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Is the resettlement suitability of migrants in arid mountainous areas high or low? A case study of ecological migration in Gansu Province, China

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Extreme climate, natural disasters, and deep poverty have triggered increasingly common migration worldwide. China's resettlement projects have relocated approximately 10 million residents from disaster-prone, drought-prone, mountainous areas to suitable resettlement sites. However, ecological migration (EM) and short-period resettlement site selection may pose potential risks to the sustainable development of resettlement. Furthermore, previous research has focused on immigrants' livelihoods but paid less attention to resettlement suitability (RS) in arid mountainous areas. This paper conducts a case study investigating the measurement, differences, and obstacles of RS for EM resettlement sites in northwest China's mountainous regions. We select 29 indicators from five dimensions, including geology, climate, economy, transportation, and public services, to construct an assessment model of RS. The results show that resettlement site suitability is inversely related to altitude and directly related to economic vitality. RS along traffic arteries and near water systems is significantly higher than in other areas. Long-distance resettlement's average suitability is 14.63% higher than short-distance resettlement, facilitating migration resettlement. Topographic and geological conditions are the primary factors hindering RS in arid mountainous areas, with an obstacle degree of 37.11%. Flat terrain, convenient water access, and medical treatment are crucial for RS. This research offers insights into EM decisions in arid mountainous areas and improving RS and regional sustainable development under global climate change.

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Introduction

Migration resettlement influences the regional ecological environment, security, and sustainable development. As a key to protecting the environment and reducing poverty, migration has become a crucial global strategy to address extreme climate change and solve disaster and poverty issues in developing nations (Beyer et al., 2022; Tang et al., 2023a; Yang et al., 2020; Zhao et al., 2024). Resettlement area location influences immigrants' safety, living environment suitability, livelihood (Ma et al., 2024; Masotti et al., 2025; Parvin et al., 2022), satisfaction, and happiness (Guo et al., 2023; Zhao et al., 2024). Additionally, approximately 1.4 billion people, including 450 million children, live in highly or significantly disaster-vulnerable areas, with Africa's drylands experiencing the most migration, resettlement, or displacement due to natural disasters (Hoffmann, 2022; Owain and Maslin, 2018). From 2010 to 2020, to eliminate absolute poverty, protect the ecological environment, and maintain regional stability, the Chinese government implemented ecological migration (EM) and other projects for approximately 10 million people in arid and impoverished mountainous areas (Liu et al., 2020; Peng et al., 2020; Yang et al., 2020). Immigrant resettlement can reduce ecosystem damage from human activities and aid ecosystem restoration and reconstruction in migrant-moved areas (Zander et al., 2022; Zhang et al., 2022). It can also assist the government in implementing spatial decision-making and governance for regional environmental protection (Fan et al., 2015; Liu et al., 2020). Thus, a suitable living environment in arid mountainous resettlement sites is crucial for ecological environment protection and migration development. However, scientifically assessing migration RS in arid mountainous areas is essential. Targeted optimization decisions can help achieve goals like improving the ecological environment, coordinating human-land relationships, and harmonizing human-nature interactions in immigration areas.

Global climate change-induced frequent natural disasters have drawn scholars' attention to migration and RS (Fernández et al., 2024; Hauer et al., 2024; Ulus and Ellenblum, 2021; Zander et al., 2022). Using United Nations survey data, scholars estimated that 143 million people globally would be exposed to climate deterioration and ecological degradation risks by 2050 (Spilker et al., 2020). They also predicted a 5.3- to 18-fold increase in climate-driven migrants in the United States due to sea level rise by 2100 (Hauer et al., 2024). Given the climate change background affecting human migration, multidisciplinary knowledge was integrated to explore climate change's impact on population mobility and resettlement suitability (RS) in African drylands (Hoffmann, 2022). Considering population transfer efficiency, construction costs, and shelter capacity constraints, a multi-objective resettlement site selection model was developed to aid resettlement decision-making (Jiao et al., 2024). Existing research uses semi-structured interviews and typology principles to explore the relationship between environmental pressure and population migration (Morrissey, 2013). Discrete choice experiments evaluate migration preferences for resettlement locations (Baert et al., 2020) and whether residential environments can mitigate landslide risks (Vlaeminck et al., 2016). Additionally, scholars have used satellite and drone-based analyses to map flood expansion risks in resettlement villages (Cheng et al., 2022). Concurrently, resettlement origins have been identified through geological hazard susceptibility assessments, and optimal locations for migration resettlement initiatives have been determined by evaluating land capacity to support these populations (Younes et al., 2022).

The rapid development of geographic information systems (GIS) and remote sensing technology has enriched RS research methods and assessment models. Scholars use field surveys and

multi-source remote sensing data to explore immigration policies' impact on immigrant family livelihoods (Liu et al., 2020; Mallick et al., 2023). They select indicators from geography, environment, infrastructure, and society dimensions, applying the analytic hierarchy process (AHP) and GIS to identify resettlement areas suitable for refugee migration (Drakaki and Tzionas, 2021; Younes et al., 2022; Zhou et al., 2023), suitable urban land areas (Bamrunghkul and Tanaka, 2022; Zhou et al., 2024), and desertification areas (Kadri and Nasrallah, 2023). Various parameters, including earthquake risk, construction cost, and population capacity, were used to build a comprehensive model for immigrant emergency shelter location selection, aiding government resettlement efforts (Amini Hosseini et al., 2022; Jiao et al., 2024). Some scholars use GIS and spatial multi-criteria analysis models to examine the impact of public service facilities like hospitals and schools on immigrants' suitability and social life stability (Nikuze et al., 2022). They also use accessibility as a proxy, combining space syntax with multidimensional decision analysis to explore spatial deprivation in concentrated immigrant settlement areas (Yang et al., 2023). Additionally, scholars combine matrix population models, flood disaster models, and immigration models to simulate and predict immigrant population spatial distribution (Hauer et al., 2024). They construct models based on land use, social economy, industrial development, and life accessibility to select preventive resettlement sites (Chen and Tsai, 2021). In summary, existing studies have provided RS assessment methods and model foundations, identifying a good geological environment, accessible transportation, and convenient public services as critical RS factors (Ma et al., 2022; Wang et al., 2025; Younes et al., 2022; Zhou et al., 2023). These studies support sustainable post-resettlement work and life development (Egze et al., 2023; Qian, 2019).

However, some scholars have explored migration resettlement issues caused by climate change, such as floods, landslides, and sea level rise in Uganda's mountainous areas (Serwajja et al., 2024), Bangladesh's delta region (Fernández et al., 2024), and the United States (Hauer et al., 2024). Previous studies provided valuable globalization resettlement experience, while several gaps remain to be filled. First, previous research has overlooked EM in arid mountainous regions, focusing mainly on disaster impacts and planning assessments to select suitability-related factors. A comprehensive evaluation is a scarcity that incorporates a multifaceted perspective, considering the ecological environment, hydrological conditions, and resource conditions particular to arid areas. Moreover, research content is limited to resettlement risks (Bodine et al., 2022; Xu et al., 2020), ecological environment assessment, and spatial distribution of RS (Younes et al., 2022). More comparisons of suitability differences before and after resettlement regarding location and distance are needed. Second, research data relies on survey interviews and questionnaire analysis (Qian, 2019), introducing subjectivity in selecting evaluation indicators and determining weights. Weight determination methods typically use a single AHP or entropy value method (EVM). New methods should integrate big data with comprehensive weighting approaches. Additionally, studies have not yet profoundly explored assessment result-based obstacles to RS for immigrants in arid mountainous areas.

Therefore, to address the research gap, this study uses an EM resettlement area in Gansu Province, China, as a case study, covering climate, topography, geology, natural ecology, economic development, location transportation, and public services. This study uses AHP and EVM to build a relatively scientific RS assessment framework. Following the technical route of data collection and processing model construction, resettlement suitability assessment, typical case comparison,

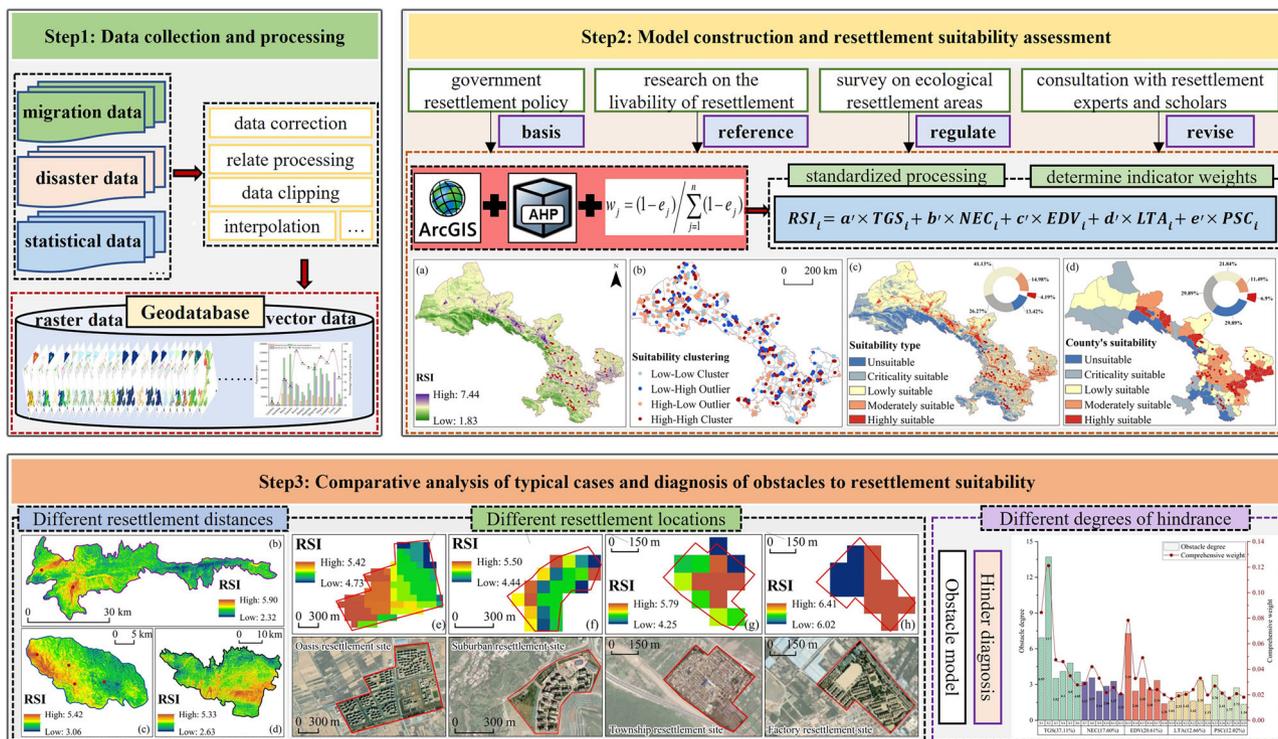


Fig. 1 Research technology route.

and suitability obstacle diagnosis, we use ArcGIS 10.8 to examine RS spatial distribution characteristics. We innovatively combine resettlement distance and location to compare RS differences before and after migration, and use the obstacle model to identify the main factors hindering RS. Our research addresses the gap in studying migrant resettlement suitability in arid mountainous areas and enriches the assessment methodology for RS. It offers a reference for governments to develop effective migration resettlement policies and better achieve regional sustainable development goals.

