Land Suitability Evaluation for Resilient Urban Planning: a Planning Practice of Pingdingshan City, China

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1. Introduction

1.1 Resilient urban planning

Cities are increasingly becoming complex systems of social, economic and ecological factors. However, they are very vulnerable when any of their subsystems are destroyed or fail to adapt to new challenges (Xiaoling Zhang, 2018). From 2005 to 2010, the world's urban population increased at a rate of 1.9%. Rapid urbanization and growing mega-cities point to a need for more resilient cities that have the capacity to withstand the shocks of population growth, rapid demographic shifts in population, and environmental catastrophes (Kevin C., 2013). Thus, fostering resilience gradually becomes an important goal for urban planning.

The concept of resilience has traditionally been used in physics and psychology to respectively indicate the ability of an object to return to its original position after receiving a hit and the ability to successfully survive a shock or trauma. It was first introduced into ecology in 1973 by Holling who described it as a measure of the ability of systems to absorb change and disturbance without losing the pre-disturbance relationships between their constituent elements (Ayyoob Sharifia, 2014). Resilience in terms of cities generally refers to the capacity of a city to rebound from destruction (ARUP, 2016), the ability to absorb, adapt and respond to changes in an urban system (Kevin C., 2013).

Urban resilience is divided into several main aspects that cover ecological, infrastructural, economic and social dimensions. The *Rockefeller Foundation* carried out a research about *city resilience index* in 2016, the result shows that the resilience of a city relates to 4 key dimensions, including people, organisation, place and knowledge. Underpinning these four dimensions, 12 goals are defined to represent the city's immune system (Tab.1). This paper is mainly concerned with the place dimension, the quality of infrastructure and ecosystems that protects, provide and connect people.

Table 1: The dimension and goals of city resilience

Dimension	**Goals**
People: health & wellbeing	Minimal human vulnerability, Diverse livelihoods & employment, Effective safeguards to human health & life
Organisation: economy & society	Collective identity & community support, Comprehensive security & rule of law, Sustainable economy
Place: Infrastructure & ecosystems	Reduced exposure & fragility, Effective provision of critical services, reliable mobility & communications
Knowledge: Leadership & strategy	Effective leadership & management, Empowered stakeholders; Integrated development planning

Source: ARUP (2016) City resilience index, The Rockefeller Foundation

1.2 Land suitability evaluation

Land suitability evaluation processes, the bases to guide the urban planning, are essential for assessing and reacting to land conditions, opportunities, and threats for urban planning. The reasonable and orderly land suitability evaluation is of great significance for ordering spatial development, guiding population resource environments and ensuring socio-economic resilient development.

The *Urbanization work conference of CPC Central Committee* in 2013 paid high attention to the improvement of ecological-living-industrial space, which means reducing industrial land, appropriate increasing living land, and delineating ecological protection red lines for agricultural space such as cultivated land, garden land, vegetable fields. Wu Yanjuan (2016) built a land suitability evaluation framework from the perspective of the ecological-living-industrial function of land resources.

Table 2: Ecological-living-industrial land classification system

Classification		**Details**
Ecological land	Important land	Conservation land for water, soil, wind and sand fixation, flood regulation, riparian protection and biodiversity, including forest land, shrub land, woodlands, grasslands, pond water, beach coating, inland tidal flats, ditches, glaciers and permanent snow land
	General land	Saline-alkali land, swamps, sand and bare land
Industrial land	Agricultural land	Paddy fields, dry land, gardens, agricultural facilities land
	Industrial land	Mining land
Living land	Urban land	Cities, towns, scenic spots, railways, highways, airports, port terminals, pipeline transportation, reservoir water and hydraulic construction land
	Rural land	Village, rural road land

Source: WU Yanjuan, YANG Yanzhao, YANG Ling, ZHANG Chao, YOU Zhen（2016）"Land spatial development and suitability for city construction based on ecological-living-industrial space−−take Ningbo City as an example", Resources Science, Vol.38: 2072-2081

1.3 Research purposes and methodology

The aim of this research is to propose a land suitability evaluation for resilient urban planning and applied it to the planning practice of Pingdingshan City, China. The methodological approaches of the Multi-Criteria Decision Analysis, Analytical Hierarchy Process and Delphi Process were used for the research. And the evaluation process is supported by a geographical information system (GIS) within the framework of ArcGIS software, combined with the Remote Sensing Image processed by ENVI (The Environment for Visualizing Images) software.

1.4 Research framework

The land suitability evaluation involves natural, agricultural and urban ecosystem resilience. From the aspect of natural ecosystem resilience, the evaluation involves three factors, including forest vegetation factor (vegetation coverage index, vegetation type index), river & reservoir factor (water level index, water quality grade index) and animal factor (biodiversity index). In the dimension of agricultural ecosystem resilience, two factors are considered, including crop factor (agricultural output value index) and farmland factor (Prime cropland area index). As for the urban ecosystem resilience, urban construction factor (elevation index, slope index, land-use situation index) and urban disaster factor (geological subside disaster index, flood disaster index) are selected. Finally, put forward resilient urban planning based on the result of land suitability evaluation (Fig.1).

