ÉLŐHELYMINŐSÉG-ÉRTÉKELÉS AZ INVEST MODELL ALAPJÁN – ZHENGZHOU, KÍNA

HABITAT QUALITY ASSESSMENT BASED ON INVEST MODEL – ZHENGZHOU, CHINA

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ABSZTRAKT

Az emberi tevékenységek és az urbanizáció globálisan befolyásolják a földterületek ökológiai integritását, az ökológiai hálózatok folyamatosságát és a természetes élőhelyek feldarabolódását okozva. A folyamatok világszerte ökológiai kockázati problémákat eredményeznek. Az egyes tájfoltok ökológiai funkciói leromlanak vagy akár el is tűnhetnek. Vizsgálni kell ezért az urbanizáció földhasználati változásokra, természetes élőhelyekre gyakorolt hatását. A kutatási terület Zhengzhou város, amely a 21. század eleji gyors urbanizáció mintapéldája Közép-Kínában. Az InVEST-élőhelyminőségi modell és az ArcGIS térinformatikai szoftver segítségével értékeltük Zhengzhou földhasználatának és élőhelyminőségének változásait 2000 és 2020-es évek között. Az eredmények azt mutatják, hogy: ① Az építési terület nagysága 2000 és 2010 között 806,76 km²-rel ugrásszerűen megnőtt, míg 2010-2020 között a növekedés üteme évi 33 km²-re lassult. A beépített területek nagy része korábban szántóföld volt. Az erdő és a gyepterület is jelentősen csökkent a térségben 2000-2010 között, de 2010-2020 között a csökkenés nem volt ennyire látványos. Ez azt jelzi, hogy a városi terjeszkedés a 2000-2010 közötti felgyorsult időszakból fokozatosan egy lassuló tendenciába fordult 2010-2020 között. A beépítések nagy része ebben az időszakban elsősorban a szántóterületeket érintették. ② A nyugati és déli hegyvidéki erdők élőhelyminősége magasabb volt, míg a keleti síkságon az alacsony élőhelyminőségű területek a városépítés fejlődésével fokozatosan bővültek. A Sárga-folyót, amely Kína legfontosabb folyója, szintén negatívan érintette az urbanizáció Zhengzhou északi részén. 2010-2020 között viszont fokozatosan javult az élőhelyek minősége. ③ Az elmúlt években a város központi területein az élőhely minősége néhány helyen javult a zöldterületek és a mesterséges tavak megjelenésének köszönhetően és a zöldterületek karbantartásának javulásával is. Azt azonban, hogy a mesterséges tavak és a nagy kiterjedésű zöldfelületek jelentik-e az optimális megoldást az élőhely minőségének javítására, érdemes tovább vizsgálni. A jövőben a gazdasági beruházások és az ökológiai előnyök szempontjából a legjobb költséghatékony ökológiai védelmi módszereket lehet keresni. ⦿

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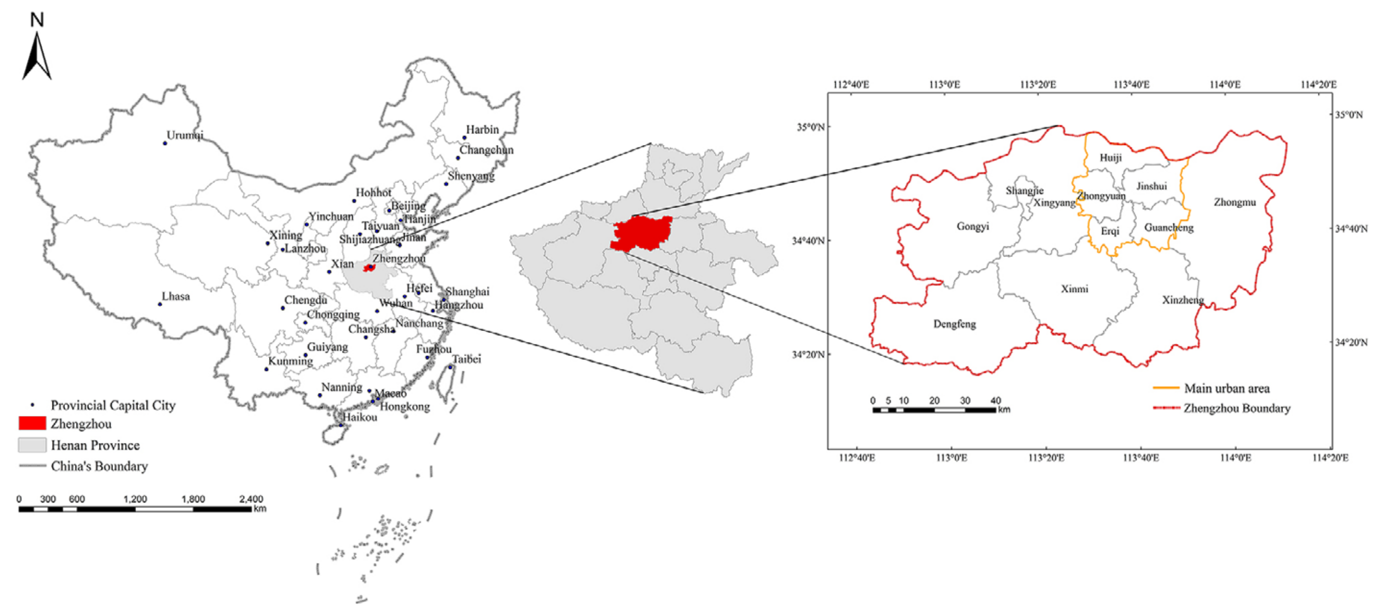
Fig. 1: Geographical location of Zhengzhou



