International Conference on Geographies of Health and Living in Cities: Making Cities Healthy for All, Healthy Cities 2016

Dynamic Land Use Change and Sustainable Urban Development in a Third-tier City within Yangtze Delta

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Abstract

The main purpose of this study is to explore the relationship between dynamic land use change and sustainable urban development in a typical third-tier city within Yangtze Delta. This study also attempts to provide suggestions in terms of land use cover change (LUCC) and land use intensity change (LUIC) for governments and planners to achieve better land use performance and more rational urban development. Spatial and regression analyses show LUCC rather than LUIC affects urban sustainability. Thus, implications for future city construction were proposed.

Keywords: Land use cover change; Land use intensity change; Sustainable urban development; Third-tier city.

1. Introduction

Cities and land use are dynamic not only because the ceaseless landscape can mirror the underlying economic and sociocultural transformations of a city[1] but also because land use changes (LUCs) in turn have profound influences on urban development. In China, developments or transitions in many cities rely heavily on land developments. Thus, land urbanization is considered a significant impetus by governments to accelerate urbanization or modernization. However, inappropriate land utilization causes several issues, such as habitat encroachment, biodiversity loss, soil degradation, food security threat, and an increase in poverty, inequity, and

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other social problems. LUCs that result from developments in a city can be identified by land use cover change (LUCC) or/and by land use intensity change (LUIC). LUCC focuses more on the process where a parcel of land loses its original type because of natural phenomena and human-related activities, whereas LUIC, which is the reverse of land expansion, implies the alteration commonly steered by compelling desires. The pursuit of high intensity is mainly meant to capture the yield gap created by different amounts of input from the agricultural, economic, or social aspect and/or its corresponding output differences measured by land area or time duration. LUIC may not bring about LUCC, but could result in ecological changes within the same type of land use cover[2]. Therefore, no relationship between more inputs and ascending production exists because reducing only the demands for land size cannot ensure fewer occurrences of negative socioeconomic and ecological effects at the same time.

Sustainable urban development (SUD) is vital to cities in eastern China, where large bottlenecks restrain long-term aspirations despite immediate economic prosperity. Rapidly growing coastal cities in the Pearl River Delta and Yangtze Delta and large cities in interior districts are always the focus of research, whereas urban change is nonstationary over space and LUCs in various places have distinct characteristics[3]. In fact, the relatively small inland cities need more attention to better identify pivotal development attributes and to help planners and governments avoid anticipated issues. Thus, this study aimed to investigate the relationship between the dynamics of LUC and SUD because changes in the quantity and quality of land use may create competitions and conflicts directly and indirectly through urban development.

2. Literature review

2.1. Land use cover change

Studies detecting and monitoring natural resources have four mainstreams, namely, detecting if a change has occurred, identifying the nature of the change, measuring the areal extent of the change, and assessing the spatial pattern of the change. Remote sensing (RS) is the most reliable and effective instrument for data gathering and quantitative analysis of temporal impacts. RS in combination with the geographic information system is more functional and appealing because it enhances classification accuracy and surveys the spatial structure of LUCCs by using adjuvant data, visual interpretation, and expert knowledge. Monitoring determines the time and location of LUCC occurrence, and knowledge of the underlying human and biophysical drivers that cause changes is important. The existing literature has proposed three types of main drivers, namely, economic development, environmental inducement, and social inducement. Rapid industrialization, urbanization, population growth, and economic reforms were argued to be major social and economic contributors to LUC in the case of Kunshan[4]. Cultural, political, technological, and natural driving forces were also important[5] as LUC mirrored location behavior and preferences[6], which further manifest that psychology and behavior are easily influenced by culture and politics.

