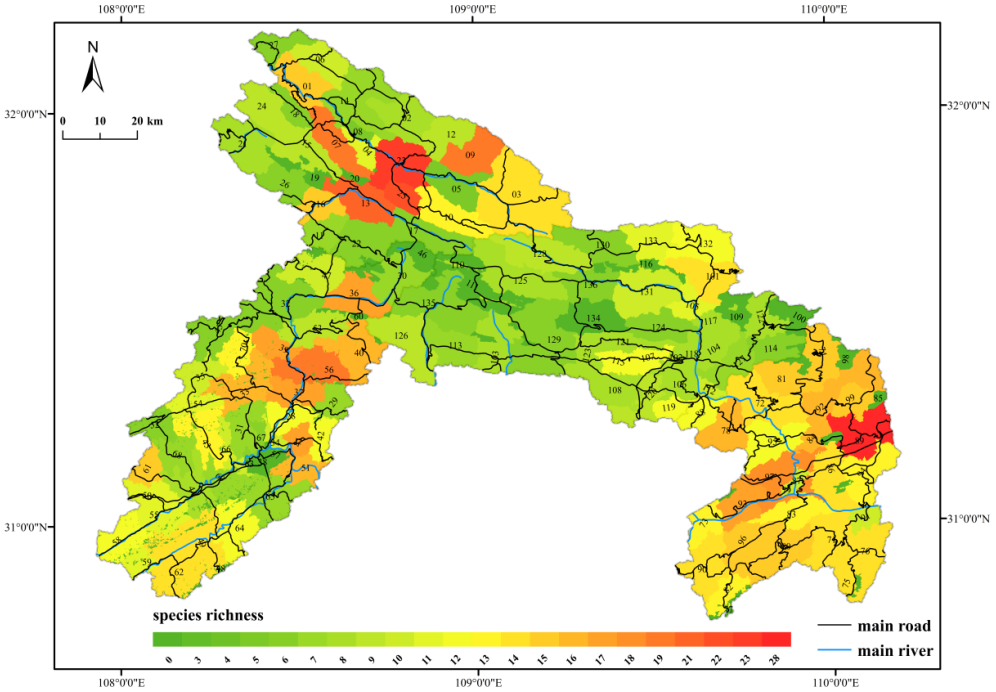


Figure 8. Distribution map of IAS. (Map serial number correspondence table is provided in Supplementary File S2).

