Research on Earth-Surface Interaction Mechanism, Process and Dynamics of Human-Earth System*: Case Study on the Geographic Belt Transect from Shenzhen in Guangdong Province to Bayanhaote in Inner Mongolia Province of China

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Abstract

China epitomizes a rapidly growing economic region typified by human-induced urbanization at a geometric rate. Considering the regional differentia of the Chinese geography, this paper chose a geographic belt transect of human-activity disparity to accomplish the earth-surface system research. The study area is a narrow southeast-northwest geographic belt transect of China, passing through six cities of China. The total study area measures 385600km^2 with a width of 100—150km and a length of 2200km. Using the GIS and database technology, this paper integrated the basic geographic information, remote sensing images, statistical data, and special-subject pictures. Subsequently the geographic information system for the Shenzhen-Bayanhaote Geographic Belt Transect was generated. Founded on the database and GIS platform, the related geographic belt transect research on earth-surface interaction mechanism, process and dynamics of Human-Earth system was carried out. This is capable of providing scientific support and the foundation for expressing the impact of human activity on earth-surface system and understanding the differentia of regional geographic process. With regard to the research mechanism of Human-Earth system interaction, the impacts of both temperature and precipitation variation and the human-dimension factors on disaster loss were discussed and analyzed in the research belt transect. When considering the process and dynamics research of Human-Earth system interaction, the spatiotemporal pattern of the ecological assets, land use change and its impact on ecological assets in the research belt transect during the last five years of 1990s were analyzed. The flood-drought disasters and its relation with spatiotemporal pattern of land use in the research belt transect were investigated and discussed. Meanwhile, for performing in-depth research of the typical sample-points in the research belt transect, this study chose the Buji river watershed in Shenzhen. Shenzhen is characterized by population-induced rapid. The land use/cover change were measured and analyzed, and various hydrological process scenarios were simulated using SWAT distributed hydrological model under the situation of lack of observation data. The ultimate objective of this process was to reveal the impact of urbanization on the land use/cover change and improve the relevant research mechanism.

Keywords

GIS, Human-Earth system interaction mechanism, process and dynamics, geographic belt transect

I. INTRODUCTION

Geography is a comprehensive discipline which studies the dynamics of human-physical interaction and their spatiotemporal distribution. In view of the complexity of earth's surface, geographical research focuses on the comprehension and integration of human, physical, and regional dimensions. Our research pays attention to key issues like the Human-Earth interaction mechanism and its optimization(Du Zheng, et al., 2001). Earth-surface process research signifies a new domain in the rising comprehensive physical geography after the earth-surface structure and pattern research. The objective of the research is to reveal the foundation of Human-Earth interaction mechanism and the impact of global change on regional development. In the 1990s, a group of Chinese scholars represented by Dr. Lansheng Zhang(Lansheng Zhang, et al., 1994; Peijun Shi, 1997) pointed out that Human-Earth system dynamics is the most important component of earth-surface dynamics, and correspondingly the core content of the Human-Earth system dynamics was put forward: the environmental effect of human activity, namely the response and feedback mechanism of physical ecosystem under the driving of human activity, and the potential nature-remodeling approaches under the physical ecosystem succession (optimal circulation). From this perspective, the Human-Earth system interaction process of earth surface can be characterized using the following two aspects: land use/cover change caused by natural resources exploitation, and ecosystem service capacity change caused by human impact on the living-environment. It is evident from the latest series of international geographical academic conferences such as the 6th Open Meeting of IHDP that the Human-Earth system dynamics research has developed from regional and comprehensive studies consisting of vulnerability, resilience and adaptation research. Therein, the goal that is emphasized is not only to serve for regional development from the resources utilization aspect, but also to serve for risk governance from the environment conservation aspect. The simulation research of

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the Human-Earth system process has also been developed from pattern monitoring to process experiment, from digital region to regional simulation, and from typical region laboratory to geographic belt transect laboratory. The geographic belt transect is a multi-scale and multi-dynamic Human-Earth system simulation platform, which is of significant research value for Human-Earth interaction mechanism understanding and system dynamic process construction.