2.2. Land use intensity change

Despite no consensus in connotation, the overall definition of urban land use intensity (LUI) depends on space scales and stresses on comprehensive benefits of land use and the structure of a city. However, in the middle and microscopic views, intensification of urban land utilization aims to yield outputs. Previous studies on evaluations of LUI in the macro scope have attracted the most concerns. Meanwhile, limited attention has been focused on a relatively narrow range of LUI. Development zones and industrial lands are major research areas of evaluation at the intermediate scale, whereas residential lands, commercial lands, and micro level remain the focus of least interests. Many factors attributed to LUI can be evaluated using various methodologies. The multiplicity of objectives and factors affecting LUI make multifactor synthetic evaluation the most widely accepted method for evaluation. The assessment results of multifactor synthetic evaluation can be easily expressed by a framework constituted of indicators and corresponding weightings. Many scholars have introduced a vast array of indicators, namely, indicators that restrict LUI, such as environmental contamination index and urban greenery coverage; indicators that reflect intensive use levels, such as input intensity and utilization intensity; land use efficiency indicators, such as land economic outputs; and land intensive use trend and sustainability indicators. Landscape-level indicators, such as plot ratio, economic output, and environmental index at least at smaller spatial scales, were also introduced. Macro indicators cover urban spatial layout, utilization intensity, output efficiency, and land sustainability, whereas

intermediate indicators are selected from land functions in the industrial, commercial, and residential zones, separately.

2.3. Sustainable urban development

Scholars seem to agree that environmental method, life cycle assessment (LCA) method, and sustainability indicator assessment method are three broad sustainability assessment methods. The environmental sphere of sustainability is the most significant among the scope of urban activities in the first method. The LCA method tends to address a broader range of urban problems in that it considers the social and economic dimensions of urban development, but it separates the environmental, social, and economic considerations into various assessments and it consumes a long time because of complicated data requirements. The sustainability indicator method is used predominantly in monitoring and measuring the overall state of progress concerning sustainability. With this method, the manageable number of indicators may be identified to represent and quantify the dynamic interaction mechanisms between physical construction and built environment, social state, and economic components. However, these assessment methods have been challenged because they neglected to predict the future state of urban development that possibly led to a misunderstanding of the relationship and feedback between the three pillars of sustainability[7], which can be improved by bridging the gap between theories and practices. China has seen the prominent trend that sustainability science is gaining popularity in urban studies. Although no national policy has been developed to promote SUD across the nation, numerous researchers have initiated explorations of SUD in China. Meanwhile, no inland city in Yangtze Delta has yet been assessed to support policy making.

Considerable attention has been focused on LUC and SUD individually in China. However, only a few studies have considered and clarified the relationship between LUC and SUD. The LUC and sustainability index scores of 29 major Chinese cities, as well as the relationship between LUC and SUD, were examined, and a similar study was conducted in 16 cities within the Yangtze River Delta[8]. Despite unprecedented attempts, the environmental sustainability index was used for sustainability assessment, which emphasized solely on environmental protection[8].

3. Study area and evaluation method

3.1. Background of study area

The study area is located in Taizhou City, one of the noted historic, cultural, park, and good habitation cities in China. Taizhou City has quite a long history spanning 2,100 years with distinctive cultural rhythm of Jiangsu Province. Despite its strategic position, Taizhou City has remained out of the public eye compared with more prosperous areas, such as Shanghai Metropolis and Northern Jiangsu within the Yangtze Delta. In contrast to its surrounding cities, Taizhou City experienced a comparatively fast development, but underwent a slow population growth from 4.96 million in 1996 to 5.06 million in 2012. The detailed study area encompassed the majority of the city proper, within which most of the LUCs have occurred during 2002–2010. Although this area accounted for only 11% of the total territory and 16% of the entire population, Taizhou City contributed approximately 27% to the total GDP in 2011. The case of Taizhou City will help enhance knowledge on the patterns, determinants, and effects of the exploratory variables of LUC at various periods. Therefore, the results of this study may present typical and representative implications for cities in mid-Jiangsu because most of its inland cities have identical economic, environmental, and social contents.

3.2. Evaluation of land use cover change

Given the unavailability of high-resolution RS of 2002, the existing land use cover map (Fig. 1(a)) was acquired from the Bureau of Land Resources Taizhou. However, the 25 land use cover types in the original map were too many and trivial to be perceived. Therefore, post-processing is a necessary step to generate this map. After the categorization and simplification of legends, seven primary land use cover types were left for comparison with the map of 2010 (Fig. 1(b)) to find the major LUCCs. In particular, agricultural land type in green contained paddy, irrigable field, arid land, orchard, forestry, and other grass that provides a direct visual expression of lands for farm use in view of its importance in food security and environmental conservation. The red patches denoted coverage of

