

Investigation and Evaluation on Suitability of Afforestation Space in Henan Province: A Case Study of Nanyang City, Henan, China

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Abstract Analysis on the investigation and evaluation data of afforestation space suitability in Nanyang City reveals that there are a total of 47,394 issued land parcels, covering an area of 102,400 hm². Among these, 20,834 parcels are suitable for afforestation with an area of 35,300 hm², while 7,220 parcels are planned for afforestation but not yet implemented, covering an area of 19,900 hm². Additionally, there are 26,560 parcels classified as unsuitable for afforestation with an area of 67,100 hm². There are also 13,614 parcels, with an area of 15,400 hm², that meet the criteria for afforestation space but have not been included in the planning. In view of discrepancies in land type classification or being outside the original evaluation scope in the investigation of afforestation space suitability evaluation, corresponding recommendations have been proposed to provide valuable references for scientifically formulating territorial greening plans and reasonably reserving afforestation space.

Keywords Afforestation space, Investigation and evaluation indicators, Indicators of land use assessment scope, Henan Province

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In order to implement the CPC Central Committee and the State Council's "double non" policy (preventing farmland "non-agriculturalization" and "non-grainization"), which strictly prohibits unauthorized afforestation on cultivated land and regulates greening construction along railways, highways, riverbanks, and around lakes and reservoirs, the Ministry of Natural Resources and National Forestry and Grassland Administration require scientifically planning afforestation spaces within territorial spatial planning and incorporating them into the "One Map" management system^[1]. The investigation and evaluation of the afforestation suitability in Nanyang City is mainly based on the land parcels issued by China, referencing the results of the Third National Land Survey and the annual land updates, and the "One Map" updates of forest resource management, in accordance with Article 4 of *Guiding Opinions of the General Office of the State Council on Scientific Greening*^[2]: "all regions shall scientifically delineate afforestation land based on the Third National Land Survey data and territorial spatial planning, considering land use structure and suitability factors for precision management." According to *Technical Scheme for Investigation and Evaluation of Afforestation Space*^[1,3], nationally issued land parcels include: "saline alkali land, sandy land and bare land suitable for afforestation, scrubland and other woodlands suitable for afforestation, and other land types meeting national regulations suitable for afforestation (excluding farmland-to-forest/

grassland conversion projects)." Based on the scheme, Henan Province has refined and extracted supplementary parcels from land survey data, including: illegally occupied/damaged forest lands from construction projects, abandoned mines for greening, as well as bare rock gravel land that meets the afforestation conditions, abandoned villages to be included in the afforestation space, legal corridor greening lands, scientifically planned farmland shelterbelts, and supplementary grassland parcels. The nationally issued parcels and supplementary parcels have undergone suitability evaluation for afforestation based on land pre-evaluation conditions (current land type, restricted land type), land suitability (precipitation, altitude, slope, soil thickness, other factors), and then are mapped in the afforestation mapping system, so as to resolve conflicts between afforestation planning and actual construction, ensure rational incorporation into the territorial "One Map", and establish a foundation for the precise expansion of afforestation spaces to realize the comprehensive and scientific improvement of forest quantity and quality.

1 Materials and methods

1.1 Overview of the study area

Located in the southwest of Henan Province, Nanyang City (10°58'–113°49' E, 32°17'–33°48' N) covers a total area of 26,600 km². It lies in the transition zone between the northern subtropical and warm temperate regions, characterized by a typical monsoon-influenced

continental humid subtropical climate, with an average annual temperature of 14.4–15.8 °C, an annual frost-free period of 225–240 d, and an average annual precipitation of 800–1,000 mm. The terrain slopes gently from north to south, forming a distinctive horseshoe-shaped basin in the central and southern areas. The city is connected to the Jiangnan Plain of Hubei Province, with yellow-brown soil as the main soil type^[4]. There are mainly Danjiang River, Tanghe River, Baihe River, Huaihe River, and Tuan River passing through the city.

According to the updated data released in 2023 by the Third National Land Survey of Henan Province, Nanyang City has a total forest land of 1,041,100 hm², including 921,200 hm² of arbor forest land, accounting for 88.49% of the total area of forest land in the city; 3,600 hm² of bamboo forest, accounting for 0.34% of the total forest land in the city; 31,400 hm² of scrubland, accounting for 3.02% of the total; 84,900 hm² of other forest lands, accounting for 8.15%. The grassland area is 35,200 hm².

