The LUCC Responses to Climatic changes in China in the last 20 years

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ABSTRACT

Adopted with Weight Centre Model(WCM) and Land Use Degree Model(LUDM), Climate data of China in recent 20 years and a 2-period Land Use /Land Cover (LUCC) data covering China are used to analyze impacts and direction of changes caused by climatic changes and human activities to China vegetation covers and land use. In the last 20 years, the dual impacts by climatic changes and economic development have led to Land Use Degree Weight Centre shift to Northeast 54km. In East-West direction, Land Use Degree Excursion Intensity is caused 81% by climatic changes and 19% by anthropogenic impacts; while in South-North direction, is caused 85% by climatic changes and 15% by anthropogenic impacts.

Key Words: China, Land use/Land cover, climate change , impacts

1. INTRODUCTION

The research on response and mechanism by terrestrial ecosystems to global changes (including climate change and human activities) is an important component of global changes research. Global warming up and picking up of human activities in the last century have drawn attention of the science community and decision-makers to focus on the impact of climatic changes to inner terrestrial ecosystems and its feedback, and on the research of Ecosystem Security in the future climate security[1, 2].

The research target of global environment changes lies in researching how global changes, influenced by human activities, impact ecosystems and human survival environment and its feedback. In order to predict the change trend of human survival environment to find counter tactics, reduce maximally the adverse impacts of global changes, and ensure the Earth, this life supporting system, develop to favor human survival and sustainable development [3~5].

Therefore, in the last 20 years, the global change research has been a hotspot in current human society. Research on global climatic changes for the last century by Climatologists reveals temperatures are rising at 0.3-0.6℃ annual average, especially in the Northern Hemisphere. [6~10] Warmest temperature period was in the 1980s, rises in temperatures mainly occurred in 1910 and the years after 1975. Global average precipitation inclined in the last 100 years (ranges 21mm/100 years)[11~18].

The climate is the main or key factor of vegetation cover in an immense scope or region. There is a certain suit of vegetation species under each climate type and every kind of vegetation corresponds to a fixed climate style since climate is the natural environment condition that vegetation depends on. Plant Ecology demonstrates that main vegetation types are corresponding to response to climate type by the Botanic, and each climate type or subarea matches a series of vegetation type. [19~22]

In the 1990s, the field of global environment changes research strengthened the research works on LUCC, which has played an important role in the global environment changes and sustainable development. In global environment changes issues, LUCC is the most consanguineous issue in the cross of nature and humanities process. [23~26]

This paper attempts to generate separate China decade zones adopting HLZM, based on climatological data for every month of the last 20 years in China, to analyze the impact of climatic changes on China nature vegetation covers. Then to analyze the impact of climatic changes on LUCC and spatial pattern changes, combining LUCC data covering China 2-period. (End of 1980s and 1990s, data from China Environmental Remote Sensing Database).

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2. DATA PREPARATION

2.1 Data

The 20-years climatological data, adopted in research, comes from China land surface climate data by China Meteorological Administration, including indexes of precipitation, average temperature, vapour pressure, sunshine percentage, relative humidity, wind speed, and so on.

Interpolation process were performed on original station data with IDW command under the GRID module provided by arc/info software environment to generate 8km 20-year climate grid dataset including monthly precipitation and monthly average temperature.

The two periods of land use data come from the Environment Remote Sensing Database of Chinese Academy of Sciences. 1:100000 land use vector data in databases was processed into 1km percentage fraction dataset to study temporal and spatial variation of LUCC. The two periods of 1km percentage fraction data were combined with climatological data to analyze the impact by climatic changes to the land use.[24-26]

Impact by climatic changes and human impacts on land covers were analyzed taking use of 20-year 8km climatological dataset,20 years in 2 periods (end of 1980s and 1990s) 1km LUCC Dataset, adopting the models of HLZM, LUDM and WCM.

2.2 Land Use Degree Model

The Land Use Degree Index Model, brought forward by Liu Jiyuan and his colleagues during their land use investigation in Tibet Autonomous Region, is a hierarchical model of land use, together with formular expression [30]:

$$\text{UINDEX} = 100 * \sum_{i=1}^{n} A_i * C_i$$

$$\text{UINDEX} \in [100,400]$$

Which: UINDEX = Land Use Degree Index

A_i = I-grade Land Use Degree Grading Index

C_i = I-grade Land Use Degree Grading Area Percentage

The value of UINDEX reflects Land Use Degree. The above formula is used to calculate China 1km grid land use degree on the basis of China two periods' 1km land use degree percentage fraction datasets.

