A VÁROSI ALRENDSZEREK ÖSSZEKAPCSOLÁSÁNAK ÉS KOORDINÁCIÓJÁNAK FELTÁRÁSA LUOHE VÁROS REZILIENCIA VIZSGÁLATÁNAK PÉLDÁJÁN

EXPLORATION OF URBAN SUBSYSTEM COUPLING COORDINATION BASED ON RESILIENCE IN LUOHE CITY

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ABSZTRAKT

Az urbanizáció fokozódásával Kínában is nőnek a városi területek területhasználati problémái. A probléma megoldása a mennyiségről a minőségre történő várostervezési módszerek adaptálása. A rendszerszemlélet, a koordináció és az integráció a tervezésben elősegíti, hogy a városi területek ellenállóbbá váljanak a kockázatokkal szemben. Jelen tanulmány Luohe város (Kína) 2022-es adatait használja példaként a rendszerek közötti összekapcsolódás koordinációs fokának (CCD) számításához, az ellenálló-képesség kiépítését akadályozó tényezők megtalálásához, és az azt akadályozó tényezők térbeli heterogenitásának további feltárásához. A módszer három modellezés eredményeit használja ("szintetikus értékelési modell", a "csatolási értékelési modell", "akadálydiagnosztikai modell") az egyes alrendszerek értékelésére és elemzésére. Az eredmények a következők: ① A szintetikus értékelés szerint az átlagos városfejlesztési érték 0,48; a magas értékű régiók a délkeleti beépített övezetben csoportosulnak. ② A városcsatlakozási koordináció átlagos értéke 0,66; a koordinációs szint 7 (mérsékelt koordináció). ③ A városi fejlettségi fok pozitívan korrelál a CCD-vel. ④ Globálisan a gazdaság a legfőbb akadályozó tényező a rugalmas növekedés szempontjából, de az ökoszisztémák, természeti területek korlátozásai nagyobbak és szélesebb körű hatással bírnak. Ez a tanulmány hozzájárul a városi, nagyvárosi területek belső hierarchikus rendszerének megértéséhez, és hozzájárulhat a területek harmonikus fejlesztéséhez, a városi ellenálló képesség, reziliencia növeléséhez. ◉

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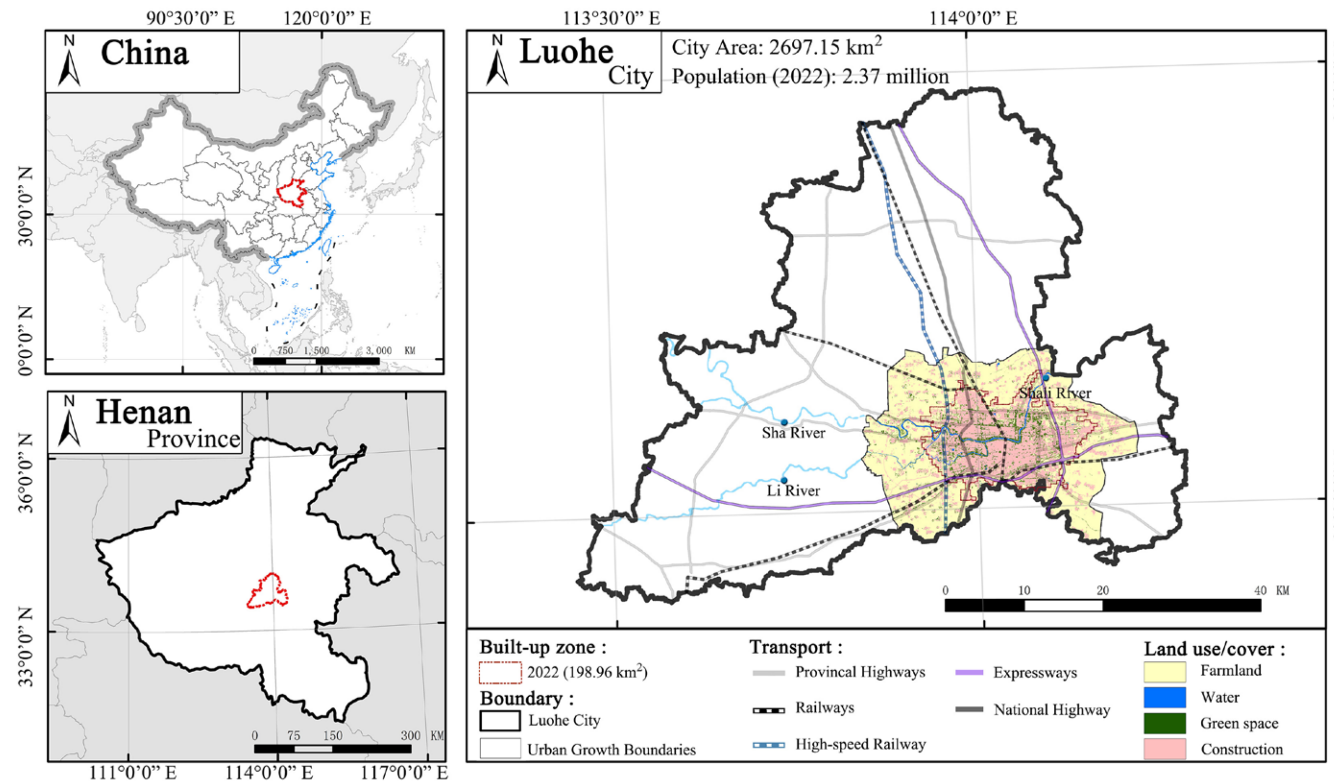
Figure 1: Location Map (GS (2020)4619)



