ASSESSMENT OF THE RELATIONSHIP BETWEEN THE ECONOMY AND THE ENVIRONMENT BASED ON ECOSYSTEM SERVICES VALUE IN NANPING CITY, CHINA

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Abstract. This study quantificationally analyzes and assesses the land-use status and the value of ecosystem services (*ESV*) in Nanping City and various counties (districts) within the area. It uses the Landsat 5 TM/Landsat 7ETM images of Nanping City taken in 1995, 2005, and 2015, the object-oriented land-use classification method, and the revised table of the equivalent value per unit area of ecosystem services for China. We also use the coefficient of sensitivity to verify the mutual dependence between *ESV* and the service value index per unit area. Lastly, we use the coordination degree between environment and economy (*CDEE*) to measure the environment and economic coordination of the study area. The results showed that the *ESV* increased significantly in Nanping City, mainly from 2005 to 2015. Concerning various counties (districts), the *ESV* showed an increase in most areas, but a decrease in Jian'ou City. The coefficient of sensitivity analysis showed that the *ESV* in Nanping City was highly dependent on the service value index per unit area, and that the service value index per unit area selected was accurate in this study. Considering all the factors, the *CDEE* value of Nanping City was 0.0080, and the environment and economic development was at a low harmonic level during the study period. In various counties (districts) studied, there were 3 types of conversion: persistent low harmonic level, low disharmonic to low harmonic, and low harmonic to low disharmonic.
Keywords: *remote sensing, sustainable development, land use, coefficient of sensitivity, Fujian Province*

Introduction

Achieving sustainable development is crucial in finding a balance in coordinating the relationship between rapid economic growth and environmental degradation and resource consumption (Asafu-Adjaye, 2016; Ayres, 2013). The coordinated development of the environment and the economy is an important factor and one of the basic requirements of sustainable development (Giddings et al., 2010; Zhang and Wen, 2008). Studying the coordination degree between the environment and the economy (*CDEE*) can quantitatively reflect the degree of coordinated development between the regional environment and the economy, enabling the facilitation of an appropriate adjustment of measures based on changes in the *CDEE*. It can also provide a theoretical basis for the coordinated and stable development of regional socio-economic systems and natural ecosystems (Zhang and Wen, 2008). In recent years, the coordinated development of the environment and the economy has become one of the most prominent areas of sustainable development research (Liao et al., 2016; Solár et al., 2016; Strezov et al., 2017).

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Ecosystem services are life-support products and services that are directly or indirectly obtained from the structure, processes, or functions of ecosystems (Costanza et al., 2017; Giddings et al., 2010; Mckenzie and Mckenney, 2012). They can be groups into two: eco-products and ecological functions that guarantee the essential quality of human life. Land use change is one of the driving factors of global environmental change and has a significant impact on ecosystem functions and services (Costanza et al., 1997). Scholars have researched land use change and *ESV* extensively (Estoque and Murayama, 2016; Kaufman, 2012; Meng and Sun, 2016; Song and Deng, 2017; Wu et al., 2015), and the most representative of these studies is Costanza et al.'s "The value of the world's ecosystem services and natural capital" (Costanza et al., 1997), which clarifies the principles and methods of the value of ecosystem service estimation in a scientific sense.

The service functions provided by the ecosystem form a basis for achieving sustainable development, and the changes in the *ESV* are closely related to social and economic development (Hu et al., 2018; Huang et al., 2011). The changes in the *ESV* are an integration and quantification of regional environment changes and can be used as a comprehensive indicator to characterize the level of regional sustainable development (Shi et al., 2005). Therefore, the level of coordinated development considering both regional economic development and environment can be measured according to the relationship between changes in ecosystem service value and socio-economic development caused by land use change over a given period.

The Economic Development Zone on the West side of the Strait is abbreviated to "Haixi" Economic Development Zone, which is mainly located in Fujian Province but with some cities in Jiangxi Province and Zhejiang Province. The goal of the development zone is to work with Taiwan, unify the motherland, and propel the regional economy into a global economic complex (Li and Ma, 2018). The study area for our research is Nanping City, which is located at the junction of Jiangxi Province, Zhejiang Province, and Fujian Province. It is the main location of the economic construction of Haixi Economic Development Zone. Additionally, it is situated at the headstream of the Minjiang River (the mother river of Fujian Province) and is the grain production base of Fujian Province. The area of cultivated land and forest land in the Nanping City area accounts for around 1/4 of Fujian province, and the area of moso bamboo stands accounts for 1/10 of the whole of China. The area is known as the "Fujian Granary" and "Chinese Bamboo Town". In recent years, the economy in Nanping City has developed rapidly, and land use changes have been driven by the radiating development of the Haixi Economic Development Zone. Therefore, the coordinated development of environment and economy to achieve sustainable development is a vital issue for the Haixi Economic Development Zone.