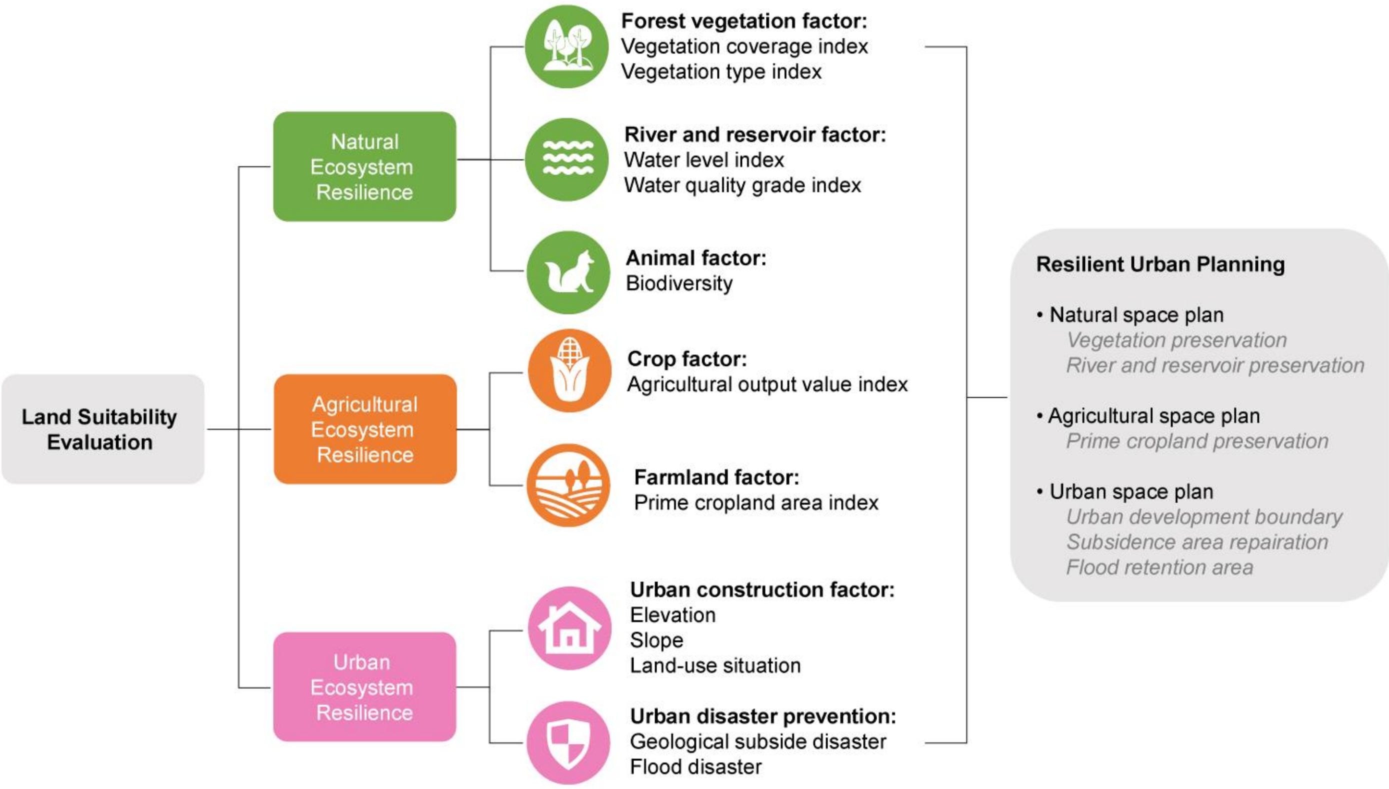

Figure 1: Research structure of land suitability evaluation

2. Land Suitability Evaluation for Pingdingshan City, China

2.1 Study area

Pingdingshan is a prefecture-level city covered 7,882 square kilometers in central Henan province, China. The city had 4,048 thousand inhabitants in 2016, 52.5% of whom lived in the urban area. Compared to similar inland cities, Pindingshan is very rich in water and ecological resources, and 42% area of the city are mountains and hills. But the urban economy has mostly relied on coal mineral exploitation for four decades, causing irreversible damage to the environment. Therefore, the planning of Pindingshan urgently needs a resilient and holistic approach of urban development and land use.