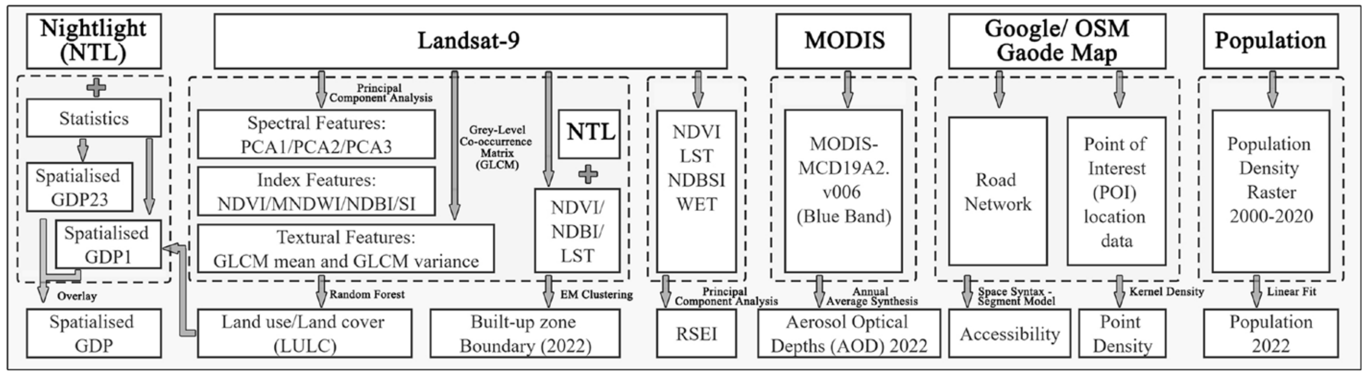
ABSTRACT

With urbanisation, the uncertainties faced by urban areas continue to increase, and in response, China's urban planning is transitioning from a focus on quantity to quality. Promoting system coupling and coordination helps to make urban areas more resilient to risk. This paper uses data from Luohe City (China) in 2022 as an example to calculate the inter-system Coupling Coordination Degree (CCD), to find the factors that obstruct resilience construction and further explore the spatial heterogeneity of the obstacle factors. The synthetic evaluation model, coupling evaluation mode and obstacle diagnosis model are used to evaluate and analyse each subsystem. The results are as follows: ① According to the synthetic evaluation, the mean urban development value is 0.48, with high-value regions clustered in the Southeastern built-up zone. ② The mean value of urban coupling coordination is 0.66, the coordination level is 7 (Moderate Coordination). ③ The urban development degree is positively correlated with the CCD. ④ Globally, the economy is the main factor obstructing resilient growth, but the core obstacle areas of the ecosystem are larger and have a wider impact. This study helps us understand the internal system of urban areas and provides data for balanced development and urban resilience enhancement.

INTRODUCTION

Urban sustainability is increasingly challenged by urban growth. Although no city can completely predict the occurrence of natural/unnatural disasters, the urban system can improve its resilience to external disturbances [1]. Urban resilience (UR) is an emerging concept that can help urban areas adapt to uncertainty and become more resilient to external disturbances to deal with these challenges.

