

Article

# Dynamics of Tradeoffs between Economic Benefits and Ecosystem Services due to Urban Expansion

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**Abstract:** Urban expansion has been proved to spur significant changes in economic development worldwide, yet it degrades ecosystem services. Seldom attempts are made to explore the dynamic relationship between economic benefits and ecosystem services. As such, we simulated land use in Wuhan, the capital city of Hubei Province in China, by employing the LANDSCAPE model (LAND System Cellular Automata model for Potential Effects) in scenarios with datasets supported. This paper analyzes the amount of variation of urban growth between its corresponding implications for ecosystem services in Wuhan, and further reveals a meaningful dynamic linkage between economic benefits (EB) and ecosystem services value (ESV). The amount of urban expansion is a critical factor affecting tradeoffs of EB and ESV. A certain amount of urban expansion (the turning point) will worsen tradeoffs between EB and ESV, and when the amount of urban growth surpasses the turning point, a small increase of EB will pay a great amount of ESV. The better the amount of urban growth is controlled, the more harmonious the EB and ESV will be. Our research is helpful to find the turning point as well as the proper amount of urban growth at the aspect of tradeoffs between EB and ESV.

**Keywords:** land use change; urban expansion; ecosystem services; economic benefits

## 1. Introduction

Natural ecosystem is vital in human survival, livelihood and wellbeing directly and indirectly [1], it affords all resources for fitness, progress and sustainability of the whole human society [2,3], and meanwhile, it also suffers. To achieve desired wellness and improvements, humans have been continuously acting on land use, and human activities pose an escalating impact on ecosystem function and ecological security to meet the demands of the population [4,5]. It has been proven that landscapes and ecosystems have been seriously damaged due to unlimited or improper land development and utilization [6–8]. Land use changes in the world have resulted in about \$4.3–\$20.2 trillion/yr. of ecosystem services emissions from 1997 to 2011 [2]. Land use changes are the most important factors of global change, and do not only change the landscape of the earth's surface, but also have important influence on water purification, soil conservation, nutrient cycles, regional climate [9], biodiversity [10,11], has seriously damaged ecosystem services [12], introduced habitat fragmentation [13] and isolation, and has affected the development of human society [14].

Urban expansion is a complex system correlated to nature and social economy [15]. Urban expansion itself, as a big factor of economic development, has been closed linked to the economic growth [16]. Economy develops, urban areas expand. However, the expansion of existing cities and newly emerged cities must be at the loss of natural or seminatural landscape [17], explicitly and implicitly leading to heavy land use changes. Influence of the urban expansion on ecological environment is obvious and serious [8,18,19]. Byproducts derived from urban expansion include urban waterlogging, urban

heat island effect, air pollution, water pollution, waste emission, solid waste pollution, etc., and are experienced daily in most cities. The latest vivid example should be urban waterlogging disaster in Wuhan in the summer of 2016. These reflect a series of conflicts between ecosystem services and economic benefits. As a dominant feature of urbanization in China, urban expansion plays a critical role in economic transformation and upgradation [20,21]. China's economic development benefits from urban expansion, but the obvious enclosed negative impact of urban expansion on ecosystem structure and function makes the whole ecosystem service vulnerable, in result obstructs economic progress [22]. Therefore, how to optimize the allocation of limited land resources to realize the coordinated development of urban expansion, economic development and ecological conservation is a challenge for decision-makers and urban planning [23]. Making a sustainable land use planning in consideration of economic development and ecosystem services become an important and urgent task for sustainable development.

Policies addressing population growth and the natural environment and disasters are crucial to the sustainable development of cities [24,25]. With growing awareness of sustainability, physical parameters such as geological hazards, topographical parameters are considered into land suitability evaluation to insure sustainable urban development [26]. George drew suitability maps for the urban growth and industrial development according to geological hazards and geological features [27]. Elevation, slope, aspect and other geographic factors were taken into consideration to predict urban growth of South Korea [28]. Furthermore, researchers have attempted to carry out related studies to simulate impacts of urban expansion on ecosystem services and economic development by setting up different land use scenarios on the basis of land suitability, so as to find sustainable land use, economic development and ecosystem protection patterns [29–31]. Zhang et al. evaluated the impacts of urban expansion on food production, carbon storage, water retention, and air purification in Beijing–Tianjin–Hebei urban agglomeration from 2013 to 2040 based on the Shared Socioeconomic pathways (SSPs) and the Land Use Scenario Dynamics-urban (LUSD-urban) model [32]. Taking the redline restriction into account in future land use planning is of great significance to the protection of landscape pattern and the sustainable development of social economy [33]. Moreover, most of existing researches showed that there were synergies, tradeoffs and loss of ecosystem services in urban regions [34]. It is also indicated that there exist tradeoffs and synergies between different functions of wetland [17], forest [35] and agricultural land ecosystem [36,37] under different land use scenarios. Tradeoffs analysis about ecosystem services value is helpful to analyze compromise of ecosystem services and economic benefits [38], which provide valuable idea and revelation for land use management and urban development.