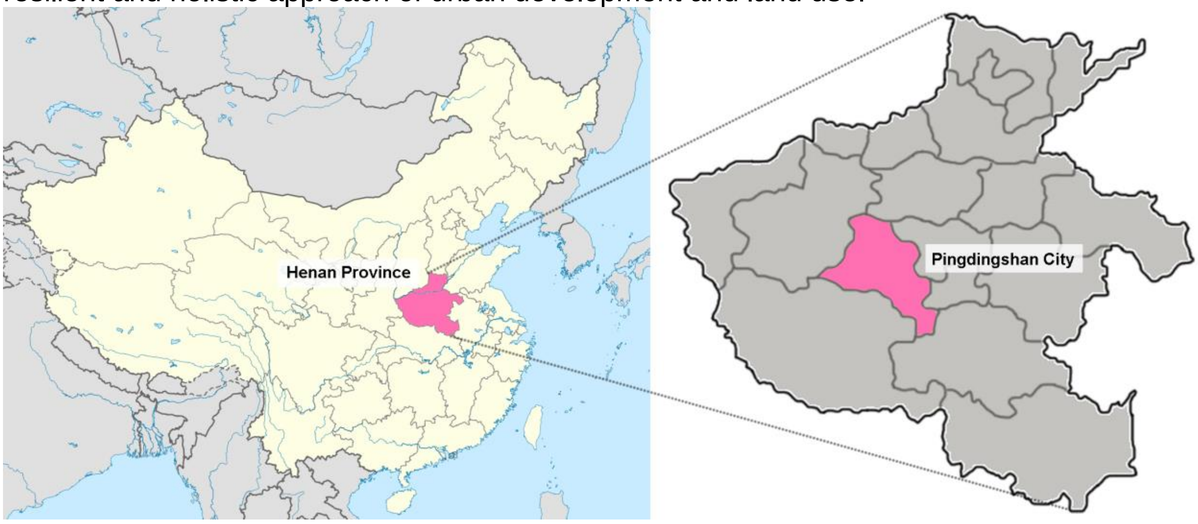

Figure 2: Location of Pingdingshan

2.2 Natural Ecosystem Resilience

For the forest vegetation factor, the area with important vegetation and high forest coverage need protecting. Normalized difference vegetation index (NDVI) was used to assess whether the area being observed contains live green vegetation or not. The formula is NDVI=(NIR-R)/(NIR+R), NIR means near infrared reflectance, and R means red reflectance. And based on the remote sensing image processed by ENVI (The Environment for Visualizing Images) software, the different area of coverage level was identified (Fig.3). Combination with the analysis of different vegetation type layout (Fig.4), the result shows that the western area of Pingdingshan has precious high coverage vegetation, which need strictly protecting. The northern and southern area of Pingdingshan has precious vegetation too, but the coverage rate is low, therefore these areas urgently need to be planed into the protection zone.

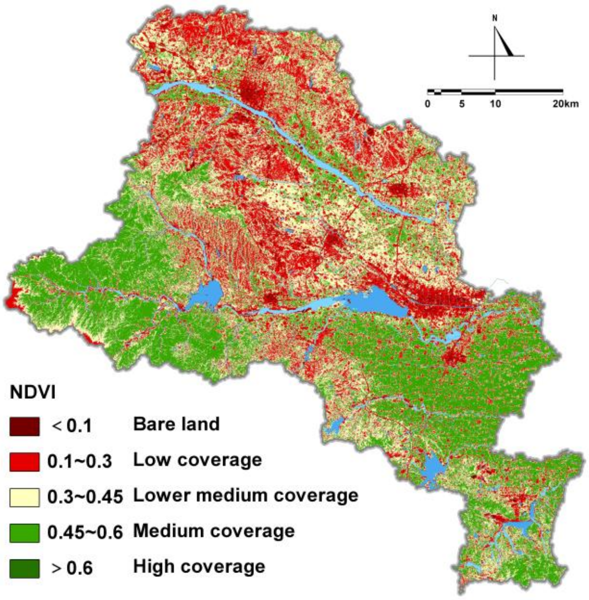

Figure 3: Vegetation coverage

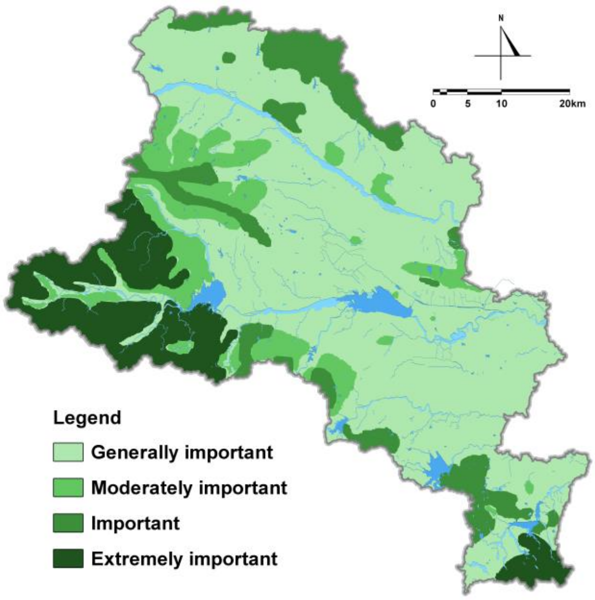

Figure 4: Layout of different vegetation type

Table 3: Importance of vegetation type

Grading standards	**Importance**
farmland, waters, wetlands	generally important
sparse shrubbery, subtropical economic forest, subtropical bamboo forest, low-to-medium coverage grassland, evergreen orchard	moderately important
subtropical broad-leaved or deciduous shrubs, high-coverage grasslands	important
natural or natural secondary subtropical evergreen broad-leaved forest, deciduous broad-leaved mixed forest, subtropical coniferous forests, evergreen deciduous coniferous broad-leaved mixed forest	extremely important

Source: Chang Bin et. al, 2014

For the river and reservoir factor, the quality, volume and grade of water are considered. And the water surrounding urban built-up area faced with serious pollution (Fig.5). One canal, five reservoirs and eight rivers are key protected objectives (Fig.6), which need strictly protection measures.

