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Study on the eco-efficiency of single element of non-agricultural land conversion base on the urbanization

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ABSTRACT

The land conversion is a major source of CO_2 in urbanization. The expansion of the extension of the city lending to agricultural land and its cover has been continuously reduced, which not only lead the green vegetation in fixed carbon to release, but also because of the lack of vegetation to absorb carbon caused a significant increase greenhouse gases in atmosphere. To reduce the CO2 in the atmosphere, this paper studies carbon emissions and coordinating between carbon emissions reduction and economic development from an efficiency point. Based on DEA environmental technology, this paper estimates eco-efficiency of carbon emissions caused by single element of non-agricultural land in the process of urbanization and industrialization, and further analyzes carbon emissions reduction and economic development coordinated degrees. Comparative of similar studies have found that carbon emissions are mainly caused by land use change, other input elements contribution to carbon emissions are in a secondary position in urbanization and industrialization process; It is mainly through the intensive use of land to achieve coordination between carbon emissions and economic development Therefore, it is crucial to use land resources rationally to achieve carbon reduction in urbanization and industrialization.

KEYWORDS

Eco-efficiency; Carbon emissions; Agricultural land conversion; DEA technology; Urbanization.

INTRODUCTION

The major source of carbon emissions in the process of urbanization is land conversion. The change in land use leads to the change of coverage vegetation and later the carbon emissions. Currently, the main features of the process of urbanization in China are gradual expansion of the construction land, incessant decrease of agricultural land and drastic reduction of green vegetation coverage. Carbon emissions generated by land conversion is half of those that is produced by combustion of fossil fuels. Carbon emissions caused by urbanization should be greatly emphasized. The pace of urbanization can not be stopped and the carbon emissions caused by it also can not be eliminated. The only way is to improve the efficiency of non-agricultural land and minimize the number of non-agricultural land, with the purpose of reducing the carbon emissions quantity.

Ehrenfeld[1] constructed efficiency indicators to measure the efficiency of land use. The level and efficiency of land use is positively correlation[2]. Land use efficiency can also be estimated by ecological footprint model[3]. If land use efficiency tends to be improved in the third regions in China, land “demand-supply” equilibrium policy should be implemented. Provided that certain amount of non-agricultural land is transferred from central and western regions to the east, the land use efficiency can be increased[4-6]. Based on the aim of farmland protection, Qu Futian and Zhu Xinhua (2008) has divided China according to agricultural regions to analyze the land use efficiency[7]. However, the above studies only concerns the disparity of land use efficiency between inter-districts, the disparity of actual land use efficiency in inner district will be greater than that of inter-district[8].

Although the objects of the above studies are land use efficiency and the change of carbon emissions in the process of land use change, the latter has always been treated as the exogenous environment cost of the former, which is not scientific. You Heyuan and Wu Cifang(2010)[9] tries to endogenize carbon emissions of land use, but they only regards the carbon emissions of coal, oil and other energy as input factors of production, which also equals to treating undesirable output as input in DEA model. Actually it is inconsistent with the fact and can not accurately measure the land use efficiency. Cuiwei and others[10-12] dynamically compare the non-agricultural land co-efficiency in the process of urbanization of China’s provinces and explore the reasons which influence co-efficiency and also measure their space performances by use of non-desired output DEA technique. These models are constrained by carbon emissions to measure the land use co-efficiency instead of being treated as the cost of input and output, which can measure non-agricultural land co-efficiency scientifically. Cui et.al (2013) compares 30 provinces’ degree of non-agricultural wastage in China in 2010[13] and it tends to show the degree of wastage has generally been increased from the east to the west. However, on one hand, sample is not typical since they only select one year for the study; on the other hand, there is deviation of the result because what they measure is total factors wastage degree instead of land wastage degree when comparing the degree of provinces’ land wastage. The main work of thesis includes three parts. The first part is to isolate the land factor on the basis of study[14] and measure the wastage degree of non-agricultural land by use of DEA environmental technique. The second part compares the non-agricultural wastage degree of 28 provinces from 2002—2011 and finds the path of land space allocation. The last part analyzes whether land wastage is the main source of resource wastage by the comparison with the result of Cui et.al (2013).