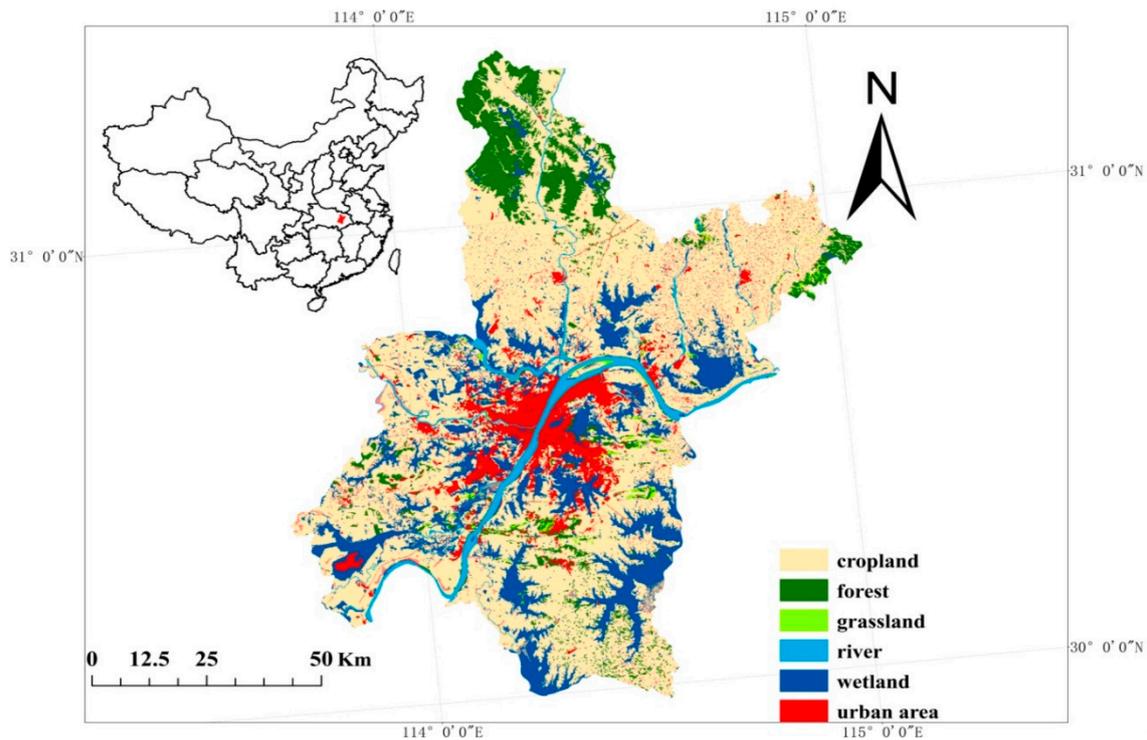
This paper focuses on dynamics of tradeoffs between ecosystem services and economic benefits by simulating land use changes driven by urban expansion for the city of Wuhan. This study aims to illustrate impact of urban size on ecosystem services and economic, and provide valuable reference for urban management units to utilize sustainable planning for ecology and economics. The LANDSCAPE (LAND System Cellular Automata model for Potential Effects) model was used to simulate land use changes in a series amount of urban expansion. In given application contexts, the amount of urban expansion always determines the relationship between economic benefits (EB) and ecosystem services value (ESV), hence opening an effective and convenient way for decision-makers to utilize and optimize the relationship of the aforementioned.

## 2. Methods and Material

### 2.1. Study Area

Wuhan is situated in the central China at the confluence of Yangtze River and Han River (Figure 1). It covers a total area of 8494 km<sup>2</sup>, and has a total population of 10.6 million in the end of 2015. In the last twenty years, Wuhan experienced rapid urbanization with a large area of urban expansion and large scale population migration, making its urban areas expand from 378 km<sup>2</sup> to 789 km<sup>2</sup> in a span

of ten years between 2000 and 2010 [39]. Wuhan is not only the biggest city in central China, but also an important transportation hub; it is the economic center of Hubei Province as well as highway, railway and airline network heart radiating the whole country. It has become an important part of Yangtze River Economic Zone in China, which is full of economic competitiveness and vitality. As the important strategic pivot to realize the development of the central region of China, it is in the critical period of rapid economic development and urbanization. A lot of ecological land will be converted into built-up land to meet the needs of urban development, which will certainly yield competition between economic benefits and ecological conservation will be more intense. Therefore, Wuhan is an ideal research area for this study.