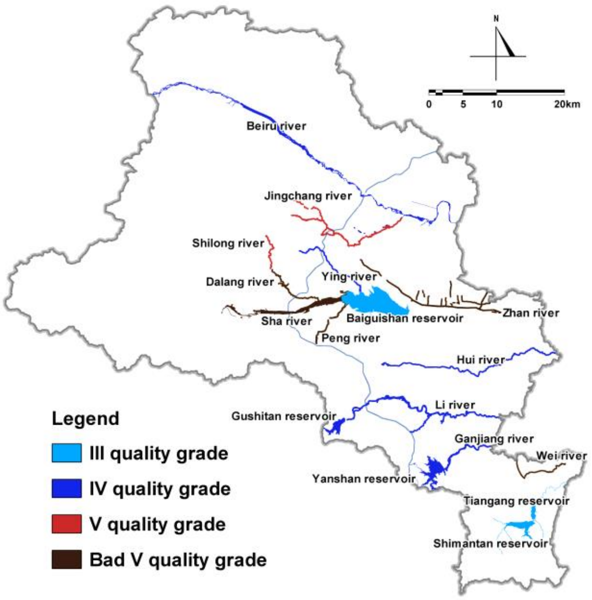

Figure 5: Water quality of river and reservoir

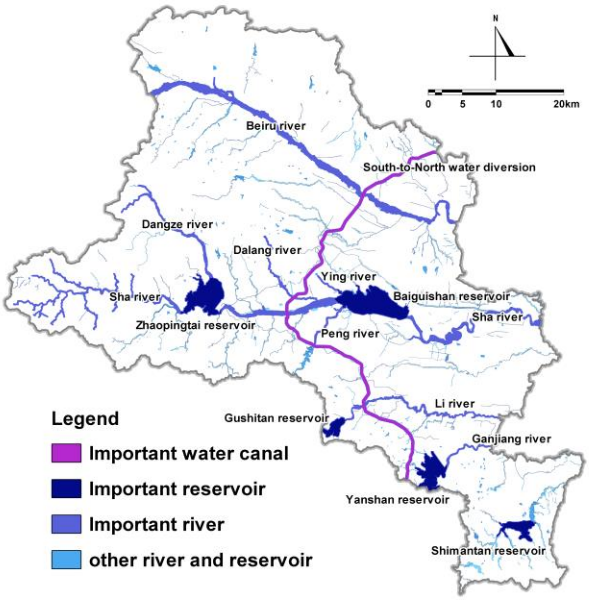

Figure 6: Important river and reservoir

Table 4: Water quality of river and reservoir

Water quality grade	The water and reservoir in Pingdingshan
III quality grade	Baiguishan reservoir, Tiangang reservoir, Shimantan reservoir
IV quality grade	Beiru river, Ying river, Hui river, Li river, Ganjiang river, Gushitan reservoir, Yanshan reservoir
V quality grade	Shilong river, Jingchagn river
Bad V quality grade	Dalang river, Sha river, Peng river, Zhan river, Wei river

Source: Pingdingshan Municipal Development and Reform Commission (2017) The "13th Five-Year" Comprehensive treatment plan for water environment in Huaihe basin in Pingdingshan

Table 5: The protection area for important water resource

Water resource	Protection area	The water and reservoir in Pingdingshan
water canal	200m land area on both sides of canal	south-to-north water diversion
reservoir	200m land area surround reservoir	Baiguishan, Zhaopingtai, Gushitan, Shimantan, Yanshan
river	100m land area on both sides of river	Ganjiang, Li, Sha, Beiru, Dangze, Peng, Ying, Dalang

Source: Pingdingshan Municipal Water Conservancy Bureau (2015) The "13th Five-Year" plan for the development of water conservancy in Pingdingshan

For the animal factor, based on biodiversity survey data, identifying the priority species living areas, assess the conservation of ecological diversity. The western and northern areas of Pingdingshan with diversity ecosystem types and species, require strict protection (Fig.7).

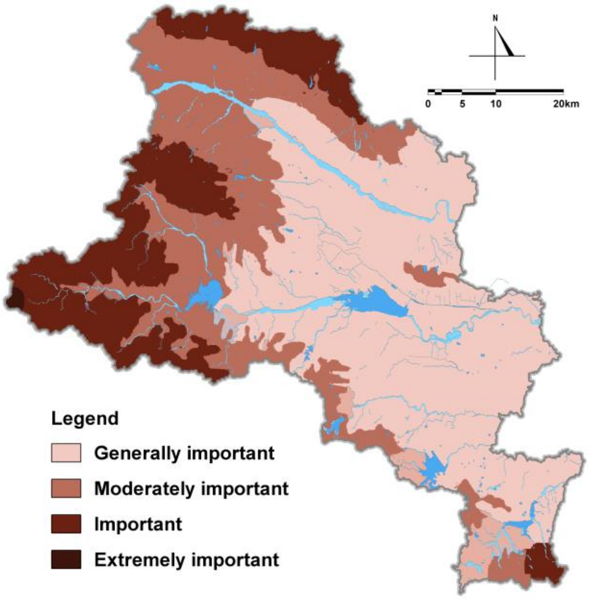

Figure 7: Importance of biodiversity

Table 6: Importance of biodiversity

The ratio of biological species to the total number of species in the city	Importance
Species ratio < 5%	generally important
5% < Species ratio < 15%	moderately important
15% < Species ratio < 30%	important
Species ratio > 30%	extremely important

Source: Chang Bin et. al, 2014

2.3 Agricultural Ecosystem Resilience

For the agricultural factors, the output value of agriculture, forestry, animal husbandry and fishery per unit area represents the capacity of agricultural production. The higher output of agriculture area has higher agricultural value, where is not suitable for large-scale construction (Fig.8).