METHODOGY

In a production process, production factor X is input N kinds, two types of output can be get which are M kinds desirable y and J kinds of undesirable u, $x=(x_1,x_1,\cdots,x_n)$, $x\in R_N^+$; $y=(y_1,y_1,\cdots,y_n)$; $y\in R_M^+$; $u=(u_1,u_1,\cdots,u_n)$, $u\in R_J^+$. This production process can be described by production set $P(x)=\{(y,u):(x,y,u)\in T\}$. T represents technology relationship in the production, $P(x)$ is the output set of all output. Hyper surface constructed by all effective production activity points (x,y,u) of $P(x)$ determines productive frontier. $P(x)$ accords with closeness, boundedness and convexity, according to the study of Chung et. al[15] (1997) and Färe et. al[16] (2007), its properties are as follows:

① $P(x)$ satisfies the strong disposability of output, which equals to if $(y,u)\in P(x)$ and $x'>x$, then $P(x)\in P(x')$.

② $P(x)$ satisfies the strong disposability of desirable output and with no cost, which equals to if $(y,u)\in P(x)$ and $y'<y$, then $(y',u)\in P(x)$.

③ $P(x)$ satisfies the weak disposability of undesirable output, it indicates that the decrease of undesirable output is at the cost of the damage to desirable output and reduces the cost of undesirable output accordingly. It equals to $(y,u)\in P(x)$ and the proportion coefficient satisfies $0\le\theta\le 1$, then it satisfies $(\theta y,\theta u)\in P(x)$.

④ $P(x)$ satisfies null-binding of desirable output and undesirable output.. It implies that as long as the desirable output exists in production, undesirable output exists inevitably. The only way to avoid undesirable output is stopping the production, which is also equals to $(y,u) \in P(x)$ and $u=0$, then $y=0$.

The above ecological environment technology combines desirable output with undesirable output together effectively, though it is easy to understand, the operability of calculation and demonstration is inefficient. Therefore, DEA can be applied to model the theory to form ecological environment DEA[17]. If there are K areas with the same meaning of K DMU, the input output of the K is (x,y,u), and if $\sum_{k=1}^{K} u_{kj} > 0$ ($j=1,2,\cdots,J$) to make sure that each undesirable output at least exists a certain area, and $\sum_{j=1}^{J} u_{kj} > 0$ ($k=1,2,\cdots,K$) which makes sure that each area at least brings one kind of undesirable output, the production process with the unchangeable scale and reward can be described as follows:

$$
\begin{aligned}
&P(x) = \{(x,y,u)\} \\
&\sum_{k=1}^{K} \lambda_k x_{kn} \le x_{0n}, n = 1,2,\cdots N \\
&\sum_{k=1}^{K} \lambda_k y_{km} \ge y_{0m}, m = 1,2,\cdots M \\
&\sum_{k=1}^{K} \lambda_k u_{kj} = u_{0j}, j = 1,2,\cdots J \\
&\lambda_k \ge 0, k = 1,2,\cdots,K
\end{aligned}
\tag{1}
$$

In the above model, λ_k is a new constructed combination ratio of DMUk of the Kth evaluation unit among an effective DMU. Subscript 0 represents the decision-making unit is the evaluation unit. Inequality constraint factors in mdoel (1) indicates that factor input and desirable output is strongly disposable and equality constraints implies that weak disposability of undesirable output and null-jointness of two kinds of outputs satisfy the conditions of ecological environment production technology.