Urban areas are perceived as complex systems, and the interrelationship between the various subsystems dramatically affects overall operational efficiency [2, 3]. As an important attribute of the urban system, UR is also a multi-dimensional system for managing urban risk to adapt to uncertainty by focusing on system integration and coordination [2, 4–6]. Currently, many studies focus on constructing a multi-criteria framework [7, 8] based on single-factor evaluations [9, 10] to provide quantitative measures of UR. The socio-economic-ecological framework is widely used in many fields [11–13]. The interrelationship of



multiple urban subsystems, especially regarding urbanisation, is gradually gaining traction [14, 15]. It can be seen that the degree of development of urban subsystems and their interrelationships are equally important in building UR. The Coupling Degree (CD) is an important indicator of system interactions [16]. Good coupling is known as coordination. The Coupling Coordination Degree considers both the coupling and the coordination relationships [13,17]. It can show the system's robustness, help balance development and reduce internal conflicts. After all, the single pursuit of economy or construction may lead to the decoupling of subsystems, causing potential problems such as industrial structural imbalance, spatial sprawl and ecological degradation [18,19].

This paper uses the classical socio-economic-ecological framework to analyse urban subsystems and their interactions through the Synthetic Evaluation Model, Coupled Evaluation Model and Obstacle Diagnosis Model (ECO model) [20]. In summary, coupled coordination research aims to contribute to UR architecture by exploring the relationships between urban subsystems. Exploring individual systemic obstacle degrees provides policymakers and practitioners with spatial detail, improves development heterogeneity and promotes urban equity.

1. MATERIALS

This section includes an introduction to the study area, the acquisition of basic data and the preliminary processing flow.

1.1 Study Area

Luohe is in the south-central part of Henan Province in central China. It is well connected and is a regional transport hub, and is crossed by the Shali River (Figure 1). Regarding its urban scale and economic level, Luohe is a good representative of most ordinary cities in China. In 2022, there was still a considerable amount of farmland within the Urban Growth Boundary (UGB). Therefore, to exclude the influence of non-urban areas, we needed to screen the boundary of the built-up zone as the study area.

1.2 Data Collection and Processing

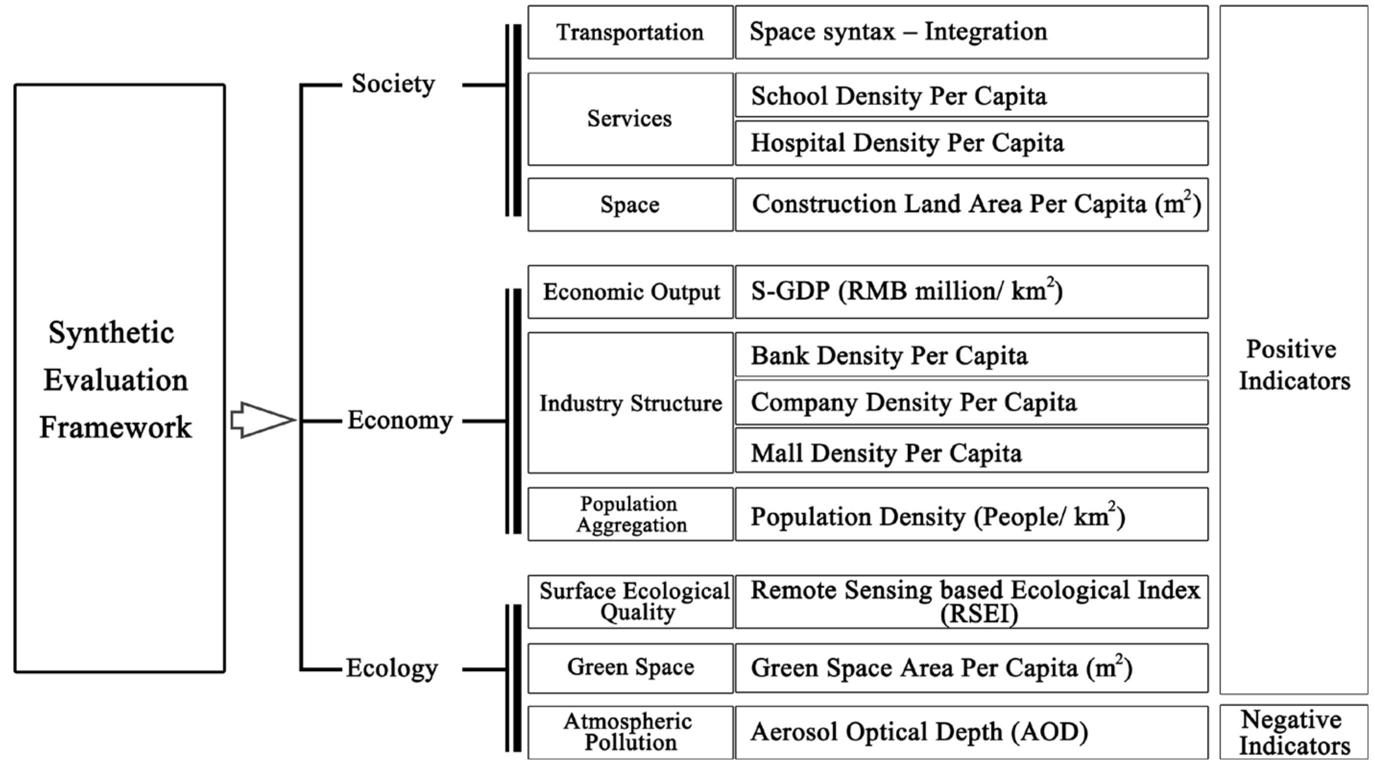
Basic satellite images were derived from Landsat-9. Annual nighttime lights (NTL) are from the NPP-VIIRS. The population was obtained from Google Earth Engine (GEE) – Worldpop collection. The Aerosol Optical Depth (AOD) is derived from the MODIS collections (Figure 2). The above basic data acquired and other indices, such as Land Surface Temperature (LST)[21], are acquired by GEE (https://code.earthengine.google.com/). Point of Interest (POI) is obtained from Gaode Map (https://lbs.amap.com/). Roads were obtained from OpenStreetMap (OSM, https://www.openstreetmap.org/) and Google Maps (Figure 2).