Data and methods

Figure 1 illustrates this research’s technical route. Step 1: Data collection and processing. After acquiring multi-source data, projection conversion and interpolation in ArcGIS are performed to establish a geodatabase containing raster and vector data. Step 2: Model construction and RS assessment. First, we select 29 indicators covering terrain geological stability (TGS), natural ecological comfort (NEC), economic development vitality (EDV), location transportation accessibility (LTA), and public service convenience (PSC). Then, the AHP and EVM will be used to determine evaluation indicator weights and construct an RS evaluation model. Finally, GIS spatial analysis tools will explore the RS spatial differentiation characteristics. Step 3: Comparative analysis of typical cases and diagnosis of suitability disorders. Based on the evaluation results in step 2, we take a typical EM resettlement area as a case to analyze the differences in RS between resettlement distance and location and use the obstacle model to identify the main obstacles to the RS.

Study area. Gansu Province, a significant ecological security barrier in western China and an important passage between the Silk Road Economic Belt and the Eurasian Continent (Tang et al., 2023b), covers approximately 455,900 km². Located between 32°11’N–42°57’N and 92°13’E ~ 108°46’E, with an altitude of 556–5825 m (Fig. 2a). Its ecological environment is fragile, with a

tense human-land relationship. Ecologically sensitive areas constitute 12.14%, and about 90% of the land is in prohibited and restricted development zones. Geologically disaster-prone areas exceed 50% of the total area. From 2015 to 2020, the local government actively implemented resettlement and EM, constructing 73 EM resettlement areas and resettling approximately 731,400 people, including around 500,000 poor individuals (Fig. 2b). The resettlement mode primarily involves long-distance centralized resettlement in counties and industrial parks, supplemented by short-distance dispersed resettlement in nearby towns (Fig. 2c).

Additionally, to reduce the threats to lives and property from landslides and debris flows, maintain regional ecological security and stability, and enhance immigrant suitability, the Gansu Provincial Government plans to complete ecological and geological disaster avoidance and resettlement projects by 2026, relocating approximately 1 million residents. Therefore, using China’s Gansu Province as a case study, research on RS distribution characteristics and suitability hindrance factors in arid mountainous areas is typical and representative.

Data collection and processing. Using ArcGIS10.8 software, we performed projection changes, geometric corrections, mask extraction, and resampling on all data to establish a 100 × 100 m primary geographic database.

Spatial data used in this study include land use data, digital elevation model (DEM) data, geological hazard points, nature reserves, geological lithology, administrative boundaries, road networks, water systems, fault zones, and meteorological data sourced from the Chinese Academy of Sciences and Environmental Center (Table 1). Remote sensing image data is from Google Earth, and EM resettlement boundaries are derived from Baidu Maps. The statistical yearbook data includes Gansu Province’s economic overview, population distribution, and per capita disposable income. This article’s data on resettlement and disaster resettlement planning originates from the Gansu Provincial Government Departments. It includes information

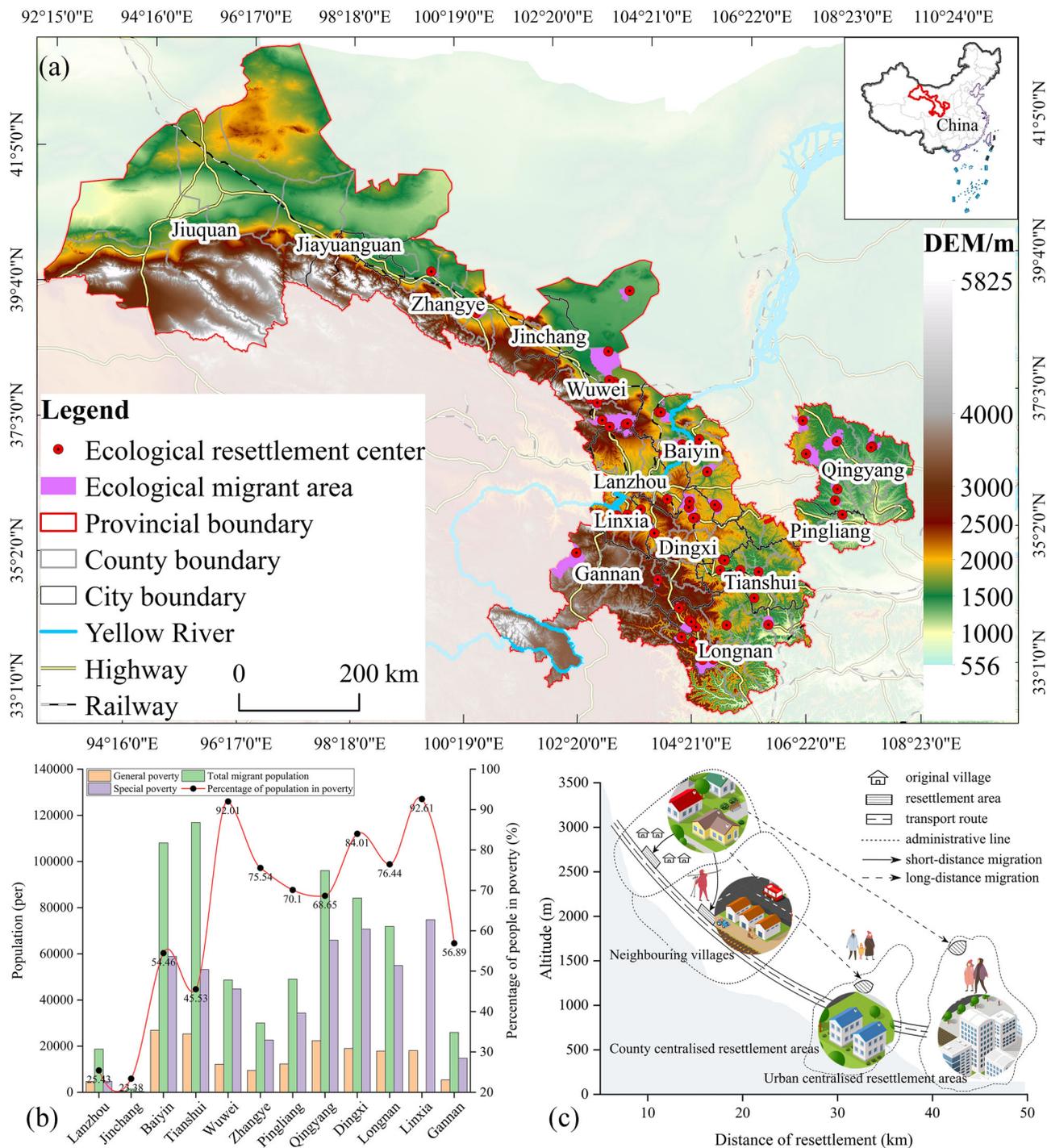


Fig. 2 Overview of the study area. Study area (a), ecological migration scale (b), ecological migration mode (c).

on implementing Gansu Province’s resettlement plan, population size, resettlement methods, timing, and locations.

We classify land use into seven categories: cities, residential areas, cultivated land, woodland, grassland, water bodies, and wasteland. Kriging interpolation was applied to meteorological data to generate spatially continuous 100 m meteorological datasets. Using ArcGIS spatial analysis tools, we calculated the core density of geological hazards and conducted buffer zone analysis around geological hazard points, nature reserves, and road network water systems. We then calculated the Euclidean distance from the center point of each ecological resettlement area to the nearest buffer zone, which informed the

corresponding suitability classification. The Baidu Map application was employed to mark points of interest (POIs) for ecological resettlement areas. Boundaries of the 73 ecological resettlement areas in the study area were delineated using vectorization and remote sensing image comparison and correction.

Research methods

Theoretical framework constructions. The human settlement environment theory is the basis of RS, the location theory is the support for the convenience of immigrants’ lives, and the sustainable livelihood theory is the guarantee for the sustainable

Table 1 Data sources.

Type	Name	Data Sources	Resolution	Time
Spatial data	weather station data	http://data.cma.cn	-	2000-2020
	DEM, LUCC	https://www.resdc.cn	30 m	2020
	NDVI	https://glovis.usgs.gov/	250 m	2000-2020
	population	https://www.worldpop.org	100 m	2020
	PM2.5, GDP	http://nnu.geodata.cn	1 km	2020
	Google Image	https://earth.google.com/	0.3 m	2020
	night light	https://ngdc.noaa.gov/	0.004°	2020
	administrative boundaries, road network, geologic lithology, water system, nature reserve	https://www.resdc.cn	-	2020
	geological disaster point	https://www.resdc.cn	-	2000-2020
	POIs	Baidu map	-	2020
Statistical data	migration data, yearbook	Gansu provincial government	-	2000-2020