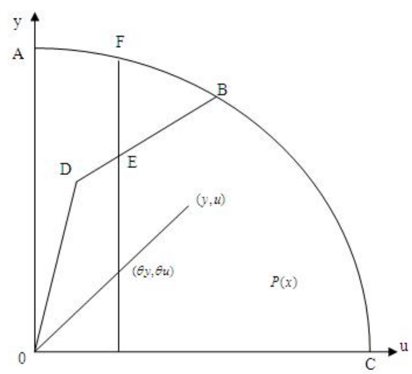

Figure 1 : Production possibility set

Figure 1 reveals that if one kind of input brings out a kind desirableoutput and undesirable output both with strong disposability, then it is consistent with the assumption of output maximization and there is no existence of ecological environment constraint, the production frontier is OAC. If desirable output is strong disposable and undesirable output weak disposable, then ecological environment constraint will work, its production frontier will become ODBC, the production function is $P(x)$, only origin satisfies null undesirable output. As is also shown, potential desirable output point E under the condition of undesirable output weak disposability, will become point F if environment constraint does not exist with the illustration that treating polluted environment needs the distance EF.

Under environmental constraints, this part contrasts the calculation model of Cui et al. (2013) and urban non-agricultural land wastage of this paper.

Model of urban non-agricultural land wastage evaluated by Cui et.al. Under the assumption of input not increasing, desirable output not decreasing, and non-desirable output in the degree of reducing in maximum, calculate it with model (2), which is called total elements of eco-efficiency.

$$Min\alpha$$
$$\sum_{k=1}^{K}\lambda_k x_{kn} \le x_{0n}, n = 1, 2, \cdots, N$$
$$\sum_{k=1}^{K}\lambda_k y_{km} \ge y_{0m}, m = 1, 2, \cdots, M$$
$$\sum_{k=1}^{K}\lambda_k u_{kj} = \alpha u_{0j}, j = 1, 2, \cdots, J$$
$$\lambda_k \ge 0, k = 1, 2, \cdots, K \qquad (2)$$

Among these elements, α ($0 \le \alpha \le 1$) is eco-efficiency used by evaluating environmental resource utilization. The smaller it is, the lower the eco-efficiency of this area is, the lower resource utilization is and the more serious the overdevelopment or waste is. As shown in (2), the point G of the possible production set $P(x)$ can move along the direction of GE to E which is located before production set, and under the circumstances of not changing input and expected output, non-desirable output will decrease, and eco-efficiency will improve.

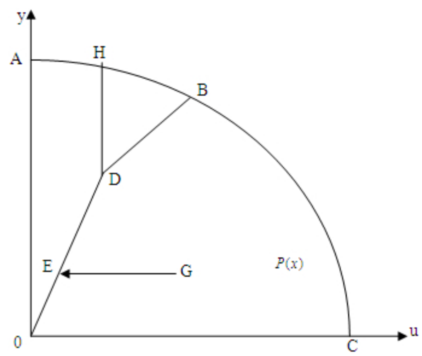

Figure 2 : Efficiency improvement

Model of urban non-agricultural land wastage used by this paper

Under the assumption of input not increasing, desirable output not decreasing, and land wastage and non-desirable output in the degree of reducing in maximum, calculate it with model (3), which is called single element of eco-efficiency. This can indicate the increasing of non-desirable output caused by land wastage.

$$Min\alpha'$$
$$\sum_{k=1}^{K}\lambda_k x_{kn} \le x_{0n}, n = 1, 2, \cdots, N$$
$$\sum_{k=1}^{K}\lambda_k x_{k0} \le \alpha' x_0$$
$$\sum_{k=1}^{K}\lambda_k y_{km} \ge y_{0m}, m = 1, 2, \cdots, M \qquad (3)$$
$$\sum_{k=1}^{K}\lambda_k u_{kj} = \alpha' u_{0j}, j = 1, 2, \cdots, J$$
$$\lambda_k \ge 0, k = 1, 2, \cdots, K$$

Among these elements, α ($0 \le \alpha \le 1$) evaluates the decrease of eco-efficiency as a result of some environmental resource wastage. The smaller it is, the more serious this resource wastage is, and the lower eco-efficiency is. Contrast α with α', if $\alpha' > \alpha$, it indicates that whether the eco-efficiency is high or not, it doesn't depend on the utilization efficiency of this resource, and other production elements are also the reasons of ecological effect; if $\alpha' = \alpha$, it implies the high-low of eco-efficiency totally depends on the utilization efficiency of this resource.; if $\alpha' < \alpha$, it reflects this resource's waste gives rise to the lower eco-efficiency, but because other input elements also have some kinds of wastage, in turn, the eco-efficiency rises. However, this kind of high-level eco-efficiency is brought by the production mode of unsustainable development and achieved by growth pattern which is featured by predation.