Built-up zone: The identification of the built-up zone drew on previous studies [22, 23]. Based on NTL/ NDBI/ LST, Expectation Maximization Clustering [24] is used to classify the UGB into three clusters (Figure 1). **Land use/ Land cover (LULC):** Based on Landsat-9, NDVI/ NDBI/ MNDWI and texture data as secondary data. Random Forest was used [23, 25]: Farmland, Water, Green space, Construction (Kappa=85.65%). **Integration:** Accessibility can characterise urban infrastructure and resource distribution efficiency. The Segment model of space syntax was chosen, and accessibility is expressed by road integration [23, 26]. **Spatialized GDP (S-GDP):** Farmland&NTL can reflect the primary GDP (GDP1) & secondary tertiary GDP (GDP23) respectively. The correction coefficients are calculated based on the statistical yearbook, spatialized GDP1 and GDP23 separately, then superimposed (Mean Absolute Errors=17.07%). **RSEI calculation:** Remote Sensing based Ecological Index (RSEI) is a more comprehensive ecological indicator. Greenness (NDVI), humidity (WET), dryness (NDBSI) and heat (LST) were synthesised by Principal Component Analysis to obtain it. **POI Density:** The POI density is calculated based on ArcMap10.8 Kernel Density. **Population:** Based on the 2000-2020 raster, a linear fit was performed to obtain population data in 2022 [11].

