Prevention and Control Strategies for Alien Invasive Plant Species in the Biodiversity Conservation Priority Area of the Songnen Plain (Jilin)

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Abstract By conducting literature research and field investigations on the species and distribution characteristics of invasive alien plants in the biodiversity conservation priority area of the Songnen Plain (Jilin region), a multidimensional risk assessment index system was constructed. A comprehensive evaluation method combining qualitative and quantitative methods was adopted to clarify the main invasive alien plant species and risk level classification in the region, and systematically evaluate their invasion risks. It could provide scientific basis for regional biodiversity conservation and invasion prevention and control.

Key words Invasive alien plants; Risk assessment; Indicator system

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As one of the three major black soil zones in the world, the Songnen Plain is home to over 60% black soil and black calcareous soil, covering diverse ecosystems such as wetlands and grasslands. It is the core area for biodiversity conservation in Northeast China. The biodiversity conservation priority area of the Songnen Plain (Jilin region) is located in the core of the Northeast Asia Economic Circle, with frequent personnel and trade activities, and prominent risks of invasive alien plants, which have posed potential threats to local species competition, ecosystem functions, and agricultural production. It can identify high-risk species in advance by conducting risk assessment of invasive plants, providing scientific support for developing precise prevention and control strategies, and ensuring ecological security and biodiversity of black soil[1].

1 Overview of the study area and research methods

1.1 Overview of the study area The Songnen Plain (Jilin) is located in the central part of Northeast China, in the northern temperate zone. The geographical coordinate is 121°38′ - 131°19′ E, 40°52′ - 46°18′ N. The total area is approximately 14 600 km^2, accounting for 7.90% of Jilin Province's total area. Administratively, it mainly includes Songyuan City (Ningjiang District, Qian Gorlos Mongol Autonomous County, Changling County, Qian'an County) and Baicheng City (Taobei District, Zhenlai County, Tongyu County, Taonan City, Da'an City). The specific location and administrative area are shown as Fig. 1 and Table 1.

1.2 Research methods Based on the traditional theory of invasive alien plants, combined with expert decision-making, the factors that directly affect plant growth, reproduction, and diffusion are comprehensively analyzed, such as natural ecological environment and human interference, the status and interaction relationships between factors are compared, and a multi-level and multi-index comprehensive risk assessment system is constructed[2]. Using the analytic hierarchy process, the relative weights of different indicators at different levels in the risk assessment system for invasive alien plants are determined, and the invasive risk of alien plants is quantitatively analyzed. Through the analytic hierarchy process, based on the establishment of an orderly hierarchical indicator system, the importance of each indicator in the same level is compared pairwise, and the weight coefficients of the indicators are calculated. Based on this, corresponding percentage scores are assigned to achieve objective quantification of the evaluation[3]. In terms of indicator selection, comprehensive consideration is given to the biological characteristics, life history characteristics, origin background, habitat type, and ecological hazards of invasive plants. Combing the climate characteristics in the biodiversity conservation priority area of the Songnen Plain, human interference level, economic loss risk caused by invasion, difficulty level of prevention and control, and public recognition, comprehensive analysis is conducted. This ensures that the evaluation factors are comprehensively covered, logically reasonable, and practically operable[4].

2 Current status of invasive alien plants in the biodiversity conservation priority area of the Songnen Plain

2.1 Composition of alien invasive plant species Based on

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field investigations and data compilation, a list and characteristics of invasive alien plants in the biodiversity conservation priority area of the Songnen Plain were compiled. A total of 22 invasive alien plants were recorded, belonging to 10 families and 20 genera. From the perspective of family composition, Asteraceae (7 species) is the most abundant group of invasive alien plants in the biodiversity conservation priority area of the Songnen Plain, accounting for 31.8% of the total recorded species. Specifically, it includes *Ambrosia trifida*, *Xanthium strumarium*, *Erigeron canadensis*, *Cosmos bipinnatus*, *Helianthus tuberosus*, *Tagetes erecta*, and *Bidens bipinnata*. Next are Gramineae (3 species), Solanaceae (3 species), and Leguminosae (3 species). Most of the invasive plants mentioned above have the characteristics of high seed yield, long lifespan, tolerance to poor soil conditions or strong stress resistance, as well as a large number of fruits and strong adaptability, possessing structures and mechanisms that are conducive to long-distance transmission and diffusion. Composition of alien invasive plant species in the biodiversity conservation priority area of the Songnen Plain was shown as Fig. 2.