**Figure 1.** Location of study area, and its land use in 2010.

## 2.2. Modeling Land Use Change in Wuhan

In order to explore the dynamics tradeoffs between ecosystem services value (ESV) and economic benefits (EB) with urban expansion, we simulated land use changes by using the LANDSCAPE (LAND System Cellular Automata model for Potential Effects) model based on the land use map in 2010. The LANDSCAPE model is a (Cellular Automata) CA-based model, capable to simulate a variety of land use changes. There are four steps in this research: (1) to develop and calibrate LANDSCAPE model based on land use map of Wuhan in 2000 and 2010; (2) to simulate land use changes driven by urban expansion; (3) to calculate economic benefits and ecosystem services value based on land use change; (4) to analyze dynamics of tradeoffs between economic benefits (EB) and ecosystem services value (ESV) due to urban expansion.

### 2.2.1. The LANDSCAPE Model

The LANDSCAPE model is a CA-based model developed by Ke et al. [40], which is capable to simulate multiple land use changes [41,42]. Similar to some CA-based models, land use types are defined as active land use and negative ones to imply allocation strategies for land use change [43,44]. It's worth noting that we ranked the allocation sequence according to resistance and inertia factors in this model. The simulation results showed that the model is reliable and accurate to simulate

various land use changes. Furthermore, this model can also be used to evaluate the impact of land use policy or ecological protection strategy on land use change. Ke et al. set four scenarios using the LANDSCAPE model to analyze direct and indirect impacts of built-up area expansion on the natural habitat, and the results are of great significance to the improvement of farmland protection [39]. At the same time, we studied the application of the model. In this paper, the LANDSCAPE model was used to simulate land use changes in Wuhan. In conclusion, the LANDSCAPE model has the following advantages: (1) being capable to simulate changes of multiple land use types; (2) implementing hierarchical allocation strategy and resistance; (3) ranking the allocation sequence for active land use, (4) calculating resistance and suitability for individual land use.

In this model, land use types are divided into active land use types and passive ones according to their competitiveness. Changes of active land use are directly driven by human demand, while changes to passive land use are occupied by changes of active land use. For example, grassland is converted into urban land to meet the needs of economic development, whereas urban land expansion directly influenced by human demand. In this paper, there are six land use types in the land use maps: cropland, wetland, forest, river, grassland, and urban land. Among of them, urban land and cropland are active land use types, and the rest are listed as passive ones.

As for the active land use types, the total transition possibility is determined by suitability and resistance [40]. Suitability represents that the attractiveness for a cell to be converted to the target land use type, while resistance indicates the difficulty for certain land use type to be converted into target land use type. The possibility of conversion is calculated as:

$$TTP_{l,tu} = \frac{P_{l,tu}}{R_{l,tu}} \tag{1}$$

where  $TTP_{l,tu}$  is the possibility of land use in location  $l$  to be converted into target land use type  $tu$ ,  $P_{l,tu}$  is the suitability for the land in location  $l$  to be transferred to the target land use type  $tu$ ;  $R_{l,tu}$  is the resistance of location  $l$  to be converted to land use type  $tu$ . Suitability is determined by natural and social factors. For instance, precipitation and slope are crucial for cropland; and distance to main road is an important consideration for urban land. Resistance is determined by characteristics of current land use types. Obviously, the resistance of river and urban land is normally greater than that of grassland, wetland and farmland. The resistance shown in (Table 1) has been calibrated by Ke et al. by simulating land use changes in Wuhan [40]. Suitability is calculated according to:

$$P_{l,tu} = (1 + (-\ln\gamma)^\alpha \times PG_{l,tu} \times Con(C_{l,tu}) \times \Omega_{l,tu} \tag{2}$$

where  $\gamma$  is the random number in the range of 0 to 1;  $\alpha$  is a parameter to control random variables, an integer between 1 and 10.  $PG_{l,tu}$  represents the relationship between land use changes and the driving forces, including natural and socio-economic factors, such as soil, slope, elevation, distance to roads, and so on.  $Con(C_{l,tu})$  represents the constraint of land use change. A cell with a  $Con(C_{l,tu})$  value of 1 indicates that the cell is changeable, while 0 represents the unchangeable cell.  $\Omega_{l,tu}$  represents the effects of neighbor land use types, which is determined by the proportion of the target land type in the adjacent land types.

**Table 1.** Resistance of land use types.

Land Use Types	Cropland	Grassland	Wetland	River	Urban Land	Forest
Resistance	1	1.25	1.25	1.5	1.5	1.25

### 2.2.2. Scenarios Designation

Urban expansion is a dynamic and continuous process. In our research, we set a series of continuous scenarios of urban expansion to analyze tradeoffs between economic benefits and ecosystem

services. It's worth noting that land use types with lower ecological coefficient are given priority to be converted for the sake of biological diversity and ecosystem services [45]. By comparing the relationship between EB and ESV in the urban expansion process, the dynamics of tradeoffs of the two can be revealed. In every scenario, urban area is set to increase by 5000 ha. That is to say, urban area is 109,385 ha in 2010 in scenario SC0, while urban area will expand 5000 ha in the scenario SC1 and 10,000 ha in scenario SC2, etc. The amount of urban area will increase to 387,685 ha in our research, which will result in the loss of cropland, forest, and wetland.