2.3 Weight centre Model

Weight centre model represents gathering, dispersion and moving of each matter and energy in space at a certain time. The moving direction, speed and intensity of weight centre are the best indexes to show the variation of a matter in space [31].

The mathematics expression of the Weight centre model is: assume there are P_1, P_2, P_3, ... P_n particles in a region, the masses (such as population, land cover type, covering area etc) are Q_1, Q_2, Q_3, ... Q_n respectively, calculate the weight centre. Assume the weight centre locates at M, the distance between $P_i(X_i,Y_i)$ and $M(X,Y)$ is R_i, then the total moment is refered as $S=\sum_{i=1}^{n} Qi*Ri$, where $Ri=\sqrt{(x-x_i)^2+(y-y_i)^2}$ (Euclidean Distance), calculate $S_{\min}$, that is:

$$\begin{cases} \partial s / \partial xi = 0 \\ \partial s / \partial yi = 0 \end{cases}$$

Based on the dataset of overlay the two periods land use data together with the same period corresponding Holdridge Life Zone data respectively, using Weight Centre Model to calculated the centre location of the land use degree index under Holdridge Life Zone type in different periods, then through the comparison of the Weight Centre displacement and magnitude of the two periods to analyze the response degree and spatial pattern variation of land use/cover to climate change and anthropogenic impacts.

3. RESULTS AND DISCUSSION

Climate change not only deeply impacts China vegetation ecology zone and the vegetation growth , but it also affects human survival and the degree of human reconstruct environment by exert impact on environment survival fitness. The paper use both 1km percentage fraction data comes from the environment remote sensing database, Chinese Academy of Sciences, and the land use degree model mentioned above to assign weight value of 1, 2, 3, 4 to the 4 main types (unutilized land grad, forest, grass, water grade, agricultural grade and town settlements grade respectively). Multiply the above weight value with

the percentage of various land use degree in 1km pixel, then multiply the results by 100 to acquire an integer, and the land use degree index on 1km pixel was educed. It is the index of discrete land use classification types change to consecutive land use degree, it facilitates the analysis of the environment change's impact on land use.