Fig. 1 Schematic diagram of biodiversity conservation priority area in the Songnen Plain

Table 1 Biodiversity conservation priority area of the Songnen Plain in Jilin Province

Regional category	Prefecture-level administrative region	County-level administrative region	Specific scope
Biodiversity conservation priority area of the Songnen Plain	Songyuan City	Ningjiang District	Huaqiao Farm
		Qianguo County	Balang Town, Pingfeng Township, and the area of the Chagan Lake National Nature Reserve located within the county's territory
		Changling County	The Yaojingzi Grassland Provincial Nature Reserve is located within the county's territory
		Qian'an County	The Dabusu National Nature Reserve and the Chagan Lake National Nature Reserve are located within the county's territory
	Baicheng City	Taobei District	Zhennan Breeding Sheep Farm
		Zhenlai County	Momoge Mongolian Ethnic Township, Dongping Town, Hatuqi Mongolian Ethnic Township, Jianping Township, Momoge National Nature Reserve
		Tongyu County	Xianghai Mongolian Ethnic Township, Xinglongshan Town, Wulanhua Town, Tuanjie Township, Xinfa Township, Zhanyu Town, Baolawendu Mongolian Ethnic Township, Xinhua Town, Xinxing Township, Sugongtuo Township, Bianzhao Town, Xianghai National Nature Reserve
		Taonan	Wafang Town, Jiaoliuhe Township, Jubao Township, Najin Town, Yongmao Township, Yema Township, Hulitu Mongolian Ethnic Township, Wanbao Township, Dongsheng Township, Fushun Township, Huhecheli Mongolian Ethnic Township, Anding Town, Erlong Township, Datong Township
		Da'an City	Chagan Lake National Nature Reserve and Moon Lake are located within the city's territory

2.2 Life forms and habitats of alien invasive plants According to the statistics of plant life forms, the invasive alien plants in the biodiversity conservation priority area of the Songnen Plain are mainly annual herbaceous plants, with a small amount of biennial and perennial herbaceous plants, and no woody invasive plants have been found. The singularity of plant life forms reflects that the dominant strategies of invasive plants in this region are high reproductive capacity, short life cycle, and rapid response to

environmental disturbances. Among the 22 invasive plants recorded, annual herbaceous plants account for 72.7% of the total. Typical plants include *A. trifida*, *Amaranthus retroflexus*, *E. canadensis*, *Solanum rostratum*, *Cenchrus echinatus*, *etc.* For some biennial and perennial herbaceous plants, such as *Melilotus officinalis*, *Melilotus albus*, and *Medicago sativa*, although their reproductive cycles are not dominant, they can still establish stable small communities in grasslands and abandoned areas, demonstrating certain ecological adaptability and sustainable renewal ability.

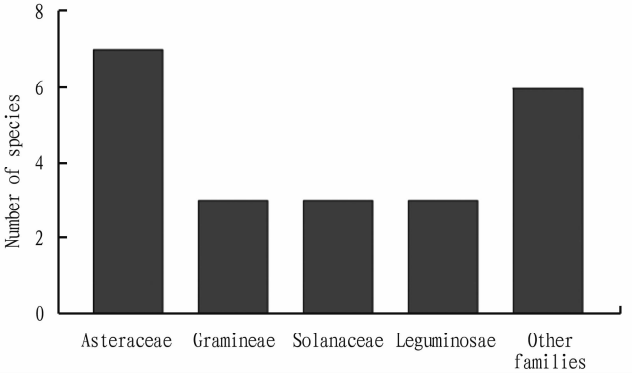

Fig. 2 Composition of alien invasive plant species in the biodiversity conservation priority area of the Songnen Plain