ABSTRACT

Human activities and global urbanisation have affected the integrity and continuity of ecological land, and resulted in the fragmentation of natural habitats and worldwide ecological security issues. Some ecological functions of landscape patches have been degraded or even lost. We need to study the impact of land use changes on natural habitats that are caused by urbanisation. As the research area, we selected Zhengzhou, a city in central China that has undergone rapid urbanisation in the early 21st century. By using the InVEST-habitat quality model and ArcGIS geographical analysis, we evaluated changes in land use and habitat quality in Zhengzhou from 2000 to 2020. The results show that: ① The area of construction land increased sharply by 806.76 km² from 2000 to 2010, while during 2010-2020 the growth rate slowed to 33 km² per year, and most of it was converted from arable land. The area of forest and grassland was also greatly reduced in 2000-2010, but did not change significantly in 2010-2020. This indicates that urban expansion gradually shifted from the acceleration of 2000-2010 to a period of stability in 2010-2020, and construction land has taken over a large amount of arable land. ② Habitat quality was higher in the mountain forests to the west and the south, while the low habitat quality areas in the eastern plain gradually expanded with the development of urban construction. The Yellow River, the most important river in China, was also negatively affected by urbanisation in the north of Zhengzhou, but its habitat quality gradually improved during 2010-2020. ③ In the central urban area, habitat quality was improved in some places due to the creation of green spaces and artificial lakes in recent years, and also through with the improved maintenance of green spaces. However, it is worth continuing to explore whether artificial lakes and large-scale green spaces are the optimal solutions to improve habitat quality. In the future, we will be able to seek the best cost-effective ecological protection methods in terms of economic investment and ecological benefits.

Keywords: land use, habitat quality, urbanisation, Zhengzhou, China

1. INTRODUCTION

The Earth's biosphere and its ecosystem services are important conditions for human survival [1]. In the current Anthropocene era dominated by human activities,

Table 1: Weight and maximum distance impacted by threat factors
Table 2: Habitat suitability of different land use types and the sensitivity to each source of threat
►►**Table 3:** Land use transfer matrix in Zhengzhou between 2000, 2010 and 2020 (km²)

THREAT	WEIGHT	MAX_DIST(km)	Spatial attenuation types
Urban area	1	10	exponential
Village area	0.6	5	linear
Arable land	0.7	8	linear
Highway	1	8	exponential
Railways	1	7	exponential
National roads	1	3	exponential

LULC	NAME	Habitat suitability	Sensitivity					
			Urban area	Village area	Arable land	Highways	Railways	National road
1	Arable land	0.6	0.5	0.35	0.3	0.7	0.55	0.8
2	Forest	1	1	0.85	0.8	0.95	0.8	1
3	Grassland	0.8	0.6	0.45	0.4	0.8	0.7	0.8
4	Water	1	0.85	0.8	0.7	0.5	0.5	0.6
5	Construction land	0	0	0	0	0	0	0
6	Unused land	0.6	0.5	0.2	0.4	0.4	0.4	0.5

global urbanisation has resulted in a variety of landscapes with significant human influence. The artificial land use pattern and the natural environment are superimposed, which to a certain extent has broken the continuity and ecology of the originally natural landscape [2]. Changes in land use patterns with human intervention have led to a series of ecological problems such as global warming, extreme weather, air pollution and geological disasters [3-4], which also have fragmented ecological landscapes, reduced species diversity and affected the functions of ecosystem services [5].

