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Human activity intensity of land surface:
Concept, methods and application in China

XU Yong[1], XU Xiaoren[1,2], *TANG Qing[1]

1. Institute of Geographic Sciences and Natural Resources Research, CAS, Beijing 100101, China;
2. University of Chinese Academy of Sciences, Beijing 100049, China

Abstract: Human activity intensity is a synthesis index for describing the effects and influences of human activities on land surface. This paper presents the concept of human activity intensity of land surface and construction land equivalent, builds an algorithm model for human activity intensity, and establishes a method for converting different land use/cover types into construction land equivalent as well. An application in China based on the land use data from 1984 to 2008 is also included. The results show that China's human activity intensity rose slowly before 2000, while rapidly after 2000. It experienced an increase from 7.63% in 1984 to 8.54% in 2008. It could be generally divided into five levels: Very High, High, Medium, Low, and Very Low, according to the human activity intensity at county level in 2008, which is rated by above 27%, 16%–27%, 10%–16%, 6%–10%, and below 6%. China's human activity intensity was spatially split into eastern and western parts by the line of Helan Mountains-Longmen Mountains-Jinghong. The eastern part was characterized by the levels of Very High, High, and Medium, and the levels of Low and Very Low were zonally distributed in the mountainous and hilly areas. In contrast, the western part was featured by the Low and Very Low levels, and the levels of Medium and High were scattered in Gansu Hexi Corridor, the east of Qinghai, and the northern and southern slopes of Tianshan Mountains in Xinjiang.

Keywords: human activity intensity; land surface; construction land equivalent; land use/cover types; China

1 Introduction

Human activity is an objective existence in the process of social development. It is a concept with extensive contents, including all possible behaviors of human and can be classified in many ways (Ye *et al*., 2001). From the perspective of human's effects on nature, human activity can be defined as human's exploitation, utilization, and protection of natural environment for their own survival and development. Since the 1970s, the international scientific communities have paid great attention to human's influence on natural process (Liu *et al*., 2006; Miler, 1994; Shi *et al*., 2009). They launched the World Climate Research Program

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Author: Xu Yong, Professor, specialized in human-environment interactions and regional development.
E-mail: xuy@igsnrr.ac.cn
***Corresponding author:** Tang Qing, PhD, E-mail: tangq@igsnrr.ac.cn

(Barry, 2003; IPCC, 2014), the International Geosphere-Biosphere Program (Leemans *et al*., 2009; Mauser *et al*., 2013), the International Human Dimensions Program (Jager, 2003) and the Biodiversity Plan (Loreau and Olivieri, 1999). All these plans considered the influences of human activities and noticed the characteristics of land cover of land surface, which was influenced by both natural processes and human activities (Turner *et al*., 1995).

In 1996, Land Use/Cover Change (LUCC) Scientific Research Program was initiated to reveal the interaction between the environmental systems and human production systems on the earth, including agriculture, industrialization, urbanization, etc (Fresco *et al*., 1996; Li, 1996). LUCC is one of the main causes of global change, and it is the issues most closely related to natural and human processes, affecting the sustainable development of cities, societies and people's daily lives (Gao *et al*., 2015; Mottet *et al*., 2006). Economic and social factors were considered in the study of causes, mechanism, driving forces, and model building (Liu and Deng, 2009; Pelorosso *et al*., 2009; Tang *et al*., 2009). Recently, land change science has emerged as a fundamental component of global environmental change and sustainability research (Turner *et al*., 2007). As much as half of the earth's ice-free land surface has been transformed by human activities (Haberl *et al*., 2007; Vitousek *et al*., 1997). It is widely speculated that modifying roughly 50% of all land is the biggest human-caused threat to biodiversity (McGill, 2015). The global and regional impact of land use change on the coupled human-environment system needs to be thoroughly assessed.

Nevertheless, some researchers realized the defects that LUCC was studied only by adopting one-dimensional indexes, including cultivation index, land development intensity and output per unit area, etc. (Fan and Li, 2009; GOSC, 2010). They attached importance to integrated research of the comprehensive indexes. According to the natural balanced state of the land natural complex affected by social factors, the synthesis indexes of land use degree were acquired by weighted and summed area (Xu *et al*., 2009; Zhuang and Liu, 1997). To some degree, synthesis index reflects the extent of human activities on land surface, and the academic significance is the framework that the synthesis index is determined in terms of characteristics of land use types. However, the degree of land use is classified roughly and its classification parameters are on an inadequate basis (Zhu and Li, 2003). The expression of the index value has not been widely recognized.