From the distribution of habitats, these alien plants are mainly concentrated in areas with frequent human activities or ecological transition zones. For example, *A. trifida* is widely distributed in the green space system of Qian Gorlos Mongol Autonomous County, commonly found around green spaces, park green belts, and other areas, posing a threat to young trees and crops. It is a typical invasive species in forest, grass, and wetland. Farmland and its peripheral areas are also hotspots for the frequent occurrence of invasive plants, with species such as *A. retroflexus*, *Avena fatua*, and *Cannabis sativa* appearing between cultivated land and field ridges, directly competing with crops. Forest edges and wastelands are another type of high-risk area. Species such as *Xanthium strumarium*, *E. canadensis*, and *Abutilon theophrasti* are mainly distributed in habitats such as forest boundaries, young forests, and abandoned forests. Meanwhile, some invasive alien plants have strong adaptability to sandy or arid soils, such as *Cenchrus echinatus* and *Cenchrus longispinus*, which are commonly found in sandy and arid environments in Tongyu County and Taonan City, demonstrating strong ecological resilience. It is worth noting that areas along roads, villages, and abandoned lands are also important distribution sites for invasive alien plants, especially ornamental plants such as *Datura stramonium*, *Tagetes erecta*, and *Cosmos bipinnatus*, which may originate from escape in horticultural cultivation. This reflects that human introduction behavior and management loopholes may have inadvertently contributed to their spread. In addition, invasive species such as *Veronica peregrina* and *M. albus*, which prefer moist environments, have been recorded in the water, riverbanks, and moist sandy areas of Taonan City and other places. Their habitats are mostly located in wetland buffer zones or irrigated farmland edges, indicating that there is also a high risk of invasive alien plants in wetland edge zones. The habitat commonalities of invasive plant species are that they are strongly disturbed and destroyed by human activities. The ecological stability of local plant communities in these habitats is weak, making it difficult to resist the competitive pressure brought by invasive alien species. Ultimately, they are at a disadvantage in resource competition, providing opportunities for the successful invasion of alien species[5].

2.3 Origin and transmission routes of invasive alien plants

The original sites of invasive alien plants recorded in the biodiversity conservation priority area of the Songnen Plain are mainly concentrated in the Americas, Europe, and Asia, with North America being the main focus. Typical species such as *A. trifida*, *E. canadensis*, *S. rostratum*, and *D. stramonium* are all native to North America. This indicates that plants originating from North America are more likely to be invasive alien plants in the biodiversity conservation priority area of the Songnen Plain, mainly due to the similar climate in the two regions, and plants originating from North America are more likely to settle and reproduce in the Northeast China. At the same time, the geographical isolation of the North American continent has accumulated many plant species that may have spread and distributed. Once these species have the opportunity to survive on another continent, they can quickly spread and spread. Therefore, in the process of introducing and cultivating plants originating from North America, the adaptability and invasiveness of the ecological environment in the biodiversity conservation priority area of the Songnen Plain should be considered first. Once the introduced plants are found to have a tendency to spread, cultivation should be stopped immediately, and effective monitoring measures should be taken.

In terms of introduction methods, these invasive plants mainly enter and spread through two pathways: unintentional introduction and intentional introduction. The main pathways for the emergence of invasive plants in this region are through plant introduction and cultivation, as well as accidental introduction of weeds from overseas. Overall, invasive alien plants exhibit obvious human dominated transmission characteristics, with specific transmission pathways mainly including: agricultural activity transmission, transportation and logistics transmission, horticultural escape and abandonment of cultivation, water and wind transmission, *etc*[6]. The sources of unintentionally introduced species are often related to international agricultural products, goods, passengers, transportation vehicles, *etc.*, such as *A. trifida*, *Erigeron annuus*, *S. rostratum*, *B. bipinnata*, *etc.* Human activities are an important driving force for their cross regional transmission. The intentionally introduced plants are mainly horticultural plants, forage plants, and medicinal plants, such as *M. sativa*, *H. tuberosus*, *C. bipinnatus*, *T. erecta*, *etc.* These plants were initially introduced for ornamental, medicinal, and forage purposes. They grew under human control in the early stages and later escaped into the

wild due to poor management, eventually becoming invasive alien plants.