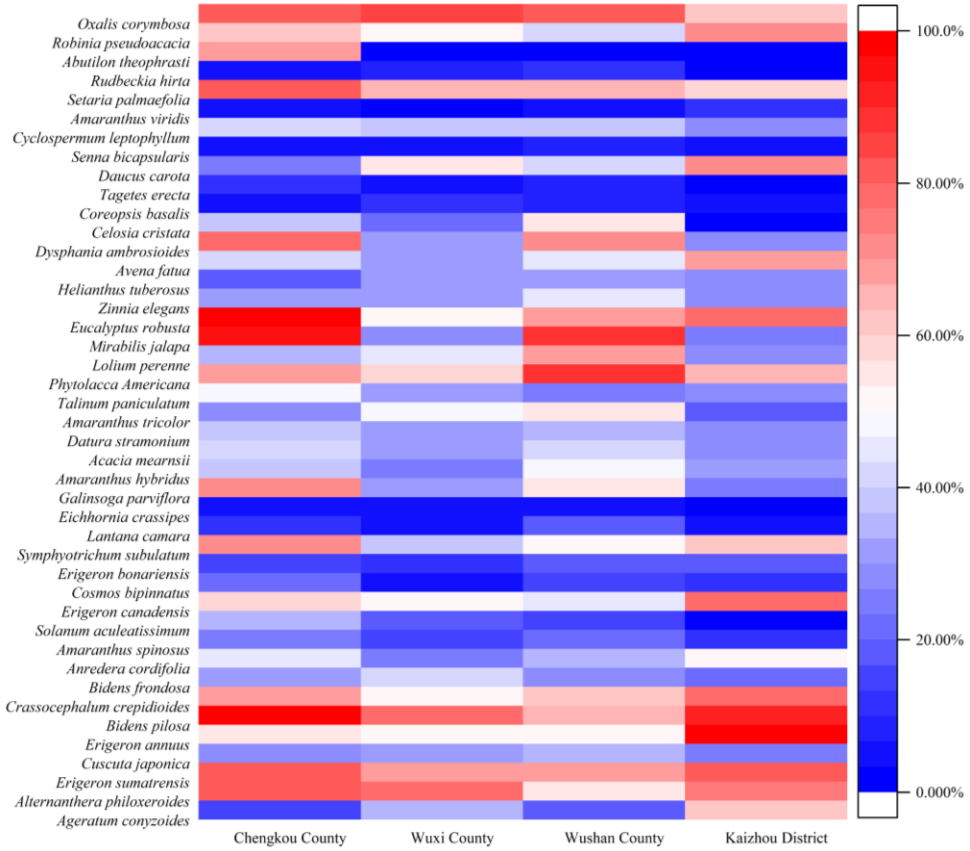


Figure 9. Distribution frequency of high- and medium-risk IAS in villages and towns. (Different colors and shades in the picture represent different distribution frequencies of IAS in various districts and counties.)

3.5. Construction and Application of Risk Assessment System

We classified the 64 IAS into three major categories according to the risk assessment system: high risk, medium risk, and low risk. The medium-risk IAS accounted for the highest proportion (25 species, 39.06%), followed by the low-risk (21 species, 32.81%), and high-risk IAS (18 species, 28.13%) (Table 2).

Table 2. Risk value and grade of invasive assessment.

Latin	Risk Value	Risk Grade	Latin	Risk Value	Risk Grade
Alternanthera philoxeroides	48	high-risk	*Ageratum conyzoides*	48	high-risk
Erigeron sumatrensis	46.5	high-risk	*Cuscuta japonica*	45.5	high-risk
Erigeron annuus	45.5	high-risk	*Bidens pilosa*	44.5	high-risk
Crassocephalum crepidioides	44.5	high-risk	*Bidens frondosa*	44	high-risk
Anredera cordifolia	44	high-risk	*Amaranthus spinosus*	43.5	high-risk
Solanum aculeatissimum	43.5	high-risk	*Erigeron canadensis*	43.5	high-risk
Cosmos bipinnatus	43	high-risk	*Erigeron bonariensis*	41.5	high-risk
Symphyotrichum subulatum	41.5	high-risk	*Lantana camara*	41	high-risk
Eichhornia crassipes	40	high-risk	*Galinsoga parviflora*	40	high-risk
Amaranthus hybridus	38.5	medium-risk	*Acacia mearnsii*	38	medium-risk
Datura stramonium	38	medium-risk	*Amaranthus tricolor*	37.5	medium-risk
Talinum paniculatum	37	medium-risk	*Phytolacca Americana*	37	medium-risk
Lolium perenne	37	medium-risk	*Mirabilis jalapa*	36.5	medium-risk
Eucalyptus robusta	35	medium-risk	*Zinnia elegans*	35	medium-risk
Helianthus tuberosus	35	medium-risk	*Avena fatua*	35	medium-risk
Dysphania ambrosioides	34.5	medium-risk	*Celosia cristata*	34	medium-risk
Coreopsis basalis	34	medium-risk	*Tagetes erecta*	34	medium-risk

Table 2. *Cont.*

Latin	Risk Value	Risk Grade	Latin	Risk Value	Risk Grade
Daucus carota	34	medium-risk	*Senna bicapsularis*	33.5	medium-risk
Cyclospermum leptophyllum	33.5	medium-risk	*Amaranthus viridis*	33.5	medium-risk
Setaria palmifolia	33.5	medium-risk	*Rudbeckia hirta*	33	medium-risk
Abutilon theophrasti	33	medium-risk	*Robinia pseudoacacia*	33	medium-risk
Oxalis corymbosa	33	medium-risk	*Veronica persica*	32	low-risk
Ipomoea purpurea	32	low-risk	*Eleusine indica*	31	low-risk
Amaranthus caudatus	31	low-risk	*Geranium carolinianum*	31	low-risk
Leucaena leucocephala	30.5	low-risk	*Euphorbia maculata*	30	low-risk
Melilotus officinalis.	30	low-risk	*Euphorbia hirta*	30	low-risk
Trifolium pratense	30	low-risk	*Celosia argentea*	29	low-risk
Trifolium repens	29	low-risk	*Opuntia dillenii*	28.5	low-risk
Verbena bonariensis	28.5	low-risk	*Salvia splendens*	28	low-risk
Chenopodium ficifolium	27	low-risk	*Medicago sativa*	24	low-risk
Ulex europaeus	21.5	low-risk	*Mimosa pudica*	21	low-risk
Oenothera glazioviana	21	low-risk	*Echinacea purpurea*	21	low-risk