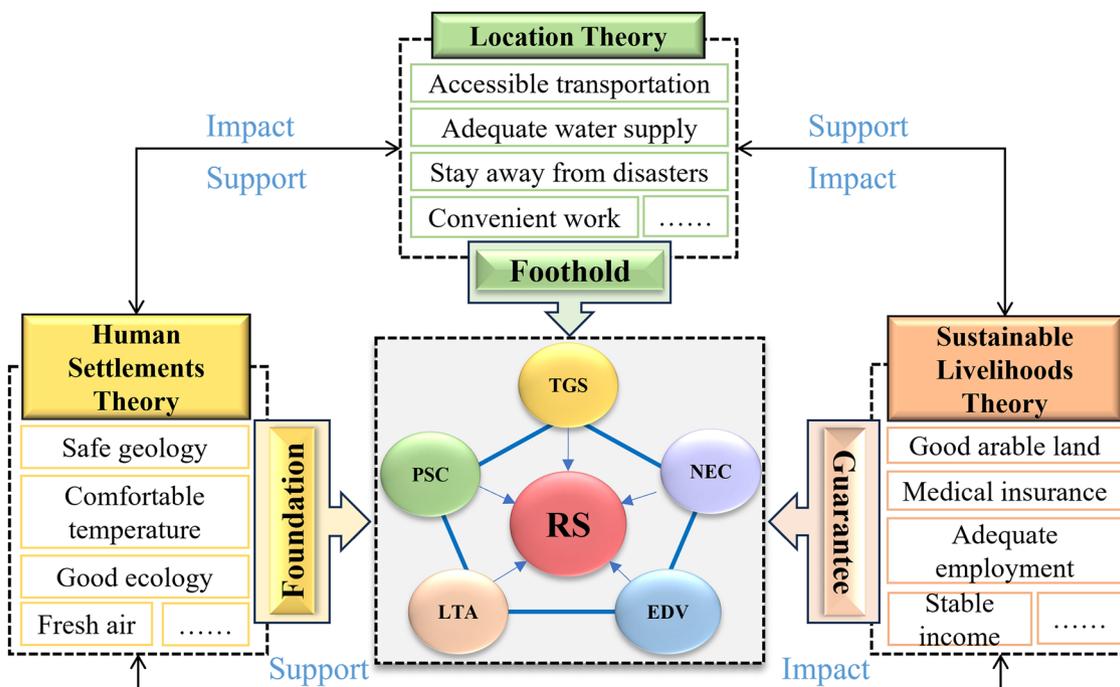


Fig. 3 Theoretical framework.

development of immigrants. This study combines the actual survey of the resettlement area to comprehensively analyze the RS of immigrants in arid mountainous areas from five dimensions: TGS, NEC, EDV, LTA, and PSC (Fig. 3).

Humans and nature are the two cores of the human settlement environment theory, which includes three significant elements: time, space, and people. Immigration projects need to consider basic elements such as topography, climate, ecology, and security in the new resettlement area (Younes et al., 2022). In addition, the migration of a large number of people to the new resettlement area in a short period will cause the new immigrants to have an impact on the residential environment and social structure. Therefore, it is necessary to refer to the human settlement environment theory to select the ideal location of the resettlement site, to repair the environmental impact caused by the short-term population agglomeration, and to gradually improve the new network of relationships between humans and nature, so that immigrants can better integrate into the new living space (Wang et al., 2017).

Location theory is a theory that explores the optimal location selection and is also a theory that explains the spatial distribution

of human economic activities and their related relationships. The resettlement area in arid areas should have a good location, such as convenient transportation, far from disasters, and close to water sources. It not only largely determines the convenience of production, life, and employment after the resettlement of immigrants but also affects the subsequent stability and sustainable development of the resettlement project (Younes et al., 2022). Therefore, the location theory helps this study to more scientifically incorporate location factors such as proximity to transportation stations and distance from disaster sites into the indicator system for evaluating the RS of immigrants living in arid areas, which helps to obtain more scientific evaluation results.

In addition, the sustainable livelihood theory shows that immigrant families acquire survival skills and social capital to maintain social competitiveness and obtain economic income through external extraction or transformation of their labor (Ma et al., 2024; Masotti et al., 2025). The government should play a role in resource allocation, ensure that immigrants have good farming and sufficient employment conditions, and fully mobilize education, medical, and public resources to improve the

Table 2 Evaluation factors and internal relationships with ecological migration.

Dimensions	Main factors	Internal relationship
Topography and Geology	Lithology Foundation Geology	Determines the feasibility of resettlement project construction Determines the stability and safety of resettlement housing Avoid geological factors affecting immigration safety
Natural Environment	Water Disaster Resource Climate Vegetation	Ensure convenient and safe water supply for migrants Threatening the lives and property of immigrants Impact on the sustainability of resettlement areas Impact on the comfort of immigrants' lives Impact on the ecological environment of resettlement areas
Economic Development	Location Transportation Infrastructure Land resources Industry	Regional accessibility affects immigrant suitability Impact on immigration transportation convenience Impact on the quality of life of immigrants Impact on immigrants' primary industry income Impact on immigration income and sustainability
Social Environment	School Hospital Culture Public services	Impact on the education of immigrant children Impact on immigrants' health Impact on immigrants' social integration Basic living and physiological needs of immigrants

livelihood capacity of immigrants. Promote the economic and cultural development of resettlement areas from multiple angles, help immigrants get rid of the threat of returning to poverty, and achieve sustainable living conditions. Therefore, sustainable livelihood theory is helpful to guide managers to comprehensively improve the livelihood capital of immigrants from the perspective of immigrants and ensure the sustainable development capacity of immigrants.

Methods to measure the resettlement suitability.

(1) Selection of evaluation indicators

First, based on implemented migration resettlement policies in China and Gansu Province, the study refers to existing research to identify EM resettlement area RS impact indicators. Then, the corresponding evaluation indicators were adjusted based on two 16-day field surveys of EM in Gansu Province. Finally, consulting authoritative immigration policy experts and scholars, the evaluation indicators were adjusted to ensure representativeness.

Due to geographical environmental influences, China and Gansu Province's resettlement site location plan follows these criteria: first, being far from natural disasters like landslides, mudslides, and geological fault zones; second, having flat, open terrain with high environmental carrying capacity and safe, accessible water sources; third, possessing complete transportation and service facilities alongside a vibrant economy and industry. Thus, when selecting indicators, this study focused on these criteria and regarded topography, geology, natural disasters, and resettlement-related public services as essential elements. Subsequently, we referred to existing related literature (Luo et al., 2021; Park et al., 2011; Ustaoglu and Aydinoglu, 2020; Yalaw et al., 2016; Younes et al., 2022; Zhang et al., 2013; Zhao et al., 2021), and field research was conducted from November 5 to 21, 2022, visiting EM resettlement sites in Gulang County, Gansu Province. Face-to-face interviews were held with local migrants and five experts to understand migrant needs before, during, and after resettlement. RS-related factors were sorted out, and their internal relationships were explained (Table 2).

Finally, to ensure the evaluation indicators' comprehensiveness and authenticity, we combined the above content and made adjustments. We increased the distance from the fault zone for geological and terrain factors. Given Gansu Province's abundant tourism resources, if immigrants can be settled near tourist attractions, it may improve the immigrants' living quality and

provide them with additional economic income. which will drive development in resettlement areas and their regions, this is categorized as an EDV.

Gansu Province experiences drought and water scarcity. Referring to the previous study (Luo et al., 2021), incorporating the meteorological index into the assessment system will make the RS assessment results of migrants in drought-stricken mountainous areas more scientific. Immigrants require water for production and daily life. Hence, rainfall and distance from the water system were included. Given the frequent landslides in Gansu Province, TGS was enhanced to account for disaster susceptibility. Using GIS's natural breakpoint method and referencing existing research, all single factors were categorized into five levels and scored (9, 7, 5, 3, and 1 points), establishing the final evaluation index system (Table 3).

(2) Determination of indicator weights

First, referring to existing research (Luo et al., 2021; Younes et al., 2022), the AHP was used to rank RS evaluation indicators by importance and construct an RS evaluation framework (Fig. 4). The AHP is widely used to calculate corresponding mathematical models for determining various factors and index weights. The main steps include constructing a judgment matrix, calculating individual factor weights, and checking consistency for single and overall judgment matrices. Based on the study area's characteristics, five experts ranked the large immigrant resettlement area's evaluation indicators by importance. Their results were incorporated into the above framework to calculate corresponding subjective weights. A consistency test was also conducted on the constructed judgment matrix to minimize human factor influence. The formula is as follows:

$$\text{Consistency Index (CI)} = \frac{\lambda_{\max} - n}{n - 1} \quad (1)$$

$$\text{Consistency Ratio (CR)} = \frac{\text{Consistency Index (CI)}}{\text{Random Consistency Index (RI)}} \quad (2)$$

In the formula, *CI* is the consistency index; *n* is the number of judgment matrix indicators; λ_{\max} is the maximum eigenvalue of the comparison matrix. When *CI* = 0, the matrix has complete consistency, and the closer it is to 0, the better the consistency, and vice versa. *RI* is the average random consistency index value. When *CR* < 0.1, the judgment matrix meets the consistency

Table 3 Evaluation indices and classification standards for resettlement suitability.

Dimensions	Indicators	Suitability classification and assignment					References
		9	7	5	3	1	
Terrain geological stability (TGS)	altitude/m (X1)	556-800	800-1800	1800-2800	2800-3600	3600-5825	(Zhang et al., 2013)
	slope/° (X2)	<5	5-8	8-15	15-25	>25	(Yalew et al., 2016)
	distance from geological hazards/km (X3)	>2	1-2	0.5-1	0.3-0.5	<0.3	(Ustaoglu and Aycinoglu, 2020)
	distance from fault zone/km (X4)	>2	1-2	0.5-1	0.2-0.5	<0.2	(Younes et al., 2022)
	disaster susceptibility (X5)	never	low	medium	high	extremely high	(Younes et al., 2022)
	geological lithology (X6)	solid	harder	softer	pliant	extremely soft	(Ustaoglu and Aycinoglu, 2020)
	precipitation/mm (X7)	277-372	207-277	133-207	68-133	23-68	-
	distance from water/km (X8)	<1	1-2	2-3	3-5	>5	(Zhang et al., 2013)
	distance to nature reserve/km (X9)	>5	4-5	3-4	3-2	<2	(Luo et al., 2021)
	vegetation cover (X10)	0.8-1.0	0.6-0.8	0.4-0.6	0.2-0.4	0-0.2	(Luo et al., 2021)
Natural ecological comfort (NEC)	meteorological index (X11)	0.8-1.0	0.6-0.8	0.4-0.6	0.2-0.4	0-0.2	(Luo et al., 2021)
	pm2.5/µg/m³ (X12)	13.9-21.9	21.9-28.2	28.2-34	34-42.3	42.3-53.9	-
	land use type (X13)	urban	settlements	barren	grass	arable water, forest	(Park et al., 2011)
	cultivation radius/km (X14)	<0.5	0.5-1	1-1.5	1.5-2	>2	-
	farmland production potential/ton/ha (X15)	>5.5	3.5-5.5	2-3.5	0.6-2	<0.6	-
	distance from factory/km (X16)	<1	1-2	2-3	3-5	>5	(Zhang et al., 2013)
	tourism development potential (X17)	0.8-1.0	0.6-0.8	0.4-0.6	0.2-0.4	0-0.2	(Younes et al., 2022)
	POI kernel density (X18)	0.63-1	0.3-0.63	0.1-0.3	0.03-0.1	0-0.03	-
	distance from national highway/km (X19)	<2	2-3	3-5	5-10	>10	(Zhang et al., 2013)
	distance from provincial highway/km (X20)	<1	1-2	2-3	3-5	>5	-
Location transportation accessibility (LTA)	distance from county road/km (X21)	<	1-2	2-3	3-5	>5	-
	distance from train station/km (X22)	<1	1-3	3-5	5-10	>10	-
	distance from town/km (X23)	<0.5	0.5-1	1-2	2-3	>3	-
	distance from county/km (X24)	<5	5-10	10-20	20-30	>30	(Younes et al., 2022)
	distance from hospital/km (X25)	<0.8	0.8-2	2-3	3-5	>5	(Younes et al., 2022)
	distance from school/km (X26)	<0.8	0.8-2	2-3	3-5	>5	-
	distance from park/km (X27)	<0.8	0.8-1.5	1.5-2	2-3	>3	-
	distance from shopping mall/km (X28)	<0.8	0.8-1.5	1.5-2	2-3	>3	-
	distance from scenic spots/km (X29)	<1	1-2	2-3	3-5	>5	-
	Public service convenience (PSC)						