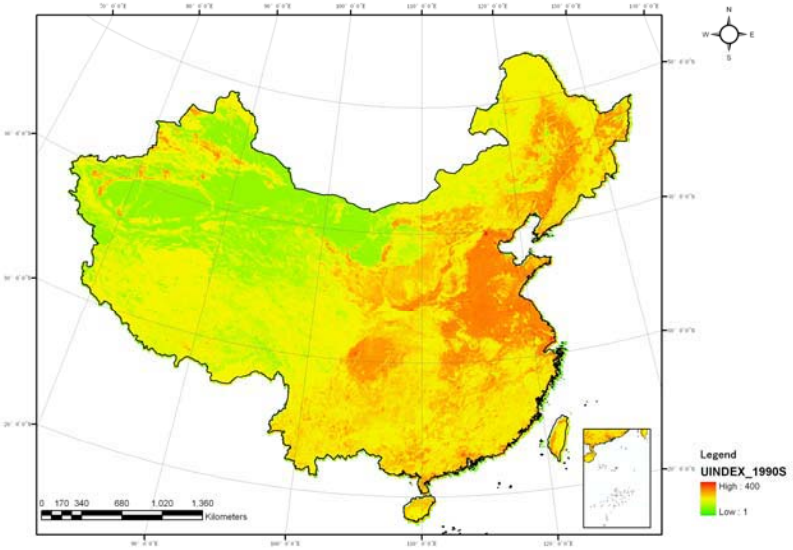

Figure 1. The landuse degree index of 1990s in China

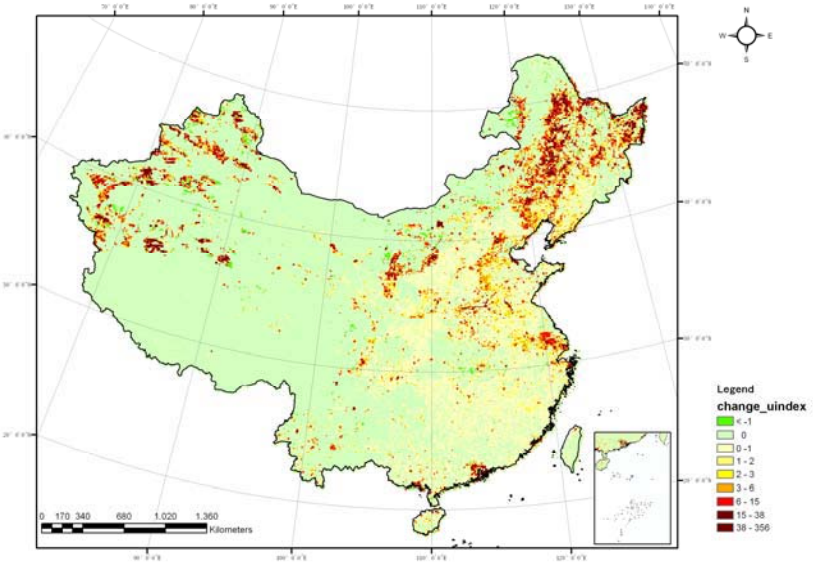

Figure 2. The changes of land use degree index the last 20a in China

As shown in Figure 1, areas with Land Use Degree Index over 300 are Town Settlement Types, distributed mostly on big and medium city settlements on Eastern Coast, and account for 6% of total national land. Areas with Land Use Degree Index between 200 and 300 are Arable Land Type, distributed most on farming available areas in East China and West China, especially in Northeast China Plain, North China Plain, Middle And Down River Plain Of The Yangtze River, and Sichuan Basin, accounting for 30% of national land. Areas with Land Use Degree Index between 100 and 200 are Forest, Grass And Water Types, distributed mostly on forest covered area in Northeast China, grassland of Inner Mongolia Plateau, Forest & shrub covered areas in South China, and Tibet Plateau Alpine-Cold Meadow Area, accounting for 50% of national land. Areas with Land Use Degree Index below 100 are unused Land Type, distributed mostly on Western Inner Mongolia Plateau, Northern Qing-Tibet Plateau, Desert area of Xinjiang, and account for 14% of national land.

In the last 20 years, rapid development within the China economy has deeply influenced land use types. Arable land became construction type; grassland and forest land has been assorted, unutilized land converted into grassland and forest land after

rebuilding and improvement; farmland on incline hills was returned to forest in the Arable Area with a big slope; and Half-Drought Arable Area was converted to pasture; thereby land use type changes led to changes on land use degree indexes.
When we subtract land use degree index 1km data of the 1980s from that of 1990s we get figure 2; changes of economy development and climate environment led to spatial variation of China land use patterns. Areas with lower land use degree index distributed in northeast China and south mountainous regions, the inner Mongolia grassland agro-pasture zigzag zone, the Xinjiang and the Qing-Tibet Plateau, due to converting arable to forest, to herd and pasture, meadow degeneration, account for 7% of national land. Areas with increased land use degree index, distributed mainly in the eastern coastal area and the south and north sides of Tianshan Mountain in Xinjiang, due to economic development that lead to increase in construction land use, grassland and forest being assarted, wasteland being utilized or converted into grassland due to changed living environment, account for 10% of total national land. There are no great changes on the basic cover of drought and half-drought grassland unutilized land covering area, therefore land use degree index maintains.
Combined Holdridge zone data of 1980s and 1990s with two period Land Use Degree Indexes data respectively, employed Weight Centre model, two periods land use Weight Centers are calculated. The weight Centre spatial excursion shifted to reveal impacts from economy development and climate change on land use.

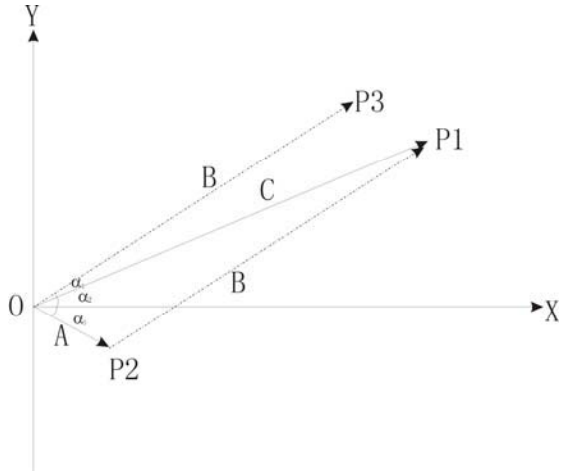

Figure 3. The weight centre displacement of Land use degree index in the last 20 years