2.4 Hazard characteristics of invasive alien plants The invasive alien plants in the biodiversity conservation priority area of the Songnen Plain not only have a wide variety of species and strong adaptability, but also have multiple negative impacts on the regional ecosystem structure, function, and economic and social activities during the invasion process. Firstly, invasive plants pose a direct threat to local biodiversity. Invasive plants often establish stable populations in a short period of time, forming a single dominant community, displacing the original local community, disrupting ecological niche balance, and leading to a significant decline in community species diversity. For example, *A. trifida* grows rapidly, and the height of a mature plant can reach 3 m. It quickly occupies resources in invasive areas, inhibits local plant growth, and ultimately leads to a single community structure or even local disappearance of native species. Secondly, the expansion of invasive plants can alter the species composition and structure of existing ecosystems, weakening their ecological functions. For example, *A. trifida* releases allelopathic substances during invasion, inhibiting the germination of surrounding plant seeds and seedling growth, thereby interfering with community succession and nutrient cycling, and leading to a decrease in the stability of grassland ecosystems. This mechanism of altering ecological processes often has deep and long-term impacts on ecosystems, reducing their ability to recover. Thirdly, some invasive plants pose a potential threat to human health. The pollen of *A. trifida* is a common allergen that can cause allergic reactions, including rhinitis, asthma, and other allergic diseases. Long term exposure to *A. trifida* and its pollen may lead to respiratory diseases and other health problems. Fourthly, it causes interference and losses to agricultural and livestock production activities. In the agricultural system, invasive plants such as *A. retroflexus*, *A. fatua*, *Ambrosia artemisiifolia*, and *A. trifida* compete with crops for water, nutrients, and space, leading to reduced crop yields, affecting the quality of agricultural products, and causing significant economic losses. In grasslands, prickly plants such as *S. rostratum* can easily cause damage to the oral and digestive systems of livestock, interfere with their feeding behavior, reduce grassland utilization efficiency, and limit the sustainable development of animal husbandry. Finally, alien invasive plants can bring high governance costs and social management burdens. With the expansion of invasive plants, local governments need to invest long-term manpower and material resources in monitoring and removal work, which increases the pressure on fiscal expenditure. The removal of alien plants along roads, green belts, wetland buffer zones, and other areas usually takes several years to achieve initial results, and some areas even require repeated management. In addition, some invasive plants grow from ornamental or greening plants (such as *T. erecta*, *C. bipinnatus*, *etc.*), exposing loopholes in introduction management and increasing the complexity of public green space management. Internationally, invasive alien species have been listed as the second leading factor in biodiversity loss after habitat destruction. The ecological and economic damage caused by invasive alien species includes both known real hazards and potential expansion risks and future uncertainties, especially in the biodiversity conservation priority area of the Songnen Plain, their long-term cumulative effects should not be underestimated.

3 Risk assessment of invasive alien plants

3.1 Comparison of risk assessment scores for invasive alien plants Based on the biological characteristics, morphological features, growth rate, harmfulness, and actual growth situation of invasive alien plants in the biodiversity conservation priority area of the Songnen Plain, the constructed risk assessment system for invasive alien plants was applied to conduct a systematic risk assessment of 22 invasive plants in the region. The risk assessment results of invasive alien plants in the biodiversity conservation priority area of the Songnen Plain were shown in Table 2.

The comprehensive score range for the risk assessment of invasive alien plants was 34 to 61 points, indicating significant differences in invasion intensity and risk among different alien plants. Among all the evaluated plants, *A. trifida* scored the highest, especially in terms of stress resistance, allelopathy, reproductive ability, and transmission mode, showing high values, making it one of the species with the highest risk of invasion in the region. Next are *S. rostratum* (60 points), *A. retroflexus* (58 points), *C. echinatus* (56 points), and *D. stramonium* (53 points). These species exhibit extensive habitat adaptability, strong seed reproduction and dispersal abilities, as well as significant ecological or economic hazards, and belong to high-risk plant groups that require special attention and management. The species with lower ratings mainly included *V. peregrina* (34 points), *P. angulata* (35 points), *M. officinalis* (36 points), *etc.* These species generally have a single habitat, limited dispersal ability, and weak ecological harm. The current invasion risk is generally controllable, but they still need to be included in the follow-up monitoring scope to prevent the ecological post effects caused by local dispersal. Further analysis from the scoring structure reveals that environmental adaptability, reproductive characteristics, and dispersal ability are the main factors that distinguish species risk levels. Among them, high-risk species often have strong adaptability, high reproductive frequency, and multi pathway transmission ability, while low-scoring species perform average in the above dimensions.