Based on the quantitative analysis of the changes in the *ESV* caused by land use change, this study introduces *CDEE* to analyze the coordination level and spatial difference of environmental and economic development in Nanping City and its districts (counties). We aimed to assess the relationship between the economy and the environment based on ecosystem services value in Nanping City and find out the key factor affecting the harmonious development between the environment and the economy in a city. It provides important theoretical support and scientific reference for sustainable economic development in cities.

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Material and methods

Study area

Nanping City is located in the southeast of China and covers an area of 26,300 km^2. It consists of 2 municipal districts, 3 county-level cities, and 5 counties, including Jianyang, Yanping, Shunchang, Pucheng, Guangze, Songxi, Zhenghe, Shaowu, Wuyishan, and Jian'ou (refer to *Fig. 1*). At the end of 2015, the total household registration population was 3.2 million, of which 2.6 million were permanent residents. The natural growth rate was 6.1‰, and the level of urbanization was 54%.

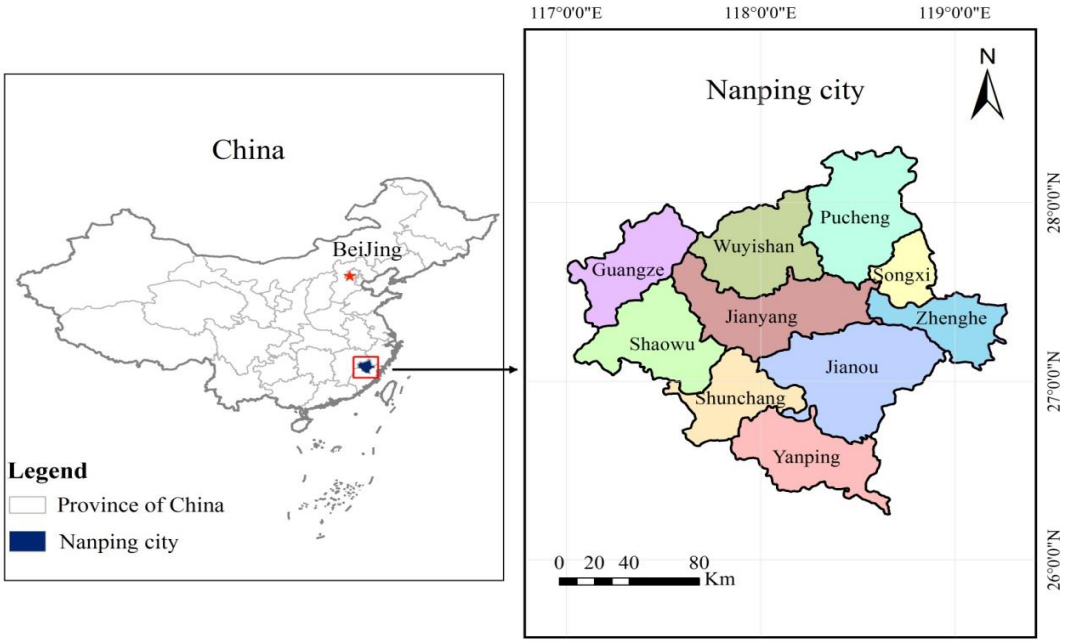

Figure 1. *Map of the study area*

The Gross Domestic Product (GDP) increased from 14.6 billion yuan in 1995 to 134 billion yuan in 2015, with an average annual growth of nearly 6.0 billion yuan (NSB, 2015). From 2011 to 2015, the total of retail sales of social consumer goods in Nanping City was 199.9 billion yuan, and the total of foreign trade imports and exports was 1.2 billion US dollars. Nanping City possesses rich tourism resources, with more than 180 tourism resource entities. Wuyishan City is one of the only four "World Natural and Cultural Heritage Sites" in China, which is not only a national scenic area and nature reserve, but also a tourism economic development zone in Fujian province.

Data collection and preprocessing

Our study used remote sensing images for three time periods (1995, 2005, and 2015) from Landsat-5 TM and Landsat-7 ETM, downloaded from the Chinese geospatial data cloud (http://www.gscloud.cn/) to study the relationship between the economy and the environment in Nanping City (details seen in *Table 1*). The socioeconomic data were collected from the relevant Nanping City statistical yearbooks (NSB, 1995; NSB, 2005; NSB, 2015). In this study, the land use types were divided into six according to the research needs: forest land, cultivated land, grassland, unused land, construction land,

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and water. The preprocessing of the remote sensing data included radiation correction, geometric correction, and mosaic and clipping. Landsat spectral bands 5, 4, and 3 were used for color synthesis of the mosaic remote sensing image enabling easy differentiation of the six land use types. The land use classification was carried out via the object-oriented classification method, and lastly, the accuracy was evaluated. The accuracy evaluation results show that the Kappa coefficient is 0.87, which is between 0.8 and 1 and indicates that the classification has high precision and can be studied further.

Table 1. *Source and description of remote sensing data*

Date taken	Source
1995-09	Landsat-5 TM
2005-10	Landsat-5 TM
2015-10	Landsat-7 ETM

The images with cloud coverage of less than 10% were selected. The spatial resolution of both landsat-5 TM and landsat-7 ETM is 30 m × 30 m

Evaluation model of ESV

Using a table of equivalent values per unit area of terrestrial ecosystem services (Xie et al., 2006, 2008) and combining it with the six land use types in this study, the table was slightly modified to create a table, which summarized the equivalent value per unit area value of ecosystem services in Nanping City, as shown in *Table 2*.