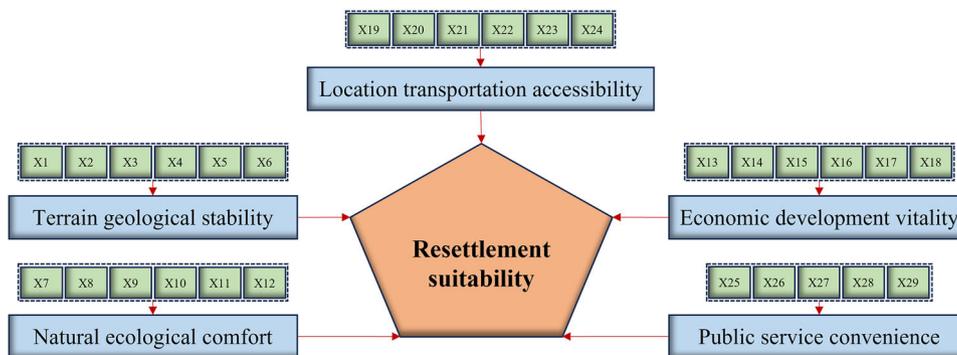


Fig. 4 A structural model framework for evaluating resettlement suitability based on AHP.

Table 4 Weights of evaluation indices for resettlement suitability of ecological migration.

Dimensions	Indicators	Attribute	Subjective weight	Objective weight	Comprehensive weight
TGS	X1	-	0.1377	0.0312	0.0845
	X2	-	0.2097	0.0327	0.1212
	X3	+	0.0638	0.0310	0.0474
	X4	+	0.0593	0.0326	0.0460
	X5	-	0.0275	0.0422	0.0349
	X6	+	0.0148	0.0407	0.0278
NEC	X7	+	0.0233	0.0340	0.0286
	X8	-	0.052	0.0319	0.0420
	X9	+	0.0342	0.0318	0.0330
	X10	+	0.0036	0.0399	0.0217
	X11	+	0.01	0.0414	0.0257
	X12	-	0.0059	0.0356	0.0207
EDV	X13	+	0.1242	0.0325	0.0783
	X14	-	0.0346	0.0310	0.0328
	X15	+	0.067	0.0310	0.0490
	X16	+	0.017	0.0324	0.0247
	X17	+	0.01	0.0382	0.0241
	X18	+	0.0088	0.0313	0.0201
LTA	X19	-	0.0021	0.0318	0.0169
	X20	-	0.0021	0.0361	0.0191
	X21	-	0.0043	0.0365	0.0204
	X22	-	0.0163	0.0318	0.0241
	X23	-	0.0301	0.0358	0.0329
	X24	-	0.0085	0.0313	0.0199
PSC	X25	-	0.0171	0.0366	0.0268
	X26	-	0.0087	0.0335	0.0211
	X27	-	0.0021	0.0326	0.0174
	X28	-	0.0043	0.0374	0.0209
	X29	-	0.0011	0.0352	0.0181

Note: + is a positive indicator, - is a negative indicator.

verification, and the quantitative indicator weight will appear; otherwise, the experts must readjust until the conditions are met. This study refers to the literature (Wang et al., 2022) and obtains a CR value of 0.053, indicating that the AHP matrix is consistent, weight analysis can be performed, and it is suitable for assessing RS.

Then, the single-factor weight calculation, the consistency test of the single judgment matrix, and the overall judgment matrix are performed individually, and the corresponding weights are calculated using the EVM for the obtained values (Younes et al., 2022). Finally, the average value calculated by the two methods is used as the final weight of the evaluation index (Table 4).

The EVM is an objective weighting method that determines the weight of an indicator based on the overall impact of its relative change on the system. It is widely used in calculating information

entropy of human settlement environment evaluation indicators, which can compensate for the impact of subjective weighting methods such as the AHP.

With m evaluation objects and n evaluation indicators, the original data matrix $R = (r_{ij})_{m \times n}$ is formed (Sun et al., 2023). The entropy for the j -th index is defined as:

$$e_j = (-1/\ln n) \times \sum_{i=1}^m P_{ij} \ln P_{ij} (0 \leq e_j \leq 1)$$

$$(i = 1, 2, 3, \dots, m; j = 1, 2, 3, \dots, n) \tag{3}$$

Where m is the number of evaluation objects. e_j is the entropy of the i -th index.

$$P_{ij} = r_{ij} / \sum_{i=1}^m r_{ij} \tag{4}$$

Where P_{ij} is the proportion of the index value of the j -th index from the i -th item. When $P_{ij} = 0$, the calculated entropy value is meaningless.

Calculate the entropy weight of the j index:

$$W_j = (1 - e_j) / \sum_{j=1}^n (1 - e_j) \quad (5)$$

(3) Evaluation model construction

This study used the range standardization method to standardize each indicator, eliminating the different dimensions of the data. The maximum effect standardized formula (6) for positive indicators was used; larger values indicate more excellent suitability and vice versa. The minimum effect standardized formula (7) for reverse indicators was applied; larger values indicate smaller suitability and vice versa. Considering topography, ecology, economy, transportation, and public services, a resettlement suitability index (RSI) evaluation model like formula (8) was constructed. The relevant calculation formulas are as follows:

$$S_{i1} = (x_i - x_{\min}) / (x_{\max} - x_{\min}) \quad (6)$$

$$S_{i2} = (x_{\max} - x_i) / (x_{\max} - x_{\min}) \quad (7)$$

$$RSI_i = a' \times TGS_i + b' \times NEC_i + c' \times EDV_i + d' \times LTA_i + e' \times PSC_i \quad (8)$$

In the formula, RSI_i is the resettlement suitability index of the i -th grid, a' , b' , c' , d' , e' are the comprehensive weights of the TGS and NEC, EDV, LTA, and PSC, respectively.

Local spatial autocorrelation. Local spatial autocorrelation, a statistical analysis method, explores local correlations in geospatial datasets. Unlike global autocorrelation, local autocorrelation analysis focuses on discovering local area correlation patterns in geospatial datasets, not the entire dataset's correlation. The derivation process can be referred to as Anselin (1995). The calculation formula is:

$$I_i = \frac{n(x_i - \bar{x})}{\sum_{i=1}^n (x_i - \bar{x})^2} \sum_{j \neq i} (x_j - \bar{x}) \quad (9)$$

Where I_i denotes the local Moran's Index, when I_i is a positive value, there is aggregation between local space units; when I_i is a negative value, the similarity values of local space units tend to be dispersed. According to the relationship between each spatial unit and its adjacent units, spatial correlation is divided into four types: "High-High," "High-Low," "Low-Low," and "Low-High." Here, x_i and x_j denote the RSI of raster i and another raster j , respectively, while \bar{x} represents the average RSI across all raster.

Obstacle model. Existing studies indicate that combining evaluation indicator weights and using the obstacle model can analyze the main RS improvement obstacles. Referring to the literature (Zhao et al., 2022), we calculated three quantifiable factors: indicator's deviation degree (F_j), degree of indicators deviation (O_j), and degree of obstruction (V_j). The calculation formula is as follows.

Calculate the factor contribution:

$$F_j = R_j \times w_j \quad (10)$$

Where R_j is the RS, and w_j is the comprehensive weight of the indicator.

Create the indicator deviation matrix:

$$H_j = 1 - F_j \quad (11)$$

Where F_j is the standardized value of each indicator through range standardization.

Calculate the degree of obstruction of indicator j :

$$O_j = \left[H_j \times F_j \sum_{j=1}^m (H_j \times F_j) \right] \times 100\% \quad (12)$$

$$V_j = \sum O_j \quad (13)$$

Where O_j is the degree of obstruction of a single indicator to the RS. The larger value of the O_j means a greater obstruction to improving the RS. And, V_j is the degree of obstruction of each criterion layer to the RS.

Result

Comprehensive assessment of resettlement suitability

Single-factor suitability of resettlement. TGS exhibits lower values in the south and higher values in the north, with the northern desert area significantly higher than the southern mountainous area. The index ranges from 0.73 to 3.16. The south's mountainous terrain and high altitude make summer precipitation prone to inducing geological disasters, threatening immigrants' lives and property. Although the north has flat terrain, it is mostly desert. Consequently, areas with unsuitable TGS are predominantly in the south, while high-suitability areas are in the north, accounting for 11.6% and 32.24% of the area, respectively (Fig. 5a). NEC exhibits higher values in the south and lower values in the north, gradually decreasing along the river system. Water sources and convenient water access ensure immigrant livelihoods and agricultural production. Thus, high-value NEC-suitable areas are mainly in the south, accounting for 8.23% of the area (Fig. 5b).