On the basis of Lambert Projection, the land use degree Weight Centre positions of 1980s and 1990s under Holdridge life zones are O（-531km，448km）and P1（-495km，488km） respectively. The Weight Centre location moved 54km eastward with 42 degree offset from north.
Since the difference between the two periods Holdridge life zones is mainly caused by climate change, we assume there is no climate change but only human activities exerting impact on land use degree. The Holdridge life zone data of 1980s is used in the calculation weight centre positions of the two periods (1980s and 1990s) land use degree, the calculated Weight Centre coordinates of the two periods are O（-531km，448km）and P2（-524km，442km） respectively. According to the coordinates of the two Weight Centres, following diagrams of Weight Centre relationship was generated:
As depicted in figure 3, point O set as origin O (0,0) represents land use degree Weight Centre in the 1980s; the rest Weight centre points changed to P1 (36km, 40km) and P2 (6.7km, -6.9km). The above analysis shows that OP1 is the vector under the composite impact of climate and human activities, and OP2 is that sole vector influenced by human activity. Assume OP3 is the vector under climate impact, according to vector synthesis theory, the following vector equation can be obtained:

$$\overrightarrow{op3} + \overrightarrow{op2} = \overrightarrow{op1};$$

Provided P3 (x, y) coordinate value, and replace above equation with p1, p2, p3 coordinate values:

$x\vec{i} + y\vec{j} + 6.7\vec{i} - 6.9\vec{j} = 36.3\vec{i} + 40\vec{j}$， hence the coordinates of P3 (30km ,47km).

On the basis of the coordinates of the above three points, figure out A=9.6km，B=55.2km,C=53.8km.
Based on coordinates of above, according to law of cosines that is

$\cos\alpha_1 = \dfrac{b^2 + c^2 - a^2}{2bc}$， get $\cos\alpha_1$=0.985, α_1=10^0, the same way it is gained α_2=42^0， α_3=44^0

According to vector synthesis theory, we can calculate that the land use degree vector in East-West direction, 81% of Land Use Degree excursion intensity is caused by climatic changes and 19% by anthropogenic impacts; while in South-North direction, 85% is caused by climatic changes and 15% by anthropogenic impacts.
Calculations show that under climate and human activities influences in the past 20 years, China land use degree spatial excursion is eastward 55km offset 52 degree from north under climate impact, and the excursion under human activities is eastward 9.6km offset 44 degree from south. The dual impact of climate and human activities make China land use degree move eastward 54km offset 42 degree from north.

4. CONCLUSIONS

On the basis of China climate and the two periods in the last 20 years, LUCC covering China data, using WCM and LUDM, this paper analyzed the impact of climate change and human activity on China vegetation cover and land use.
In the last 20 years, due to economy development and climate change, China's land use Weight Centre moved eastward 54km offset 42 degree from north. It moved eastward 55km offset 52 degree from north under climate impact, and the excursion under human activities is eastward 9.6km offset 44 degree from south. The land use degree excursion intensity in the west-east direction at 81% attributed to climate impact and 19% to human activity, for north-south direction, they are 5% and 15% respectively.

The above land use degree excursion results are related to economy development. China's 20 years climate change is north warm and south cold with more precipitation, which made unutilized land convert to grassland, grassland to woodland or agricultural land, agricultural land to construction land in north China; this is land use degree upgrading, the upgrading mainly occurred in north China to leaf to land use degree move northeastward. In the past 20 years, the impact of human activities mainly occurred at southeast coastal China, since China economy development gave priority to this area during the period, this made land use degree change in the area is from agricultural land to construction, and led human activities impact on land use degree move southeastward.

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REFERENCES

1. IPCC.Land-Use Change, and Forestry. A special report of the IPCC.2000, Cambridge University Press
2. IGBP SCIENCE NO.1. The terrestrial biosphere and global change: Implications for natural and managed cosystems. Synthesis of GCTE and related research.
3. Wang Lianxi, Yang Youlin, etc. Discussion of research methods on relationship between climate change and plant.Chinese Journal of ecology, 2003,22（1）:43～48
4. Zhou Guangsheng, Wang Yuhui. The feedback of land use/cover change on climate. Journal of natural resources, 1999,4(4):318-322(in Chinese)
5. Zhou Guangsheng, Zhang Xinshi. Study on Climate-vegetation classification for global change in China. Acta Botanica Sinica, 1996 , 38 (1) : 8～17(in Chinese)
6. Houghton J T , Jenkins G T , Ephraums J J. Climate change : the IPCC scientific assessment . Cambridge : Cambridge University Press ,1990.
7. Jones, P. D., Wigley, T. M. L., and Wright, P. B. Global Temperature Variations between 1861 and 1984. *Nature,1986a,* **322**: 430–434
8. Karl, T. R., Knight, R.W., and Plummer, N. Trends in the High-Frequency Climate Variability in the Twentieth Century, *Nature,1995,* **377**: 217–220
9. Weihong Qian, Yafen Zhu. Climate change in China from 1880 to 1998 and its impact on the environmental condition. Climatic Change,2001, 50: 419–444
10. Jiang, J., Zhang, D., Fraedrich, K. Historical Climate Variability of Wetness in East China (960–1992): A Wavelet Analysis. *Int. J. Clim.1997,* **17**: 968–981
11. Ding Yihui, Dai Xiaosu. The 100a Climate Change in China. Weather, 1996, 20(12):19-26(in Chinese)
12. Shi Neng, Chen Jiaqi. 4-hoase Climate change Features in The last 100 year over China. Acta Meteorological Sinica ,1995,