Next, contrast the coordination degree between urban non-agricultural land wastage and economic development of this paper with Cui et.al (2013). Coordinated model between urban non-agricultural land wastage and economic development measured by Cui et.al. Under the assumption of input not increasing, desirable output as large as possible, and non-desirable output as small as possible, calculate it with model (4), which is called total elements of coordinated model.

$$\begin{aligned}
&Max\beta \\
&\sum_{k=1}^{K}\lambda_k x_{kn} \le x_{0n}, n=1,2,\cdots,N \\
&\sum_{k=1}^{K}\lambda_k y_{km} \ge (1+\beta)y_{0m}, m=1,2,\cdots,M \\
&\sum_{k=1}^{K}\lambda_k u_{kj} = (1-\beta)u_{0j}, j=1,2,\cdots,J \\
&\lambda_k \ge 0, k=1,2,\cdots,K
\end{aligned} \quad \textbf{(4)}$$

Here we still use directional distance function, a direction vector oriented by output. The lower the coordination degree β ($0 \le \beta \le 1$) between desirable output and non-desirable output, the lower their conflict is and the easier it coordinates.

Coordinated model between urban non-agricultural land wastage and economic development evaluated by this paper

Under the premise of input not increasing, desirable output as large as possible, and land input and non-desirable output caused by it as small as possible, calculate it with formula (5), which is called single element of coordinate model. It's mainly about under the premise that land wastage is lowest, coordination degree of desirable output and non-desirable output caused by land wastage. It is used to calculate the coordinate ability between non-desirable output because of land wastage and economic development. In contrast with (4), model (4) measures the coordinate ability and non-desirable output due to land waste, and the coordinate co-efficient calculated from it is used to make non-desirable output as small as possible as a result of total input elements and desirable output as large as possible.

$$\begin{aligned}
&Max\beta \\
&\sum_{k=1}^{K}\lambda_k x_{kn} \le x_{0n}, n=1,2,\cdots,N \\
&\sum_{k=1}^{K}\lambda_k x_{k0} \le (1-\beta)x_0 \\
&\sum_{k=1}^{K}\lambda_k y_{km} \ge (1+\beta)y_{0m}, m=1,2,\cdots,M \\
&\sum_{k=1}^{K}\lambda_k u_{kj} = (1-\beta)u_{0j}, j=1,2,\cdots,J \\
&\lambda_k \ge 0, k=1,2,\cdots,K
\end{aligned} \quad \textbf{(5)}$$

β' ($0 \le \beta' \le 1$) evaluates the effect of intensification of some environmental resource on the maximum of desirable output and minimum of non-desirable output. The lower β' is, the easier it coordinates desirable output to its maximum and non-desirable output to minimum by intensification of using land.

Contrast β' with β. If $\beta' = \beta$, it indicates that the minimum of non-desirable output and maximum of desirable output is mainly coordinated by using land efficiently to improve its coordinate ability; if $\beta' = \beta$, it implies in order to make desirable output maximum and non-desirable output minimum, it not only requires to use land intensively, but to use other input elements intensively; $\beta' > \beta$ won't happen because β includes the coordination degree of non-desirable output caused by land element and economic development, hence the coordination degree due to land element is higher than that caused by total input elements won't take place.

RESULT AND DISSCUSS

Eco-efficiency of built-up area non-agricultural land of different districts in China from 2002 to 2011 is calculated based on the above theory and model. Furthermore, eco-efficiency of total elements and one element eco-efficiency are compared in this part.