EDV presents a circular structure that gradually decreases from the central city to the surrounding areas. Spatially, the quality of urban economic development is significantly higher than that of the surrounding villages. As the provincial capital, Lanzhou City is centrally located with a concentrated population and a complete industrial structure. Although the north has good farming conditions and high farmland production potential, its sparse population and limited resources make high-value EDV suitable areas concentrated in Lanzhou's central urban area, accounting for only 1.24%. Unsuitable areas are mainly in the northern mountainous zone, accounting for 54.65% (Fig. 5c). LTA shows a spatial distribution that gradually decreases from the core to surrounding nodes, with traffic trunk lines and railways exhibiting a dendritic distribution (Fig. 5d). PSC is spatially dispersed yet locally concentrated, ranging from 0.10 to 0.94. Central urban areas have significantly higher public service quality than surrounding areas (Fig. 5e). Gansu Province's vast territory, sparse population, undulating terrain, and underdeveloped economy mean road networks and public service facilities need improvement. High-transportation accessibility and PSC resettlement areas are concentrated in the central urban area, with the most diminutive proportions at 1.96% and 0.31%, respectively.

Comprehensive suitability of resettlement. In the study area, RS is spatially higher in the central and northern low-altitude central urban areas than in the southern high-altitude mountainous areas. Proximity to the central urban area correlates with higher suitability. RSI along transportation lines is significantly higher for suitability values than in mountainous areas. Central urban areas generally have higher RSI than rural areas, with the highest value at 7.44 and the lowest at 1.83 (Fig. 6a). Using GIS spatial analysis tools, we explored RS cluster distribution and found that high-low clusters are concentrated in the north, high-high

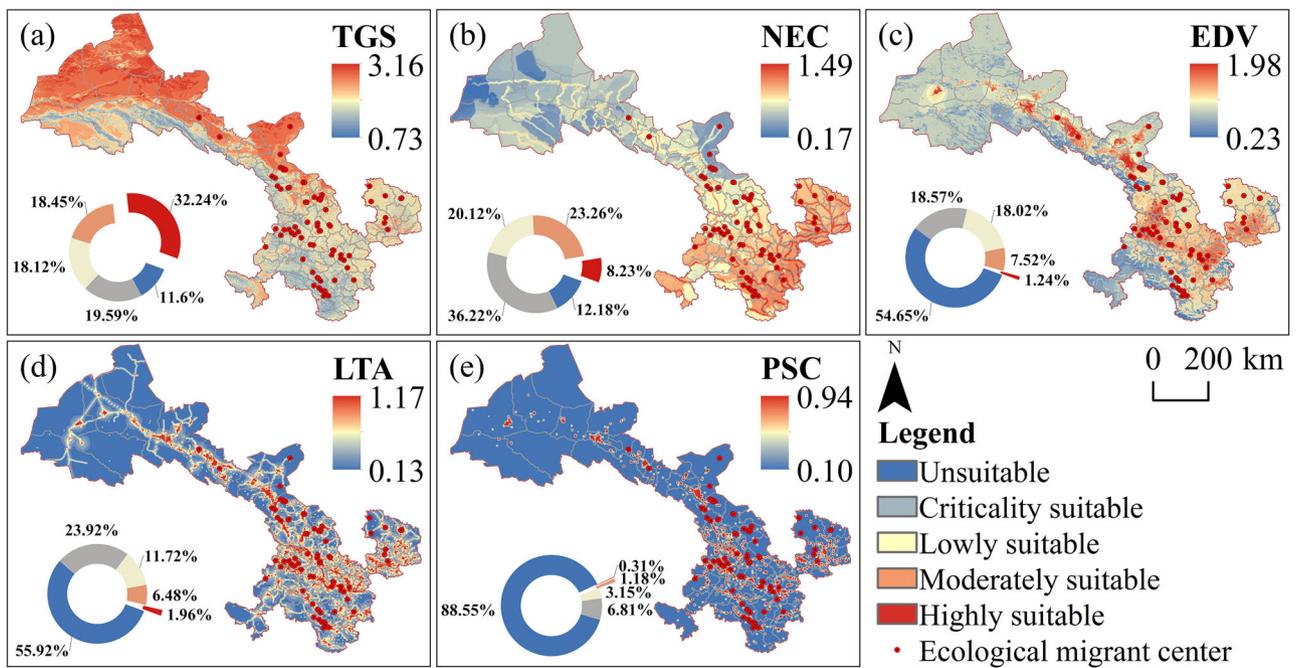


Fig. 5 Spatial distribution and type proportion of single-factor suitability of ecological migration. Terrain geological stability (a), natural ecological comfort (b), economic development vitality (c), location transportation accessibility (d), public service convenience (e).

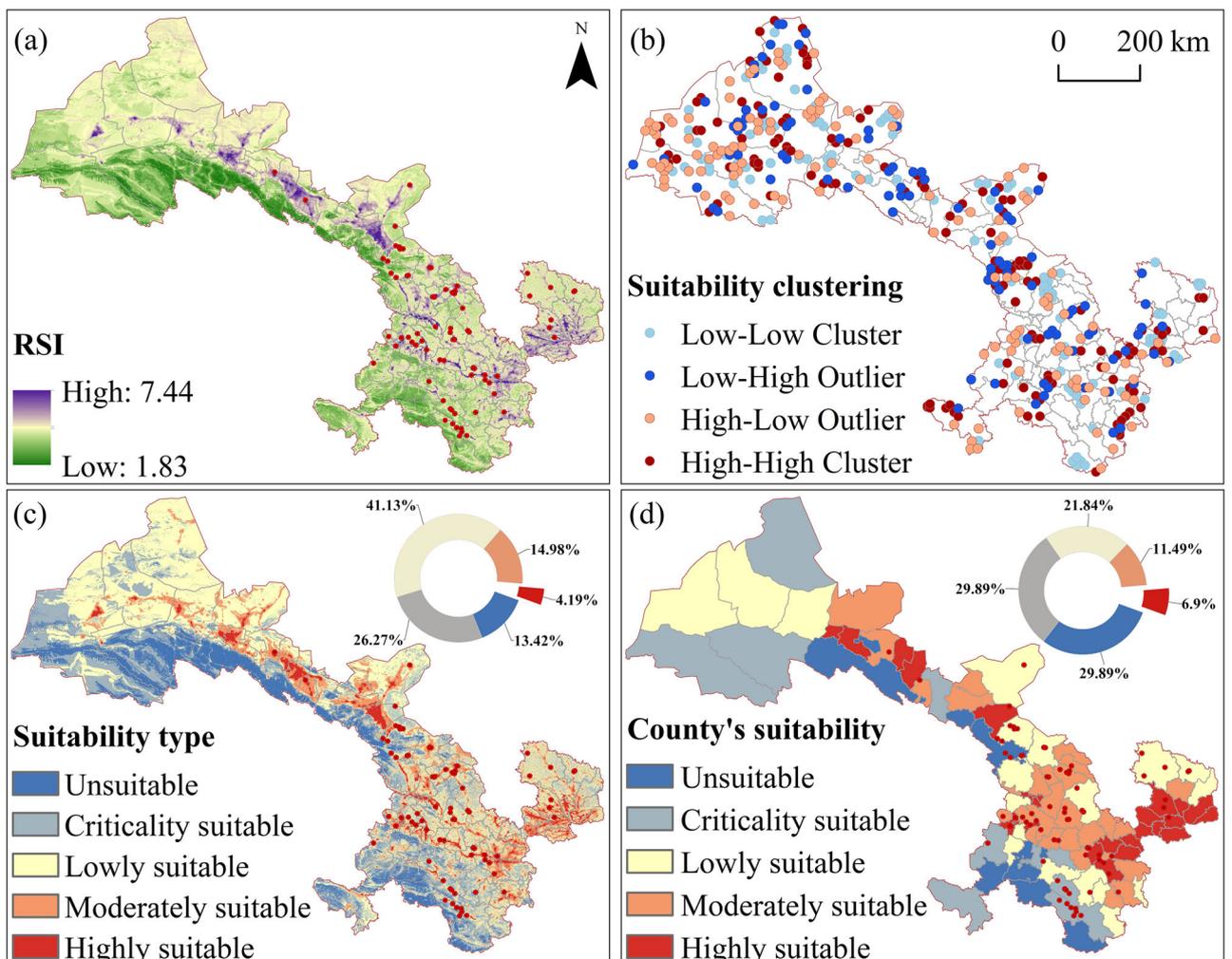


Fig. 6 Spatial differentiation of the comprehensive suitability of ecological migration. Resettlement suitability index (a), Suitability clustering (b), Suitability type (c), Suitability of counties (d).

Table 5 Comprehensive suitability classification area and proportion.

Suitability rating	Suitability index range	Area (km ²)	Proportion (%)
Unsuitable area	1.83-3.41	56,006.58	13.42
Criticality suitable area	3.41-3.98	109,628.27	26.27
Lowly suitable area	3.98-4.47	171,623.07	41.13
Moderately suitable area	4.47-5.13	62,497.13	14.98
Highly suitable area	5.13-7.44	17,485.45	4.19

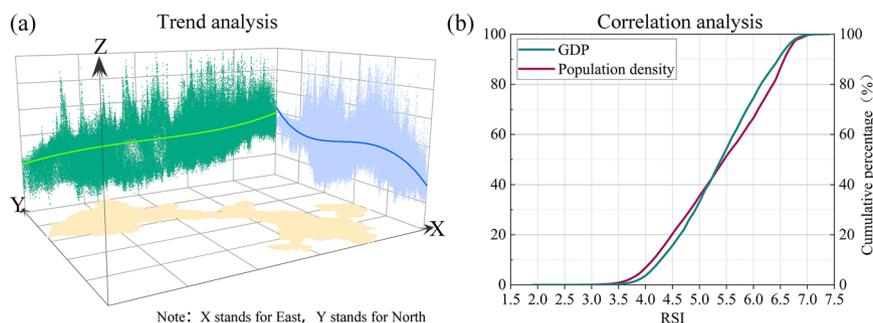


Fig. 7 Spatial trend distribution and correlation analysis of resettlement suitability. Suitability distribution trend (a), Suitability correlation analysis (b).

clusters in the middle, and low-high and low-low clusters are scattered (Fig. 6b).

For suitability classification, critical suitability and unsuitable areas have the most significant proportions. They are concentrated in the southern mountainous area, while low-suitability areas are in the north. The tiniest proportions of medium and high suitability areas are concentrated in the central city (Fig. 6c). Remote mountainous areas with high altitudes have relatively backward transportation and are prone to natural disasters, making them less suitable for immigrants. In contrast, the central urban area has a concentrated population, complete facilities, and convenient transportation services. Thus, proximity to the urban area implies higher RSI.