1.2 Study methods

The afforestation suitability evaluation was conducted on both the nationally designated land parcels and supplementary parcels provided by provincial municipalities. The geographic information system (GIS) software was used to overlay all parcels within the evaluation scope with the images of current cultivated land, cultivated land reserves, planned construction land, core protected areas of natural reserves, permanent basic farmland and permanent basic

farmland reserves, and the parcels unsuitable for afforestation were excluded^[5-6]. Then, according to the evaluation indicators of land use scope and the investigation and evaluation indicators, the parcels that were included and not included in the afforestation space were determined. The suitability evaluation was conducted according to *Technical Scheme for Afforestation Spatial Survey and Evaluation in Henan Province*^[1], incorporating local suitability indicators (precipitation, altitude, slope, soil thickness, and other factors) in counties (cities/districts) under the administration of Nanyang City. The parcels verified as suitable were included in the afforestation space, while unsuitable ones required on-site verification when necessary. For on-site verification, National Land Resource Cloud App was used to conduct filed surveys, take photos as evidence, and provide supporting materials like on-site photo and relevant documents. Parcels verified as unsuitable or non-compliant through on-site surveys were not included in the afforestation space.

2 Discussion and analysis

2.1 Indicators of land use evaluation

The indicators of land use evaluation are the criteria to determine whether the land

parcels of Nanyang issued by the state and self supplemented parcels are included in the scope of afforestation suitability evaluation. The indicators of land use evaluation are as shown in Table 1.

As is shown in Table 1, the land types included in afforestation suitability evaluation are the parcels of other land, scrubland, other forest lands and supplementary parcels. Among them, other lands are mainly saline alkali land, sandy land and bare land. Scrubland is mainly other shrub land; other forest lands are mainly sparse forest lands, cut-over lands and burnt forest lands; the supplementary parcels mainly include 6 types—abandoned mines to be included in afforestation space, bare rock and gravel land meeting afforestation conditions, abandoned villages to be included in afforestation space, legally compliant green corridor construction land, scientifically planned farmland shelterbelt land for hazard-specific protection and other grassland; young afforested land and other non-standing tree forest lands shall be included in the afforestation space according to the local evidence and actual situation. There are 4 land types that are not included in the scope of afforestation suitability evaluation—other lands (mainly idle lands, facility agricultural lands, field

ridges and bare gravel lands), scrubland under special national regulations, nursery lands and farmland-to-forest conversion lands.

2.2 Investigation and evaluation indicators

As is shown in Table 2, the indicators for investigation and evaluation are classified into 2 categories—pre-evaluation conditions and land suitability indicators. The pre-evaluation conditions primarily consider 2 factors: current land type status and restricted land types^[7-8]. For afforestation suitability evaluation, land parcels with other non-standing tree forest lands can be included in the afforestation space, while 7 land types are excluded, namely, arbor forest land, bamboo forest land, scrubland under special national regulations, nursery lands, young afforested land, other land unsuitable for forestation but afforested land meeting greening standards and used for construction. As for restricted land types, 8 land types are prohibited from including in afforestation space: current arable land, planned arable land, reserve resources of arable land, nature reserve core area, planned construction land, planned wetland, urban development boundary and other land prohibited for afforestation by laws and regulations. Land suitability indicators include precipitation, altitude, slope,

Table 1 Indicators of land use evaluation

Included or not	Land type			Additional parcels	Note
Included in afforestation space suitability evaluation	Other land	Scrubland	Other forest land		
	Saline alkali land	Other scrubland	Sparse forest land	Abandoned mines to be included in afforestation space	Young afforested land and other non-standing tree forest lands shall be determined based on actual conditions.
	Sandy land		Cut-over forest land	Bare rock and gravel land meeting afforestation conditions	
	Bare land		Burnt forest land	Abandoned villages to be included in afforestation space	
Not included afforestation space suitability evaluation				Legally compliant green corridor construction land	Farmland-to-forest conversion land
				Scientifically planned farmland shelterbelt land for hazard-specific protection	
				Other grassland	
	Idle land	Scrubland under special national regulations	Nursery land		
	Facility agricultural land				
	Field ridges				
	Bare gravel land				