the city and organic town, whereas the black areas represented rural settlements as human encroachment has usually been regarded as a core indicator of the significant loss of valuable agricultural land. Highway, railway, port, and wharf land occupied the main lands reserved for transportation, and these patches were distinguished by the color purple. With smooth transportation connections, transregional industrial clusters were created. Thus, advantage resources can be concentrated and reorganized to promote regional coordinative development. Considering the city's vision of maintaining the traditional characteristics of a water town, water and facility land involving various water bodies and relevant water conservancy construction were distinguished by the color blue. Orange defined special use land, which included mining land and scenic spots. Finally, bare land and other grassland were classified as other land and distinguished by the color gray.
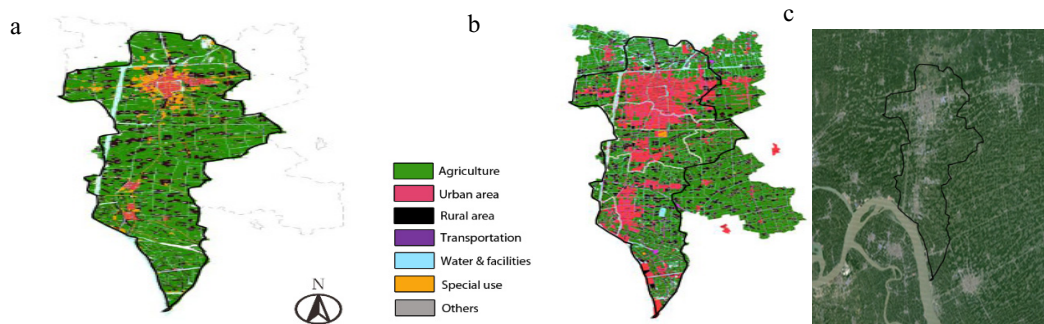

Fig. 1. (a) 2002 land use map; (b) 2010 land use map; and (c) 2010 original RS imagery.

The 2010 original RS imagery (Spot 6 & 7) with high resolution (1.5 m for panchromatic imagery and 6 m for multispectral imagery) was selected for land use cover classification. Seven land use types were recognized by the supervised classification method using the Esri ERDAS software and compared with the map of 2002 (Fig.1 (b)). Furthermore, the administrative boundary was enlarged during nine years. Thus, the original boundary of 2002 was outlined in black bold line in Figs.1 (a), 1 (b), and 1 (c) as the same comparative area. After comparing the land use cover maps of 2002 and 2010, the related findings and analyses are presented in the subsequent section.

3.3. Evaluation of land use intensity change

Table 1. Framework for the evaluation of LUIC.

Component	Indicator	State
Economic(B1:0.5)	Investment in fixed assets per area(C1:0.1429)	Present
	GDP per area(C2:0.2857)	Present
	GDP and built-up land increase elasticity(C3:0.0715)	Future
Social(B2:0.1875)	Employment per area(C4:0.0703)	Present
	Population load(C5:0.0938)	Present
	Population and GDP increase elasticity(C6:0.0234)	Future
Environmental(B3:0.3125)	Rate of sewerage disposal(C7:0.1172)	Present
	Residential garbage disposal cleared(C8:0.1172)	Present
	Coverage rate of green area developed(C9:0.0781)	Present

The multifactor synthetic evaluation method was used to structure the evaluation framework. The indicators were selected through literature review and face-to-face interviews with planners and officials in the Bureau of Land Resources, and the corresponding weightings assigned to each indicator were obtained using the AHP method. As land is tightly related to the industry, capital, population, and ecology, C1 and C2 reflected the economic inputs and outputs and C3 denoted the development trend of LUI. Social factors (C4, C5, and C6) signified the urban land's

attraction to employment, its present holding capacity, and the future tendency for people. Environmental factors (C7, C8, and C9) marked environmental protection significance. C3 and C6 illustrated the future state of LUI. Before processing the original data, specific measurements of each indicator were defined first. According to the hierarchy of levels in the evaluation framework, each upper level outcome was the accumulation of its lower level values. Standardization was applied to process raw data from the yearbooks to ensure dimensional consistency and reduce the magnitude difference.