Data Sources and Selection

TABLE 1 : Statistics of input output indicators of various districts in China from 2002-2012

Indicators	Units	Maximum	Minimum	Mid-Value	Average	Standard Deiation
Capital Stock	Million	237216091.65	2456121.18	35377728.56	47965876.97	43270210.24
Labor Force	Million	4533.40	126.60	1160.00	1500.41	1085.70
Land	Hectare	646412.00	1017.00	35714.00	41894.94	45772.93
GDP	Million	3142881.00	42798.51	790679.81	961706.30	640430.14
Carbon Dioxide	Ton	6806718.36	10709.01	376068.42	441153.70	481988.94

To keep the data scientific, 28 provinces in China from 2002 to 2011 are chosen as the objects (statistics of Sichuan includes Chongqing's; Taiwan, Hong and Macao are not included; Tibet and Hainan are eliminated because of incomplete of statistics). Labor force is (x_1), capital represented by (x_2) and land represented by (x_3) are input, GDP(y) is desirable output, carbon dioxide resulted from non-agricultural land is undesirable output(u). Choice of each indicator's statistics refers to the settlement in Cui et.al(2013). Talbe 1 describes the statistics of input and output.

According to model (2) and (3), eco-efficiency α and α' of non-agricultural land can be obtained, specific results of different provinces can be found out from TABLE 2 and TABLE 3.

TABLE 2 : Comparison between α and α' of different provinces from 2002 to 2006

	2002		2003		2004		2005		2006	
	α'	α	α'	α	α'	α	α'	α	α'	α
Beijing	0.03	0.03	***0.44***	***0.08***	0.26	0.26	0.08	0.08	***0.49***	***0.46***
Tianjin	0.24	0.24	0.99	0.99	-	1.00	1.00	1.00	1.00	1.00
Hebei	0.15	0.15	0.25	0.25	0.22	-	0.23	0.23	***0.70***	***0.64***
Shanxi	0.09	0.09	0.16	0.16	0.22	0.22	***0.35***	***0.15***	0.58	0.58
Inner Mongolia	0.06	0.06	0.10	0.10	0.27	0.27	***0.39***	***0.13***	0.33	0.33
Liaoning	0.37	0.37	0.38	0.38	0.11	0.11	***0.68***	***0.29***	***0.57***	***0.56***
Jilin	0.17	0.17	0.39	0.39	0.27	0.27	***0.48***	***0.28***	0.54	0.54
Heilongjiang	-	-	-	1.00	1.00	1.00	-	0.79	1.00	-
Shanghai	1.00	1.00	1.00	1.00	0.35	0.35	***0.93***	***0.47***	1.00	1.00
Jiangsu	0.27	0.27	0.67	0.67	1.00	-	1.00	1.00	0.94	0.94
Zhejiang	***0.75***	***0.05***	***0.11***	***0.10***	0.08	0.08	***0.13***	***0.12***	***0.52***	***0.49***
Anhui	-	-	1.00	1.00	0.96	0.96	0.22	0.22	0.80	0.80
Fujian	0.17	0.17	0.21	0.21	0.16	0.16	0.19	0.19	0.61	0.61
Jiangxi	0.92	0.92	0.78	0.78	0.68	0.68	0.34	0.34	0.86	0.86
Shandong	0.07	0.07	0.15	0.15	0.1	0.1	***0.62***	***0.16***	0.52	0.52
Henan	0.09	0.09	0.26	0.26	0.14	0.14	-	0.21	***0.76***	***0.72***
Hubei	0.26	0.26	0.3	0.3	0.24	0.24	***0.42***	***0.21***	0.68	0.68
Hunan	0.72	0.72	0.79	0.79	1.00	1.00	0.30	0.30	1.00	1.00
Guangdong	***0.17***	***0.07***	***0.17***	***0.12***	0.10	0.10	***0.81***	***0.11***	0.46	0.46
Guangxi	0.08	0.08	0.24	0.24	-	-	***0.54***	***0.16***	0.49	0.49
Sichuan	0.09	0.09	0.22	0.22	0.25	0.25	***0.55***	***0.16***	0.68	0.68
Guizhou	1	-	1	1	1	1	-	1.00	0.64	0.64
Yunnan	***0.76***	***0.08***	0.42	0.42	0.23	0.23	0.16	0.16	0.53	0.53
Shaanxi	0.05	0.05	0.15	0.15	0.57	0.57	0.14	0.14	0.60	0.60
Gansu	0.02	0.02	0.09	0.09	-	-	0.10	0.10	***0.39***	***0.33***
Qinghai	0.03	0.03	0.07	0.07	0.06	0.06	0.10	0.10	0.36	0.36
Ningxia	0.02	0.02	0.03	0.03	0.02	0.02	0.03	0.03	0.11	0.11