The concept of the terrestrial belt transect originates from the ecological belt transect, which refers to a narrow special district of very typical or comprehensive ecosystem types, namely a research area composed of a series of research sample-points along a changing grads of a main global-change driving factor (Kock G W., et al., 1995; Jian Ni, et al., 1999). The belt transect research strives to exploit spatial information to extract and replace time information, and emphasize the coupling from the small-scale process to the regional process research. The latter aspect aims to procure more information about the large-scale space. China is one of the most typical regions influenced by human-activity. Hence, in this paper, considering the regional differentia of the Chinese geography, using the point and area combining research method, and exploiting the database and GIS technology, a geographic belt transect of human-activity disparity and natural-zone regional differentia is designed and built to perform earth-surface system research. A simulation and integration analysis system platform is established for comprehensive resources, ecosystem, environment and disaster research in the research belt transect. This platform not only supposed to make some contribution to the theory and methodology development of comprehensive geography, but also to provide scientific supporting for regional sustainable development decision-making.

II. GEOGRAPHIC INFORMATION SYSTEM FOR THE SHENZHEN-BAYANHAOTE GEOGRAPHIC BELT TRANSECT

A. General introduction of the geographic belt transect

The study area in this research is a narrow southeast-northwest geographic belt transect of China (Figure 1), which traverses six cities namely Shenzhen, Hengyang, Changde, Xi'an, Yingchuang and Bayanhaote. The total area measures 385600km^2 with a width of 100—150km and a length of 2200km. From the south to the north, it totally includes 8 provinces (municipalities) namely Guangdong province, Hunan province, Hubei province, Chongqing municipality, Shang'xi province, Ningxia province and Inner Mongolia province, covering 137 counties all together.

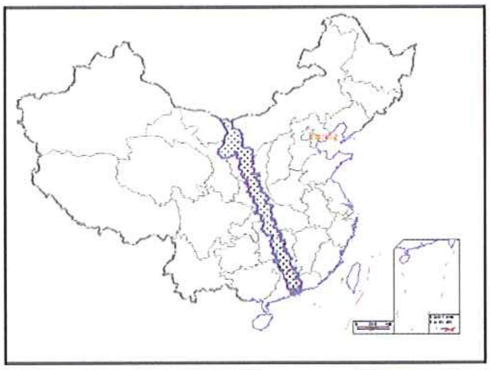

Figure 1. The belt transect location in China

(i) Physical condition

This research belt transect involves the main climate types of China, from the south sub-tropical humid climate in Shenzhen City to the mid-temperate extreme arid climate in Bayanhaote Town, which is a reflection of the change in the temperature and precipitation gradient from the southeast to northwest of China (Table 1). Moreover, this research belt transect includes plenty of geomorphic unit types, with each unit exhibiting a specific landscape and land-cover feature of its own.

(ii) Socioeconomic situation

The Shenzhen—Bayanhaote geographic belt transect has a population of over 24.5 million (2006). The regional economic development situation is significantly unbalanced from the southeast to the northwest part of the belt transect. In 2006, the GDP of Shenzhen City reached 581.4 billion RMB, while that of Alxa city, which is 135 times larger in area, merely got 8.6 billion RMB, only 1.5% of that of Shenzhen (Table 2). The southeastern part of the belt transect, including Guangdong

Table 1. Physical features of the 6 typical cites in the geographic belt transect

	Alxa (Bayanhaote)	Yinchuan	Xi'an	Changde	Hengyang	Shenzhen
Average annual precipitation(mm)	120	198	604	1274	1355	1948
Average annual temperature(¡æ)	8	8.5	13.3	16.8	18	22.4
Climate zone	Mid-temperate extreme arid climate	Mid-temperate arid climate	warm temperate sub-humid climate	North sub-tropical humid climate	Mid-subtropical humid climate	South tropical humid climate
Geomorphic type	Piedmont aggraded flood plain	Alluvial plain	Alluvial plain	Lake alluvial plain	Basin alluvial plain	Coastal plain and terrace
Watershed	Ephemeral rivers in west Henan Mount	Yellow River	Weihe River	Ruanjiang River	Xiangjiang River	Shenzhenghe River