Table 2. *Equivalent weighting factor of ecosystem services value per hectare of terrestrial ecosystem in Nanping City*

Types	Forest land	Grassland	Cultivated land	Water	Unused land
Gas regulation	3.50	0.80	0.50	0.00	0.00
Climate regulation	2.70	0.90	0.89	0.46	0.00
Water conservation	3.20	0.80	0.60	20.38	0.03
Soil formation and protection	3.90	1.31	1.46	0.01	0.02
Waste treatment	1.31	1.95	1.64	18.18	0.01
Biodiversity conservation	3.26	1.09	0.71	2.49	0.34
Food production	0.10	0.30	1.00	0.10	0.01
Supply of raw materials	2.60	0.05	0.10	0.01	0.00
Entertainment and culture	1.28	0.04	0.01	4.34	0.01

Using *Table 2* and *Equations 1* and *2*, per unit area of the *ESV* in Nanping City was obtained (*Table 3*). *Equations 1* and *2* are as follows (Xie et al., 2003):

$$E_a = \frac{1}{7} \cdot T_a \cdot T_b \quad \text{(Eq.1)}$$

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where E_a denotes the service value per hectare of cultivated land in the study area (yuan/hm^2), T_a represents the average grain yield (kg/hm^2), and T_b is the average purchase price of grain in China.

Grain value is volatile, and the average purchase price of grain varies annually. In this study, the service value per hectare of cultivated land was calculated using the average purchase price of grain in China (T_b, 5.24 yuan/kg) and the average grain yield in Nanping (T_a, 5700 kg/hm^2) in 2015. And all the service value per hectare of cultivated land of the three years had been calculated based on 2015 data.

$$VC_{ij} = E_a \cdot f_{ij} \quad \text{(Eq.2)}$$

where VC_{ij} is a specific ecosystem service unit area value (yuan/hm^2·year) and f_{ij} is the equivalence factor of a specific ecosystem service of a specific land use type.

Table 3. *Value per unit area of ecosystem services of landscape types in Nanping City (Ten thousand yuan/hm^2)*

Types	Forest land	Grassland	Cultivated land	Water	Unused land
Gas regulation	1.4933	0.3413	0.2133	0.0000	0.0000
Climate regulation	1.1520	0.3840	0.3797	0.1962	0.0000
Water conservation	1.3670	0.3413	0.2560	8.6953	0.0128
Soil formation and protection	1.6640	0.5589	0.6229	0.0042	0.0085
Waste treatment	0.5589	0.8320	0.7012	7.7567	0.0042
Biodiversity conservation	1.3909	0.4651	0.3029	1.0624	0.1450
Food production	0.0427	0.1280	0.4267	0.0427	0.0042
Supply of raw materials	1.1093	0.0213	0.0427	0.0042	0.0000
Entertainment and culture	0.5461	0.0171	0.0042	1.8517	0.0042
Total	9.3243	3.0891	2.9497	19.6136	0.1791

Using *Table 3* and *Equation 3* (Xu et al., 2019), the *ESV* in Nanping City was obtained. *Equation 3* is as follows:

$$ESV = \sum_{i=1}^{n} \sum_{j}^{m} A_i \times VC_{ij} \quad \text{(Eq.3)}$$

where the *ESV* denotes the total ecosystem service value (yuan) and A_i represents the area of a specific land use type.

Coefficient of sensitivity

The coefficient of sensitivity (*CS*) refers to the change in the *ESV* caused by a 1% change in the *VC* (Zhou et al., 2010). The purpose of the *CS* is to determine the

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dependence of the *ESV* on the *VC* over time, and to verify whether the *VC* selected is suitable for the study area (Wu et al., 2011). In this paper, the *CS* is calculated by respectively increasing and decreasing the *VC* of various land use types by 50%. The *CS* can be calculated using *Equation 4:*

$$CS = \left| \frac{\left(ESV_j - ESV_i\right) \div ESV_i}{\left(VC_{jk} - VC_{ik}\right) \div VC_{ik}} \right| \quad \text{(Eq.4)}$$

where *CS* denotes coefficient of sensitivity, ESV_i and ESV_j represent the total *ESV* before and after adjustment of the *VC* respectively; VC_i and VC_j are specific ecosystem service unit area values before and after adjustment; and *k* is a kind of land use type.

If $CS > 1$, it indicates that the *ESV* has a low dependence on the *VC*, and the larger the *CS*, the lower the dependence of the *ESV* on the *VC*. If $CS < 1$, it indicates that the *ESV* is highly dependent on the *VC*. It also indicates that the *VC* selected for this paper is accurate.