4. Discussion

4.1. The High Level of Invasion on the Southern Side of the Daba Mountain Area

When considering the conservation of biodiversity in a particular area, it is fundamental to know which IAS are present. However, no prior studies have revealed the current state of IAS on the southern side of the Daba Mountain area. In this study, 64 species of IAS were identified through field research. The indicated that the southern side of the Daba Mountain area is a vital aspect of the invasion pathway and has the potential to promote IAS expansion in global ecoregions; this is also consistent with previous studies [80–82].

Our findings indicated that the most prevalent IAS were Asteraceae and *Amaranthus*, which was consistent with previously published studies [31,83–85]. Asteraceae was the most prominent dicotyledon plant family. The naturalization success could be because many Asteraceae species develop a flower head, which is especially attractive for insect pollination; and they can produce a large seed crop [86,87]. In addition, most *Amaranthus* plants are edible, allowing them to be spread by people and livestock, resulting in a wide distribution. In addition, once their seeds fall to the ground, they become difficult to remove [88]. All these features contribute to their wide distribution.

Plant life forms are characterized by their adaptation to environmental conditions. The different life types and habitat types determine the invasive range in which IAS can survive and adapt. In this survey, herbs (annual and perennial herbs) constituted 82.81% of all IAS. Herbs have short generation times, and are more likely to establish and spread rapidly. Annuals are less persistent than perennials and may be replaced by the latter, but they can readily spread throughout a country without restriction [89].

Habitat diffusion is related to the growth characteristics and the influence of the external environment [90,91], such as human activities [92,93]. Our team also found a similar phenomenon in this study: in the areas with significant human disturbance (such as roadsides and houses), the ecosystems were fragile and significantly harmed by plant invasion. This was most likely because these regions combined the two main factors that favor IAS: first, relatively high levels of disturbance that create new habitats; and second, high propagule pressure because landscaping provides seed sources that are easily dispersed [91,94,95].

In addition, it has also been reported that most of the IAS in China originated in America [96,97]. Similarly, IAS from America accounted for 68.75% in this study. Presumably the climate of the Daba Mountains is similar to that where plants are found in their natural environment in America, allowing IAS to colonize and spread more readily. One reason for the high levels of invaders from the American continent is that many have been reported to exert clear allelopathic effects on native species [98–101]. Intentional introduction also constitutes a high percentage (65.63%) in all pathways of introduction. This provides a

warning that the origin and ability to self-renew and grow must be audited and monitored if there is a need to introduce and cultivate IAS.

4.2. Distribution Patterns and Influencing Factors

Our results demonstrated that anthropogenic determinants (regional population) and environmental factors (river and road network proximity) are the two primary factors that affect the distribution of IAS. Successful invasion is usually closely related to human activities; for example, Xiuqi town (Position 3 in Figure 5), with the largest number of permanent residents in Chengkou County, was strongly influenced by IAS. Tourist attractions may also be one of the factors affecting the distribution of IAS, such as in Luoping Town in Wushan County (Position 72 in Figure 5), Heyu Township in Chengkou County (Position 24 in Figure 5), and Wenquan Township in Kaizhou (Position 37 in Figure 5). The species and quantity of IAS were higher in the areas with high tourist activity than those without. Several previously published works have also reported a similar phenomenon [102,103]. Additionally, in the same region, the number of IAS in the urbanized areas was the largest, followed by scenic sites and nature reserves [104,105]. Previous studies have also revealed that the most essential and statistically significant predictor is generally human population or density, which becomes a reliable predictor of the spatial distribution of IAS [106,107]. Therefore, human activities and behaviors should be a prioritized field of intervention for regional managing authorities. Anthropogenic factors can influence the time, amount, and pathways of IAS, and environmental factors can affect how many species can persist when introduced to new locations [101,108]. In this research, the distribution rate of IAS on both sides of rivers and roads was exceptionally high, and presented a pattern of spreading from rivers and roads to vertical sites. Roads and rivers enhance exotic species invasion in this landscape by acting as corridors or agents for dispersal, providing suitable habitats, and containing reservoirs of propagules for future episodes of invasion [31,109,110].