1.3 Framework and Methods

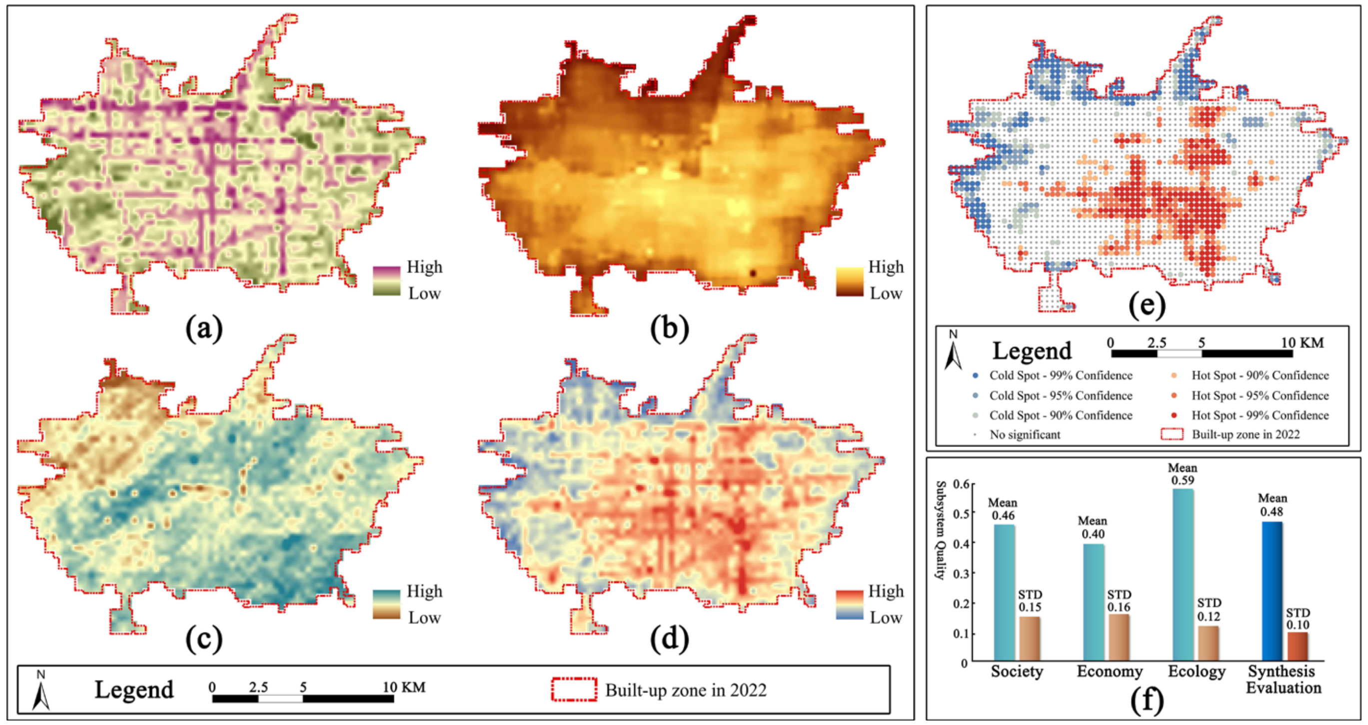
The individual indicators are weighted and overlaid with McHarg's Layer Cake and CRITIC models. The results are

◂◂ **Figure 2** : Data processing flowchart
Figure 3: Synthetic Evaluation Framework
Figure 4: Synthetic Evaluation Framework



Urban Subsystem	Weights (%)	Indicators	Weights (%)
Society	38.23	Space syntax - Integration	60.16
		School Density Per Capita	7.46
		Hospital Density Per Capita	7.81
		Construction Land Area Per Capita (m^2)	24.57
Economy	34.64	S-GDP (RMB million/ km^2)	43.32
		Bank Density Per Capita	5.68
		Company Density Per Capita	17.83
		Mall Density Per Capita	7.31
		Population Density (People/ km^2)	25.86
Ecology	27.13	RSEI	34.91
		Green Space Area Per Capita (m^2)	18.04
		AOD	47.05

Figure 5: Evaluation results. (a)-(b) Social/ Economic/ Ecological subsystem of development degree; (d) Synthesis urban development degree; (e) Cold/Hot spots of urban development degree; (f) Statistic of the subsystem/synthesis development degree
▸▸**Figure 6:** Coordination classification based on CCD with corresponding area percentage
▸▸**Figure 7:** (a) Coordination classification; (b) Joint coordinate axis of Development Degree - CCD



then analysed regarding their coupling with the Coupling Evaluation/ Obstacle Diagnosis Model.

Synthetic Evaluation Model: the social subsystem considers how to provide the three main needs: transport, education & health, and space. The economic subsystem considers the economic structure (POI density) and output (GDP). Finally, ecosystems also focus on green space quantity and land ecological quality. Atmospheric quality (AOD) is also an important part of the environment. Humans should be the central focus of the urban environment. Some indicators are further weighted by population (Figure 3).

CRITIC model: given the unavoidable multicollinearity between the indicators, we chose the Criteria Importance Through Intercriteria Correlation (CRITIC) model [27] to calculate the weights of each one. This method includes the intensity of the contrast and the conflict in the framework.