From the perspective of the ecological environmental problems caused by human activities, some young scholars established comprehensive index system of human activities and carried out evaluation research. Wen first studied the concept of human activity intensity and its quantification (Wen, 1998). Index weights were determined by hierarchical analysis or expert scoring method. In the end, human activity intensity was calculated by weighted and summed indexes. Later this method was improved by Li Xiangyun, Zhang Cuiyun, Hu Zhibing, and so on. They were engaged in empirical application research in the northwestern arid area (Li *et al*., 2004; Wang *et al*., 2013; Zhang and Wang, 2004), the upper reaches of Minjiang River (Hu *et al*., 2007), Hutuo River Basin (Wang *et al*., 2009) and the southern hilly region of red soil (Zheng *et al*., 2010). The advantages of this method are strong pertinence on problems and unique local characteristics. The deficiencies are its broad concept and index selection varying from place to place. Moreover, the physical meanings of comprehensive indexes are not clear and it's not convenient to make interregional contrast.

Although the comprehensive research of human activity intensity has made some progress, researchers have not yet formed such comprehensive index algorithms as Ecological Footprint (Rees, 2001; Wackernagel and Rees, 1997) and Global Warming Potential (Sekiya and Okamoto, 2010) which have strong universality and are widely used. This paper tries to learn from Ecological Footprint and Global Warming Potential on their academic ideas and research framework. From the perspective of the relationship between land use/cover and human activity, comprehensive indexes of human activity intensity are built to reflect the effect and influence of human activities on land surface objectively, including concept definition, key parameters to be determined, model building, empirical application, etc. We expect that this study could strengthen the comparability of related research results at regional, national and global levels, and provide a parameter or indicator for the comprehensive research of global environmental change.

2 Concepts and methods

Land use and land cover are two concepts describing land surface status. Currently, it is widely agreed in academia that land use is the comprehensive reflection of resources and natural environment on land surface influenced by human economic and social activities. It is the result of interaction between human activities and natural process (Wu and Guo, 1994). Due to different research perspectives, there are some differences in defining land cover. IGBP and IHDP define land cover as the natural state of land surface and ground layer (Turner *et al*., 1995), and the result of interaction between human activities and natural process. USSGCR regards it as the vegetation covering land surface and other characteristics (US-SGCR/CENR, 1996). Graetz considers land cover to be the rolling land surface covered with vegetation, snow, ice or water, the soil layer included (Graetz, 1993). In general, land cover can be defined as the complex of all key elements of surface covered by natural and artificial buildings, including vegetation, soil, lakes, marshes, and various kinds of buildings. Therefore, the two concepts have close relation, but there is difference. Li Xiubin (1996) believes that land use is the most important factor affecting the land cover, while the change of the latter, in turn, acts on the former.

Based on the perspective of the land use/cover concept, human activity intensity of land surface is defined as the degree of natural cover use, transformation and exploitation of land surface by human in a certain region. This degree can be reflected by land use/cover types. Obviously, human activity intensity of land surface belongs to the conceptual category of the general human activity intensity, which refers to the influence of economic and social activities on a certain regional natural complex. The use, transformation, exploitation of land surface can be seen as the main body of human activity, but not the whole. Human activity intensity of land surface can be expressed as:

$$HAILS = \frac{S_{\mathrm{CLE}}}{S} \times 100\% \tag{1}$$

$$S_{CLE} = \sum_{i=1}^{n} (SL_i \times CI_i) \tag{2}$$

where *HAILS* is human activity intensity of land surface; S_{CLE} is the area of construction land equivalent; *S* is the total land area; SL_i is the area of land use/cover type *i*; CI_i is conversion coefficient of type *i* for construction land equivalent; *n* is the numbers of land use/cover types.

Construction land equivalent (CLE) is used to compare effects on land surface by different human activities and is reflected by land use/cover types. Construction land is regarded as a land use/cover type with the strongest effects of human activities. So construction land equivalent is stipulated as the basic unit to unify the measure of the effects on land surface.