Xingjiang	0.15	0.15	0.10	0.10	0.27	0.27	***0.55***	***0.01***	0.29	0.29

TABLE 3 : Comparison between α and α' of different provinces from 2007 to 2011

	2007		2008		2009		2010		2011	
	α'	α	α'	α	α'	α	α'	α	α'	α
Beijing	0.18	0.18	***0.42***	***0.15***	0.38	0.38	0.20	0.20	-	0.23
Tianjin	1.00	1.00	1.00	1.00	0.47	0.47	-	0.02	-	0.22
Hebei	***0.61***	***0.67***	0.62	0.62	0.40	0.40	0.24	0.24	0.29	0.29
Shanxi	0.57	0.57	0.73	0.73	0.40	0.40	0.42	0.42	0.21	0.21
Inner Mongolia	0.37	0.37	-	0.40	0.34	0.34	0.27	0.27	0.19	0.19
Liaoning	-	0.65	0.66	0.66	0.28	0.28	0.31	0.31	0.18	0.18
Jilin	0.63	0.63	0.56	0.56	***0.63***	***0.57***	0.33	0.33	0.25	0.25
Heilongjiang	-	-	1.00	1.00	-	1.00	1.00	1.00	1.00	1.00
Shanghai	1.00	1.00	-	1.00	1.00	1.00	0.67	0.67	0.19	0.19
JiangSu	0.83	0.83	0.63	0.63	0.38	0.38	0.24	0.24	***0.54***	***0.28***
Zhejiang	0.41	0.41	0.35	0.35	0.22	0.22	0.15	0.15	***0.89***	***0.16***
Anhui	0.76	0.76	***0.84***	***0.58***	0.59	0.59	-	0.84	0.38	0.38
Fujian	0.58	0.58	***0.58***	***0.41***	0.28	0.28	0.27	0.27	0.21	0.21
Jiangxi	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Shandong	0.45	0.45	0.38	0.38	0.28	0.28	0.24	0.24	-	0.29
Henan	-	0.66	0.64	0.64	-	0.37	***0.41***	***0.22***	***0.91***	***0.28***
Hubei	-	0.64	0.51	0.51	-	0.42	0.27	0.27	0.16	0.16
Hunan	-	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.79	0.79
Guangdong	0.40	0.40	0.32	0.32	0.20	0.20	0.05	0.05	***0.79***	***0.26***
Guangxi	***0.65***	***0.38***	0.31	0.31	0.23	0.23	0.13	0.13	0.20	0.20
Sichuan	0.60	0.60	***0.68***	***0.56***	0.48	0.48	-	0.42	1.00	1.00
Guizhou	0.70	0.70	-	0.71	0.44	0.44	-	0.56	1.00	1.00
Yunnan	0.53	0.53	0.45	0.45	0.34	0.34	0.19	0.19	0.19	0.19
Shaanxi	0.60	0.60	0.45	0.45	0.32	0.32	0.29	0.29	0.25	0.25
Gansu	0.29	0.29	0.25	0.25	0.15	0.15	0.08	0.08	0.11	0.11
Qinghai	0.34	0.34	0.29	0.29	0.21	0.21	0.15	0.15	0.14	0.14
Ningxia	0.12	0.12	0.13	0.13	0.10	0.10	0.11	0.11	0.10	0.10
Xinjiang	***0.50***	***0.49***	0.46	0.46	0.53	0.53	-	0.49	0.22	0.22