Evaluation of coordinated development of environment and economy

The coordination degree between environment and economy (CDEE)

Coordination refers to a state of equilibrium between two systems or each component element within the systems. The coordinated development of the environment and the economy refers to the interaction between environmental subsystems and the economic subsystem. Additionally, the relationship of the two subsystems should show reciprocal symbiosis in the process of regional development, to the overall interests of the region as well as to facilitate continuous improvement. Coordination is a quantitative indicator used to measure the coordinated development status between systems or elements (Li et al., 2007).

Currently, there is no uniform standard for the coordinated development of the environment and the economy, and *CDEE* is a relative indicator. Therefore, according to the analysis of the coordinated development of the environment and the economy and the relationship between these factors, we introduced *CDEE* to the study (Zhang et al., 2014).

CDEE refers to the ratio of the change rate of the total *ESV* (*ESpr*) and the change rate of GDP (*GDPpr*) during the study period (Wu et al., 2007). *CDEE* can be calculated using *Equation 5:*

$$CDEE = \frac{ES_{pr}}{GDP_{pr}} = \left[\frac{ES_{pj} - ES_{pi}}{ES_{pi}} \right] \div \left[\frac{GDP_{pj} - GDP_{pi}}{GDP_{pi}} \right] \times 100\% \quad \text{(Eq.5)}$$

where ES_{pi} and ES_{pj} denote the total *ESV* at the beginning and end of study, and GDP_{pi} and GDP_{pj} represent the GDP at the beginning and the end of study.

Division of coordination types

According to the relationship between the coordinated development of the environment and the economy, relevant research results were used for reference to divide coordinate types (Su and Zhang, 2009), as shown in *Table 4*.

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Table 4. *Division of coordination types between environment and economy*

Standard of classification		Meanings
Primary classification	**Secondary classification**	
CDEE ≥ 1	High harmonic or economic development constrained by environment	It indicates that the growth rate of the *ESV* is not lower than the rate of economic growth. There are two possibilities for the actual development: First, the coordination between the environment and economic development is very good, and the regional environmental economic development is highly harmonic. Second, if regional economic development in the initial stage has seriously damaged the ecology, to improve the regional ecosystem's ability to support the social and economic systems, ecological conservation measures must be implemented. At this point, economic development is obviously constrained by environment
0 ≤ CDEE < 1	0.5 ≤ CDEE < 1 (Moderate harmonic) 0 ≤ CDEE < 0.5 (Low harmonic)	This indicates that the growth rate of the *ESV* is lower than that of economic growth during the study period, but that the *ESV* is increasing. Although economic development has not caused the deterioration of environment, there are potential crises. The smaller the *CDEE* value, the lower the level of environmental and economic coordination
-1 ≤ CDEE < 0	-0.5 ≤ CDEE < 0 (Low disharmonic) -1 ≤ CDEE < -0.5 (Moderate disharmonic)	This indicates that the increase in the *ESV* is negative during the study period, and social and economic development has already had a negative impact on the environment. Regional environmental economic development is in an uncoordinated state, and there are conflicts between economic development and environmental protection
CDEE < -1	Severe disharmonic	This indicates that the *ESV* has decreased significantly during the study period, the environment is deteriorating, and the regional economic development is unsustainable

Results and analysis

Area changes of land use types

Using the statistical analysis tool called Summary Statistics of ArcGIS10.1 software, the areas of different land use types in 1995, 2005, and 2015 were obtained for Nanping City (*Table 5*). Forest land, cultivated land, and grassland accounted for more than 89% of the total study area from 1995 to 2015. The area of forest land and construction land increased during the 20-year study period, of which forest land increased by 2075.90 km^2 and the area increased rapidly during 2005-2015. This rapid increase is due to soil and water conservation work that was carried out, and broad-leaved forests and trees with certain economic value and water conservation functions being planted on the top of the mountains and on gentle slopes since 2010. At the same time, a combination of bamboo and wood plantations was also used to control soil erosion, which significantly contributed to the increase in forest area during this period. Additionally, the area of construction land increased by 329.99 km^2 during the study period. The main reason is that Nanping City is in the core area of the Haixi Economic Development Zone, and the city most involved in the development of the economic zone. The large-scale

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construction of the city and the rapid development of the economy led to a significant increase in the area of construction land.

In contrast, the area of other land use types decreased, with the largest reduction being that of cultivated land area, which decreased by 1198.70 km^2 during the 20 years. Nanping City has a subtropical monsoon climate and natural disasters such as floods and cold waves occur frequently. From 2005 to 2015, there was an increase in the severity of natural disasters and the problem of cultivated land being abandoned became increasingly serious, resulting in a decrease in the cultivated land area (You, 2014). Meanwhile, due to the continuous transfer of rural laborers to cities, rural labor shortages were becoming severe, also resulting in the significant abandonment of cultivated land. However, some rural and semi-urban areas of cultivated land with better site conditions were converted into forest land after being abandoned, which is another reason for the increase in the area of forest land.