Table 2. Socioeconomic features of the 6 typical cites in the geographic belt transect (2006)

	Alxa(Bayanhaote)	Yinchuan	Xi'an	Changde	Hengyang	Shenzhen
year-end population(million)	0.1821	1.4468	7.5311	6.085	7.265	2.0089*
GDP(billion yuan)	8.603	24.407	145.002	72.384	67.207	581.356
proportion of first industry(%)	5.35	2.86	4.88	24.52	23.52	0.12
GDP per capita(yuan)	40400	16900	19300	13300	10100	289400
Land area per capita(ha.)	148.38	0.64	0.13	0.30	0.21	0.10
GDP per km^2(million yuan)	0.0318	2.6529	14.5002	3.9771	4.3926	290.678
urbanization(%)	68.15	63.32	45.65	35	37	100

*It's the registered population of Shenzhen City, while the permanent population is 8.46 million in 2006.

Province, Hunan Province, Hubei Province, has a higher level of economic development, compared to the northwestern part, including Inner Mongolia province, Ningxia Province, Shang'xi Province. By and large, this belt transect represents the regional differentia of both the human activity intensity and the natural zones.

B. Geographic information system of the geographic belt transect

(i) Database construction

Using the point and area combining research method and exploiting the earth-observing database and GIS technology, this paper integrated basic geographic information, remote sensing images, statistical data, and thematic pictures, and built the database for the Shenzhen-Bayanhaote Geographic Belt Transect. The database construction aims to provide the foundation for the related geographic belt transect research on comprehensive analysis, and earth-surface interaction mechanism, process and dynamics of Human-Earth system. The database is developed based on geographic units, "3S" technology, and dynamic simulation method. Such development endeavors to form the research foundation for the whole research belt transect, which can be applied to do the comprehensive analysis of regional geography and the dynamic process simulation for Human-Earth system.

The research belt transect database contains the following data types:

- Image data, including aero-images, and remote sensing images such as TM, SPOT, MODIS, QuickBird of several periods, etc.
- Vector data, including geographic space data and digital topographic maps, etc.
- Statistical data, including county-level disaster data, social and economic data and thematic statistical data from different government departments, etc.
- Data from monitoring and investigation, including standard daily data from nationwide meteorological stations and data from field investigation
- Documentary files, including various kinds of files collected in the project implementation process, temporary data and stage results during research process, research results and reports, etc.

In the ACCESS database software, tasks such as linking, querying, and updating of the natural and social statistical data are accomplished by building a database with these data and setting the county code as primary key, using the county as basic unit. Subsequently, using the GIS and remote sensing software such as MAPINFO, ARCGIS and ERDAS, it's feasible to extract and integrate multi-source data and make thematic diagrams of land use, ecological assets and natural disasters, etc.

(ii) Construction of database platform

Considering the Shenzhen City in the research belt transect as an example, the data types associated with Shenzhen are found to be abundant and the data volume is large, including space images, vector images, statistical data from all government departments, and various kinds of documentary files and research results collected and archived by project researchers. Based on the SQL database, the Shenzhen sample point's database is constructed using the Java Script language for data integration. Next, the database platform is built using the Java Script and SuperMap GIS software. This database platform facilitates online browsing, and offers functionalities for searching querying updating image and thematic data. Besides, operations such as database management, content search, ambiguous query, and download of documentary files and thematic maps are also possible. It can be comprehensively stated that a database system integrating all kinds of attribute data, raster and vector data, remote sensing data and field investigation data, has been built for the belt transect research, which is referred as "Shenzhen Laboratory" from this research perspective.

Besides the aforementioned "Shenzhen Laboratory", the similar "Xiangjiang River Basin Laboratory", "Jinghe River Basin Laboraoty", and "Alxa Laboratory" have been constructed with the same research objective, which contribute to the whole Geographical Information System construction for the belt transect, and even to the multi-scale and multi-dynamic simulation platform construction for the earth-surface interaction of Human-Earth system.