Conversion coefficient of land use/cover type for construction land equivalent means converting the effects on land surface by human activities into construction land equivalent. Different land use/cover types reflect diverse degree of land use, transformation, and exploitation by human. “Use” refers to the use of the surface, but the attributes of the natural cover do not change, such as grassland. Transformation means that the natural cover changes, but water, nutrient, air and heat exchange normally, such as garden plot and farmland. Exploitation indicates that artificial insulation layers are added to the surface, leading to the block of the water, nutrient, air and heat exchange, such as reservoir and construction land. The change of natural attributes above can be used to determine the conversion coefficient of construction land equivalent by the following two-level algorithm step by step:

(1) At the first level, 0 is set for the eigenvalue whose natural attributes do not change and natural cover has not been used. 1 is set for those surfaces that have artificial insulation layers and where water, nutrient, air and heat exchange are blocked. Five equal parts are divided between 0 and 1, marked by such characteristics as change of natural cover and the exchange of water, nutrient, air and heat. The eigenvalue corresponding to each characteristic sign is 0.2. The corresponding value with the superposition of several characteristic signs is multiples of 0.2.

(2) At the second level, 3 equal parts are divided between 0 and 0.2, marked by the surface natural cover unchanged but used, natural cover changed and perennial planted, natural cover changed and annual crops planted, respectively. The degree of natural change is incremental. When the natural cover is unchanged but used, its eigenvalue is 0.067. Under the second circumstance above, it is 0.133. The last value is 0.2 with natural cover changed and annual crops planted.

The above eight characteristic signs and their corresponding eigenvalues are the fundamental basis for determining the conversion indexes of different land use/cover types for construction land equivalent (Table 1). But in the particular calculation process, special attention should be paid to the relationship and difference between the five feature signs at the first level and the three at the second level. The two levels interrelate through natural cover change at the first level and land cover change with annual crops at the second level. Consequently, both of the corresponding eigenvalues are 0.2. The characteristic signs at the first level are higher than that at the second level. Three characteristic signs in the second level belong to natural cover change in the first one. The eigenvalues at the first level are independent and could accumulate in the calculation. The eigenvalues in the second level are incremental. The maximum among the 3 values should be selected in the calculation. The conversion coefficient for construction land equivalent is calculated as follows:

$$CI_i = FCS1_i + FCS2_i + FCS3_i + FCS4_i + FCS5_i \tag{3}$$

$$FCS1_i = \max(CS1_i,\ CS2_i,\ CS3_i) \tag{4}$$

where $FCS1_i$, $FCS2_i$, $FCS3_i$, $FCS4_i$ and $FCS5_i$ are the corresponding values at the first level for land use/cover type i, respectively; $CS1_i$, $CS2_i$, and $CS3_i$ are the corresponding values at the second level for land use/cover type i, respectively. With this method, conversion coefficients of the construction land equivalent are given in Table 2.

Table 1 Characteristic signs and corresponding eigenvalues of land surface

Level	Category	Characteristic signs	Eigenvalue
		Natural cover of land surface does not change and is not used.	0
The second level	CS1	Natural cover of land surface does not change but is used.	0.067
	CS2	Natural cover of land surface changes and perennials are planted.	0.133
	CS3	Natural cover of land surface changes and annual crops are planted.	0.2
The first level	FCS1	Natural cover of land surface changes.	0.2
	FCS2	There are artificial insulation layers on the surface. Water could be exchanged. The exchanges of nutrient, air and heat are blocked.	0.2
	FCS3	There are artificial insulation layers on the surface. Nutrient could be exchanged. The exchanges of water, air and heat are blocked.	0.2
	FCS4	There are artificial insulation layers on the surface. Air could be exchanged. The exchanges of water, nutrient and heat are blocked.	0.2
	FCS5	There are artificial insulation layers on the surface. Heat could be exchanged. The exchanges of water, air and nutrient are blocked.	0.2
		There are artificial insulation layers on the surface. The exchanges of water, nutrient, air and heat are blocked.	1

Table 2 Conversion coefficients of different land use/cover types for construction land equivalent