Table 5. *Area size of different land use types in three periods (km^2)*

Year	Land use types					
	Forest land	**Grassland**	**Cultivated land**	**Water**	**Unused land**	**Construction land**
1995	19304.79	2172.78	2305.14	657.49	955.46	771.64
2005	19495.21	2362.45	2124.34	712.06	1076.98	498.94
2015	21380.69	1644.75	1106.44	624.84	410.36	1101.63
Net change in 20 years	2075.90	-528.03	-1198.70	-32.65	-545.10	329.99

ESV in Nanping and various counties (districts)

The changes in the total *ESV* were obtained using *Equation 3* for the study period of 20 years in Nanping and various counties (districts) in the area (*Table 6*). Overall, the *ESV* increased significantly in Nanping City during the 20 years. The total *ESV* in Nanping City was 206.582 billion yuan in 1995 and 220.034 billion yuan in 2015, an increase of 13.452 billion yuan during the 20 years. The main reason for this marked increase is that the forest land ecosystem had a high *VC*. Due to the increase of the area of forest land, the total *ESV* showed a continuous increasing trend.

In the various other counties (districts), only the *ESV* in Jian'ou showed a decreasing trend. Its value decreased by 1.014 billion yuan, which indicates that the environment of Jian'ou City has deteriorated in the past 20 years, a matter that should be urgently addressed by the relevant departments. In contrast, the *ESV* in all the other regions showed an increasing trend, of which the *ESV* of Shunchang increased the most, with an added value of 3.766 billion yuan. This indicates that the environment in Shunchang improved significantly from 1995 to 2015. Shunchang is followed by Pucheng and Wuyishan, of which the ESV increased by 2.711 and 2.591 billion yuan respectively. Compared to other areas, the rate of change was higher in Songxi, at 18.63%, while the *ESV* in Shaowu increased by very little, only 0.347 billion yuan.

Sensitivity analysis

The *CS* was calculated by increasing and decreasing the *VC* (*Table 3*) of various land use types by 50% according to the calculation method of the *CS* (*Eq. 4*), and the total *ESV* and *CS* in Nanping City during the study period were obtained (*Table 7*). *Table 7*

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shows that the *CS* of all the land use types were all less than 1, and most of them were less than 0.1, which indicates that the *ESV* in Nanping City was highly dependent on the *VC*, and that the *VC* selected for this study is accurate.

Table 6. *Changes of the ecosystem services value by region in the study area from 1995 to 2015 (billion yuan)*

Regions	Year	Land use types						Variation in 20 years	Rate of change in 20 years (%)
		Forest land	Grassland	Cultivated land	Water	Unused land	Total		
Yanping	1995	14.697	0.479	0.260	6.124	0.007	21.567	0.437	2.03
	2005	16.287	0.734	0.553	2.149	0.021	19.743		
	2015	19.455	0.472	0.170	1.904	0.005	22.004		
Jianyang	1995	24.991	0.663	0.569	2.356	0.018	28.597	1.124	3.93
	2005	21.019	1.142	1.056	2.266	0.027	25.511		
	2015	28.295	0.865	0.122	0.435	0.004	29.721		
Shaowu	1995	20.718	0.806	0.901	0.241	0.002	22.668	0.347	1.53
	2005	18.952	0.839	0.680	1.347	0.028	21.847		
	2015	21.409	0.828	0.363	0.409	0.007	23.016		
Wuyishan	1995	19.895	0.748	0.717	0.638	0.036	22.033	2.591	11.76
	2005	20.628	0.716	0.644	1.269	0.017	23.274		
	2015	23.119	0.595	0.202	0.677	0.031	24.624		
Jian'ou	1995	30.366	0.966	0.326	1.201	0.041	32.900	-1.014	-3.08
	2005	24.662	1.732	0.859	1.490	0.010	28.754		
	2015	28.918	0.285	1.205	1.466	0.012	31.886		
Shunchang	1995	12.758	0.527	0.829	0.755	0.001	***14.872***	***3.766***	25.32
	2005	14.437	0.623	0.355	0.560	0.008	***15.983***		
	2015	15.558	0.320	0.120	2.636	0.003	***18.637***		
Pucheng	1995	23.103	0.773	1.197	0.965	0.041	26.079	2.711	10.39
	2005	26.941	0.853	0.624	1.692	0.009	30.119		
	2015	25.805	0.534	0.544	1.903	0.003	28.790		
Guangze	1995	16.392	0.611	0.528	0.376	0.002	17.909	1.416	7.91
	2005	18.594	0.281	0.490	0.514	0.035	19.914		
	2015	17.517	0.669	0.219	0.918	0.001	19.325		
Songxi	1995	6.051	0.590	0.502	0.105	0.021	7.268	1.354	18.63
	2005	8.885	0.152	0.412	0.566	0.005	10.020		
	2015	7.867	0.162	0.136	0.452	0.005	8.622		
Zhenghe	1995	11.024	0.548	0.971	0.134	0.002	12.679	0.729	5.75
	2005	11.373	0.226	0.594	2.112	0.032	14.337		
	2015	11.417	0.351	0.182	1.456	0.003	13.409		
Nanping	1995	180.004	6.712	6.799	12.896	0.171	***206.582***	***13.452***	6.51
	2005	181.779	7.298	6.266	13.966	0.193	***209.502***		
	2015	199.360	5.081	3.264	12.255	0.074	***220.034***		