Ecosystem services are defined in the Millennium Ecosystem Assessment (MEA) as "the benefits people obtain from ecosystems" and are divided into four service functions: supporting services, provisioning services, regulating services and cultural services [1]. Biodiversity is closely related to ecosystem "provisioning services", and habitat quality directly affects the service function of biodiversity. Habitat quality means the suitable ecological environment that the ecosystem can provide for various organisms and populations to survive and continue to develop, which can reflect the ability of an area to provide good conditions for species continuation and biodiversity development [6]. Good habitat patches are key to promoting the improvement of regional biodiversity, and are the most important source of ensuring regional ecological security and maintaining ecosystem service functions. In recent years, more and more researchers have focused on the evaluation and analysis of habitat quality. There are generally two methods: constructing an index system and model assessment. Bazelet established a dataset evaluation system by selecting some habitat species indicators [7]; Nelson simulated regional biodiversity conservation levels with habitat quality assessment [8]; Dresit assessed the impact of hydrology changes on regional habitat quality [9]; Bhagabati selected tigers as an example to explore the relationship between ecosystem services and habitat quality [10]; Baral identified the key areas for conservation and mapped regional conservation priorities through habitat quality assessment [11]. This shows that the assessment of habitat quality has gradually become the focus of related research fields, but most of them just pay attention to a single period, and the spatial-temporal impacts of land use on habitat quality have not been fully explored. This study employs model assessment methods to compare the habitat quality of different periods and to

Year	Land use type	Arable land	Forest	Grassland	Water	Construction land	Unused land
2000–2010	Arable land	3869.48	121.24	27.14	131.45	788.09	0.00
	Forest	253.12	484.76	17.13	6.06	113.91	0.00
	Grassland	200.23	45.42	351.10	1.04	91.45	0.00
	Water	48.58	5.50	0.51	119.87	19.54	0.00
	Construction land	184.39	16.54	0.96	4.34	660.23	0.00
	Unused land	0.80	1.73	0.00	0.09	0.00	0.00
	Net inflow	687.13	190.44	45.75	142.98	1012.99	0.00
	Net outflow	1067.92	390.22	338.14	74.14	206.23	2.62
	Net change	–380.80	–199.78	–292.39	68.83	806.76	–2.62
2010–2020	Arable land	3928.97	79.62	21.63	68.02	458.43	0.00
	Forest	61.36	554.93	5.89	3.40	49.64	0.00
	Grassland	20.26	7.16	356.43	1.44	11.59	0.00
	Water	26.24	9.69	0.13	204.58	22.12	0.00
	Construction land	151.73	46.95	6.00	7.09	1461.55	0.00
	Unused land	0.00	0.00	0.00	0.00	0.00	0.00
	Net inflow	259.59	143.43	33.65	79.94	541.78	0.00
	Net outflow	627.70	120.29	40.45	58.18	211.78	0.00
	Net change	–368.10	23.14	–6.80	21.76	330.01	0.00

explore the impact of land use changes on habitat quality during rapid urbanisation in China.

China is a developing country with a vast territory and a large population. Since the establishment of the People's Republic of China in 1949, urbanisation has gradually been accelerating. Especially in the past 30 years, the achievements of urban construction have been remarkable [12]. The current urbanisation rate in China increased from 17.92% in 1978 to 64.72% in 2021. Rapid urbanisation has also brought more urban ecological problems. In 2000, the concept of "maintaining national ecological environment security" was put forward in the "National Ecological Environmental Protection Outline" policy for the first time [13], highlighting that solving ecological problems had become an important task of urban development in China.

Our research area was the city of Zhengzhou in central China, where the urbanisation rate increased from 32.4% in 1978 to 79.1% in 2021, [14] and urban expansion was obvious. The study on the evolution of habitat quality in Zhengzhou during the urbanisation process is representative in the formulation and implementation of ecosystem protection policies in China.