Figure 8: Importance of agricultural output

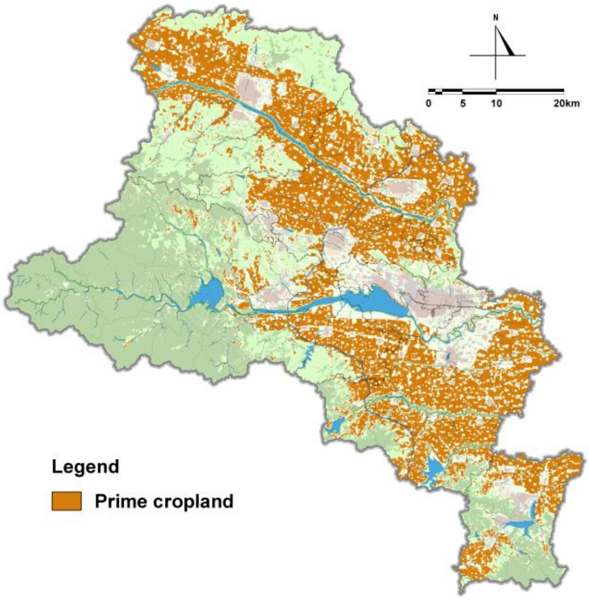

Figure 9: Layout of prime cropland

Table 7: Importance of vegetation type

Production value of agriculture, forestry, animal husbandry and fishery per unit area (10,000 yuan/km2)	Importance
production value per unit area＜100	generally important
100＜production value per unit area＜200	moderately important
200＜production value per unit area＜300	important
300＜production value per unit area	extremely important

Source: Chang Bin et. al, 2014

2.4 Urban Ecosystem Resilience

For the urban construction, the areas where elevation is higher than 120 meters (Fig.10), the slope more than 15° (Fig.11), are high ecological sensitive for construction. The highly ecological sensitive areas of elevation and slope are concentrated in the west, north, south of the city. And the urban built areas are low ecological sensitivity.

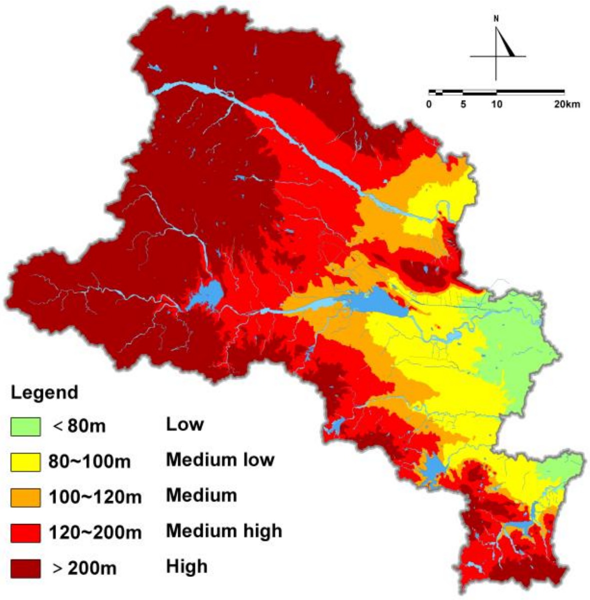

Figure 10: Elevation of Pingdingshan

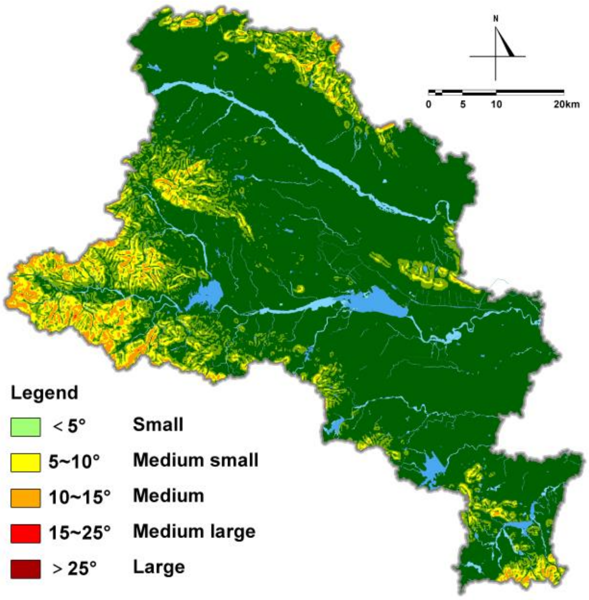

Figure 11: Slope of Pingdingshan

For the urban disaster prevention, geological subside disaster and flood disaster are the two main disasters in Pingdingshan. Because the urban economy has mostly relied on coal mineral exploitation for four decades, Pingdingshan is threatened by geological disasters such as landslides, landslides, ground fissures and mudslides. The coal mining subsidence areas are scattered and need to be strictly controlled and protected (Fig.12). Pingdingshan belongs to flood-disaster-prone areas, in particular, the area surrounding Baiguishan reservoir has a greater hazard of flooding. Therefore, it is necessary to plan the flood disaster prevention partition (Fig.13).