At the county scale, RS spatial distribution matches the provincial pattern, showing spatial differentiation with the northeast significantly higher than the southwest. RS increases with proximity to the central county. There is a noticeable concentration effect on critical area suitability. The study area is dominated by borderline suitable and unsuitable counties (29.89%), while highly suitable counties account for only 6.9% (Fig. 6d). RS-classified areas show the following order: lowly suitable area (3.98–4.47) > criticality suitable area (3.41–3.98) > moderately suitable area (4.47–5.13) > unsuitable area (1.83–3.41) > highly suitable area (5.13–7.44). The lowly suitable area is 171623.07 km² (41.13%), and the unsuitable area is 56006.58 km² (13.42%) (Table 5).

Distribution trend of RS and its correlation with population density. Using ArcGIS’s trend analysis tool, we analyzed RS and found its distribution trend shows an ‘S’-shaped ‘slowly rising from west to east’ and ‘first falling, then rising, then falling’ from north to south (Fig. 7a). RS fluctuates sharply in the north-south direction, with the highest suitability value concentrated in the central part. Lanzhou City, the study area’s administrative center, has complete urban functions, a concentrated population, complete facilities, and a developed transportation network. Thus, RS shows a ‘high in the middle, low at both ends’ distribution. However, the surrounding rural areas have relatively scarce resources and less robust supporting facilities. Moreover, the immigration environment’s suitability declines rapidly from the center to the surrounding areas. This also verifies the necessity of ecological immigration in the southern mountainous areas (Zhang et al., 2022).

Analyzing the correlation between RS, population density, and GDP involves three steps. First, ArcGIS’s spatial analysis module will align RSI with population density and GDP data. Then, the corresponding grid’s suitability index, population density, and GDP will be calculated, and the data will be imported into SPSS for Pearson correlation analysis. Finally, plot the cumulative percentage curve in Fig. 5b. Results show that the study area’s population density and GDP distribution are spatially similar to RS. Higher RSI correlates with greater population density and GDP, with fitting curves showing an ‘S’ shape (Fig. 7b). When the RSI exceeds 3.5, the fitting curves for population and GDP rise rapidly. The curve slope is most significant at RSI 5. When RSI exceeds 4, the cumulative proportions of population density and GDP exceed 95%, indicating that higher population concentration and economic development vitality correspond to higher suitability, and vice versa. This result confirms the RS evaluation model’s validity (Wang et al., 2017).

Comparison of resettlement suitability in ecological migration.

For comparative case analysis, we selected three areas with the largest resettlement scales in Gansu Province’s resettlement project and four EM resettlement sites with different resettlement types. This allows us to clarify whether out-migration improves suitability and the differences in RS at different resettlement distances. Figure 8 presents the spatial locations, RSI, and resettlement types of these areas and sites.

Differences in suitability at different placement distances and locations. We conducted a comparative analysis of different resettlement distances. The high RSI values for short-distance immigrants were concentrated in two western towns, showing a strip distribution. Long-distance immigrants’ high RSI values are widely distributed, concentrated, and contiguous. In contrast, the original residence’s high RSI values are concentrated in the south and are smaller than in the two resettlement areas. Additionally, the average RSI shows that long-distance resettlement is 14.63% higher than short-distance resettlement, with significantly higher TGS. However, the original core area’s relatively complete infrastructure in short-distance resettlement results in slightly higher average NEC, EDV, LTA, and PSC values than in long-distance resettlement areas.

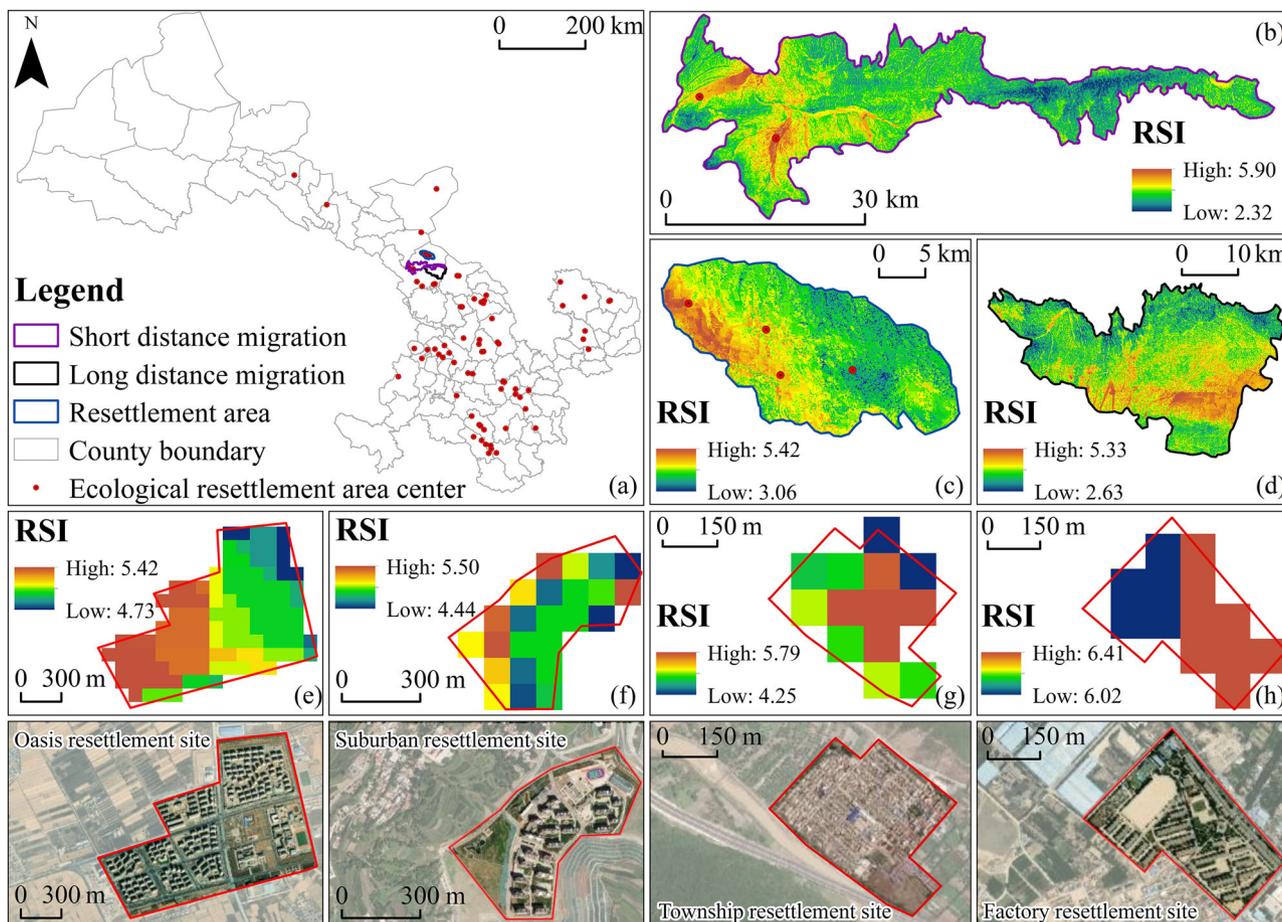


Fig. 8 Suitability of different ecological migration types. Note: Resettlement site location (a), short-distance resettlement (b), long-distance resettlement (c), original resettlement location (d), oasis resettlement site (e), suburban resettlement site (f), township resettlement sites (g), industrial park resettlement sites (h).

Table 6 Resettlement suitability of different ecological migration types.

Type		Average value					
		TGS	NEC	EDV	LTA	PSC	RSI
Placement distance	Short distance	2.02	0.56	0.71	0.33	0.15	3.76
	Long distance	2.73	0.52	0.66	0.28	0.13	4.31
Placement location	Immigration area	2.29	0.69	0.68	0.22	0.11	3.99
	Oasis resettlement	2.83	0.74	0.99	0.42	0.11	5.11
	Suburban resettlement	0.19	0.88	1.01	0.59	0.56	4.92
	Township resettlement	2.42	1.41	0.89	0.44	0.19	5.35
	Factory resettlement	2.78	0.72	1.56	0.74	0.54	6.33

The study selected four resettlement types and used remote sensing images to compare RS differences. Immigrants resettled in industrial parks and near towns have higher RS than those in oases and suburbs. The average RSI of the four resettlement locations is ordered as follows: industrial park (6.33) > oasis (5.11) > suburbs (4.92). Moreover, industrial park resettlement sites have significantly higher average EDV, LTA, and RSI than the other three patterns. The average EDV is as high as 1.56, 75.28% higher than township resettlement sites (Table 6).

Differences in the resettlement suitability of 73 ecological migration. Among Gansu Province’s 73 EM resettlement areas, 50 (68.49%) have a high RSI, 17 (23.29%) have moderate suitability, and six (8.22%) have low suitability. Critical suitability and

unsuitability proportions are 0, with over half of the EM resettlement sites in highly suitable areas (Fig. 9). Resettlement in Gansu Province aims to protect the ecological environment and reduce poverty. Most built EM resettlement areas are far from nature reserves and ecologically sensitive areas, close to factories and traffic arteries, with relatively flat terrain and low altitude. The number and proportion of indicators in five dimensions for the 73 EM resettlement areas in highly suitable areas are LTA > EDV > NEC > TGS > PSC. Moreover, the number of TGS, NEC, EDV, and LTA indicators in moderate and high suitable ranges is significantly higher than that of PSC. Due to imperfect infrastructure construction in resettlement areas and minimal investment in public service facilities, 21 of 73 large resettlement areas have PSC values in unsuitable areas, accounting for 28.77%.