III. INTERACTION MECHANISM, PROCESS AND DYNAMICS OF HUMAN-EARTH SYSTEM

A. Mechanism: impacts of physical and human dimension factors on meteorological disaster losses

Based on the database of Shenzhen-Bayanhaote Geographic Belt Transect, the impacts of variability of precipitation and temperature on meteorological disasters as well as the impacts of human dimension factors on drought were analyzed, using the Pearson Correlation. To analyze the impact of different combination of physical and human dimension factors on disaster losses, this study chose some representative indicators using the expert scoring method, and then analyzed 137 counties in the research belt transect using hierarchical cluster analysis. The data used here were all from the Geographic Information System of the research belt transect, and included the national 1: 4,000,000 vegetation map, topographic map of China, and land-use map of China in 2000 from the Institute of the Geographical Sciences and Natural Resources Research of China Academy of Science, the precipitation and temperature data from the national weather stations of China Meteorology Administration from 1951 to 2005, and the 1990—2004 meteorological disaster data and the 2000 county-level socio-economic statistics from the Key Laboratory of Environment Change and Natural Disaster of Ministry of Education of China. The results show that (Meiqin Zhou, et al., 2008):

(1) During 1990—2004, the frequency of floods and drought disasters accounts for more than 80% of meteorological disasters in the whole belt transect, and the duration more than 90%. The regional disparity of disaster types is evident. Meteorological disasters primarily consist of frequent floods in the southern region and drought disasters in the northern region (Figure 2 and Figure 3), which accords well with the physical geography law and field investigation.

(2) The meteorological disasters are significantly influenced by the coefficients of temperature and precipitation variation. There were obvious positive correlations between the physical variation and the disaster indices, especially for drought disasters. The correlation coefficient between the drought disaster duration and the temperature variation coefficient is the most remarkable one, with the value of 0.675 (Table 3).

(3)A higher value of the first-industry GDP ratio to the total GDP indicates that the region is more vulnerable to the drought disaster. Hence, the frequency and duration of the drought disasters in that region is relatively larger. Human activity has a great impact on drought disasters, whose frequency and duration were positively correlated with the ratio of first-industry GDP to the total GDP (respectively the correlation coefficients r were 0.310 and 0.259), but negatively correlated with the first industry GDP (respectively the correlation coefficient were –0.315 and –0.445). Further study shows that the greater first-industry GDP is, the more input the agricultural

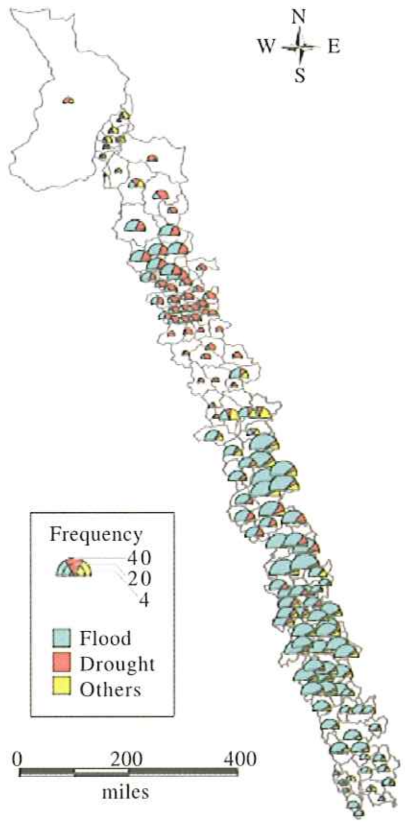

Figure 2. Frequency diagram of meteorological disasters in the research belt transect (1990—2004)

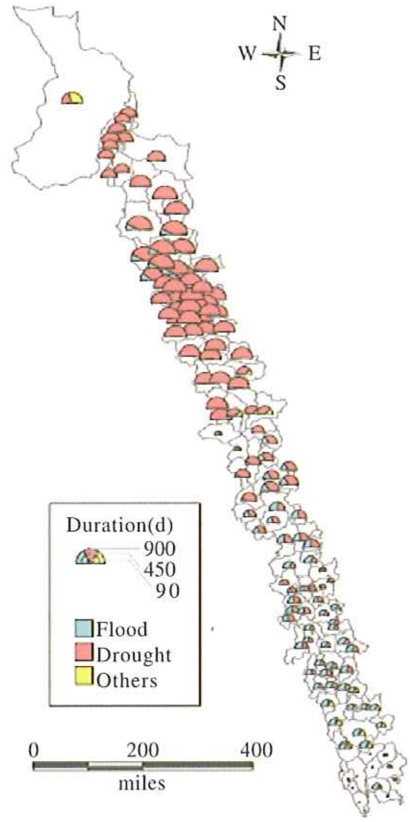

Figure 3. Accumulatively durative time of meteorologic disasters in the research belt transect (1990—2004)