Regarding the *CS* according to different land use types, the *CS* of cultivated land, grassland, construction land, water, and unused land were all small, while the *CS* of forest land was the highest, the value ranging from 0.8677 to 0.9060. It shows that forest land had the largest contribution rate to the *ESV* in the study area. Compared to

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other land use types, the *ESV* of forest land was also the most dependent on the *VC*. When the *VC* of forest land increased by 1%, the total *ESV* increased by between 0.8677% and 0.9060%. The main reason is that forest land was not only superior in area, but also had a high *VC*, which made its total *ESV* the highest.

Table 7. *Changes in the total ecosystem services value and the coefficient of sensitivity resulting from adjustment of the VC*

	***ESV* (billion yuan)**					***CS***		
	1995	**2005**	**2015**	**Variation**	**Rate of change (%)**	**1995**	**2005**	**2015**
Forest land *VC*+50%	296.58	300.39	319.71	23.13	7.80	0.8713	0.8677	0.9060
Forest land *VC*-50%	116.58	118.61	120.35	3.77	3.24			
Grassland *VC*+50%	209.94	213.15	222.57	12.64	6.02	0.0325	0.0348	0.0231
Grassland *VC*-50%	203.23	205.85	217.49	14.27	7.02			
Cultivated land *VC*+50%	209.98	212.64	221.67	11.68	5.56	0.0329	0.0299	0.0148
Cultivated land *VC*-50%	203.18	206.37	218.40	15.22	7.49			
Water *VC*+50%	213.03	216.49	226.16	13.13	6.16	0.0624	0.0667	0.0557
Water *VC*-50%	200.13	202.52	213.91	13.77	6.88			
Unused land *VC*+50%	206.67	209.60	220.07	13.40	6.48	0.0008	0.0009	0.0003
Unused land *VC*-50%	206.50	209.41	219.10	13.50	6.54			

Evaluation of the coordinated development of ecology and economy

Economic development

On the whole, the GDP in Nanping City increased continuously during the 20-year study period (*Table 8*), with its value increasing from 14.59 billion yuan in 1995 to 133.94 billion yuan in 2015. During the period, the growth rate of the GDP in Nanping City was 817.78%. In various other counties (districts), the regions with a higher GDP growth rate than that of Nanping City were Wuyishan with 1596.42%, Guangze with 998.10%, Pucheng with 896.40%, and Shaowu with 854.15%. This indicates that they made the largest contribution to the overall growth of the GDP of Nanping City.

Analysis on the coordinated development of the environment and the economy

We analyzed the coordinated development of the environment and the economy by using *CDEE* (*Eq. 5*) in Nanping City and various counties (districts). The coordinated development of the environment and the economy had two forms, which are low harmonic and low disharmonic (*Table 8*). The value of *CDEE* in Nanping City was 0.0080 (*CDEE* < 1) before the study period, and the values of *CDEE* in the 1995-2005 and 2005-2015 periods were also less than 1, which indicates that overall, Nanping City was at a low harmonic level (*Table 9*). This indicates that the environment and the economy in Nanping City were in a state of coordinated development during the study period. In terms of various other counties (districts) in the area (*Fig. 2*), Jian'ou—located in the southeast of the study area—was at a low disharmonic level, while other regions were at a low harmonic level.

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Table 8. *Changes in the gross domestic product in Nanping and various counties (districts) from 1995 to 2015*

Regions	Year					
	1995 (billion yuan)	**2005 (billion yuan)**	**2015 (billion yuan)**	**1995-2005 GDPpr (%)**	**2005-2015 GDPpr (%)**	**1995-2015 GDPpr (%)**
Yanping	3.15	9.14	27.71	190.37	203.18	780.34
Jianyang	1.73	3.43	15.18	97.90	343.11	776.89
Shaowu	2.01	4.97	19.20	147.11	286.12	854.15
Wuyishan	0.82	3.01	13.89	267.57	361.52	1596.42
Jian'ou	2.47	4.62	19.87	86.94	330.31	704.44
Shunchang	1.34	2.68	9.09	99.79	239.20	577.69
Pucheng	1.19	3.00	11.88	151.89	295.57	896.40
Guangze	0.71	1.58	7.85	120.88	397.14	998.10
Songxi	0.53	1.15	4.29	119.00	271.94	714.57
Zhenghe	0.64	1.17	5.00	82.77	326.76	679.97
Nanping	14.59	34.75	133.94	138.10	285.47	817.78

Table 9. *The coordination degree between environment and economy of Nanping and other counties (districts)*