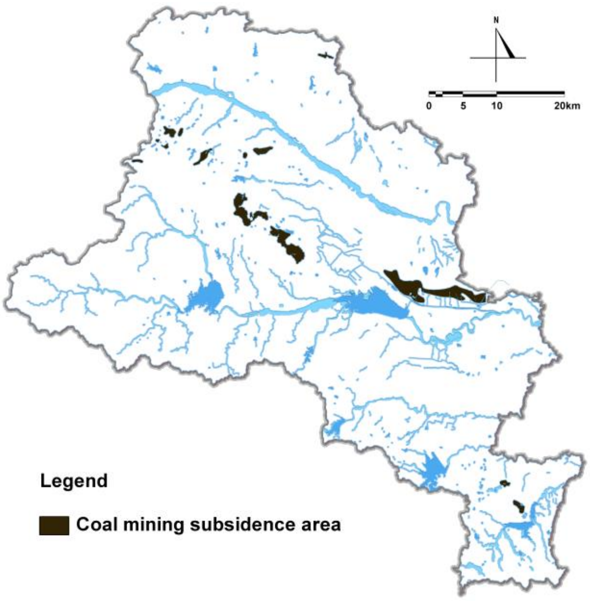

Figure 12: Elevation of Pingdingshan

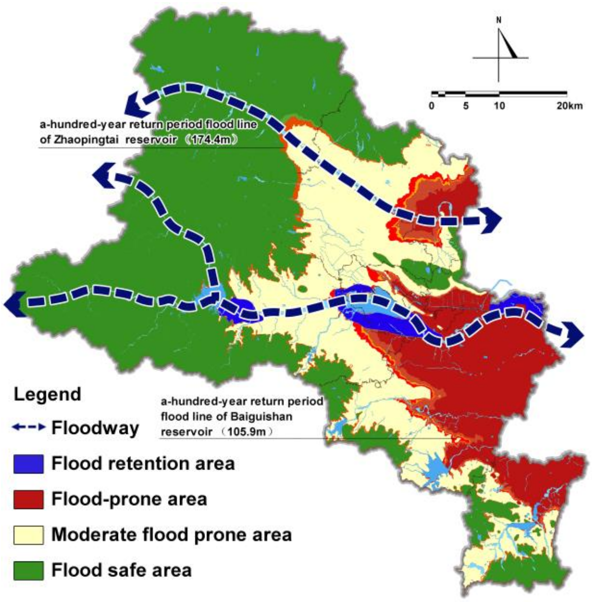

Figure 13: Flood disaster prevention partition

Table 8: Flood disaster prevention partition

Flood disaster prevention partition	**Location**
Flood safe area	the areas where elevation is higher than 174.4m, the one-hundred-year return period flood line of Zhaopingtai reservoir
Moderate flood prone area	the areas where elevation is between 105.9m and 174.4m, between the one-hundred-year return period flood line of Zhaopingtai reservoir and Zhaopingtai reservoir
Flood-prone area	the areas where elevation is lower than 105.9m, the one-hundred-year return period flood line of Baiguishan reservoir
Flood retention area	downstream of Zhaopingtai reservoir, Baiguishan reservoir, Sha river
Floodway	Dangze river, Sha river, Beiru river

2.5 Comprehensive Land Suitability Evaluation

Using GIS overlays the vegetation coverage, slope and elevation (other factors cannot be overlaid to the GIS due to the data type reason). The ecological sensitivity is divided into five levels. Ecologically high and medium high sensitive areas have high ecological value and need strictly protecting. These areas mainly locate in Lushan County, Wugang City, and Ruzhou City. There are also distributions in the north of Pingdingshan, the southwest of Ye County, and the northern part of JiaCounty. The low sensitive and medium low sensitive areas are suitable for construction. These areas are mainly located in built urban areas with low elevation, gentle slopes, and low vegetation coverage.