As shown in Figure 3. In the most of provinces from 2002 to 2012, $\alpha = \alpha' \neq 1$, it indicates that the major reason of low eco-efficiency of urban non-agricultural land lies in land input element, over non-agricultural farmland leads to the low eco-efficiency of these provinces. However, the low eco-efficiency of non-agricultural land has connection with capital and labor force input elements in some months and districts. Disaccord between α and α' is frequently occurred in 2005 in many districts including Shanxi, Inner Mongolia and so forth.. Let's take Shandong as an example, eco-efficiency caused by land wastage still has the room for improvement of 38 percent and eco-efficiency brought by total elements input wastage needs to be improved by 84 percent and eco-efficiency due to poor efficiency input of capital and labor force should be improved by 46 percent.

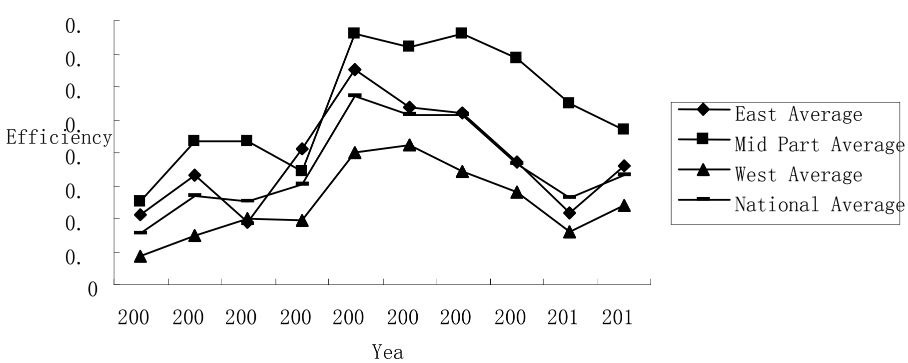

Figure 3 : The change trend of α' of three districts from 2002 to 2006

From the aspect of districts, the change trend of α' is as shown in Figure 3. The Figure indicates that utilization efficiency of non-agricultural land has been progressively decreasing from the mid part to the east and then the west. The result is coincident with Cuiwei's[12](2013) but different from Cui et.al's (2013). The research finds out that more quantity of samples can better help evaluate wastage of non-agricultural land. The conclusion made from the samples from 2002 to 2011 is that land requisition-compensation balance policy should be implemented. Figure 3 indicates the mid district should allocate more non-agricultural land since the non-agricultural land co-efficiency is the highest while the west and the east should allocate agricultural land, such kind of land allocation can maximize land utilization efficiency of each district.

CONCLUSION

This paper mainly studies the carbon emissions of single element of non-agricultural land in the process of urbanization. It also measures and calculates the utilization efficiency of non-agricultural land with the carbon dioxide brought by the land conversion as the constraint condition. The study is contrast to Cui et. Al's (2013), which measures and calculates the wastage degree of the total elements instead of the non-agricultural land wastage in the process of calculating non-agricultural land wastage degree, and takes only the samples of 2010 as the study object, hence the result is limited representativeness. Based on the above analysis, the study separates out the land element and calculates the eco-efficiency of non-agricultural land in the city.