Regions	*CDEE*			Coordination types		
	1995-2005	**2005-2015**	**1995-2015**	**1995-2005**	**2005-2015**	**1995-2015**
Yanping	-0.0444	0.0564	0.0026	**Low disharmonic**	Low harmonic	Low harmonic
Jianyang	-0.1102	0.0481	0.0051	**Low disharmonic**	Low harmonic	Low harmonic
Shaowu	-0.0246	0.0187	0.0018	**Low disharmonic**	Low harmonic	Low harmonic
Wuyishan	0.0211	0.0160	0.0074	Low harmonic	Low harmonic	Low harmonic
Jian'ou	-0.1449	0.0330	-0.0044	**Low disharmonic**	Low harmonic	**Low disharmonic**
Shunchang	0.0749	0.0694	0.0438	Low harmonic	Low harmonic	Low harmonic
Pucheng	0.1020	-0.0149	0.0116	Low harmonic	**Low disharmonic**	Low harmonic
Guangze	0.0926	0.0199	0.0079	Low harmonic	Low harmonic	Low harmonic
Songxi	0.3181	-0.0513	0.0261	Low harmonic	**Low disharmonic**	Low harmonic
Zhenghe	0.1579	-0.0198	0.0085	Low harmonic	**Low disharmonic**	Low harmonic
Nanping	0.0102	0.0176	0.0080	Low harmonic	Low harmonic	Low harmonic

In terms of development stage (*Fig. 3*), there were 3 conversion forms of coordination degree, namely persistent low harmonic, from low disharmonic to low harmonic, and from low harmonic to low disharmonic. Among the counties, Wuyishan, Shunchang, and Guangze were at a persistent low harmonic, which indicates that they focused on the coordinated development of the economy and environment during the process of regional development. Therefore, they made a greater contribution toward the environment and economic development of Nanping City (Chen, 2011).

The regions that went from low harmonic to low disharmonic were Pucheng, Songxi, and Zhenghe in the northeast of Nanping City. This indicates that economic development has already had a negative impact on the environment of these regions, and the environment and economic development were in an uncoordinated state (Zhang, 2014). A conversion form of low disharmonic to low harmonic was observed in Yanping, Jianyang, Shaowu, and Jian'ou, and the *CDEE* in these areas were small. It

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indicates that the degree of coordination between environment and economic development was still unstable, and the government should keep a close watch on these regions (Wu, 2014).

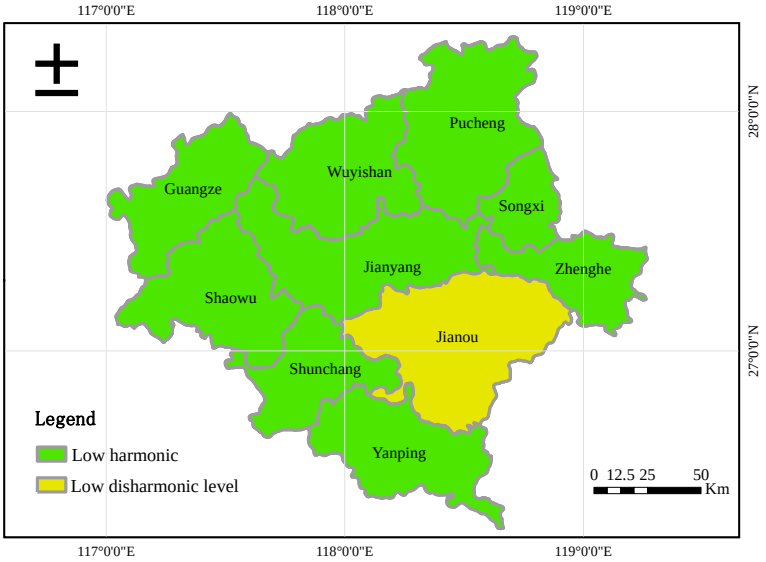

Figure 2. *Coordination level of eco-economy in the study area*

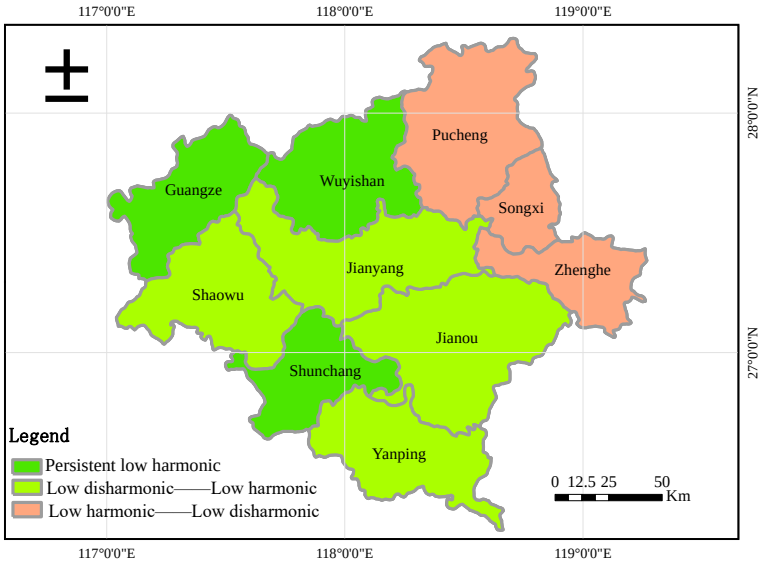

Figure 3. *Conversion form of coordination degree in the study area*

Discussion

The environment and economic development in Nanping City, Wuyishan, Shunchang, and Guangze were at a low harmonic level from 1995 to 2015, which indicates that these regions were focusing on the protection of the environment during economic development. However, the growth rate of the *ESV* was obviously lower than the rate of economic growth. Pressure on the regional environment will continue to

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increase in the long-term, which could easily affect the *CDEE*, decreasing it into negative numbers. This will cause ecological and economic development to become uncoordinated.