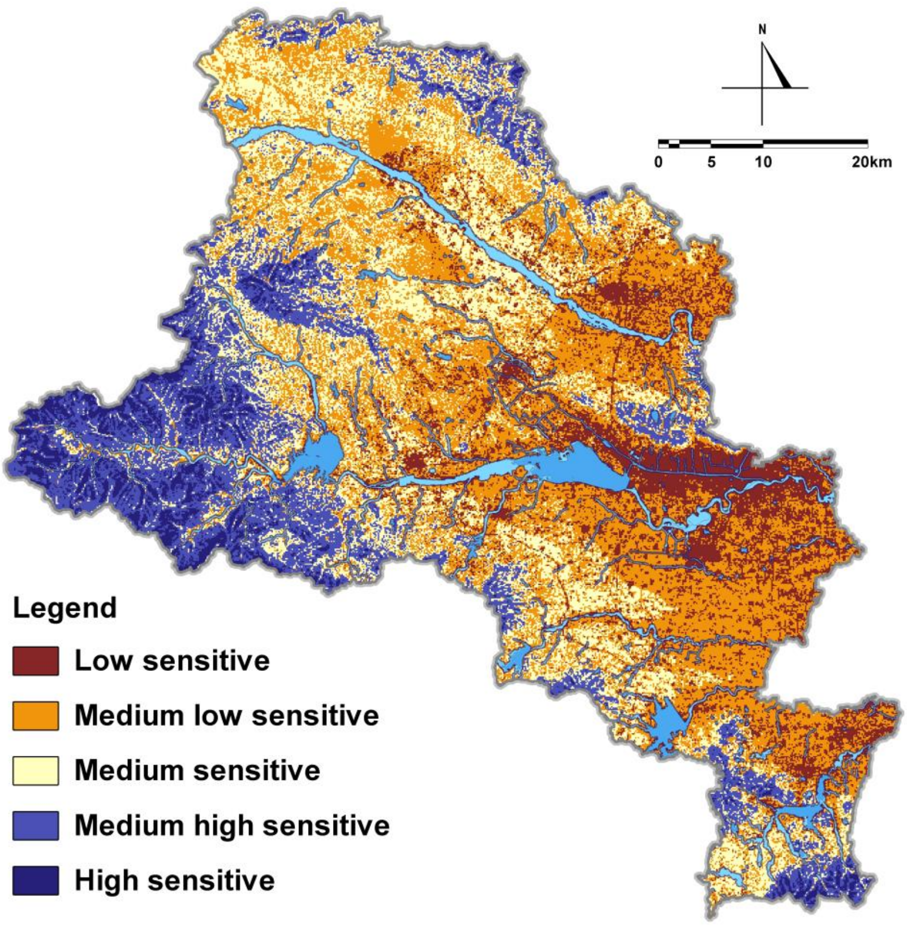

Figure 14: Ecological sensitivity area analysis

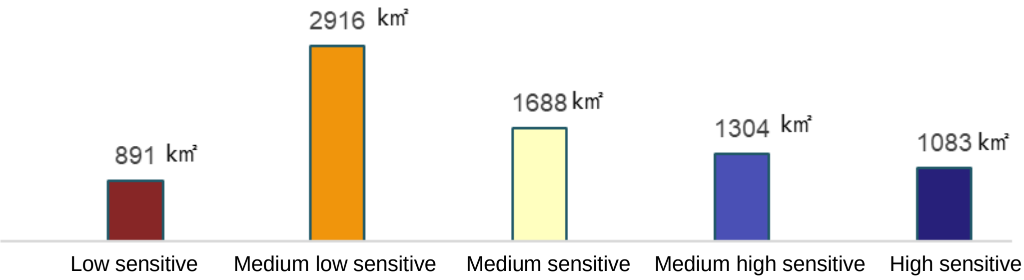

Figure 15: Area of Ecological sensitivity spaces

Table 9: The indexes of ecological sensitivity spaces

Index	**Low sensitive**	**Medium low sensitive**	**Medium sensitive**	**Medium high sensitive**	**High sensitive**	**weight factor**
Vegetation Coverage	＜0.1	0.1-0.3	0.3-0.45	0.45-0.6	＞0.6	0.4
Slope	＜5°	5°-10°	10°-15°	15°-25°	＞25°	0.3
Elevation	＜80m	80-100m	100-120m	120-200m	＞200m	0.3

3. Resilient Urban Planning for Pingdingshan City, China

3.1 Natural space plan

In current situation, only Jia county and Baofeng county has the ecological red line planning, the coverage is too small to protect the whole area. Therefore, based on the land suitability evaluation, plan ecological red line area 2433.7 square kilometres, accounting for 31% of the total Pingdingshan city. The ecological red line including vegetation preservation area and river & reservoir preservation area, any development and construction unrelated to the protection in the area shall be forbidden. For the vegetation preservation area, based on the five existing forest parks and five existing scenic spots, plan ten vegetation preservation areas with a total area of 1600.97 square kilometers. The river and reservoir preservation area are totally 832.73 square kilometers.

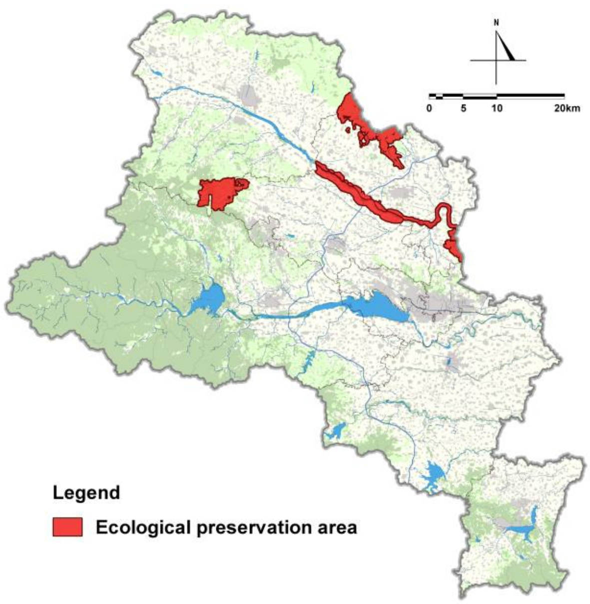

Figure 16: Current ecological red line

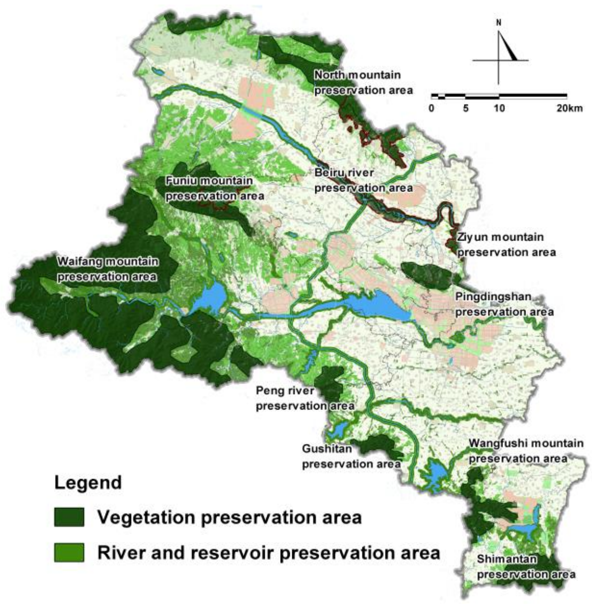

Figure 17: Planning ecological red line

3.2 Agricultural space plan

Based on the existing prime cropland planning of Pingdingshan, plan 3,049 square kilometers agricultural spaces, accounting for 39% of the total area of Pingdingshan. The agricultural spaces include 2,723 square kilometers of prime cropland, 79.6 square kilometers of general cropland, and 246.4 square kilometers of village area.