2. METHODS AND DATA

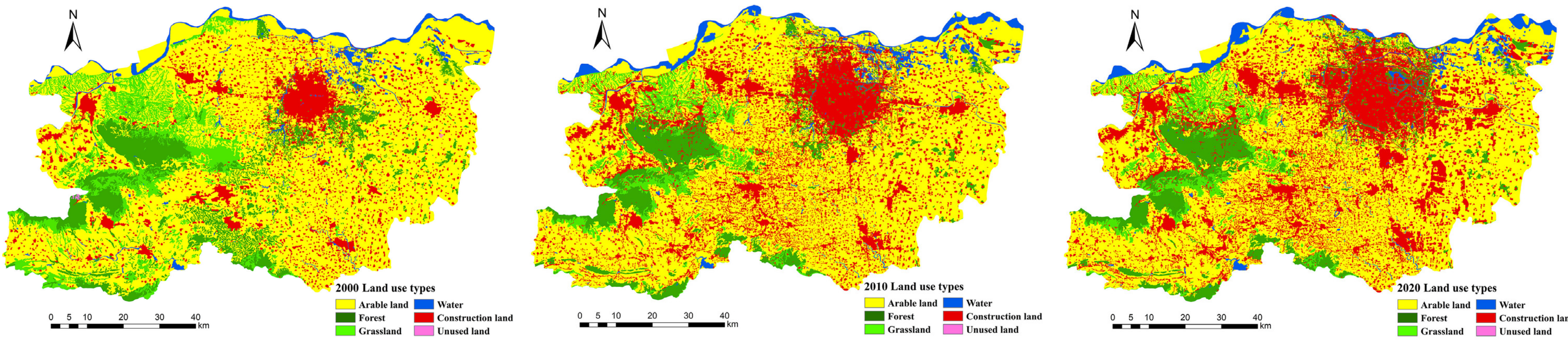
This chapter introduces the basic information about the research area, including geographical location, topographic features, administrative divisions and socio-economic development. In addition, we detail the data sources used in this study, data pre-processing, research methods and the introduction of the related tools.

2.1 Study area

Zhengzhou is the capital city of Henan Province in central China (34°16'–34°58'North Latitude, 112°42'–114°14'East Longitude), which has five prefecture-level cities, one county and six districts. Zhengzhou covers a total area of approximately 7,567 km², of which the main urban area is 1,010 km². The overall terrain of Zhengzhou is relatively flat. The Song and Fuxi Mountains are to the south-west, the loess hilly area along the Yellow River in the north-west, and the alluvial plain formed by the Yellow River system to the east. The Yellow River is the most famous river in China and one of important ecological sources in Zhengzhou.

Zhengzhou has a large population, with around 12 million in 2021. It is an important transportation hub in

Fig. 2: Zhengzhou land use classification in 2000, 2010 and 2020



China because of its advantageous geographical location, which also makes it the core city of the "Belt and Road". The first Zhengzhou-Europe International block train started running from 2013, strengthening the connection between China and Europe. All of the points above are reflected in the fact that Zhengzhou is heavily impacted by urbanisation.

2.2 Data resource

The basic data used in this paper include Zhengzhou Landsat-8TM and Landsat-7 remote sensing image data (30m×30m resolution), Zhengzhou 2000/2010/2020 land classification data (30m×30m resolution), Zhengzhou Statistical Yearbook data, and road data. These are taken respectively from the United States Geological Survey (http://earthexplorer.usgs.gov/), Chinese Academy of Sciences (http://www.resdc.cn/), Zhengzhou Municipal Bureau of Statistics, and Baidu Map Data.

The land use data of this study is classified by combining the classification data of the Chinese Academy of Sciences (CAS) and the supervised classification data of Landsat image data. Since the CAS data unified all types of the land inside the main urban area as construction land, there is no accurate classification of the main urban area. We used ArcGIS to collect supervised samples by visual interpretation and employed the random forest supervised classification method to classify the land use of the main urban area. Then we tested the Kappa accuracy of the three years' classification results and all of them were more than 80%, which means the data can be used for research and analysis. Finally, we compared and combined the data from supervised classification with the CAS data to get the final and more accurate land classification results.

2.3 Transfer matrix of land use types

The land use pattern is an important factor affecting ecosystem services and one of the important factors in assessing habitat quality. Therefore, a clear evolution of land use is a prerequisite for exploring the evolution of habitat quality. Based on land use data, we superimposed the data in 2000/2010/2020 year with the raster calculator tool in ArcGIS 10.2, then obtained the changes and transfer of land use types in the study area between 2000-2010 and 2010-2020. The transfer matrix of land use types is shown in Chapter three (Table 3).

2.4 Habitat Quality Analysis

We analysed the habitat quality of Zhengzhou using the InVEST-Habitat Quality model tool. The InVEST model is a comprehensive model for ecosystem assessment and trade-offs jointly developed by Stanford University, the Nature Conservancy (TNC) and the World Wide Fund for Nature (WWF) [6]. It defines habitat as the area which has the resources and conditions to provide a suitable living environment for a given organism. The sources of threat to habitat are the lands affected by human activities. Habitat quality depends on the suitability of habitat patches and the sensitivity of a habitat patch to these threats.