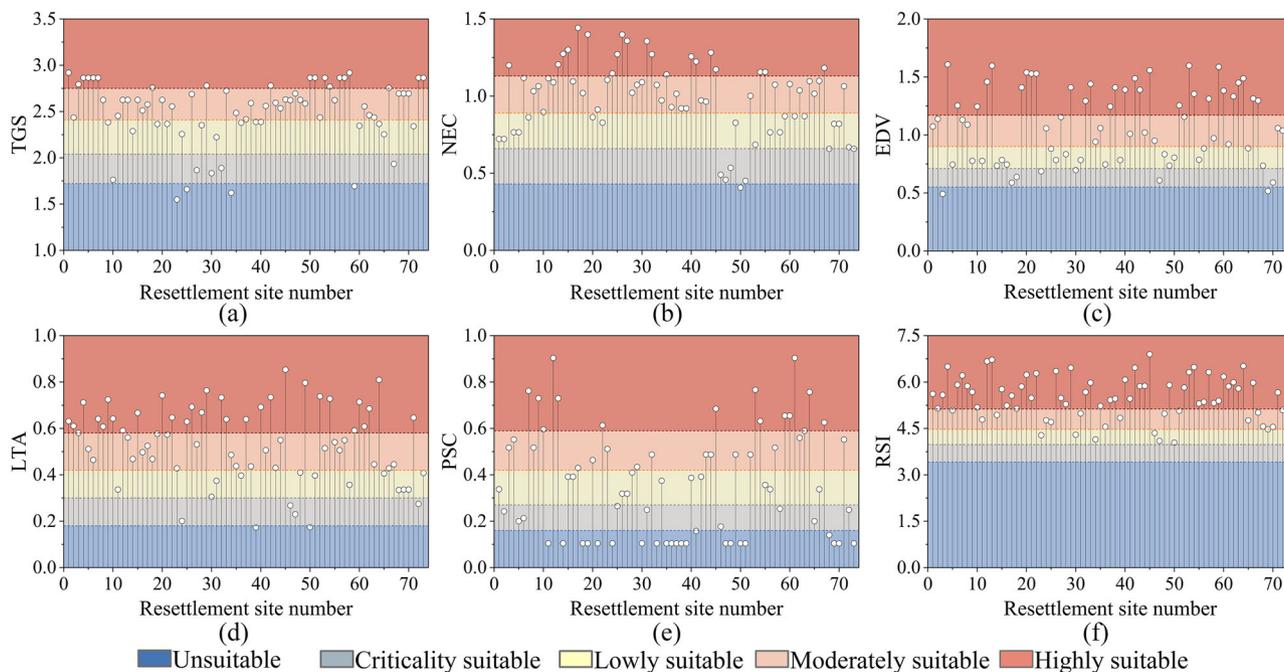


Fig. 9 Differences in resettlement suitability among 73 migration sites. Terrain geological stability (a), natural ecological comfort (b), economic development vitality (c), location transportation accessibility (d), public service convenience (e), Resettlement suitability index (f).



Fig. 10 Living environment of migrants in arid mountainous areas of Gansu Province before and after migration.

Differences in resettlement suitability before and after migration. To verify the reliability of EM resettlement RS assessment results, we combined experimental evaluations with field surveys of resettlement sites. We conducted face-to-face interviews with residents and local governments. We collected abundant data on pre- and post-migration living environments (Fig. 10). Data analyses revealed significant post-resettlement improvements in RS and quality of life, mainly in three aspects: First, residents now reside in an area characterized by flat terrain, convenient transportation access, and a relatively favorable natural environment, accompanied by substantial improvements in municipal infrastructure and enhanced residential amenities. Second, resettlement areas have implemented ecological protection and restoration projects like returning farmland to forests and grasslands, reducing ecological pressure and improving the environment. Third, resettlement has increased job opportunities, transformed agriculture from extensive to modern, significantly raised incomes, and introduced diversified leisure and entertainment, refreshing residents’ mental outlook.

Analysis of obstacles to resettlement suitability. We used the obstacle degree model to diagnose factors hindering suitability based on the RS evaluation. Results show that at the criterion level, the degree of obstruction to RS is TGS (37.11%) > EDV

(20.61%) > NEC (17.60%) > LTA (12.66%) > PSC (12.02%) (Fig. 11). At the indicator layer, the slope is the most significant single factor hindering RS improvement, with a hindrance degree of 13.70% and the highest comprehensive weight. The most minor hindering factor is distance from the county seat (1.33%). The top five hindering factors are slope, land use type, altitude, disaster susceptibility, and distance from fault zones, with only one from EDV and the rest from TGS. Additionally, the natural environment has more hindrance factors than the humanistic environment, with a higher comprehensive weight. Although NEC and PSC have low obstacles to RS, water sources (3.57%) and distance from hospitals (3.78%) are significant. These results indicate that during resettlement implementation, ensuring terrain and geological safety requires providing maximum convenience for immigrants’ water collection and medical treatment.

Discussion

The impact of different migration resettlement modes on suitability. This study developed a new framework to evaluate EM resettlement suitability in China’s arid mountainous areas, considering climate, geology, economy, transportation, and public services. Results showed that no EM resettlement sites were in unsuitable areas, indicating successful resettlement in ecological and geological disaster contexts (Sun et al., 2023; Yang et al.,

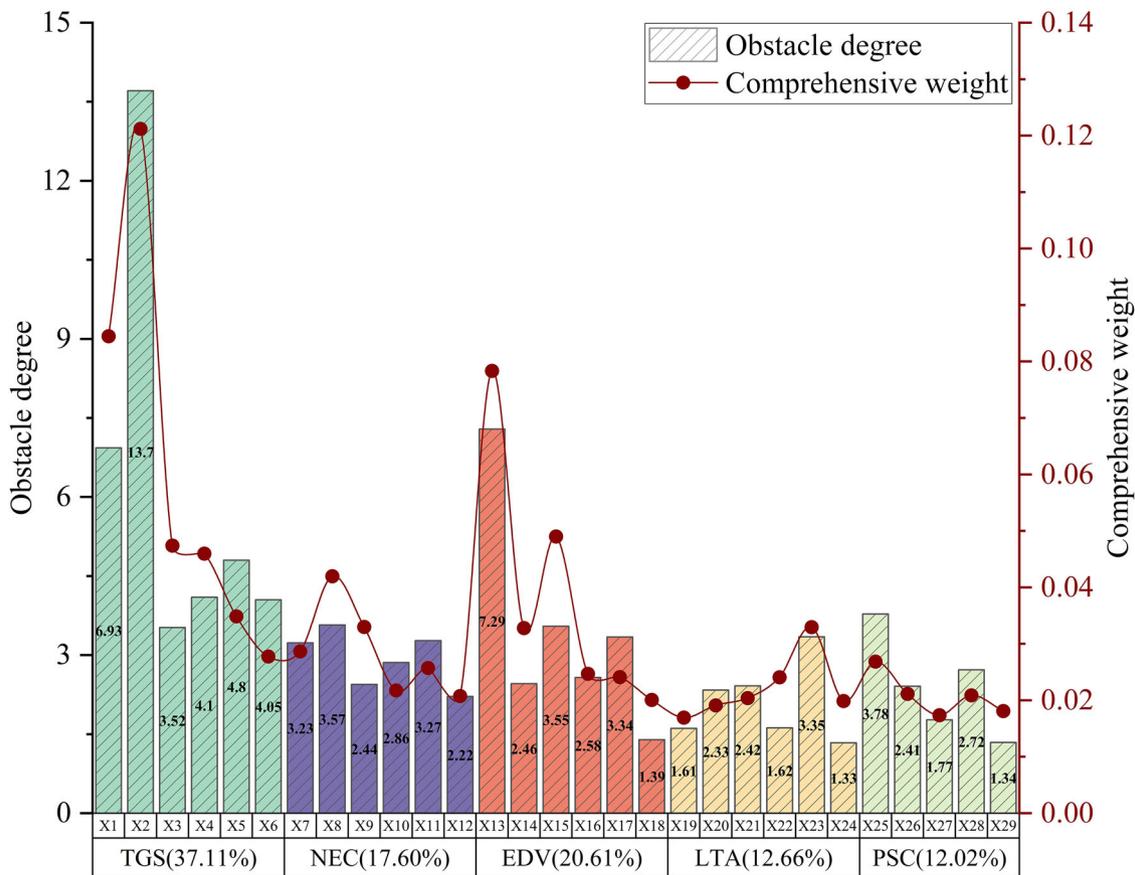


Fig. 11 Obstacle degree and comprehensive weight of resettlement suitability factors.

2023; Yokoyama et al., 2023; Zhu et al., 2021). Although short-distance resettlement saves funds by reducing transportation and construction costs, the original public service facilities can accommodate few immigrants. Relocating immigrants to newly planned distant areas improves RS and meets the EM of new immigrants' living needs through infrastructure expansion, aligning with existing research (Nikuze et al., 2022; Younes et al., 2022).

Moreover, comparing three resettlement locations, LTA and PSC may be key factors in immigrants' resettlement from their original residence. Our study found that resettlement location significantly impacts RS. Placing immigrants in industrial parks and near factories increases their income and allows the surrounding relatively complete infrastructure to meet new immigrants' needs. Providing convenient jobs ensures immigrants have considerable income, effectively helping them start anew (Fan et al., 2015; Peng et al., 2020). Resettlement in the other three locations may offer a comfortable ecological environment and convenient public services, but could affect the quality of life due to lower income. Additionally, governments should recognize the social disruption from short-distance resettlement and the importance of building social capital for stable, sustainable resettlement communities (Zhao et al., 2024).

It is worth noting that the slope is the greatest obstacle to the RS of EM in Gansu Province. Gansu Province's EM policy is mainly to relocate poor people living in mountainous areas with high altitudes, rugged terrain, and severe soil erosion to plains with flat terrain and relatively abundant resources (Zhang et al., 2022). In addition, the slope will have a significant adverse impact on the ecosystem of Gansu Province. For example, the original settlements in southern Gansu Province that need to be relocated are mostly in steep mountainous areas. Sudden rainstorms in

summer will cause severe soil erosion in the area, which may induce major geological disasters such as Zhouqu mudslides (Xiao et al., 2013), which will seriously affect the safety of migrants. In addition, Gansu Province has complex terrain, steep mountainous areas, poor soil, and high costs for agricultural facility construction and irrigation, which affect the way migrants use cultivated land and agricultural layout. Too high a slope will make the construction of infrastructure, such as roads, complex and costly, which is not conducive to the economic development of the original settlements of migrants. Therefore, for arid mountainous areas with undulating terrain, such as Gansu Province, the choice of resettlement areas and modes for migrants should take into account the capacity of the new area to accommodate migrants, as well as natural geographical factors such as flat terrain and being away from disasters, and social and humanistic needs such as the livelihoods of immigrants and community integration in the new environment.