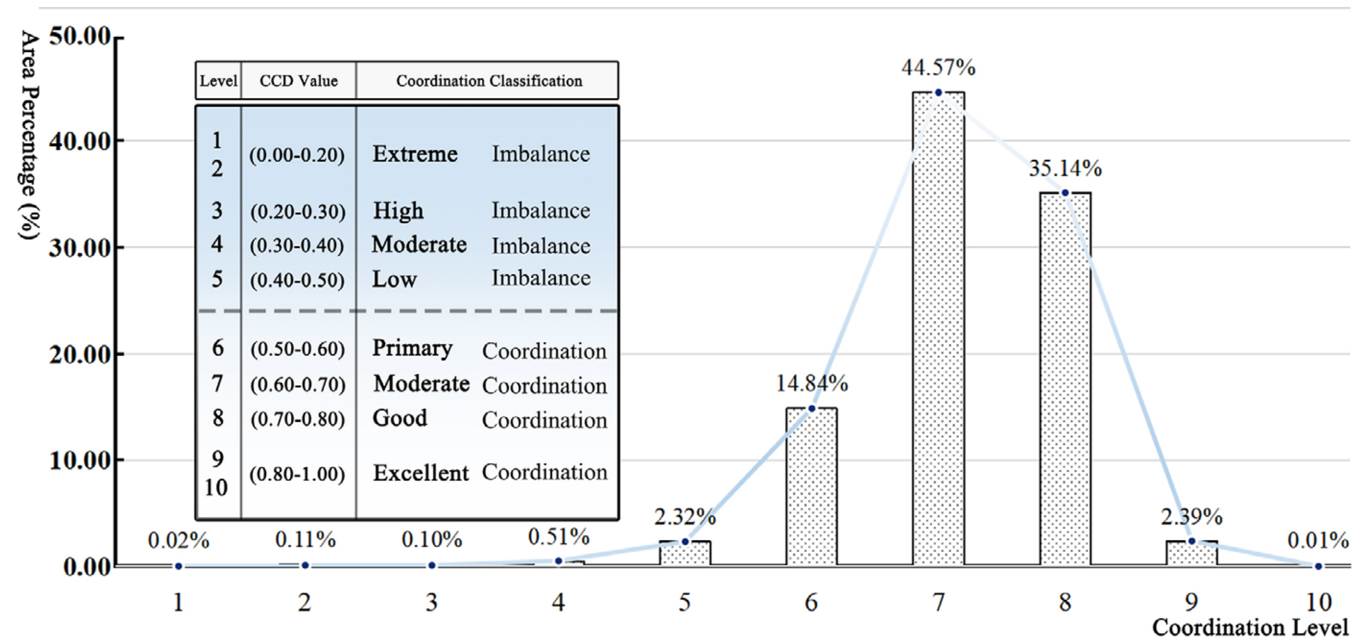
Coupling Evaluation Model and Obstacle Diagnosis Model: based on the synthesis evaluation, firstly, the coordination level between the subsystems was analysed using the Coupling Evaluation Model. The Coupling Coordination Degree (CCD) has a higher value, indicating better coordination between subsystems and more resilience within the overall system. At the same time, the Obstacle Diagnosis Model was used to analyse the main obstacle factors of the urban system. A higher O value (O, O= [0.0, 1.0]) indicates that the subsystem is less developed and has greater development needs [12]. The Obstacle Diagnosis Model provides insight into the subsystems that require more resources and effort to overcome obstacles and achieve their maximum potential.