The InVEST-Habitat quality model requires three main factors: the relative weight of the various sources of threat, the maximum distance impacted by the source of the threat, and the sensitivity of different habitats to each threat factor (the anti-interference ability of the habitat). In this study, we set urban areas, rural settlements, arable land, important traffic routes (highways, railways, national roads) as sources of threat. The relative weights are set according to the software instruction manual and related research, and are between 0 and 1 (Table 1). The habitat suitability and the sensitivity values to threats are set between 0 and 1: the closer to 1, the better the habitat suitability and the higher the sensitivity, as shown in Table 2.

3. RESULTS

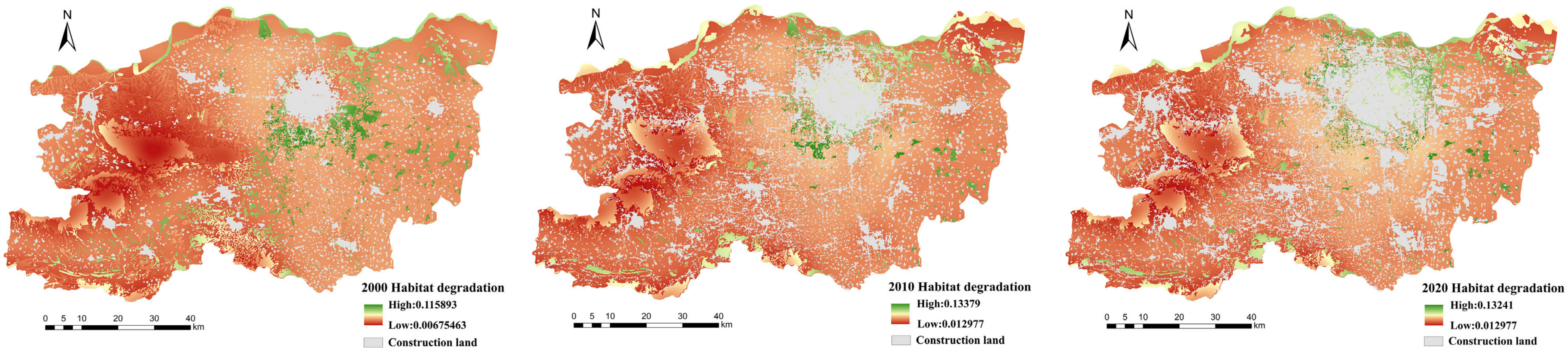
Through the data processing and analysis as set out above, we obtained the land use classification results of Zhengzhou in 2000, 2010 and 2020, as shown in Figure 2. This chapter shows the transfer matrix between these six land use types from 2000 to 2020, and the spatial-temporal changes of habitat degradation and habitat quality.

3.1 Changes in land use pattern

By superimposing the raster data of land use classification in 2000, 2010 and 2020, we obtained the land transfer results as shown in Table 3. Overall, the transfer in 2000-2010 was more significant than in 2010-2020. It mainly occurred between arable land and construction land. The water area continued to increase.

From 2000 to 2010, the area of arable land, forest and grassland decreased, while the area of construction land increased significantly. Arable land decreased

Fig. 3: Degree of habitat degradation in 2000, 2010, and 2020



by 380.80 km², which was mainly converted into construction land. The forest decreased by 199.78 km² and the grassland area decreased by 292.39 km². Both were mainly replaced by arable land, followed by construction land. The growth of construction land was particularly obvious, with net growth of 806.76 km². Most of this came from arable land, up to 788.09 km². During this period, the water area increased by 68.83 km², which was mainly converted from arable land, and part of it was also in the meantime converted into arable land. That's because some rivers in rural regions became dry and were replaced by arable land. However, arable land occupied by new urban areas developed with various artificial lakes, such as Longzi Lake and Long Lake in the Jinshui District, resulting in an increase of the water area in the city.

From 2010 to 2020, the transfer of arable land and construction land was similar to that of the previous period. But the change in forest was wholly different from 2000-2010, increasing by 23.14 km², mainly from arable land. The main reason is that the "Returning Farmland to Forest" policy had achieved some results in certain areas during 2010-2020. It also reflects that government calls and increased ecological awareness are having an important influence on environment change. Construction land increased by 330.01 km². Compared with 2000-2010, the growth rate decreased by 59.10%. Although the urban construction area continued to expand, the urbanisation of Zhengzhou gradually slowed down and reached a relatively stable state.