However, with the changes in global extreme climate and the actual needs of migrants in other arid areas, these obstacles may also change. Therefore, subsequent researchers and managers should dynamically adjust the RS evaluation indicators for migrants. For example, for migrants in arid areas such as the Sahel and mountainous areas such as the Andes, local governments need to consider the potential threats to migrants from sea level rise and glacier melting based on referring to indicators such as geological disasters, convenient transportation, and public services covered in this study, as well as factors such as land use rights of migrants after cross-regional resettlement driven by climate into the evaluation criteria (Elagib et al., 2021). At the same time, it is also necessary to consider the seasonal mobility characteristics and migration patterns of regional long-distance migrants, the protection of security and human rights, and the

reasonable avoidance of local war conflicts and tribal control areas (Freeman, 2017), to choose the most appropriate resettlement site and model to ensure the safety and long-term livelihood of immigrants.

Migration resettlement projects should be dynamic and sustainable. Resettlement projects should mark the start of a better life for immigrants, not the end of the local government's responsibilities. The government should enhance post-resettlement compensation and assistance policies to boost immigrants' economic income (Egze et al., 2023). In addition, the management department can make scientific and dynamic decisions based on the three stages of resettlement: before, during, and after resettlement.

Before resettlement, geological surveys and the adoption of immigrants' wishes should be done well. A safe and stable geological environment is the basis for resettlement, and the adoption of the will of the masses determines the effective promotion of relocation policies. Therefore, in order to better achieve ecological protection and sustainable development of immigrants, before implementing immigration policies, the safety of the geological environment and the different psychological needs of immigrants must be fully considered. In the future, immigrants in other arid areas around the world can learn from this study's comprehensive analysis of multi-source data such as geology, hydrology, disasters, and location, combine immigration planning with the goals of ecological protection and socio-economic development on the premise of ensuring the safety of housing projects, publicize relocation policies through various channels, fully respect the wishes of the relocated people, and ensure the smooth implementation of policies.

During resettlement, pay attention to the livelihood development of immigrants and the carrying capacity of regional resources and the environment. Immigrants' livelihoods determine the sustainable development of their lives, and the carrying capacity of resources and the environment is related to the stability of the regional ecosystem (Ma et al., 2024; Masotti et al., 2025). Through face-to-face communication with immigrants, we found that individual costs in immigration projects may impact immigrants' sustainable development. For impoverished families unable to build or buy new houses, the government should offer more support, even free housing, to prevent immigration-induced 'secondary poverty' (Yang et al., 2020). In enhancing RS, the government should address natural challenges like geological disasters and terrain issues while focusing on cultural heritage preservation and humanistic projects, such as transportation network improvement, to manage better extreme disaster risks for migrants (Chen and Tsai, 2021). In addition, during the resettlement process, it is necessary to grasp the resource conditions of the resettlement area timely, continuously improve the ecological compensation system, understand the non-agricultural skills needs of immigrants, and adopt more comprehensive and fairer strategies to protect the lives of immigrants, such as changing the living and production methods of rural residents, increasing manual skills training and diversified employment opportunities to reduce their dependence on and damage to ecological resources (Liu et al., 2020; Zhang et al., 2022).

After resettlement, pay attention to the quality of immigrants' living environment and social relationship integration. It is crucial to expedite the establishment of immigrant communities and public entertainment venues, improve the humanistic quality of resettlement areas, and accelerate immigrants' status transformation and community integration (Guo et al., 2024). Good public service facilities and living quality can not only improve

the quality of life of immigrants in the context of climate change but also help improve immigrants' happiness and policy satisfaction. Immigration is not simply moving residents from one place to another; it also needs to ensure their stable and long-term livelihoods and a rich spiritual world after migration (Upadhyay, 2024). After promoting stable employment for migrants, the government should actively improve the relationship between people and land under traditional agricultural production, increase the construction of facilities in the migrant area, and improve the economic income of migrants by improving the compensation and assistance policies after resettlement (Yang et al., 2020). By establishing migrant communities and public entertainment venues, regularly carrying out local entertainment activities and cultural programs, improving the sense of integration and cultural identity of migrant communities, and enriching the spiritual needs of migrants, the sustainable development of migrants can be achieved.

Strategies to improve the resettlement suitability of immigrants. Strategies to improve the RS for different types of immigrants. First, accelerate integrated infrastructure construction in arid mountainous areas with low suitability and criticality to enable the co-construction and sharing of regional transportation networks and public services. Second, ecological environment protection and regional environmental carrying capacity evaluation should be actively conducted to enhance regional transportation accessibility. Enhancing immigrants' ecological protection awareness is crucial, focusing on ecological civilization construction and preventing fragile ecosystem damage from human production and life disorders (Younes et al., 2022). Third, the ecological priority development strategy in unsuitable arid mountainous areas should be implemented, focusing on topographic and geological safety, disaster risk reduction, and eliminating natural disaster threats to resettlement at the source. Targeted guidance directs the population to moderately and highly suitable living environments, achieving sustainable regional human and natural development.

Strategies to improve the RS for immigrants in different geographical locations. Priority should be given to immigrants around industrial parks with flat terrain and slopes less than 5°. For resettlement areas with sufficient sunlight and water resources but the risk of wind and sand intrusion due to climate change, ecological projects such as afforestation and windbreak and sand fixation should be accelerated, and green agricultural products such as fruits and vegetables should be vigorously developed. The construction of agricultural industrial chains should be accelerated to achieve economic prosperity in resettlement areas (Zhang et al., 2022). For resettlement areas with obvious location advantages but a lack of industries, the government should give play to the transportation advantages, take the construction of industrial parks as the starting point, create a labor-intensive industrial cluster of a "15-minute living circle", achieve regional linkage development, and increase the income of immigrants. For resettlement areas with obvious tourism resource advantages, the government should improve supporting construction, reasonably arrange public activity venues, give play to the advantages of the service industry dominated by tourism, and improve the living environment and income level of immigrants. At the same time, for areas with possible disaster risks, the government should improve the construction of disaster warning systems in resettlement areas, stabilize employment, reasonably allocate public service facilities, and improve the connectivity between resettlement areas and central urban areas on the premise of ensuring the safety of

immigrants' lives and property, to achieve safe, stable and sustainable development in resettlement areas.

Limitations and prospects. Although the RS evaluation system of arid mountain areas in this study cannot be fully extended to the global immigration practices in arid areas such as the Sahel or the Andes Mountains, the design ideas of this study are still of great significance for the decision-making of arid area immigration in the background of global extreme climate. First, this study starts with the RS in arid mountain areas, combines multi-source data related to immigration and field surveys in EM areas, and overcomes the subjective factors of traditional research data. Secondly, the research content covers TGS, NEC, EDV, LTA, and PSC that need to be considered in global immigration planning, providing scientific evaluation index selection dimensions and decision-making basis for arid area immigrants, and constructing an index system for the RS of arid area immigrants suitable for specific regions. Finally, the correlation between the RS and population density distribution is verified, and based on the results of the suitability study, important strategies for improving the RS of different types and geographical locations are proposed.

However, this study also has some limitations. First, this study selected the most appropriate 100×100 m resolution based on the actual characteristics of the resettlement area after field investigation, but different resettlement site sizes require the selection of their appropriate research scales and more detailed cases, such as internal groups in the resettlement area, are used to test the results. In addition, the analysis results of the local Moran index may be spatially non-stationary, and the GWR and GTWR models need to be used to improve their research accuracy. Second, the data in this study are static, but immigration and climate are dynamic, and the obstacles to the RS will also change with time and environmental changes (Wang et al., 2025). In addition, the AHP and EVM may have potential impacts on the research results. Dynamic time series data, such as RCP 4.5/8.5, can improve the RS evaluation index system for arid areas. Third, this study focuses on the impact of factors such as natural geography on RS and insufficient consideration of human factors such as psychology, family, and community (tribe) of the immigrant group, ignoring the impact of the heterogeneity of individual immigrants and the cohesion of immigrant communities on the happiness of immigrants. In the future, the natural and human factors related to immigration should be comprehensively considered to avoid the impact of the homogeneity of resettlement sites on research results, and the RS should be comprehensively analyzed from multiple levels, such as natural, livelihood, psychological, and cultural aspects.

Global extreme climate change is rapid, immigration resettlement projects are complex, and the influencing factors involve a wide range of dimensions and a large number, which requires a targeted selection of indicators and refined calculations. Therefore, future research on immigration decision-making and RS assessment can be deepened from the following perspectives. In data selection, the advantages of questionnaire survey data and remote sensing satellite data can be combined to improve the accuracy of research results jointly. When weighing indicators, the AHP, EVM, and comprehensive index method can be combined to determine the weights of evaluation indicators comprehensively, and regression models and robustness analysis can be used to improve the reliability of research conclusions. In dynamic analysis, long-term remote sensing satellite data can be combined with immigration survey statistical data to conduct a comprehensive analysis of ecological

environment monitoring before and after immigration, natural disaster simulation, and suitability influencing mechanisms. Select a reasonable time interval to explore the ecological restoration and human settlement changes before and after immigration resettlement, as well as the social integration, happiness, and satisfaction of immigrants. It will help to propose targeted, preventive, and scientific decisions to achieve the sustainable development goals of a comfortable living environment, harmonious human-land relations, and a stable social structure in the immigration area.

Conclusion

This paper focuses on EM resettlement sites in Gansu Province's arid mountainous areas. Through policy reference, literature review, field research, and expert consultation, we constructed an RS evaluation index system and model. Using the obstacle degree model, we diagnosed the main factors hindering RS. The key conclusions are: (1) RS is spatially higher in central and northern low-altitude urban areas than in southern high-altitude mountainous areas. Over half of the resettlement sites are in high-suitability areas. Resettlement areas along traffic arteries and near water systems are more suitable than other areas. (2) Long-distance resettlement in arid mountainous areas is more effective for EM projects than short-distance resettlement. The average RSI is 14.63% higher than short-distance resettlement, with significantly higher RS than the original locations. Industrial and adjacent town resettlement sites have much higher RS than oases and suburbs. (3) Topographic and geological stability is the biggest obstacle to improving RS in arid mountainous areas, with slope hindrance at 13.70%. Natural environmental obstacles outnumber humanistic ones. Moreover, distance to water sources and hospitals affects RS and post-resettlement sustainable development.

Data availability

The original datasets used in the study are included in the article; further inquiries can be directed to the corresponding author.

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WZ: Conceptualization, methodology, writing—original draft. LZ: writing—original draft, review & editing, Supervision. YZ: Methodology, writing—review & editing. CX: writing—review & editing. All authors reviewed the manuscript.

Competing interests

The authors declare no competing interests.

Ethical approval

This article does not contain any studies with human participants performed by any of the authors. Ethical approval was not relevant.

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