	Land use/cover types	Explanations of characteristic signs	CI
Farmland	Irrigated paddy field/rained paddy field/irrigable land/dry land/vegetable land	Natural cover of land surface changes and annual crops are planted.	0.2
Garden plot	Orchard/mulberry field/tea garden/ rubber plantation/other gardens	Natural cover of land surface changes and perennials are planted.	0.133
Forest land	Closed forest land/shrub land/forestland	Natural cover of land surface does not change and is not used.	0
	Young afforested land/nursery	Natural cover of land surface changes and perennials are planted	0.133
	Cut-over land	Natural cover of land surface changes	0.2
Grassland	Natural grassland/improved grassland	Natural cover of land surface does not change but is used.	0.067
	Tame pasture	Natural cover of land surface changes and perennials are planted.	0.133
Other agricultural land	Livestock and poultry breeding land	There are artificial insulation layers on the surface. The exchanges of water, nutrient, air and heat are blocked.	1
	Land for protected agriculture /country road/riser of terrace	Natural cover of land surface changes.	0.2
	Aquiculture area/pond	Natural cover of land surface does not change but is used.	0.067
Residential, industrial, and mining land	Urban land/town area/rural residential area/independent industrial and mining land/land for special use	There are artificial insulation layers on the surface. The exchanges of water, nutrient, air and heat are blocked.	1
	Salt pan	Natural cover of land surface changes. The exchanges of air and heat are blocked.	0.6

(*to be continued on the next page*)

(*Continued*)

Land use/cover types		Explanations of characteristic signs	CI
Land for transportation	Land for railway/highway land/civil airport/port and pier/pipeline transport	There are artificial insulation layers on the surface. The exchanges of water, nutrient, air and heat are blocked.	1
Land for water facilities	Hydraulic building land	There are artificial insulation layers on the surface. The exchanges of water, nutrient, air and heat are blocked.	1
	Reservoir	Natural cover of land surface changes. The exchanges of air and heat are blocked.	0.6
Unused land	Wild grass ground/sand/bare rock gravel land/saline-alkali soil/marsh land/barren land	Natural cover of land surface does not change and is not used.	0
Other unused land	River/lake/reed/intertidal zone/glaciers and permanent snow	Natural cover of land surface does not change and is not used.	0

3 Results

3.1 Change of human activity intensity at national and provincial levels

According to the land use data in China from 1984 to 2008, this paper calculates the national area of construction land equivalent and human activity intensity as shown in Figure 1. The human activity intensity change of provincial units is illustrated in Table 3. They present the following characteristics:

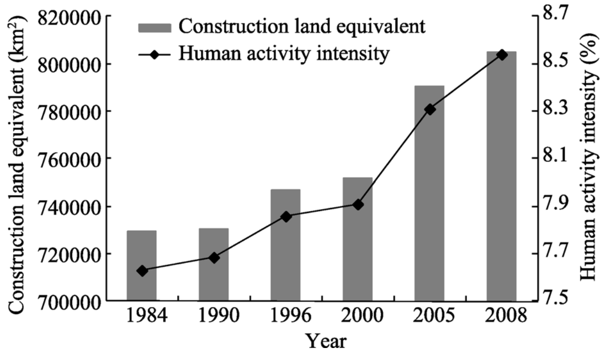

Figure 1 Changes of construction land equivalent area and human activity intensity of China in 1984–2008

(1) The construction land equivalent area and human activity intensity in China rose slowly from 1984 to 2000, while rapidly after 2000. The total construction land equivalent area increased from 72.96×10^4 km^2 in 1984 to 80.51×10^4 km^2 in 2008. During the 24 years, the average increment was 3145 km^2/y. The average increment in the early stage was 1401 km^2/y, and increased dramatically to 6634 km^2/y in the late stage. The human activity intensity grew from 7.63% in 1984 to 8.54% in 2008. During the 24 years, it increased by 0.91%. The average growth rate per year in the early stage was below 0.02%, but increased to 0.08% in the late stage.