3.4. Evaluation of sustainable urban development

Table 2. Framework for the evaluation of SUD.

Component	Indicator	Measurement
Environmental(A1)	Wastewater(B1)	Ratio of treated industrial waste water up to the discharge standards per capita(C1:1/9)
	Quality of ambient air and atmosphere(B2)	Total volume of industrial sulphur dioxide removed per capita(C2:1/9)
	Waste generation and management(B3)	Percentage of industrial solid wastes utilized in a comprehensive manner(C3:1/9)
Economic(A2)	Consumption and production patterns(B4)	Annual power consumption per capita(C4:1/9)
	Economic development(B5)	GDP per capita(C5:1/9)
	Research and development(B6)	Living expenditures for consumption of recreation, education and cultural services per capita(C6:1/9)
Social(A3)	Education, security and health(B7)	Total expenditures for education, social security and public health(C7:1/9)
	Housing(B8)	Floor area of living space per capita(C8:1/9)
	Poverty(B9)	Difference between dispensable income and expenditure per capita(C9:1/9)

The combination of LCA method and sustainability indicator assessment method was employed to develop the evaluation framework, considering the city's vision similar to that of Hong Kong with its Sustainable Development for the 21st Century. In particular, a less developed city should include environmental and social concerns, as well as economic aspects, into city development that attains sustainability. Poverty and income inequality are increasingly serious in Taizhou, and economic development with social stability is crucial. By contrast, the environmental constraint has become the major barrier to future developments of the society and economy. Given the availability of data and local conditions, measurements of indicators were described (column "Measurement"), as follows: C1, C2, and C3 were from the liquid, gas, and solid perspectives. Economically, annual power consumption per capita (C4), GDP per capita (C5), and living expenditures for the consumption of recreation, education, and cultural services per capita (C6) were employed to measure indicators. Total expenditures for education, social security, and public health (C7), the floor area of living space per capita (C8), and the difference between dispensable income and expenditure per capita (C9) were employed as social instruments. Each indicator was entitled to the same weightings (1/9) because all the three components were equally important in a perfectly sustainable city. The calculation method of the score of urban sustainability was the same as that of LUI assessment.

4. Findings and discussions

4.1. Performance of LUCC

Spatially, LUCC was determined to be characterized by the expansion of urban built-up areas at the cost of agricultural land and rural areas and by the emergence of polycentric urban clusters around the urban core or along the transportation arteries. A possible explanation for this finding is that Taizhou is strictly an inland city restricted by geographical location that radiates to its neighborhood or gets radiated by adjacent metropolis, such as Shanghai

or Nanjing. Active performance in developing transportation is essential to change its passive location. As a result, settlements or workplaces of urban residents gradually scatter for optimal distribution and finally locate sporadically for economic or social purposes. Arable land; urban, town, rural, and mining land; and water and facility land were the top 3 types with the most amounts of changed areas, whereas orchard land and grassland were persistent categories with nearly no dynamics. Furthermore, arable land, forestry land, and water and facility land were the only types that had net losses over the years. All of the land types reflected relatively high swap levels, with the exception of forestry land, whose swap area was approximately close to zero that implied its consistency as well. Moreover, the majority of the lands undergoing changes in areas was through quantitative transformation instead of location shift. This finding echoes the fixed location of land and the difficulty in changing the use of land from one kind to another kind.

Urbanization, tertiary industry, investment in real estate, road area per capita, agricultural output, and aquatic output were major factors that cause LUCC. As for economic factors, urbanization can create higher demand for labor, higher quality of life, and larger domestic demand. Thus, people from suburban areas were attracted to the city. In addition, Taizhou was at such a key stage of development of high and new technology industry, and the biotechnology and medicine field was an important mission for adjustment of industrial structure manifested by preferential policy for tertiary industry. Socially, improving social security and offering better public infrastructure and living space increased the government's investment in real estate industry and municipal construction, such as roadwork to maintain social stability. In terms of the environmental aspect, the reaction to the government's call on protecting arable land has registered as agricultural output and aquatic output directly.
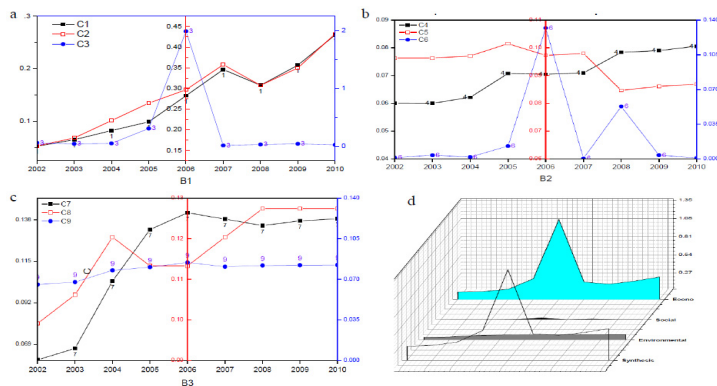
4.2. Performance of LUIC