Looking at land use changes in 2000-2020, it is clear that a lot of arable land was occupied by urban expansion, and that arable land suffered a considerable degree of loss. It also caused problems in agricultural production and food security. Therefore, some forest and grassland continued to be occupied and developed into arable land. This is a vicious circle caused by socio-economic development and the expansion of the area covered by human activities, which also has a negative influence on the ecological environment and agricultural security.

3.2 Dynamic evolution of Habitat degradation

The degree of habitat degradation indicates the impact of the degradation sources (threats) on the surrounding habitat. The greater the impact, the higher the degradation (Figure 3). It can reflect suitability for the development of natural communities. The urban area and rural settlements belong to construction land and there is no more degradation, so we extracted the other landscape types to analyse the degradation.

In terms of spatial distribution, the degree of habitat degradation in Zhengzhou is highest around the main urban area, and gradually decreases with increasing distance from the main urban area. In the mountainous areas, the degree of habitat degradation was lower, and reached a low in the Song-Fuxi Mountains in the west, an area with high ecological value and protection needs.

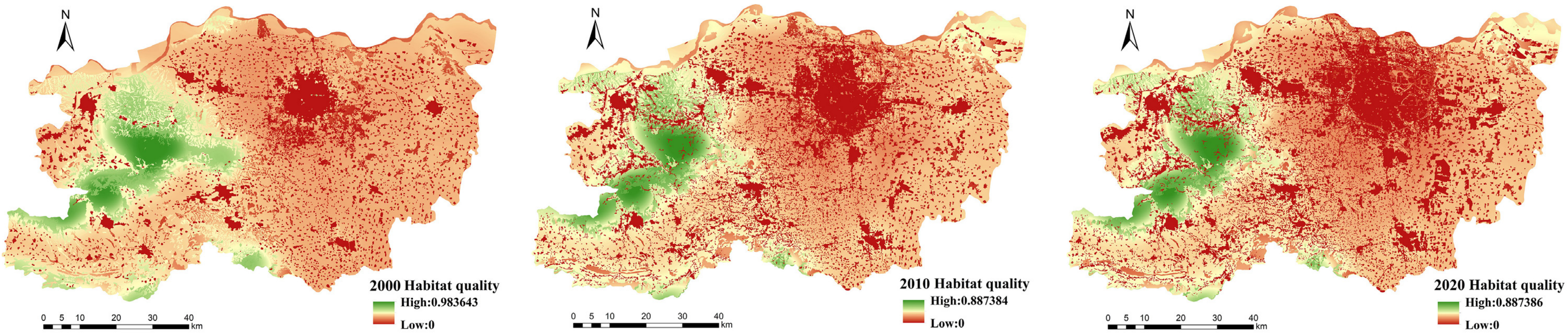
From the temporal perspective, we compared the degree of habitat degradation in 2000, 2010 and 2020. It was clear that the value attributed to the degree of habitat degradation continued to increase from 2000 to 2020. In 2000, the value was in the range of 0.00675-0.11589, while in 2010, the range increased to 0.01298-0.13379. This means the impact from sources of degradation increased, with even the lowest value doubled. The value of habitat degradation in 2020 didn't change much compared with 2010. However, with the expansion of urban construction land, the area of high habitat degradation spread outwards, which apparently affected the habitat quality of surrounding arable land.

In 2000, the main urban area was small, there were not too many artificial threat factors like highways, railways or paved roads, so the negative impact on the surrounding habitat was limited. In 2020, the construction area greatly expanded, and the impact had spread to the three prefecture-level cities: Gongyi, Dengfeng and Xinmi in the mountain area to the west. This reduced the habitat quality of the mountain forest areas compared to before, and particularly affected the habitats near the foot of mountains. Although there were no significant changes in the habitat degradation value during 2010-2020, the areas with low habitat quality expanded and the distribution was more even.

3.3 Changes in habitat quality

The evolution in the trend of habitat quality is like the degree of habitat degradation, as shown in Figure 4. The habitat quality value is between 0 and 1. The closer to 1, the better the habitat quality is. To display the temporal and spatial changes of habitat quality more clearly, we used the ArcGIS reclassification tool to divide habitat

Fig. 4: Habitat quality map in 2000, 2010 and 2020



quality results into five grades: 1 is the worst (0-0.2), 2 is bad (0.2-0.4), 3 is medium (0.4-0.6), 4 is good (0.6-0.8), 5 is the best (0.8-1), and calculated the area changes of different habitat quality grades as shown in Figure 5.