3.3 Urban space plan

According to the analysis of ecological sensitivity, plan the urban development boundary in the low and medium low sensitive area, and all the construction should happen within the boundary. The coal mining subsidence areas are totally 124 square kilometers, and the green belt not less than 500 meters wide between the living area and the mining area. In 2035, the area of urban development boundary is totally 690 square kilometres, and 60% of the area are concentrated in the core development area. The plan of urban development boundary follows three principles. The first principle is the protection of ecological core resources. Based on the existing ecologically protected red line and permanent basic farmland, protecting river ecology and agricultural core resources. The second principle is the protection and restoration of ecological fragile area, protecting ecologically fragile areas and gentle slope repair areas, avoiding subsidence areas and flood storage areas. The third principle is protecting natural patches inside urban development boundaries, including rivers, wetlands, mountains and important ecological corridor.

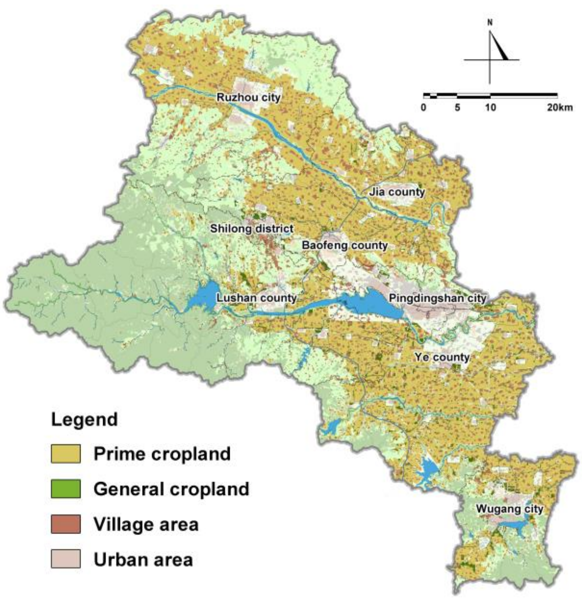

Figure 18: Layout of different cropland

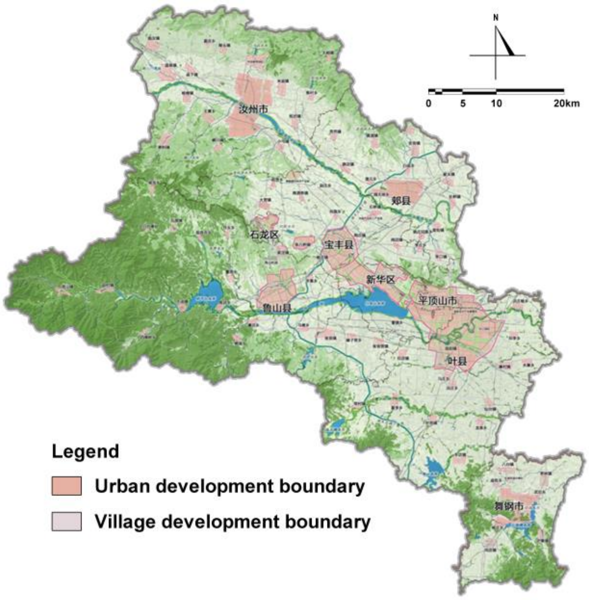

Figure 19: Urban development boundary plan

3.4 Resilient urban planning

Plan prohibited-construction, restrained-construction and construction area. In prohibited-construction area, any urban development and construction are forbidden. The area is 6,288 square kilometers, accounting for 80% of the total area, including prime cropland, mountain forest land, river reservoirs and ecological parks. Urban and rural construction should be avoided as much as possible in restrained-construction area. The area is 179 square kilometers, accounting for 2% of the total area, including geological subsidence area and independent construction land. The construction could appropriately expand based on the built-up area according to the traffic location conditions, and all the constructions should be controlled within the construction area. The area is 1415 square kilometers, accounting for 18% of the total area.

Figure 19: Natural, agricultural, urban elements

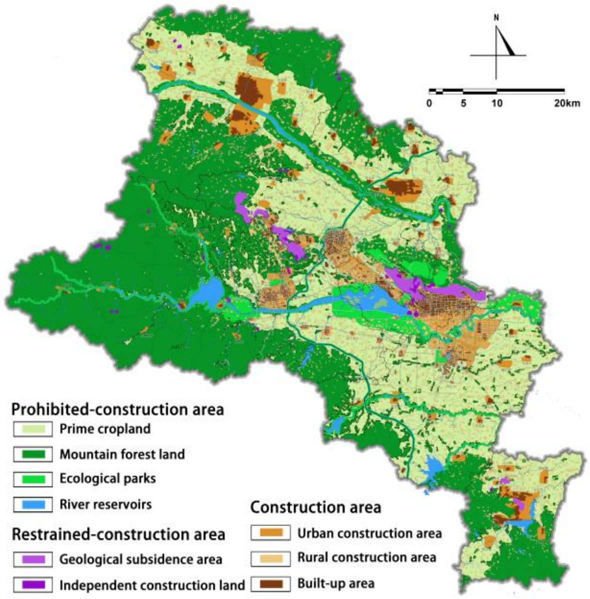

Figure 20: Resilient urban planning

4 Conclusion and Discussion

Overall, the output of this study can be used as the basis for land suitability evaluation in urban planning processes. In the process of ecological strategy planning, the land suitability evaluation model is used to identified the ecological valuable and sensitive areas, providing an ecological basic framework for land-use planning. The model has the capacity to provide decision makers with a clear and comprehensive picture of the urban infrastructure and ecosystems resilience development proposal and supports them in making better informed decisions to deliver cooler cities in our warming planet.

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