### 2.3. Data Sources for Simulating Land Use Changes

Five datasets were required in the LANDSCAPE model: land use data, terrain data, accessibility data, soil data, and climatological data. Land use data was obtained from the Data Centre of Resources and Environment, Chinese Academy Science (CAS) [46]. Land use data in 2010 was used as the initial land use map for the simulation, which is with a spatial resolution of 30 m. Since the maximum size of land use data in current version of the LANDSCAPE model is  $4000 \times 4000$  cells, land use data was resampled to a spatial resolution of 100 m using a majority method of ArcGIS 10.2. Historical land use datasets show that both the location and the area of river in Wuhan are relatively stable during 2000–2010. Thus, we supposed that the river would be fixed in the near future in simulation of this research.

Distance to the nearest urban land and distance to the nearest road were used to calculate the accessibility. Location of urban land was extracted from historical land use map. The transportation dataset came from the Traffic Atlas of Wuhan, which was used to calculate the distance to the nearest road (including railways, highway, national roads, provincial roads, main roads and minor roads).

Slope and elevation were used to calculate the suitability maps. The DEM (Digital Elevation Model) dataset was obtained from the Shuttle Radar Topography Mission (SRTM) [47]. The spatial resolution of the SRTM DEM in the study area is 90 m. As to be consistent with the land use dataset, the DEM dataset was resampled to a spatial resolution of 100 m. Based on the DEM dataset, slope was calculated by the SLOPE tool of ArcGIS 10.2.

Soil and meteorological datasets are essential to agricultural suitability. Soil datasets, including soil types, soil phosphorus content, and soil nitrogen content were collected from the China Soil Database (gis.soil.csdb.cn). Temperature and precipitation data from 1981 to 2010 were obtained from the ground meteorological observatory in Hubei Province. Then, we got the meteorological datasets of every cell by Kriging interpolation tool in ArcGIS 10.2. Finally, both soil datasets and meteorological datasets were resampled to a spatial resolution of 100 m to consistent with the resolution of land use datasets.

### 2.4. Evaluation of Ecosystem Services Value

Various approaches existing could be employed to estimate the value of ecosystem services, nevertheless, approach proposed by Costanza et al. [2,48] has been widely used. In this approach, ecosystem services have been specified into 17 major categories and 10 biological groups in monetary have been estimated. Xie et al. [49] improved the method of ecosystem services evaluation by developing a new method for the values per unit area of ecosystem services based on the method of Costanza et al. [2]. Then this improved approach is applied extensively to evaluate China's ecosystem services value. In this paper, we relied on Xie's method to evaluate ecosystem services value. In this method, ecosystem services value per unit area for each ecosystem should be figured out firstly. Consequently, subtotal ecosystem services for each ecosystem should be calculated by multiplying the ecosystem services value per unit and area of certain ecosystem. Finally, total ecosystem services

should be figured out by summing up all the subtotal ecosystem services for each ecosystem. In general, total value of ecosystem services in an area can be calculated by the following formula:

$$ESV = \sum_{i=1}^n (B_i \times VC_i) \quad (3)$$

where ESV is the total ecosystem services value in an area,  $B_i$  is the area of ecosystem  $i$ ,  $VC_i$  represents ecosystem services value per unit area for ecosystem  $i$ .

### 2.5. Estimate Economic Benefits of Land Use

Economic growth in a country or a region is promoted by natural resources, human resources, capital accumulation and technological progress on the grounds of the economic growth theory [50]. It is determined by the quantity, quality and efficiency of the above referred promoting factors [51]. The Cobb–Douglas production function was popular to measure the relationship between factors and economic growth [51]. The basic function is described as:

$$Y = AK^\alpha L^\beta \quad (4)$$

where  $Y$  is the total of economic output;  $A$  is the coefficient, which is in response to the development level of science and technology;  $\alpha$  and  $\beta$  are the production elasticity of capital input  $K$  and labor input  $L$ .

In this paper, the EB of land use was calculated by the following formula:

$$EB = AK^\alpha L^\beta C^\gamma \quad (5)$$

where EB is economic benefit of land use;  $K$  is the capital input;  $L$  is the labor input;  $C$  is the input of land into economic development; and  $\alpha$ ,  $\beta$ ,  $\gamma$  are the elasticity of each output factors respectively.