Fig. 2. (a) Economic performance; (b) Social performance; (c) Environmental performance; and (d) Synthesis performance.

The land input level (C1) generally maintained the same trend as land productivity (C2); however, both of them dropped to the bottom in 2008 possibly because of the economic crisis where the real estate industry was bogged down (Fig. 2(a)). Comparatively, the indicator C3 was used to predict the future direction of the relationship between land increase for construction and the extra output from the added land area, but failed to provide stable and persuasive hints because it exhibited a series of ups and downs and its performance indicated the unnecessary link between GDP gains and more land used. Until 2008 (Fig. 2(b)), the holding capacity (C5) of urban land exhibited a stable upward trend that was inconsistent with the land attraction level that tempted employed labor (C4), which implies that land capacity to hold people is limited and declines once the maximum capacity is reached. Whether the population increased at the expense of more construction land for living, working, or playing still remained unknown (C6). On top of the green coverage ratio (C9), the fluctuations in waste disposal ability in terms of sewage (C7) and garbage (C8) has placed the city in an adverse position because improper treatment of waste can cause undesired effects that may influence the entire city physically and psychologically, thus reducing urban sustainability (see Fig. 2(c)). Relative steady coverage of the greenbelt may not be regarded as a completely good hint to demonstrate environmental sustainability of the city because city development is not static and greener space will be required for population growth. Obviously, economic scores made the most significant contribution to the

comprehensive results of LUI (Fig. 2(d)). This finding is partly due to the uneven weightings and reflects the blind land use strategy that strives for economic benefits rather than benefits to the society and the environment.

4.3. Performance of SUD

Taizhou was environmentally conscious and marched toward the protection of its environment for nine years. However, the obvious progress of its SUD in 2008 corresponded to LUI performance. Considerable efforts have been exerted to limit pollution to air (B2) during 2007 to 2010, which may have resulted from the adjustment of industries with high consumption of energy and heavy pollution to air as people began to seek a better quality of life. Power consumption (B4) and GDP gains (B5) increased simultaneously without significant changes, whereas living expenditures for the consumption of recreation, education, and cultural services (B6) increased to its peak in 2005 and decreased to its bottom in 2008 (Fig. 3(b)). The bad environment of the world economy appears to depress the citizens' confidence in investing in ideology product whose returns are difficult to pay back in the near future. After all, these factors are unnecessary for living when there is no affluent money to spare. The continuous increase in total expenditures on education, social security, and public health (B7) showed the government's persistence in meeting the needs of people even at a difficult time. People shared less floor area (B8) of living space in 2008 but quickly gained compensation in the subsequent year as the economy was powered up. Surplus buying power (B9) guaranteed a prosperous life and stable society. The overall scores and environmental aspect performed with similar patterns as their increase slopes did not differ largely (Fig. 3(d)). Economic performance suffered most from economic depression. Socially, the performance not only underwent large fluctuations but also had a relatively low level all the time.
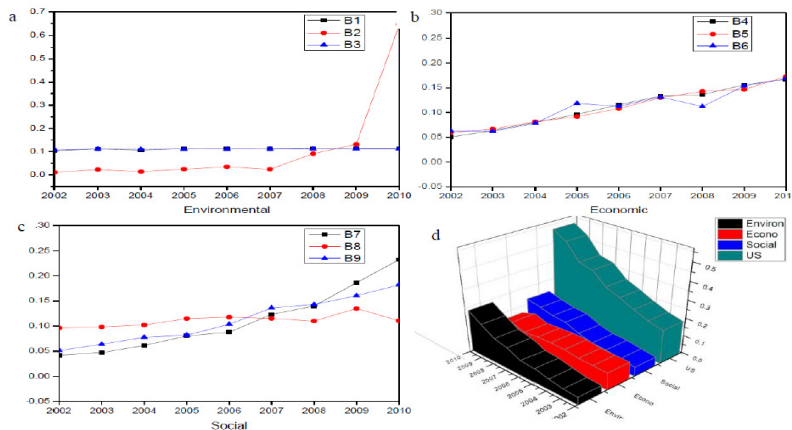