The habitat quality was best in 2000, with 6147.93 km^2 of medium and above grades, accounting for 81.3% of the whole area. From 2000 to 2010, the quality of the habitat decreased significantly. The area of good and best grades even decreased by 43.1%. From 2010 to 2020, the area of habitat quality within each grade changed little, and the overall habitat quality decreased slightly. Grades 4 and 5 remained basically unchanged, indicating that the protection of important habitat areas was achieved. Compared with the land use transfer matrix, the growth area of construction land continued to increase but the annual growth rate decreased, which is the main factor leading to the gradual stabilisation of habitat quality after the deterioration.

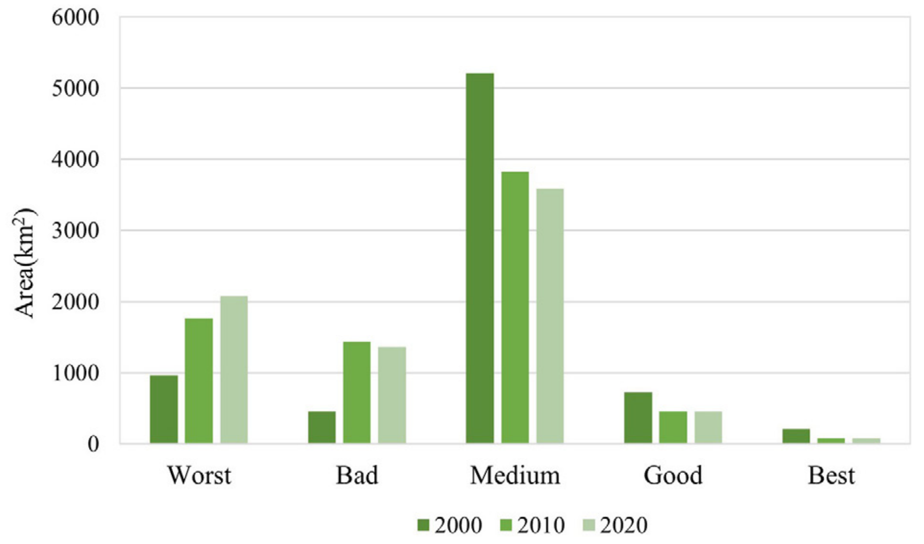
To further explore the distribution characteristics in the spatial dimension, we analysed the change in habitat quality in 2000-2020, as shown in Figure 6. The colour from red to green represents the change in habitat quality from decline to improvement, and yellow indicates the areas with no change. The major decrease was mainly distributed near the new construction land. For example: the expansion of the urban area to the north had led to the deterioration of the habitat quality of the Yellow River; the new industrial zone and airport in Xinzheng in the south had caused the deterioration of the nearby agricultural habitat. The western mountainous area was far from the main urban area, and transportation was not as convenient as in the eastern region, habitat quality was higher in 2000. With the development of transportation and urbanisation, the habitat quality of the Song-Fuxi Mountain in the west decreased slightly, and the habitat quality of western counties and towns also declined. Although the decline in the western area was greater than in the eastern area, it's still higher than in the eastern area in terms of the spatial dimension.

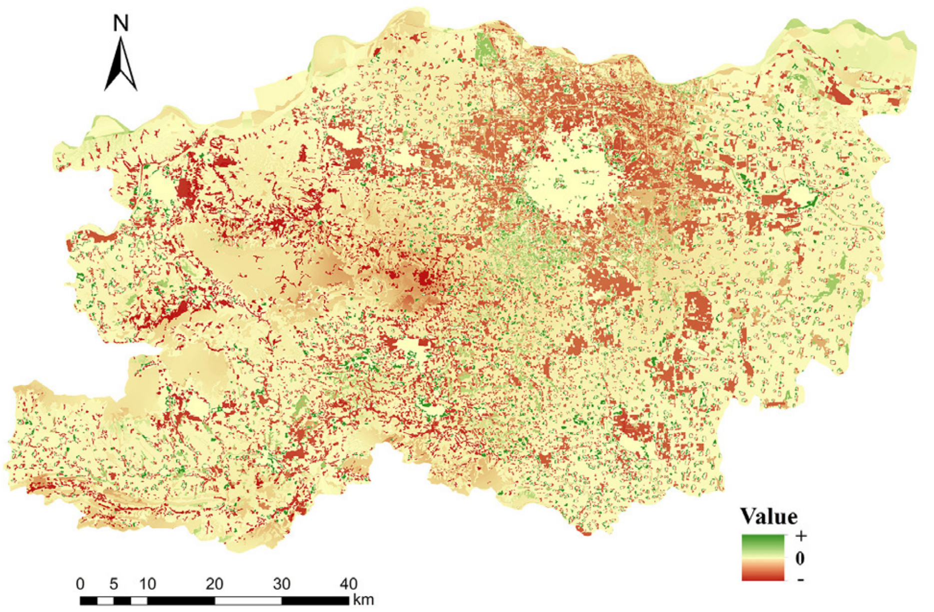
While the overall habitat quality deteriorated, some areas improved a little (Figure 6). In the main urban area, there were some new large-scale green spaces and lakes in the Jinshui District in the east, such as Zhengzhou Zhilin Park, Ruyi Lake, Longzi Lake, etc., which reflected the positive effect of urban green spaces and parks on habitat improvement. The protection and maintenance of rivers also improved the quality of the river habitat in the urban area. There was some improvement in habitat quality in certain sections of the Yellow River in the north-east, showing that the government has sought to protect the ecology of the Yellow River habitat. The ecological level of the surrounding environment was improved and prevented urban development from damaging the habitat of the Yellow River.