Four types of data in 2001 to 2015 were required to figure out parameters  $\alpha$ ,  $\beta$  and  $\gamma$  (Table 2): economic data, labor population data, capital data, and land use data. Economic data, labor population, and capital data are all obtained from statistical yearbook of Wuhan 2001 to 2015. Land use datasets were obtained from the Data Centre of Resources and Environment, Chinese Academy Science (CAS) [46].

### 2.6. Illustration Dynamics of Tradeoffs between EB and ESV of Land Use

Analysis of tradeoffs [52] between EB and ESV was undertaken on the basis of land use change driven by urban expansion. The analysis aimed to figure out the relationship between EB and ESV. In this paper, we used the coordination degree between economic benefits and ecosystem services (CDEE) [53] to identify the relationship between EB and ESV, which can be calculated by the following formula:

$$CDEE = \frac{ES_{pr}}{EB_{pr}} \quad (6)$$

$$ES_{PR} = \frac{ES_{pj} - ES_{pi}}{ES_{pi}} \quad (7)$$

$$EB_{PR} = \frac{EB_{pj} - EB_{pi}}{EB_{pi}} \quad (8)$$

where CDEE is coordination degree between economic benefits and ecosystem services value;  $ES_{pr}$  is the rate of ecosystem services value change;  $EB_{pr}$  is the rate of economic benefits change;  $ES_{pj}$  and  $ES_{pi}$  represent ecosystem services value of time points  $j$  and  $i$  respectively;  $EB_{pj}$  and  $EB_{pi}$  represent economic benefits of land use of time points  $j$  and  $i$  respectively.

**Table 2.** Data used to estimate economic development.

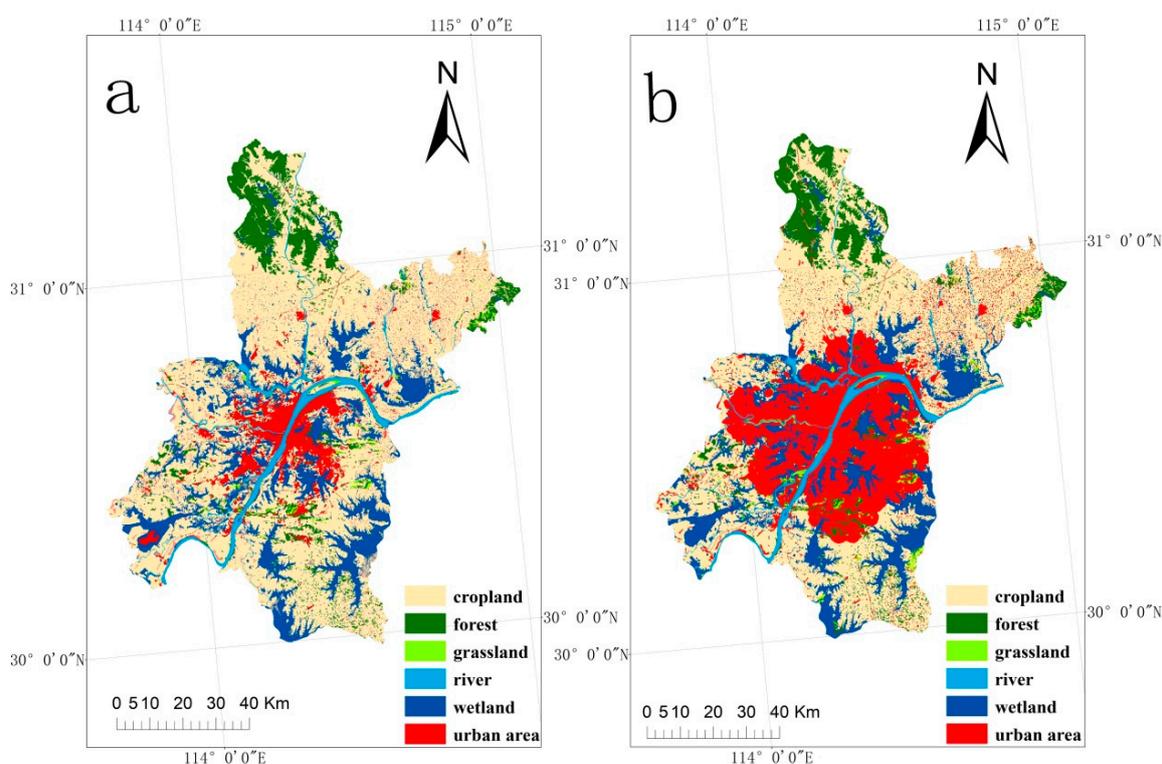
	Description	Data Source
Economic data	Land economic output ( $10^8$ \$)	Statistical yearbook of Wuhan
Labor population data	Secondary and tertiary industries employed population ( $10^4$ )	Statistical yearbook of Wuhan
Capital data	Total investment in fixed assets ( $10^8$ \$)	Statistical yearbook of Wuhan
Construction land area data	Urban building area (ha)	Data Centre of Resources and Environment, Chinese Academy of Science

### 3. Results

In this research, we simulated land use changes in a continuous process with urban expansion on a scale of 5000 ha in every scenario we designed. Then EB and ESV were calculated based on land use change maps. Naturally, relationship between EB and ESV could be represented briefly with curve. By comparing coordination degree of EB and ESV, the dynamics of tradeoffs between EB and ESV of land use can be figured out further.