53(4):431-439(in Chinese)
13. Wang Shaowu. Diagnostic studies on the climate change and variability for the period of 1880-1990. Acta Meteorological Sinica, 1994, 52(3):261-273 (in Chinese)
14. Wang Shaowu. Scientific intersection of PAGES and CLIVAR. Acta Meteorological Sinica, 1997 , 55 (6) : 662 – 669(in Chinese)
15. Wang Shaowu, Cai Jingning, Zhu Jinhong. The interdecadal Variations of annual precipitations in China During 1880's-1990's. Acta Meteorological Sinica, 2002 , 60 (5) : 637- 639
16. Tu Qipu, Deng Ziwang, Zhou Xiaolan. Study of regional characteristics on mean annual temperature variation of near 117 years in China. Quarterly Journal applied meteorology ,1999,10(Supplement):34-42
17. Chen Longxun, Zhou Xiuji, Li Weiliang. Characteristics of the climate change and its formation mechanism in China in Last 80 years. Acta Meteorological Sinica, 2004, 62 (5) :634-646(in Chinese)
18. Zhang Cunjie, Li Dongliang, Wang Xiaoping. Study on precipitation variability in last 100 years and trend prediction in northeast Asia in future 10-15 years. Plateau Meteorology, 2004, 23(6):919-929(in Chinese)
19. Zhou Guangsheng, Zhang Xinshi. Study on Chinese climate-vegetation relationship. Acta Phytoecological Sinica, 1996 , 20 (2) : 113～119(in Chinese)
20. Zhou Guangsheng, Zhang Xinshi. Study on Climate-vegetation classification for global change in China. Acta Botanica Sinica, 1996 , 38 (1) : 8～17(in Chinese)
21. Zhou Guangsheng, Zhang Xinshi. A natural vegetation NPP model. Acta Phytoecological Sinica, 1995 , 19 (3) : 193～200(in Chinese)
22. Zhou Guangsheng, Zhang Xinshi. Study on NPP of Natural vegetation in China under global climate change. Acta Phytoecological Sinica, 1995, 20 (1) : 9～17
23. Chen Yiyu. The orientation of Global changes study in China. Advance in earth sciences，1999,14(4):11～17
24. Liu Jiyuan, Zhang Zengxiang, Zhuang Dafang. A study on the spatial-temporal dynamic changes o fland-use and driving forces analyses of China in the 1990s. Geographical Research, 2003, 22:1～12
25. J.Y.Liu, D.F.Zhuang,D.Luo etc.Land-cover classification of China: integrated analysis of AVHRR imagery and geophysical data. INT.J.Remote Sensing, 2003, 24(12):2485～2500
26. Liu Jiyuan, Liu Mingliang, Zhuang Da Fang. Study on spatial pattern of land-use change in China during 1995-2000. Science in China(Series D) ,2003, 46(4):374-386
27. Chen Yufeng. Research on impacts of Global climate change to Holdridge's life zones of China by Geo-information system. Journal of Remote Sensing,1997,1(1):74～80
28. Zhou Guangsheng, Wang Yuhui. The study and prospect of Global change and climate-vegetation classification. Chinese Science Bulletin,1999, 44(24):2587～2593
29. Yang Zhengyu, Zhou Guangsheng, Yang Dianan. Comparison of simulated vegetation distribution in China produced by four popular climate-vegetation classification models. Acta Phytoecological Sinica, 2003，27（5）:587～593
30. Gao Zhiqiang, Liu Jiyuan, Zhuang Dafang. The relationship between the ecological background and landuse degree. Acta Geographica Sinica,1998, 53 (Supplement):36～42
31. Gao Zhiqiang, Liu Jiyuan, Zhuang Dafang. The dynamic changes of the gravity center of the farmland area and the quality of the farmland ecological background in China.Journal of natural resources, 1998, 13(1): 92～96(in Chinese)