Table 3. Correlations between temperature/ precipitation varitation and disaster frequency/duration*

	Coefficient of variation (Temperature)	Temperature Changing Trend	Coefficient of variation (Precipitation)
Duration(meteorological disasters)	0.659	0.284	0.356
Frequency(floods)		−0.29	
Duration(floods)		−0.223	
Frequency(drought disasters)	0.394		
Duration(drought disasters)	0.675	0.31	0.421

*Correlation coefficient of 0.01 significance level

water conservation infrastructures will have, which can be proved by the result that the first-industry GDP and the effective irrigation area have a significant positive correlation ($r = 0.369$); With the increase of the available irrigation area, drought losses can be reduced, with the negative correlation coefficient of −0.177. So it can be indicated and concluded that effective human activities can reduce the impact of agricultural disasters and mitigate the disaster losses (Table 4).

Table 4. Correlations between drought disasters and human dimesion factors*

	First-industry GDP	First-industry GDP/GDP	Available irrigation
Frequency (drought disasters)	−0.315**	0.310**	
Duration (drought disasters)	−0.445**	0.259**	−0.117*
Effective irrigation	0.369**		

*Correlation coefficient of 0.01 significance level; **Correlation coefficient of 0.05 significance level

(4) The results obtained from the Hierarchical Cluster Analysis method evince that the research belt transect can be divided into six combination zones, which differ from each other in terms of natural and human conditions. The differences are particularly more pronounced in terms of the disaster spatial differentia and distribution-discipline disparity. The specific clustering indicators considered are as follows: average annual temperature and precipitation, their variation coefficients, temperature changing trend, frequency and duration of meteorological disasters, floods, and drought disasters, the proportion of each type of land use(7 types), topographic features(7 types) and vegetation(7 types). Using the Continental Distance Square to measure the samples' affinities, the Ward's method to express both the affinities between samples and subcategories, and the affinities between the subcategories and subcategories, the Z-scores method for variable standardization, the cluster analysis work was realized by the statistic software SPSS. After comparing the analysis of the results, the spatial differentia of six classification classes were concluded. From the north to the south, the six classified regions respectively are: the Northwest Sandstorm Area, the Loess Plateau Area, the Weihe River Plain Area, the Qinling Mountain Area, the Nanling Mountain Area (Dongting Lake-Xiangjiang River-Nanling Mountain area), and the Pearl River Delta Area. The natural and human environment features of each region are listed in Table 5, while Figure 4 and Figure 5 show the frequency and duration of meteorological disasters.

B. Process and dynamics

(i) Land use change of the belt transect and its impact on ecological assets

Based on the "Technical Standards for Land-use Investigation" (National Committee of Faming Zoning, 1984) and other factors such as the land use types, management traits, and utility modes, considering the actual situation of the research belt transect, the land use was divided into seven types, i.e. cropland, woodland, grassland, shrub, urban and rural build-up land, water and unused land. Using remote sensing image processing software ERDAS IMAGE 8.5, the land use maps of the belt transect in 1995 and 2000 were derived from two temporal TM images (Figure 6). The general land use patterns (Table 6) and land use conversion matrix (Table 7) were calculated on the basis of the land use map. Combining the results of ecological assets survey and measurement result in China(Yaozhong, Pan, et al., 2004), the characteristics of land use change and ecological assets change, as well as the impacts of land use change on ecological assets were analyzed over a period ranging from 1995 to 2000.