4. DISCUSSION

There is a game relation between construction land, arable land and ecological land. How to balance the three effectively to achieve unified and coordinated development is one of the important issues to be considered in future urban development. Taking this study area as an example, urban development and expansion occupied a large area of arable land in the eastern plains. To ensure the food supply, some forest and grassland in the western mountainous area have been developed into arable land, and the ecological environment of the whole city has been severely impacted. Therefore, for cities with growth in their population and economy, we should consider how to improve the quality of the living environment and people's sense of happiness, rather than blindly expanding and pursuing an increase in the urban construction area.

Ecological protection policies and urban green spaces can effectively improve habitat quality. By comparing the urban habitat quality in Zhengzhou from 2000 to 2020, the habitat quality in some urban areas has improved significantly because of the newly-built urban green spaces, including a number of small street green spaces, open parks, residential green space, etc. Encouraged by the policies such as "the Construction of Ecological Civilization", "National Forest City", and "National Ecological Garden City" launched by the Chinese government, many local governments have responded with a series of green space protection regulations. This has been effective in improving the ecological environment. At present, when the protection of the ecological environment is taken as an important development task, all regions in China are paying attention to the protection of natural habitats and the construction of urban green spaces, and habitat quality has gradually stabilised and improved. However, whether new large-scale artificial lakes and green spaces are the most cost-effective way to improve habitat quality still needs to be explored.





◂◂ **Fig. 5:** Area of different habitat quality grades in 2000, 2010 and 2020
Fig. 6: Changes in habitat quality from 2000 to 2020

5. CONCLUSIONS

The land use changes and ecological problems that emerged during the urbanisation of Zhengzhou are representative of the situation in most cities in China. This study explores the spatial and temporal evolution of land use patterns and habitat quality under the influence of urbanisation. Its conclusions are as follows:

① In 2000-2010, the area of forest and grassland was significantly reduced, and mainly converted into arable land and construction land. In 2010-2020, the construction area continued to increase, but the growth rate decreased, and the forest area increased slightly. This shows that urbanisation in Zhengzhou accelerated from 2000 to 2010, and then was relatively stable in 2010-2020. Urbanisation has a significant impact on the land use pattern.

② Habitat quality in the city of Zhengzhou is not very good. The Song-Fuxi Mountains in the west and the Daxiong Mountains in the south have higher habitat quality. The northern Yellow River habitat was affected by urban expansion, but gradually improved in 2010-2020. In 2000-2010, the low habitat quality area increased considerably with the expansion of the main urban area. In 2010-2020, habitat quality decreased slightly, and there were some small improvements in the areas such as the north-eastern section of the Yellow River, some reservoirs and the areas surrounding the Song-Fuxi Mountains.

③ Habitat quality in the Jinshui District in the main urban area improved in 2000-2020 because of some new large-scale parks and lakes created there, such as Zhengzhou Zhilin Park, Ruyi Lake and Longzi Lake. This reflects the positive effect of urban green and blue spaces on habitat improvement. Government policies and local response also play a crucial role in maintaining and improving the ecological environment.

④ The InVEST model can effectively simulate habitat quality and display it visually. It has a powerful auxiliary function for people to conduct ecological environment research, identify important habitat areas, and analyse changes in habitat quality. Moreover, it could be used in large-scale regional planning and small-scale ecological design in the future. ◉

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