4.3. Invasion Risk Assessment

AHP detected a total of 43 high- or medium-risk IAS. Most of the 64 IAS were assessed as medium-risk, which accounted for 39.06%. Medium-risk plants mainly have weak vitality and live in a few habitats or are cultivated species that are greatly influenced and spread by human activities. The risk assessment of *Alternanthera philoxeroides*, *Erigeron sumatrensis*, *Symphyotrichum subulatum*, *Anredera cordifolia*, *Crassocephalum crepidioides*, and *Amaranthus spinosus* is consistent with the existing investigation [74,78,111,112], which shows that the risk assessment system can accurately evaluate the invasion risk and has reference value. *Ageratum conyzoides* was evaluated as a high-risk plant in this study, whereas it was previously regarded as a medium-risk plant [111,113]. This may be because it is used to decorate flower beds in the investigation area and its branch diffusion ability is strong. *Cuscuta japonica* scored highly in this assessment, because it has strong parasitic ability, high adaptability to the local environment and good overall growth. We believe that the risk assessment system has good application to IAS on the southern side of the Daba Mountain area, because it can fit the environmental conditions, evaluate the latest growth state change, and predict the future IAS development trend. In this risk assessment system, the risk score of IAS is positively related to the distribution and diffusion ability. It is also helpful for us to evaluate the spatial distribution characteristics of IAS with different risk scores by combining the risk assessment systems.

5. Limitations

Although this study was designed carefully to minimize bias, there remain several limitations: (1) Our investigation of environmental factors was limited, especially as it only considered river and road networks; these influencing factors are partial. Nevertheless, the research direction from the diffusion of traffic networks was necessary and correct. In further work, anthropogenic and environmental influencing factors of the IAS distribution pattern should be considered more comprehensively. (2) Some IAS may be

affected by seasons; our investigation time was short, and the plants in the area could not be inspected and verified throughout the year. Monitoring the dynamics of IAS over time, if possible, will form a solid basis for any planning with a temporal perspective. (3) AHP was used to determine the risk level in the risk assessment process. However, the factors in the hierarchy only consider the key factors that affect the invasion risk assessment in the Daba Mountain area. Therefore, although the hierarchy was appropriate for IAS in the Daba Mountain area, popularizing and assessing IAS in other areas should be considered carefully. (4) A larger score index of IAS spatial distribution is needed in the future to clarify the correlation between the spatial distribution and the risk assessment. Furthermore, it is also necessary to add a proper analytical section for evaluating the correlation between the spatial distribution and the risk assessment. 5) Decision-makers set the indicators and scores of AHP, so we must admit that subjectivity is a disadvantage of AHP, which should not be ignored.

6. Conclusions

Our study provided the first comprehensive catalog and detailed spatial distribution pattern and risk level assessment (based on AHP) of IAS on the southern side of the Daba Mountain area. We found numerous IAS (64 species), mainly distributed in areas with frequent human activities, tourist hotspots, riverbanks, and on both sides of roads. Proportions of the high- and medium-risk IAS were extremely high (67.19%). Effective control measures against these potential drivers of IAS distribution patterns are, therefore, urgently needed to mitigate the invasion.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/d14121019/s1, File S1: Description of specific steps of AHP, Table S1. Matrix of the judgment, Table S2. The importance of scale, Table S3. The mean random consistency index. File S2: Corresponding table of map serial numbers and township locations, Table S4. Corresponding table of map serial numbers and township locations.

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