3.2 Risk classification analysis of invasive alien plants According to the risk assessment level standards for invasive alien plants, the risk levels of 22 invasive alien plants were classified, and the results were shown in Table 3. There are two types of low-risk invasive plants, accounting for 9.1%. These species currently have weak invasiveness and limited harm, and can be considered as acceptable levels of invasive risk objects. It is recommended to maintain regular observation without implementing special prevention and control measures, but classified files should be retained to prevent risks from increasing due to environmental chan-

ges. There are 10 invasive plants with average risk levels, accounting for 45.5%. These plants have certain risks and require further information or preventive monitoring measures. There are 4 species of invasive plants with high risk levels, accounting for 18.2%. These plants have significant potential in habitat adaptation, reproduction, or dissemination, and some species have shown an expansion trend in local areas. It is recommended to list them as key monitoring and early intervention targets, implement phased inventory, appropriate screening, and control experiments to avoid large-scale spread. There are 6 species of invasive plants with extremely high risk levels, accounting for 27.3%. These species have outstanding performance in multiple indicators such as stress resistance, seed reproduction ability, propagation speed, and ecological impact. They have the potential for rapid expansion and are difficult to control, and are prone to causing serious interference to regional ecosystems. They need to be prioritized for management, strengthen long-term monitoring and rapid response mechanisms, and develop comprehensive management plans as soon as possible. Overall, the proportion of species at risk levels I and II is close to 50%, indicating that the current pressure of invasive alien plants in the biodiversity conservation priority area of the Songnen Plain is relatively heavy, and there is a trend of multiple sources, mechanisms, and risk levels coexisting. Based on the results of this evaluation, combined with the ecological characteristics, distribution range, and diffusion trends of each species, differentiated management strategies should be implemented, with priority given to targeted management of extremely high and high-risk species.

Table 2 Risk assessment results of invasive alien plants in the biodiversity conservation priority area of the Songnen Plain

Plant name	Score//points	Level	Plant name	Score//points	Level
Ambrosia trifida	61	I	*Lepidium densiflorum*	39	III
Xanthium strumarium	52	II	*Amaranthus retroflexus*	58	I
Erigeron canadensis	59	I	*Cannabis sativa*	40	III
Abutilon theophrasti	42	III	*Solanum rostratum*	60	I
Datura stramonium	53	II	*Cenchrus echinatus*	56	I
Medicago sativa	37	III	*Ipomoea purpurea*	44	III
Cosmos bipinnatus	37	III	*Melilotus officinalis*	36	III
Helianthus tuberosus	42	III	*Cenchrus longispinus*	56	I
Avena fatua	49	II	*Melilotus albus*	37	III
Tagetes erecta	37	III	*Physalis angulata*	35	IV
Veronica peregrina	34	IV	*Bidens bipinnata*	47	II

Table 3 Risk assessment levels of invasive alien plants

Risk level	Invasive plants (sorted by score from high to low)
Extremely high	*Ambrosia trifida*, *Solanum rostratum*, *Erigeron canadensis*, *Amaranthus retroflexus*, *Cenchrus echinatus*, *Cenchrus longispinus*
High	*Datura stramonium*, *Xanthium strumarium*, *Avena fatua*, *Bidens bipinnata*
General	*Ipomoea purpurea*, *Helianthus tuberosus*, *Abutilon theophrasti*, *Cannabis sativa*, *Lepidium densiflorum*, *Medicago sativa*, *Cosmos bipinnatus*, *Tagetes erecta*, *Melilotus albus*, *Melilotus officinalis*
Low	*Physalis angulata*, *Veronica peregrina*

4 Countermeasures for prevention and control of invasive alien species based on evaluation results

To effectively address the ecological security risks brought by different invasive alien plants in the biodiversity conservation priority area of the Songnen Plain, it is recommended to adopt a comprehensive management strategy of "graded classification, differential control, and overall promotion" based on the risk assessment results of invasive plants[7]. The overall idea is to implement hierarchical management based on risk levels, and to plan and coordinate responses to common problems.