(2) Human activity intensity at provincial level changed diversely. In the eastern coastal areas, it increased quickly, but the growth rate was small in the western regions. There was decrease in some individual provinces. During the 24 years, Shanghai and Tianjin had the greatest change, increasing by 20.58% and 12.6%, respectively. The following were Beijing, Guangdong, Shandong, Zhejiang, and Jiangsu, increasing by 6.06%, 5.39%, 5.31%, 4.92% and 4.67% respectively. The increments of Anhui, Hunan, Hubei, and Henan were between 2% and 3%. All other provinces were below 2%. Shanxi and Shaanxi had negative growth,

decreasing by 0.84% and 0.4%, respectively, which were caused by returning farmland to forest and reclamation in mining districts. In addition, there existed slight fluctuation in parts of the provincial units.

Table 3 Changes of human activity intensity of China's land surface by provinces in 1984–2008 (%)

Provincial unit	1984	1990	1996	2000	2005	2008	Changes during the 24 years
Shanghai	25.73	33.57	33.57	35.79	39.14	46.30	20.58
Tianjin	27.46	29.47	29.65	30.36	38.44	40.06	12.60
Jiangsu	25.03	24.22	24.64	25.26	29.26	29.69	4.67
Shandong	22.80	24.36	25.26	25.70	27.58	28.12	5.31
Beijing	18.42	19.52	20.61	21.03	23.64	24.48	6.06
Henan	21.79	22.91	23.43	23.58	23.71	23.91	2.13
Anhui	19.20	19.23	19.75	19.89	21.90	22.16	2.96
Hebei	16.49	16.70	17.08	17.35	17.33	17.72	1.24
Liaoning	15.02	14.69	15.07	15.26	15.89	16.04	1.02
Chongqing	14.19	12.85	13.00	13.29	15.02	15.19	1.01
Zhejiang	9.93	10.59	11.08	11.41	13.93	14.85	4.92
Guangdong	9.07	10.14	11.33	11.87	14.10	14.45	5.39
Hainan	12.77	12.34	13.04	13.25	14.51	14.27	1.50
Hubei	11.62	11.72	11.87	11.95	13.90	14.10	2.47
Shanxi	12.94	11.78	11.86	11.93	11.95	12.10	–0.84
Jilin	10.86	11.88	11.79	11.84	11.95	12.03	1.16
Ningxia	11.50	11.60	11.90	12.44	11.75	11.94	0.44
Hunan	8.80	9.40	9.58	9.69	11.53	11.72	2.92
Guizhou	8.40	9.18	9.11	9.09	10.09	10.16	1.76
Jiangxi	9.46	7.78	8.04	8.15	9.57	9.82	0.36
Shaanxi	9.99	10.28	10.28	10.12	9.55	9.59	–0.40
Heilongjiang	9.13	9.01	9.06	9.09	9.40	9.16	0.03
Sichuan	8.38	7.76	7.92	8.00	8.70	8.76	0.38
Fujian	8.42	6.26	6.85	7.12	8.18	8.60	0.19
Guangxi	8.27	7.16	7.33	7.48	8.33	8.49	0.22
Gansu	7.24	7.20	7.24	7.23	7.46	7.48	0.24
Yunnan	5.68	5.73	5.78	5.86	6.56	6.65	0.97
Inner Mongolia	6.24	6.63	6.72	6.52	6.38	6.43	0.18
Qinghai	3.53	4.28	4.34	4.34	4.94	4.40	0.86
Tibet	3.71	3.70	3.70	3.70	3.63	3.73	0.02
Xinjiang	3.28	3.02	3.22	3.25	3.35	3.37	0.09
China	7.63	7.69	7.86	7.91	8.31	8.54	0.91

(3) There existed great differences in human activity intensity among provinces. In the period of 1984–2008, the difference had an expanding trend. According to the spatial distribution of human activity intensity at the provincial level (Figures 2 and 3), there were five provinces where human activity intensity was above 20% in 1984, including Tianjin, Shanghai, Jiangsu, Shandong, and Henan. Beijing and Anhui were added in 2008. It was between 13% and 20% in Beijing, Anhui, Liaoning, Hebei and Chongqing in 1984. Zhejiang, Hubei, Guangdong and Hainan were added in 2008. It was below 5% in Xinjiang, Tibet and Qinghai. Human activity intensity was between 5%–13% in other provinces. Tianjin had the highest human activity intensity, whereas Xinjiang had the lowest in 1984. They were 27.46% and 3.28% respectively. In 2008, Shanghai had the highest human activity intensity (46.30%), which was nearly 43% higher than that of Xinjiang.