Table 2 Investigation and evaluation indicators

Evaluation indicators		Included in afforestation space	Not included in afforestation space
Pre-evaluation conditions	Land type status	Other non-standing tree forestland	Arbor woodland, bamboo grove, specially designated scrubland, nursery land, young afforested land, other land unsuitable for forestation but afforested land meeting greening standards and used for construction
	Restricted land type		Planned arable land, current arable land, reserve resources of arable land, nature reserve core area, planned construction land, planned wetland, urban development boundary and other land prohibited for afforestation by laws and regulations
Land suitability indicators	Precipitation	Over 400 mm	Annual precipitation below 200 mm
	Altitude		Altitude over 3 500 m
	Slope		Slope over 35° and unsuitable for afforestation by aerial seeding and sealing off for afforestation and grassing
	Soil thickness		Soil thickness below 30 cm and unsuitable for afforestation by aerial seeding and sealing off for afforestation and grassing
	Other factor		Other restricted factors that are considered as unsuitable for afforestation

soil thickness and other factors. Among them, the land with precipitation above 400 mm is included in the afforestation space, and the precipitation below 200 mm is not included in the afforestation space; the land with altitude below 3,500 is included, while over 3,500 is excluded; the land with the slope below 35° is included, while the land with the slope above 35° is excluded for being not suitable for afforestation by aerial seeding and sealing off for afforestation; the land with soil thickness over 30 cm is included, while the land with soil thickness below 30 cm is excluded for being not suitable for afforestation by aerial seeding and sealing off for afforestation; the lands with other factors that are considered as unsuitable for afforestation at local place are also not included.

2.3 Investigation and evaluation results

2.3.1 Analysis on suitable and planned afforestation space parcels. As is shown in Table 3, Nanyang City has a total of 39,992 issued land parcels, covering an area of 89,913 hm². In addition, the counties (cities, districts) of Nanyang City have added 7,402 parcels according to the requirements for supplementary parcels in the land use scope evaluation indicator table, with an area of 12,473 hm². Therefore, the total number of parcels for the suitability evaluation of afforestation space in Nanyang City is 47,394, with a total area of 102,387 hm².

Among the nationally issued land parcels, 20,834 parcels covering 35,300 hm² are suitable to be included in the afforestation space, accounting for 39.26% of the total area. Among the parcels included in the suitable afforestation space, 7,220 parcels are included in planned afforestation space, covering an area of 1,987 hm², accounting for 22.10% of the total. The number of parcels suitable to be included in the afforestation

space but not planned is 13,614, with an area of 15 427 hm², accounting for 17.16% of the total.

2.3.2 Analysis on unsuitable and unplanned afforestation space parcels. In Nanyang City, 26,560 land parcels covering 67,087 hm² have been identified as suitable for afforestation, mainly including land types of other lands, scrublands, and other forest lands. The main reasons for their unsuitability are as follows: water resource constraints; unsuitable site conditions for afforestation requirements; land with already completed afforestation operations; land being currently used as construction sites or other purposes; restricted land types belonging to the scope of cultivated land; others^[9].

In Nanyang City, there are 13,614 land parcels with an area of 15,427 hm² that are identified as suitable for afforestation but excluded from planning. The primary reasons for the exclusion include: current cultivated lands and those reclassified as cultivated lands during 2021–2022; parcels within existing or planned grain production zones and high-standard farmland construction areas; land parcels with slopes below 25° marked with restoration attributes; reserve land resources for cultivation; core protection zones of nature reserves; areas designated for construction land planning; other reason.

2.3.3 Analysis on supplementary patch suitability. According to *Technical Scheme for Afforestation Spatial Survey and Evaluation in Henan Province*^[10] and the land use scope evaluation indicator table, there are 7,402 of supplementary forest land parcels suitable for afforestation in Nanyang City, with an area of 12,473 hm², accounting for 5.51% of the total area of supplementary forest land parcels suitable for afforestation. There are 1,347 supplementary

grassland parcels, with a total area of 2,713 hm², accounting for 8.13% of the total area of supplementary grassland parcels suitable for afforestation in Henan Province. After evaluation, 2,581 supplementary forest land parcels are included in the planning afforestation space, with an area of 8,913 hm², and 943 additional grassland parcels are included in the planning of afforestation space, with an area of 1,793 hm².

3 Conclusions and suggestions

3.1 Conclusion

(1) After the investigation and evaluation of the issued land parcels and supplementary land parcels, there are a total of 47,394 land parcels suitable for afforestation among the issued parcels, covering an area of 35,300 hm²; there are 7,220 planned afforestation parcels with the area of 19,873 hm².