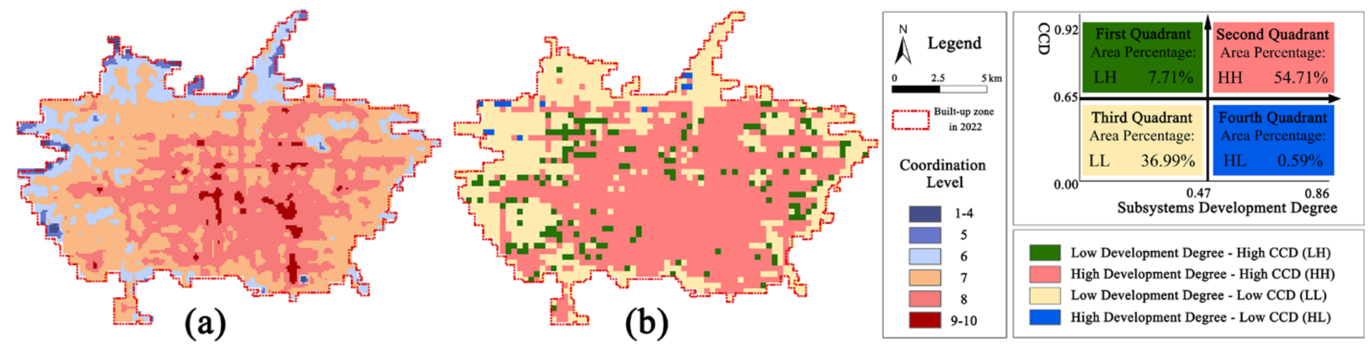
2. RESULTS

These include the results of the system development assessment, the overall coupling coordination statistics. They also include the correlation between coupling coordination and system development degree, and finally the obstacle degree hotspot analysis.

2.1 Synthetic evaluation results

Weight of each indicator: the weights calculated by CRITIC are shown below (Figure 4). The ranking of the importance of the subsystems shows: Society > Economy > Ecology.





Synthetic evaluation results: based on the mean, we can observe that the development degree of these systems is ranked as follows: Ecology > Society > Economy. The standard deviation (STD) represents the data dispersion degree, i.e. the imbalance and heterogeneity of development (Figure 5 (f)). As a result, the economic system exhibits higher heterogeneity (STD=0.16), while the ecosystem is relatively more balanced (STD = 0.12). Spatial details are equally important, and both ecological and economic systems exhibit an upward trend in the Southeast and a downward trend in the Northwest, except for the social system (Figure 5 (a)-(c)). Furthermore, we visualised the aggregation of the values using the Hot Spot Analysis method. Hot Spots represent areas with high-value aggregation, while Cold Spots represent areas with low-value aggregation. The synthesis evaluation tends to be high in the centre and low in the surroundings, with the Southeast exhibiting high values and the Northwest exhibiting low values (Figure 5 (d-e)).

2.2 Coupling Coordination and Obstacles

Coupling Coordination Degree: CCD statistics are shown in Figure 6 (mean=0.66, STD=0.09). Luohe City belongs to the moderate coordination classification.