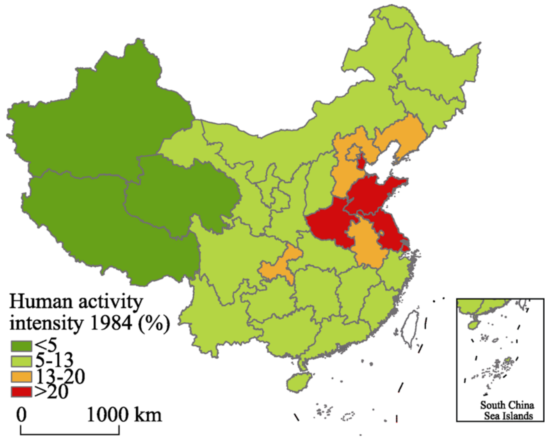

Figure 2 Differences of human activity intensity of China's land surface by provinces in 1984

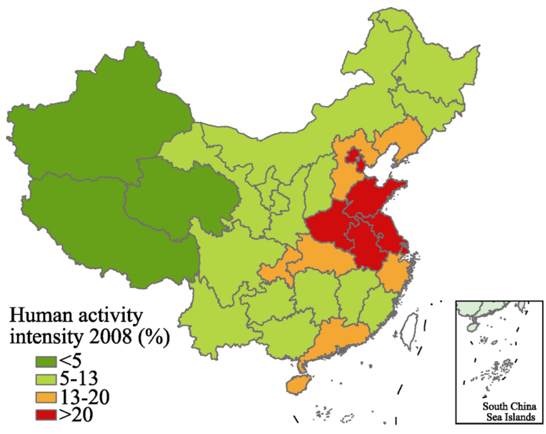

Figure 3 Differences of human activity intensity of China's land surface by provinces in 2008

3.2 Spatial differentiation of human activity intensity

According to the land use change data at county level in 2008, this paper used county-level administrative map of 2004 as the spatial unit and calculated human activity intensity of each unit so that their spatial characteristics of land surface could be revealed more clearly. Using GIS and the method of natural fracture, human activity intensity by counties could be divided into five levels including Very High, High, Medium, Low, and Very Low, rating by above 27%, 16%–27%, 10%–16%, 6%–10%, and below 6%. The results and its spatial distribution were shown in Table 4 and Figure 4.

Table 4 Classification of human activity intensity of China's land surface by counties in 2008

Type	Grading standard (%)	Number	Average human activity intensity (%)	Average area of construction land equivalent (km^2)
Very High	>27	487	32.52	341.78
High	27–16	478	20.99	361.50
Medium	16–10	459	12.43	310.07
Low	10–6	493	7.56	323.28
Very Low	<6	458	3.29	342.01

The human activity intensity in China was spatially split into eastern and western parts by the line of Helan Mountains-Longmen Mountains-Jinghong in 2008 (see the blue dashed line in Figure 4). Human activity intensity was high in the eastern part, while it was low in the western part. The eastern part was characterized by the levels of Very High, High, and Medium, and human activity intensity of Low and Very Low levels were zonally distributed in mountainous and hilly regions. The western part was featured by the Low and Very Low levels. There existed scattered types of Medium and High in Hexi Corridor in Gansu, the loess plateau in the east of Qinghai, northern and southern slopes of Tianshan Mountains in Xinjiang. The characteristics and spatial distribution of each level were as follows:

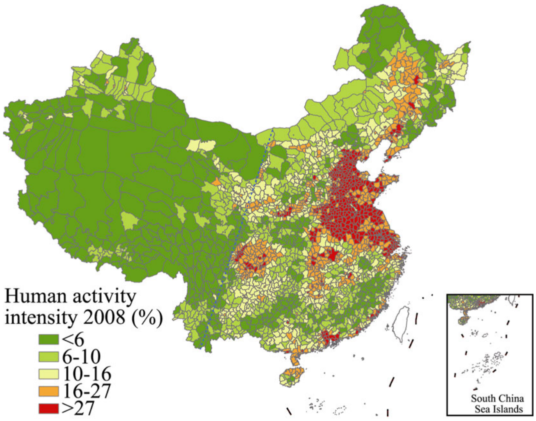

Figure 4 Spatial differences of human activity intensity of China's land surface by counties in 2008