4.1 Prevention and control measures of hierarchical management

4.1.1 Grade I extremely high-risk species: strengthening monitoring and prioritizing treatment. A special testing system should be established. It should set up fixed sampling sites and warning stations in key distribution areas, and carry out high-frequency and timely dynamic monitoring. It should organize multi departmental joint governance actions, promote collaborative efforts among forestry, agriculture, ecology, transportation and other departments, integrate resources, and implement policies in different areas. Emergency response plans should be developed. It should implement a "detecting and handling immediately" quick response mechanism for rapidly expanding or new occurrence points to prevent their spread. It should strengthen publicity, education, and public mobilization, improve the ability to identify high-risk plants, and build a public group prevention and control system.

4.1.2 Grade II high-risk species: included in key control and implementing restricted area management. Control areas and buffer zones are defined, and limited area cleaning is carried out for areas that have already become densely distributed. Population

density control experiment is conducted, and reasonable combinations of physical, chemical, and biological prevention and control measures are explored. Regular risk assessment and review are conducted. Combined with changes in ecological disturbance intensity and management intervention, it should adjust management priorities in a timely manner. It should promote research and integrated demonstration of prevention and control technologies, establish typical governance sample areas, and accumulate applicable technologies and case experience.

4.1.3 Grade III general-risk species: maintaining monitoring and preventing local spread. It should maintain and update basic databases, improve basic information archives such as distribution range, diffusion path, and ecological characteristics. The diffusion dynamics of human interference environment should be monitored, especially focusing on sensitive points such as traffic routes, farmland boundaries, and urban green spaces that are prone to invasion. It should implement ecological restoration technology, promote local planting restoration in low invasive density areas, and weaken the ecological niche advantages of invasive plants.

4.1.4 Grade IV low-risk species: included in the observation list, with low intervention strategy. They are included in the annual observation list, and regular on-site review and literature tracking should be conducted. It should pay attention to the impact of regional environmental changes, especially the potential promoting effects of extreme climate and land use changes on low-risk species. It should explore and utilize the potential assessment, and individual plants have certain economic or ornamental value, which can be moderately utilized in combination with invasion risk.

4.2 Prevention and control measures of common governance

On the basis of hierarchical control, effective prevention and control of invasive alien plants also require comprehensive protection of systematic, forward-looking, and collaborative governance measures. It is suggested to promote the common management of invasive alien plants from the following four aspects:

4.2.1 Improving the source prevention and control system. It should strengthen the entry management and introduction approval of high-risk alien species, and strictly implement the inspection and quarantine system. Relying on scientific research institutions, pre introduction assessment of potential risk species is conducted, a list of key species and early intervention measures are established, thereby reducing the probability of introduction from the source.

4.2.2 Establishing monitoring, early warning, and emergency response mechanisms. A normalized monitoring system covering priority areas and surrounding sensitive areas is established. Combining remote sensing monitoring, field inspections, and public reports, the occurrence and expansion trends of invasive plants are dynamically grasped[8]. For known high-risk species, it should develop specialized emergency response plans, clarify emergency teams, material reserves, and response processes, and enhance emergency response capabilities.

4.2.3 Promoting the construction of the rule of law and departmental cooperation mechanisms. It should accelerate the formulation or improvement of local regulations on the management of invasive alien plants, clarify the division of responsibilities and coordination mechanisms among departments such as agriculture, forestry, and ecological environment, and establish cross departmental joint prevention and control mechanisms. At the same time, it should strengthen supervision and performance evaluation to ensure that governance tasks are effectively implemented.

4.2.4 Strengthening public participation and science popularization education. It should intensify science popularization and training efforts to enhance the public's ability to identify, prevent, and report invasive plants. Communities, schools, research institutions, and other organizations are encouraged to participate extensively in the monitoring and management of invasive plants, and a diverse governance atmosphere of "government led, departmental collaboration, and public participation" is created.

In summary, the promotion of the management of invasive alien plants should adhere to the principles of prevention first, combination of prevention and control, classified policy implementation, and coordinated promotion. It should use systematic governance methods to ensure the ecological security and sustainable development in the biodiversity conservation priority area of the Songnen Plain.

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