Fig. 3. (a) Environmental performance; (b) Economic performance; (c) Social performance; and (d) Synthesis performance.

4.4. Relationship between LUC and SUD

The economic situation, urbanization, industry structure, and LUCC were hypothesized to achieve a sustainable environment. First, Fig. 3(d) reflected that striking standpoint of SUD in 2008 when the economic crises upset all industries. As such, GDP per capita was used to denote the economy. Second, urbanization indicates people relocating to the city and causing a heavy environmental burden. Industrial upgrade and industry category significantly affect the environment. Secondary industry constitutes traditional or pillar industries, such that its share in the gross contributions to GDP was selected and compared with that of the primary industry. Finally, road area per capita and arable land area exhibited a striking LUCC pattern. Land covered by the road may replace arable land area for improved transportation. By contrast, more roads meant more vehicles that exhaust gas to the air, thus resulting in severe air pollution. Therefore, in regression analysis, the environmental scores of SUD were used as the dependent variable and GDP per capita, urbanization, secondary industry, tertiary industry, road area, and arable area were employed as the independent variables. The curve fit results showed GDP per capita, road area per capita, and square of road area per capita were related to environmental sustainability under a confidence level of 95%.

That is, their fitness values (Sig < 0.05) of quadratic regression were proven to be statistically significant in the *F* and *t* tests. However, as the coefficients of variables were negative, a high GDP was obtained or, with more roads constructed, the environmental performance would become worse, which indicates that the economic condition and LUCC are significant threats to achieving environmental sustainability. When the coverage of the road reached a certain degree, the environmental performance would be improved. The same procedures and calculations were conducted to test the relationship between LUI and economic sustainability of SUD. GDP per area, investment in fixed assets, and population load were considered the independent variables. The result indicated no necessary link between an increase in GDP or population and more land input.

5. Recommendations and conclusion

5.1. Recommendations

Taizhou City marched toward urbanization in the urban landscape, and only slight variations in SUD were observed during 2002–2010. The prevailing environmental performance of SUD revealed the government's efforts. However, land urbanization was more striking than population urbanization at the cost of LUC. SUD focused more on the physical form of a city, whereas the spiritual and aesthetic aspects have been largely ignored. Therefore, the government is encouraged to intervene to achieve a more comprehensive urbanization of civilization, permeability, and lifestyle transformation because the true core of LUI is somehow intangible and can actually avoid the disadvantages of population flow by increasing the efficiency and quality of land use. The government is also encouraged to deal with its role in land use and enforce the overall legal system regarding the land market. More detailed and basic mandatory regulations and requirements are needed to regulate the irrational behavior of land use. Furthermore, education and awareness promotion by professional institutes, social organizations, and government bodies are also effective means for rational land use and SUD.

5.2. Conclusion

With the investigation into the patterns of LUCC from the temporal and spatial perspectives, the dynamics of LUCC was identified by clarifying the characteristics, causes, and outcomes. With regard to LUIC, LUI performances in different time points were evaluated and compared to analyze the discrepancies, inducements, and consequences. Moreover, the relationship between LUC and SUD was explored through regression analysis and reliability test. The results showed that arable land suffered a significant loss because of urban construction and that different land types experienced various change patterns. LUI and SUD exhibited a general upward performance and improvement potentials in the social aspects. LUCC has been proven to affect SUD to a certain extent, whereas SUD was not influenced by LUIC. Moreover, more inputs in population and fix assets can be placed on land to obtain a high LUI. This study provides a significant reference for inland cities in the lower reaches of the Yangtze River Delta with respect to achieving efficient land use and SUD.

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