(1) Very High level. Human activity intensity was above 27%. There were 487 county units, where the average construction land equivalent was 341.78 km^2. The average human activity intensity of the units was 32.52%. The concentrated distribution areas were the Huang-Huai-Hai Plain, the Yangtze River Delta and the Pearl River Delta, and the scattered areas were such urban agglomerations as Sichuan Basin, middle reaches of the Yangtze River, the Northeast China Plain, the southeast coastal zone and Fenhe-Weihe river valley.

(2) High level. Human activity intensity was between 16% and 27%, 478 county units included. The average construction land equivalent of the units was 361.5 km^2, and the average human activity intensity was 20.99%. Their distribution trend was consistent with that of Very High level, whereas they were distributed in a large scale in the Northeast China Plain, Liaodong Peninsula, Shandong Peninsula, the middle and lower reaches of the Yangtze River, Sichuan Basin, Fenhe-Weihe river valley, the middle and east of Gansu, Hetao Plain of the Yellow River, Leizhou Peninsula, the northeast of Hainan Island, etc.

(3) Medium level. The human activity intensity was between 10% and 16%. There were 459 county units. The average construction land equivalent was 310.07 km^2, and the average human activity was 12.43%. They were distributed around the High level areas, such as the western Loess Plateau, Sanjiang Plain and Yunnan-Guizhou Plateau.

(4) Low level. Human activity intensity was between 6% and 10%, 493 county units included. The average construction land equivalent was 323.28 km^2, and the average human activity intensity was 7.56%. To the west of the line of Helan Mountains-Longmen Mountains-Jinghong, north of the Tianshan Mountains, the Loess Plateau in the east of Qinghai, southwestern Yunnan and areas along the Yarlung Zangbo River and two other rivers of Tibet were parts of the Low level. In the east of the line, its distribution trend was in accordance with that of Very Low level, except the middle and east of Inner Mongolia.

(5) Very Low level. Human activity intensity was below 6%. There were 458 county units. The average construction land equivalent was 342.01 km^2, and the average human activity

intensity was 3.29%. In the west of the line of Helan Mountains-Longmen Mountains-Jinghong, the southern Tianshan Mountains, Alxa League in Inner Mongolia, the west of Sichuan and the northwestern Yunnan were parts of the above areas. In the east of the line, the Very Low level areas were mainly mountains and hills, including Greater and Lesser Hinggan Mountains-Changbai Mountains, Yanshan Mountains-Taihang Mountains, loess hilly-gully areas, Qinling-Daba Mountains, Wuling mountainous area, etc.

4 Discussion

There are different ways to describe human activity intensity of land surface. This paper takes the ratio of construction land equivalent area to the total land area to delineate human activity intensity, emphasizing its total ratio and spatial differentiation. Construction land area equivalent per capita could also be adopted to describe the concept. This expression could compare human activity intensity in different regions from the perspective of “per capita occupancy”.

Human activity intensity correlates with the population density. The correlation analysis between human activity intensity and population density could verify the feasibility and effectiveness of human activity intensity measurement methods from one side. By matching human activity intensity of the 2365 counties with the corresponding population data in 2008, this study finds out that there exists exponential function relationship between them (Figure 5). The correlation coefficient is 0.8156, indicating that the expression and measurement methods of human activity intensity are feasible and effective. The fitting exponential function could be expressed as follows.