#### 3.1. Simulation of Land Use Change Due to Different Amount of Urban Expansion

The simulation results of land use tape spatial distribution are illustrated in Figure 2. As seen in the simulation results, land use change in Wuhan is characterized by the increase of urban area and the reduction of cropland, grassland, forest, and wetland. A noteworthy feature is the increase of urban area will mainly come from the decrease of cropland and wetland. During the simulation period, the urban area in Wuhan will increase by a factor of 2.54, from 109,385 ha to 387,685 ha. Cropland will decrease 144,281 ha, which will account for 51.8% of the increase area. Wetland, forest, and grassland will decrease 85,738 ha, 36,209 ha, and 12,072 ha, contributing 30.81%, 13.01%, and 4.33% to the increased urban area respectively.



**Figure 2.** Land use change simulation results. (a) Land use map in 2010; (b) final land use map in our simulation.

According to Figure 3, land use changes in Wuhan can be divided into three stages. In the early stage, cropland will decrease sharply. Wetland, forest, and grassland will not change basically. Then with the decrease of cropland, food security will be under threat. Under the pressure of basic farmland protection policies, the decrease of cropland will become slowly. Forest and wetland will be the main source of urban expansion. In the final stage, heightened resistance of land use changes increase integrated with the lack of suitable land for urban expansion, build-up area will not increase as expected.

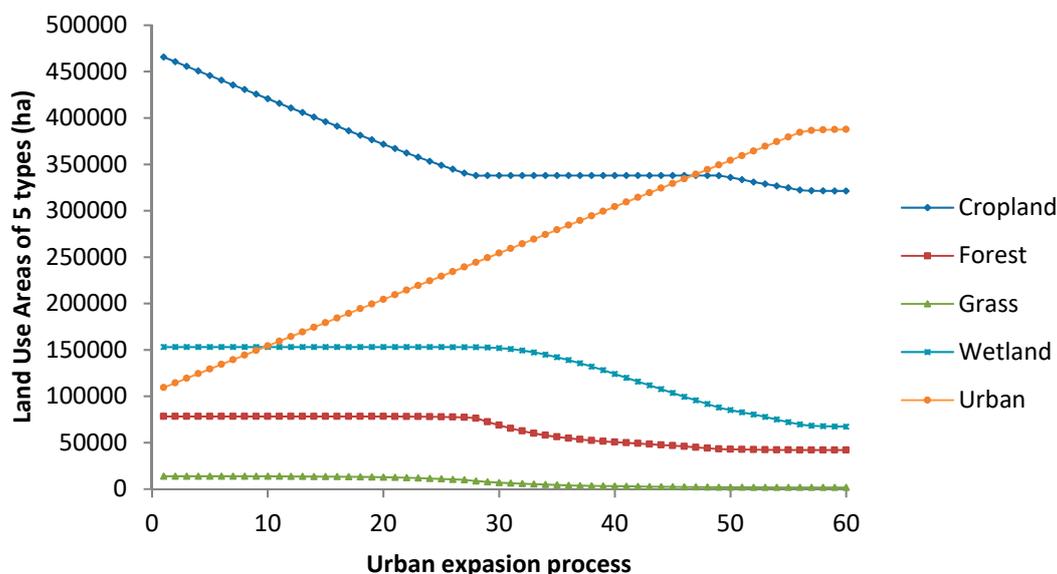
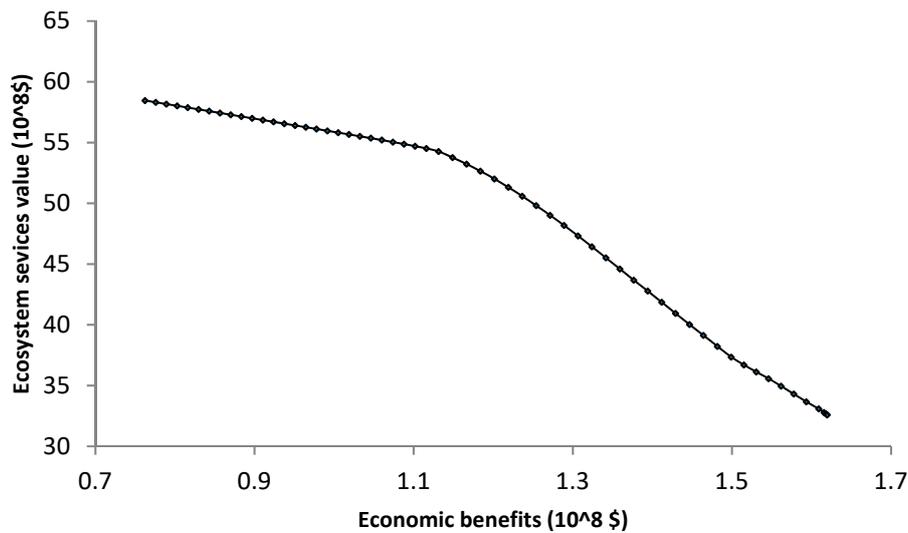