The study shows that the low eco-efficiency of the urban non-agricultural land in most districts is caused by land wastage, and of course the low efficiency can also be caused by low efficiency of utilizing capital and labor elements in some districts of certain years instead of only land wastage. On the whole, enhancing land use efficiency is an important way to improve the eco-efficiency of urban non-agricultural land in different provinces. The study further finds out that spatial allocation of land with different types is also one of the important methods to improve the eco-efficiency of urban non-agricultural land. The mid district is the place with the highest eco-efficiency, while the eastern and western districts are relatively worse. Therefore, more non-agricultural land can be allocated in central area, while more farm lands should be kept in eastern and western areas, and the policy of the balance of occupation and compensation helps, on one hand, improve the eco-environment, and on the other hand, meet the land demands of different types of different district development.

REFERENCES

[1] J.R.Ehrenfeld; Eco-efficiency: philosophy, theory, and tools, Journal of Industrial Ecology, **9**, 6-8 **(2005)**.

[2] Liuyong; On the Relationship between Land Use Degree and District Eco-efficiency of Jiangsu Province, China Land Science, **4**, 19-24 **(2010)**.

[3] Cheng Bihai, Wang Qing, Liu Jianxing; Comparative analysis on eco-efficiency of arable land ecological footprint in Hubei, Wuhan University Journal of Natural Sciences, **11(4)**, 1052-1085 **(2006)**.

[4] Chen Fujun; Preliminary Study on the Production Function of Cities in China, Dongbei University of Finance and Economics Journal, **1**, 13-15 **(2001)**.

[5] Chen Jianglong, Qu Futian, Chenwen; Spatial Differences of Land Conversion Efficiency and Inspiration on Adjustment of Land Use Policy, Management World, **8**, 37-43 **(2004)**.

[6] Jiang Kaihong, Chen Jianglong,Chenwen; Comparative Advantage Theory and District Land Allocation——Taking Jiangsu as an Example, Rural Economy of China, **12**, 16-21 **(2004)**.

[7] Qu Futian, Zhu Xinhua; Analysis on dynamic cultivated land of different Grain-Producing district and Regional disparity, China Land Science, **3**, 34-40 **(2008)**.

[8] Tanrong, Qu Futian, Guo zhongxixng; Analysis on Regional Differences of Economic Increase distribution of Land Conversion in China, Chinese Journal of Mechanical Engineering, **14(3)**, 277-281 **(2005)**.

[9] You Heyuan, Wu Cifang; Carbon Emissions Efficiency of Land Use and Low Carbon Optimization——Based on Energy Consumption, Journal of Natural Resource, **11**, 1875-1886 **(2010)**.

[10] Cuiwei, Miao Jianjun, Yangjing; Empirical Studies on Eco-efficiency of Urban Non-Agricultural Land Considering Carbon Emissions, System Engineering, **30(12)**, 10-18 **(2012)**.

[11] Cuiwei, Miao Jianjun, Yangjing; Analysis on Eco-Efficiency of Urban Non-Agricultural Land and Influence Factors Based on Carbon Emissions, China Population, Resources and Environment, **23(7)**, 63-69 **(2013)**.

[12] Cuiwei, Miao jianjun, Leina; Spatial Disparity analysis on Urban Non-Agricultural Land Use Performance Based on Carbon Emissions, China Land Sciences, **8**, 33-38 **(2013)**.

[13] Cuiwei, Feng Junchao, Miao Jianjun; Analysis of Non-agricultural Land Eco-efficiency considering the Carbon Emissions in Build-up Regions, International Journal of Applied Mathematics & Statistics, **51(21)**, 609-617 **(2013)**.

[14] Jin-Li Hu, Shih-Chuan Wang; Total-factor energy efficiency of regions in China, Energy Policy, **34**, 3206-3217 **(2006)**.

[15] Y.H.Chung, R.Färe, S.Grosskopf; Productivity and undesirable outputs: A directional distance function approach, Journal of Environmental Management, **51(3)**, 229-240 **(1997)**.

[16] G.Färe, S.Grosskopf, Jr C.A.Pasurka; Environmental production functions and environmental directional distance functions, Energy, **32(7)**, 1055-1066 **(2007)**.

[17] E.Hirst, J.Jackson; Historical patterns of residential and commercial energy uses, Energy, **2(2)**, 131-140 **(1975)**.