(2) There are 26,560 land parcels unsuitable for afforestation in Nanyang City, with an area of 67,087 hm². The number of parcels suitable to be included in the afforestation space but not planned is 13,614, covering an area of 15,427 hm².

3.2 Suggestions

(1) The results from Third National Land Survey and its annual updates should be integrated with multi-source data like forestry-grassland-wetland resource monitoring data, high-resolution remote sensing imagery, national soil survey results, meteorological and hydrological datasets, terrain characteristics (slope, aspect, altitude), ecological conservation redlines, permanent basic farmland, boundaries. Through establishing a standardized spatial database, the integration will develop a multi-source data fusion evaluation system, thereby laying the groundwork for conducting more accurate

Table 3 Parcels of investigation and evaluation of planned afforestation and greening space

Statistical unit	Work base map		Suitable afforestation space			Planning afforestation space			Suitable afforestation space without planning		
	Number of parcels	Area hm ²	Number of parcels	Area %	Area percentage/%	Number of parcels	Area hm ²	Area percentage/%	Number of parcels	Area hm ²	Area percentage/%
Nanyang city	39,992	89,913	20,834	35,300	100.00	7,220	19,873	100.00	13,614	15,427	100.00
Wancheng district	208	153	35	13	0.04	10	7	0.03	25	7	0.06
Wolong district	3,253	2,480	3,704	3,160	8.94	765	1,120	5.62	2,939	2,040	13.22
Nanzhao county	6,787	19,200	2,671	4,107	11.63	129	187	0.94	2,542	3,920	25.38
Fangcheng county	9,197	29,200	2,366	9,267	26.24	1,547	5,787	29.11	819	3,480	22.55
Xixia county	4,261	2,307	2,295	1,960	5.56	1,171	960	4.83	1,124	1,000	6.50
Zhenping county	1,453	1,347	781	1,307	3.70	30	33	0.16	751	1,273	8.27
Neixiang county	2,038	2,460	618	3,887	11.01	512	3,760	18.91	106	127	0.83
Zhechuan county	7,473	26,920	7,141	10,233	28.99	2,726	7,687	38.68	4,415	2,547	16.50
Sheqi county	107	900	75	120	0.34	43	60	0.31	32	60	0.38
Tanghe county	567	253	79	393	1.12	1	1	0.003	78	393	2.54
Xinye county	1,869	973	364	267	0.75	69	60	0.31	295	200	1.31
Tongbai county	1,163	1,340	472	447	1.27	127	160	0.80	345	287	1.87
Dengzhou city	1,616	2,387	233	147	0.42	90	60	0.30	143	87	0.57

evaluations in the future.

(2) When utilizing “One Map” forest resource management system of forestry sector and the annual updated results of the Third National Land Survey as reference basemaps for afforestation space suitability investigation, discrepancies in land type identification standards between the 2 systems may lead to misclassification. Some land parcels that should be included in suitable afforestation areas might be identified as “unsuitable” by mistake. Furthermore, areas beyond the current evaluation scope—including rural peripheral spaces (“four-side” gaps), abandoned mining sites, and strictly controlled land types—also possess potential for afforestation. Therefore, it is recommended that relevant authorities enhance coordination to unify land classification standards at the technical level. This standardization will enable truly rational and accurate evaluation, ultimately achieving the goal of scientifically planning afforestation spaces.

(3) The various ecological restoration projects implemented by forestry and grassland departments—including low-quality and inefficient forest transformation, degraded forest rehabilitation, and similar initiatives—are carried out through methods like manual afforestation, aerial seeding and forest quality improvement. These projects constitute an integral component of national land greening efforts. However,

current afforestation space suitability evaluation fail to adequately account for these restoration-oriented afforestation demands. It is theretofore recommended that subsequent national land afforestation planning should proactively allocate dedicated afforestation and task quotas for the diverse ecological restoration projects administered by forestry and grassland departments at all levels.

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display, and through strategies such as the networking of vertical corridors and spatial superimposed design, the continuity, safety and cultural recognizability of waterfront space were strengthened. However, the public participation mechanism is relatively weak in the planning and implementation, and fails to fully integrate community needs and local wisdom, which may lead to deviations between the use of space and the expectations of citizens. In addition, the feasibility analysis of economic costs and long-term maintenance has not been systematically carried out yet, which may affect the sustainable promotion of the strategies. Overall, this research provides a scientific and operational paradigm

for the landscape renewal of waterfront areas, and its concepts and methods have important reference significance for the regeneration of waterfront space in cities of the same type.

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