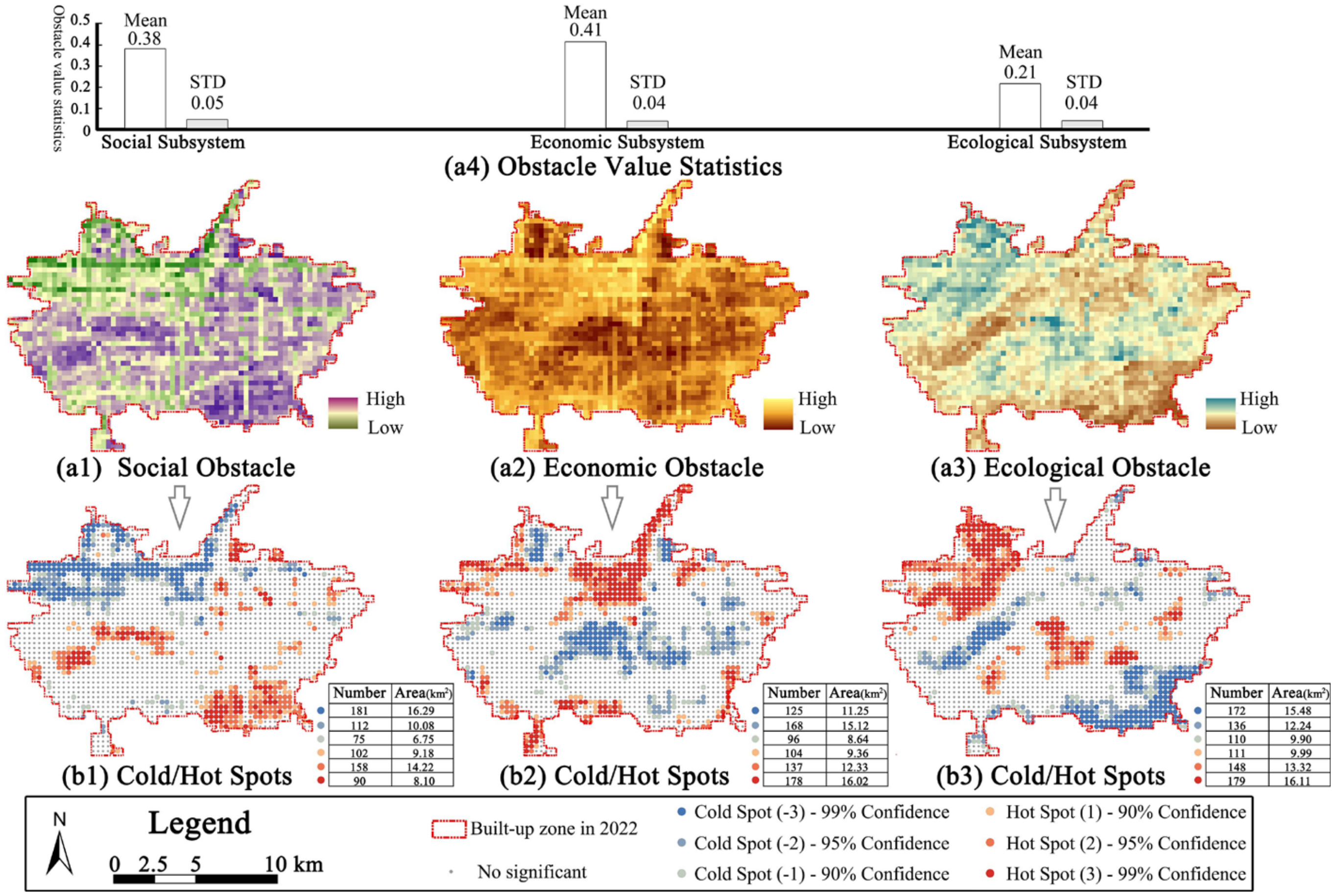
Based on the coordination classification levels (Figure 6), we can obtain spatial details (Figure 7 (a)): high in the Southeast and low in the Northwest. In order to visually represent the relationship between development degree and CCD, the two are linked based on the cartesian coordinate (Figure 7 (b)). The pixels were grouped into four categories, with classification thresholds determined by Jenks natural breaks. The highest percentage of High Development Degree – High CCD (HH) region is a trend that needs to be maintained, and the High Development Degree – Low CCD (HL) and Low Development Degree – High CCD (LH) regions are tiny (Figure 7 (b)).

Obstacle Degree: globally (Figure 8 (a4)), the economy is the main obstacle to improving the CCD (Mean=0.41). However, we observe that the core obstacle areas of the ecosystem are much larger (Hot Spot (3)=16.11km²). Therefore, even though the economic system shows a higher obstacle degree on average, the development needs of the landscape, especially in its core obstacle areas, should not be ignored.

3. DISCUSSION AND CONCLUSIONS

This paper's indicators are based on land use (except Atmospheric Pollution). This is primarily because the

Figure 8: Subsystem obstacle statistics/ heterogeneity/ hotspot analysis



land is the physical base for urban activities, is undergoing significant change and is subject to the most dramatic impacts during urbanisation [11]. Society is dominated by accessibility. Transit-oriented Development (TOD) theory considers transport essential for heterogeneous urban expansion. GDP dominates the economy. The AOD dominates the ecosystem.

The urban development degree (Mean) and CCD in Luohe are 0.48 and 0.66 respectively. The proportion of positively correlated regions (HH and LL) between the two is over 90%. With urban development, resilience is becoming a prerequisite for integral construction. Urban growth, which should be seen as systemic change, is the combined effect of all subsystems rather than any individual subsystem [17]. The relationship between the size of obstacle areas and residents' perceptions may be an essential factor. Despite a lower global obstacle degree, larger ecological obstacle areas may substantially impact residents' perceptions due to their more visible and tangible nature. This could amplify the perceived importance of ecological issues within the urban environment, necessitating a more focused approach to ecological development in urban planning strategies. Adjusting development heterogeneity can better help multi-system coordination and balance development. Based on the results of the barrier degree analysis, targeted filling of ecological low-value areas and promoting a balanced development of the landscape will help the coupling and coordination of urban systems.

The different frameworks and indicators may significantly influence the study's results. Conducting multi-temporal studies, refining indicators and maintaining the robustness of the evaluation framework will be the next step [1]. ⦿

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