$$HAILS = 1.5045X^{0.4036} \quad (5)$$

$$R^2 = 0.6652$$

The conversion coefficients of different land use/cover types for construction land equivalent are determined by the following four steps. The first step is level division based on whether there exist artificial insulation layers of non-primary production on the surface. Those with insulation layers belong to the first level, while those without belong to the second one. The second step is to explore characteristic signs used as quantitative basis. By studying different types of construction land, rainfall infiltration and water environment effect (Hou *et al*., 2006; Liu *et al*., 2011; Zhu *et al*., 2009), whether natural cover of surface changes, its water, nutrient, air and heat exchanges are thought as the five characteristic signs in the first level. By analyzing soil nutrients and water infiltration (She *et al*., 2014; Wang *et al*., 2003; Yu *et al*., 2014), three characteristic signs in the second level including natural cover unchanged but used, changed natural cover with perennials, changed natural cover with annual plants, are determined. In the third step, this study refers to the ideas of quantitative classification of land use by Liu Jiyuan (Xu *et al*., 2009; Zhuang and Liu, 1997). According to the principle that attributes are equally important, five characteristic signs in the first level are used to divide 1 into five equal parts. Three characteristic signs in the second level are utilized to divide 0.2 into three equal parts. Finally, based on the eight eigenvalues, conversion coefficients of different land use/cover types for construction land equivalent are determined by correspondence relation.

Problems remain to be further discussed. When this paper presents the concept of human activity intensity and its measurement method, it does not consider the following problems: the aggravation of water loss and soil erosion caused by steep slope reclamation, grassland degradation brought about by overgrazing, the deterioration of the environment led by energy-intensive and pollution-high industrial technology, land subsidence caused by groundwater overexploitation, "urban disease" resulting from urban spreading expansion. The "suitability" of human activity intensity involving regional characteristics of natural environment, endowment of resources and development level of technology and economy, is not taken into account. In particular areas, reasonable way of human activity and appropriate human activity intensity need to be studied in the future.

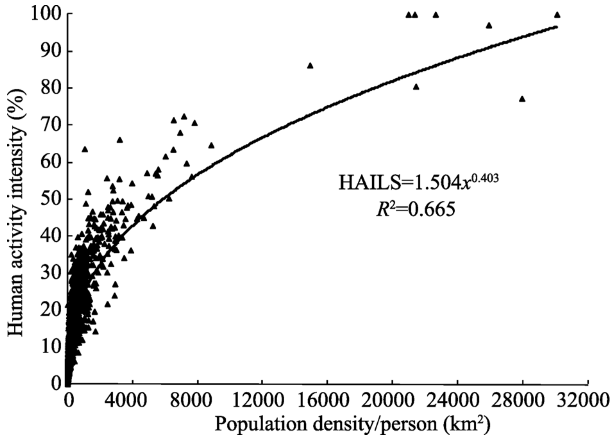

Figure 5 Correlation between human activity intensity and population density by counties in China in 2008

5 Conclusions

The results show that it is accurate to define human activity intensity as the degree of natural cover use, transformation and exploitation of land surface by human beings, and it is an effective method to determine the conversion coefficients of different land use types for construction land equivalent by the characteristic signs of natural attribute change caused by human activity. The application and the correlation analysis between human activity intensity and population density indicate that it is feasible to take the ratio of construction land equivalent area to the total area as an indicator of human activity intensity.

Based on natural attribute change of land surface caused by land use, transformation and exploitation, this paper adopts a two-level and eight-eigenvalue method to determine general standard of converting different land use/cover types into construction land equivalent, and presents a method for calculating the conversion coefficients for construction land equivalent. It also builds a coefficient table for construction land equivalent of 49 land use types based on the latest land use classification system in China.

The human activity intensity in China has rapidly increased since the year of 2000, from 7.63% in 1984 to 8.54% in 2008. Human activity intensity at provincial level changed diversely. In the eastern coastal areas, it increased sharply, but the changing rate was small in the western regions. There was a slight decrease in Shanxi and Shaanxi.

Human activity intensity could be divided into five levels including Very High, High, Medium, Low, and Very Low, according to the human activity intensity at county level in 2008, which was rating by above 27%, 16%–27%, 10%–16%, 6%–10% and below 6%. The human activity intensity in China was spatially split into eastern and western parts by the line of Helan Mountains-Longmen Mountains-Jinghong. Human activity intensity was high in the eastern part, while it was low in the western part. The eastern part was characterized by the levels of Very High, High, and Medium. Human activity intensity at Low and Very Low levels had zonal distribution in its mountainous and hilly areas. The western part was featured by the Low and Very Low level. There existed scattered types of Medium and High in Hexi Corridor in Gansu, the Loess Plateau in the east of Qinghai, and northern and southern slopes of the Tianshan Mountains in Xinjiang.

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