Figure 3. Simulation of land use change by using LANDSCAPE model.

### 3.2. Relationship between EB and ESV Due to Different Amount of Urban Expansion

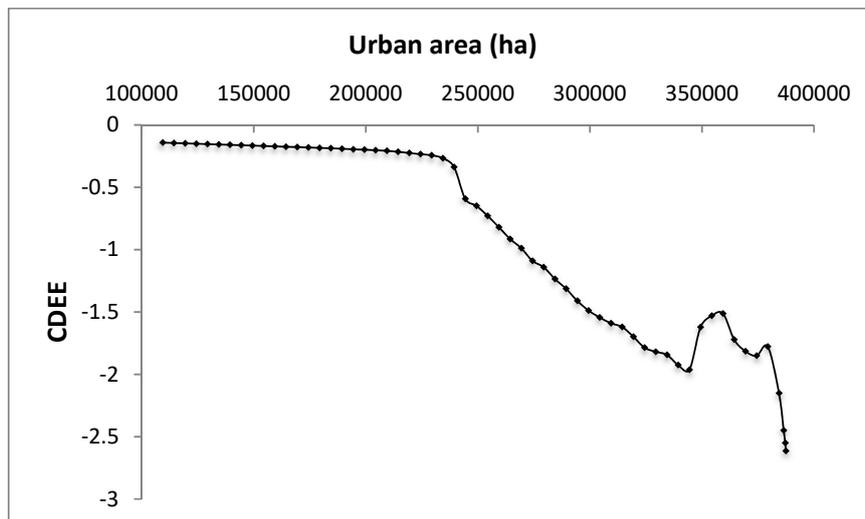
The curve in Figure 4 shows relationship between EB and ESV of land use changes driven by urban expansion. The curve demonstrates a negative nonlinear relationship between ESV and EB in Wuhan, which means that the increase of EB will result in the loss of ESV due to urban expansion. As seen in Figure 4, urban expansion in Wuhan will result in a decrease of ESV with a total value of \$2.59 billion, which is about 44.26% of the total ESV of Wuhan in 2010. Meanwhile, the total EB from land use of Wuhan will increase by a factor of 1.12, from \$0.76 hundred million at the beginning of our simulation to \$1.62 hundred million at the end of the simulation. Furthermore, the relationship between EB and ESV can be divided into three stages with the scale of urban expansion. In the first stage, ESV will decrease slowly with the increase of EB from land use. In the second stage, the slope of the curve will become steeper, which means that ESV will decrease more sharply than the previous phase. In the last stage, the slope of the curve will slow down more than in the second stage, but the relationship between ESV and EB remains extremely uneven.



**Figure 4.** Relationship between ESV and EB of land use.

### 3.3. Tradeoffs between EB and ESV due to Different Amount of Urban Expansion

In Figure 5, the curve of CDEE illustrates the dynamics of tradeoffs between EB and ESV due to urban expansion. Coordination degree between ESV and EB shows an overall decline trend with urban growth. The curve can be divided into three stages as well, corresponding to the curve concerned relationship between ESV and EB. In the first stage, the confliction between ESV and EB will be in low level, the change of CDEE is not significant. In the second stage, confliction of the two will increase rapidly; CDEE will decrease from  $-0.59$  to  $-1.96$ . In the third stage, the confliction will continue to increase after it rebounds slightly. Though the rate of confliction will go down for a short while at the beginning of the third stage, the level of confliction will remain in high level.