The regions with a low harmonic to low disharmonic conversion form were Pucheng, Songxi, and Zhenghe. The main reason for this conversion form is that these regions were traditional agricultural counties, which typically develop at the cost of plundering resources. Non-point source pollution was a serious matter caused by the use of pesticides and fertilizers, and the speed of economic development exceeded the speed of environmental protection.

The regions that went from low disharmonic to low harmonic were Yanping, Jianyang, Shaowu, and Jian'ou. The main reason for this change is that Yanping and Jianyang are the previous and current the seat of the government, which means that both regions are great policy assets. Shaowu and Jian'ou are adjacent to Jianyang and Yanping in terms of location. In addition to the concept of radiating development, the above areas are also key forest areas and bases for the processing of timber products in Fujian Province. The forest resources of these regions are very rich, and due to the increasing intensity of afforestation, economic development has not yet caused the deterioration of environment.

In summary, the management and protection of the environment should be urgently addressed in the future in Jian'ou, Pucheng, Songxi, and Zhenghe. Additionally, the government should promote regional sustainable development by increasing environmental governance, for the sake of reducing the constraints of the environment on regional economic development.

Compare the results of this study against results of other authors based on the same method, we can find out the key factors affecting the coordinated development of the environment and the economy. Su et al. (2009) measured the environment and economic coordination of Daqing City in China. The results showed that the *CDEE* value of Daqing City was -0.0193, and the status of the environment and economic development was at a low disharmonic level. In this study, the *CDEE* value of Nanping City was 0.0080, and it was at a low harmonic level. Daqing City, the largest petrochemical base in China, is the world's tenth-largest oil field. In the study of Su et al. (2009), the GDP of Daqing City was 162.03 billion yuan, while the GDP of Nanping City was 133.951 billion yuan in this study. The difference in GDP between the two cities is not significant, that is, economic development of them is at the same level. However, compared to Daqing City, the environment and the economy of Nanping City are in a coordinated state. The main reason is that the forest coverage rate in Nanping City is as high as 74.75%, while Daqing City is only 12.87%. Therefore, higher forest coverage is one of the key factors for the coordinated development of the environment and the economy.

Conclusion

Based on the three time periods of remote sensing data interpretation of land use, the change in land use areas was analyzed during a period of 20 years in the study area. The *ESV* was assessed according to a modified table of the equivalent value per unit area value of ecosystem services in Nanping City. Meanwhile, *CS* was used to verify the dependence of the *ESV* on the *VC*, and *CDEE* was used to calculate the coordination

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level of the environment and economic development. The following main conclusions were reached:

The most prevalent land use types in Nanping City were forest land, cultivated land, and grassland during the study period. The areas of forest land and construction land increased significantly during the 20 years, of which the area of forest land increased the most, with an increase of 2075.90 km^2. This rapid increase is due to soil and water conservation work that was carried out by government since 2010 and a combination of bamboo and wood plantations was also used to control soil erosion, which significantly contributed to the increase in forest area during this period. Contrastingly, the areas of other land use types showed a decreasing trend, with the area of cultivated land decreasing the most, with a reduction of 1198.70 km^2. The main reason is that there was an increase in the severity of natural disasters and the problem of cultivated land being abandoned became increasingly serious, resulting in a decrease in the cultivated land area during the study period. Meanwhile, due to the continuous transfer of rural laborers to cities, rural labor shortages were becoming severe, also resulting in the significant decrease of cultivated land.

The *ESV* increased significantly, with an increase of 13.452 billion yuan in Nanping City from 1995 to 2015. In various other counties (districts), only the *ESV* in Jian'ou showed a decrease. The main reason of the decrease of *ESV* in Jian'ou is the decrease in the area of forest land with a high *VC* in Jian'ou. The *CS* of different land use types were all less than 1 during the study period, which indicates that the *ESV* in Nanping City was highly dependent on the *VC*, showing that the *VC* selected in this study was accurate and that the results are credible.

There were two forms of coordinated development between environment and economy, namely low harmonic and low disharmonic. In various counties (districts), Wuyishan, Shunchang, and Guangze were at a low harmonic level during the study period. Yanping, Jianyang, Shaowu, and Jian'ou stayed at a low disharmonic level before 2005, while environment and economic development was at a low harmonic level in the above regions after 2005. In contrast, Pucheng, Songxi, and Zhenghe kept a low harmonic level before 2005, and kept a low disharmonic level after 2005.

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