**Figure 5.** Coordination degree between ecosystem services values and economic benefits due to urban expansion.

## 4. Discussion

Like most other studies, our research shows that confliction between EB and ESV exists in land use changes due to urban expansion. It means that the unilateral pursuit of economic efficiency of land use would result in a decline of ecosystem services due to land use changes caused by urban

expansion. Furthermore, our study found that the degree of conflicts between EB and ESV would be dynamic in different amount of urban expansion. Compared to the static analysis relationship between EB and ESV, the dynamic tradeoffs can achieve a more meaningful measurement of the relationship between EB and ESV under constantly urban expansion, making our results more important reference for policy makers in decision making of land use [42]. On the one hand, urban expansion should take into full account the influence of EB on human welfare. On the other hand, ecological restoration is significant to ecosystem services. By depicting the dynamic trend of tradeoffs between EB and ESV with urban expansion, we presented the impacts of land use changes on urban sustainability. Contrary to the decline of ESV, EB increase with urban expansion. There is a turning point on the curve of relationship between EB and ESV of Wuhan. Before the turning point, the increase of EB will lead to a relatively gentle decline in ESV. After the inflection point, a small increase of EB will lead to a sharp decline of ESV. Consider the sustainable development and ecological security, urban expansion has to be in control to avoid the coming of the turning point on the curve of relationship between EB and ESV.

Further analysis found that dynamics of tradeoffs between EB and ESV is related to initial land use types which would be converted to urban area. In our study, we allocated land use changes according to suitability and resistance. According to the resistance of land conversion, ordinary farmland was given priority to convert into construction land since it holds relatively lower ecosystem services value per unit area. However, basic farmland is set as the greatest resistance to the transformation due to the basic farmland protection policy. In the early stage, cropland will decrease sharply; while wetland, forest, and grassland will rarely change. Then, under the pressure of basic farmland protection policies, the decrease of cropland will slowly become due to continuous urban growth. Forest, wetland, and grassland would become the main source of urban expansion. Nevertheless, the conversion of land use types with high ecosystem services coefficients (such as forest) to build-up land will greatly reduce ESV of a region. In our urban expansion scenarios, cropland will be occupied in priority, then forest and wetland will began to be occupied under the pressure of cropland protection. It can explain the sharp conflict between EB and ESV on the curve of relationship between EB and ESV in Wuhan due to different amount of urban growth.

Land planning is critical to ecosystem service changes, for ecosystem services is closed related land use type. It means that rational land planning may avoid amount of ecosystem service changes under land use change. In order to achieve the win-win goals of economic development and ecological security, land planning and land use management are urgently needed. Comprehensive land management which combines ecological security with economic development in urban development planning can optimize land use ecological suitability and modify confliction between EB and ESV.

However, our attempts to simulate land use change in Wuhan and figure out the tradeoffs between EB and ESV at different scale of urban expansion have several limitations. First, according to Ke et al., the LANDSCAPE model has been provided to have good accuracy for revealing and simulating land use change [40]. As we know that urban expansion and land use changes are affected by many factors, we can't predict how decision makers make the planning of land use in the future. So the simulation results in this research can only figure out the trend of land use changes in the future rather than an accurate prediction. Second, it is possible that the ecosystem services of land use types will enhance or reduce due to ecological restoration or human disturbance. Given uncertainties, we are not able to predict the changes of ecosystem services value coefficient, so we used the fixed ecosystem services value coefficient to calculate the ecosystem services value. Third, economic development is related to land, labor force, technology, capital and other factors. In this research, to figure out EB from land use, only land was taken into consideration in the C-D production function.

## 5. Conclusions

Taking the land use map of Wuhan in 2010 as an example, we simulated land use change with a different amount of urban area by using LANDSCAPE model. In this paper, on the basis of integrated driving factors of land use changes such as policy, socioeconomic indicators, and the

natural environment; different conversion rules and constraints were set for different land use types. Our results suggest that with the process of urbanization, a mount of cropland, wetland, and forest will be converted into urban land. More specifically, cropland will be preempted in the early stage of the simulated urban expansion process; amount of wetland will be occupied under the combined pressure of urban expansion and basic farmland protection in the very next process. This method of simulating a series of continuous land use changes can precisely and intuitively demonstrate land use change processes and provide an idea for researching complex eco–economic relations in the process of land use changes.

Therefore, further study found there will be a contradiction between ecosystem services and economic growth, and this contradiction will be aggravated with the urban expansion process. Dynamics of tradeoffs between EB and ESV show that ESV is negatively related to EB. Conflict between two of these will become more violent with further urban expansion processes. A small increase of EB may pay a great amount of ESV in some stage of urban expansion. It indicates that the amount of urban growth should be controlled to a certain number to avoid worsening the conflict between EB and ESV. Future urban development plans should focus on controlling the scale of urban, improving the economic efficiency of construction land, optimizing land layout, make efforts to realize harmonious development of economic and ecology.

**Author Contributions:** Y.H. wrote the manuscript. Y.Z. contributed to the analysis of dynamics of tradeoffs between ESV and EB and helped with the writing of the manuscript. X.K. put forward the concept of this article, led the development of methodology and helped with the modifying of the manuscript. All authors contributed to write, review, correct in this manuscript.

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**Conflicts of Interest:** The authors declare no conflicts of interest.

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