The results illustrate that(Juan Du, et al., 2005), the land-use change of the research belt transect is significantly influenced by rapid urbanization, industrial restructuring and ecological-environment improving policies. On one hand, the main land use type is transferred from cropland to woodland, leading to an increment of ecological assets (89.9 billion RMB yuan). Moreover, wetlands (including water) play an important role in preserving and enhancing the total ecological assets in this belt transect. On the other hand, urbanization and desertification also resulted in a decline of ecological assets in some parts of the belt transect.

(ii) Land use change and its impact on flood and drought disasters

The flood and drought data were collected from the daily newspapers of various provinces and the national newspapers, and this comprised nearly 20,000 pieces of flood and drought

Table 5. Natural and human environment characteristics in the six regions of the geographic belt transect

Six regions	Northwest sandstorms area	Loess Plateau area	Weihe River Plain area	Qinling Mountain area	Nanling Mountain area	Pearl River Delta area
County number	12	12	19	14	70	10
Main topographic features	Aeolian accumulation, Plain	Loess-hilly, Loess Plat	Loess Plat, Plain	Mountain	Mountain, Hilly	Plain
Main types of land use	Grassland (31.5%) Unused land (61.9%)	Grassland (61.2%) Cropland (34.4%)	Cropland (62.4%)	Woodland (63.0%) Grassland (22.8%)	Woodland (58.4%) Shrubs (21.1%) Cropland (15.6%)	Cropland (49.6%) Waters (25.4%)
Agricultural vegetation ratio	3.76%	33.07%	79.47%	10.73%	12.39%	68.9%
Average annual temperature (°C)	8.7	9	11.6	14.2	17.4	22.2
Average annual precipitation (mm)	194	508	587	746	1483	1808
Coefficient of Variation (Temperature)	0.085	0.077	0.052	0.044	0.028	0.024
Temperature Changing Trend (0.1°C)	0.358	0.329	0.209	0.296	0.14	0.244
Coefficient of Variation (Precipitation)	0.346	0.239	0.235	0.212	0.183	0.2
Gross Domestic Product (ten thousands)	193338	66288	466965	114387	3368997	5963546
First-industry GDP/GDP	13.50%	27.49%	9.08%	31.72%	25.42%	3.44%
Affected irrigation (ha)	17406	5342	16233	10529	20982	5057

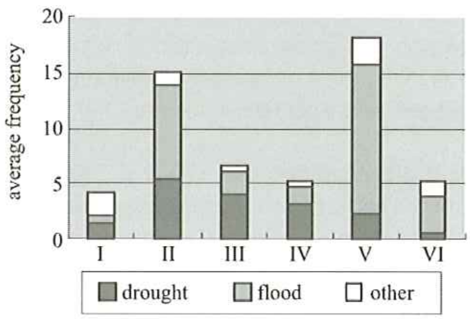

Figure 4

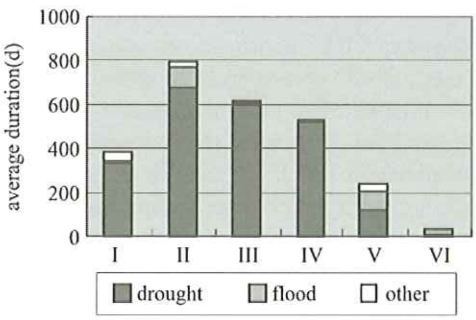

Figure 5

I: The northwest sandstorm area; II: The loess plateau area; III: The weihe river plain area; IV: The qinling mountain area; V: The hilly area in central China(Dongting Lake-Xiangjiang River-Nanling Mountain area); VI: The pearl river delta area

reports. The data covering 137 countries of 8 provinces, which were traversed by the Shenzhen-Bayanhaote belt transect, were extracted to establish a disaster database in the belt transect geographic information system. Statistical analysis of flood and drought disaster data provided the frequency and average index of floods and droughts in this belt transect from 1995 to 2000. The interaction and relationship between the land use pattern and flood/drought disasters was revealed by analyses performed in conjunction with the land use maps(Qui Pu, et al., 2005).

The overall result is that, flood and drought disasters accounted for nearly 70% of all the natural disasters during the period from 1990 to 2000. This implies that flood and drought disasters are the major types of natural disasters in

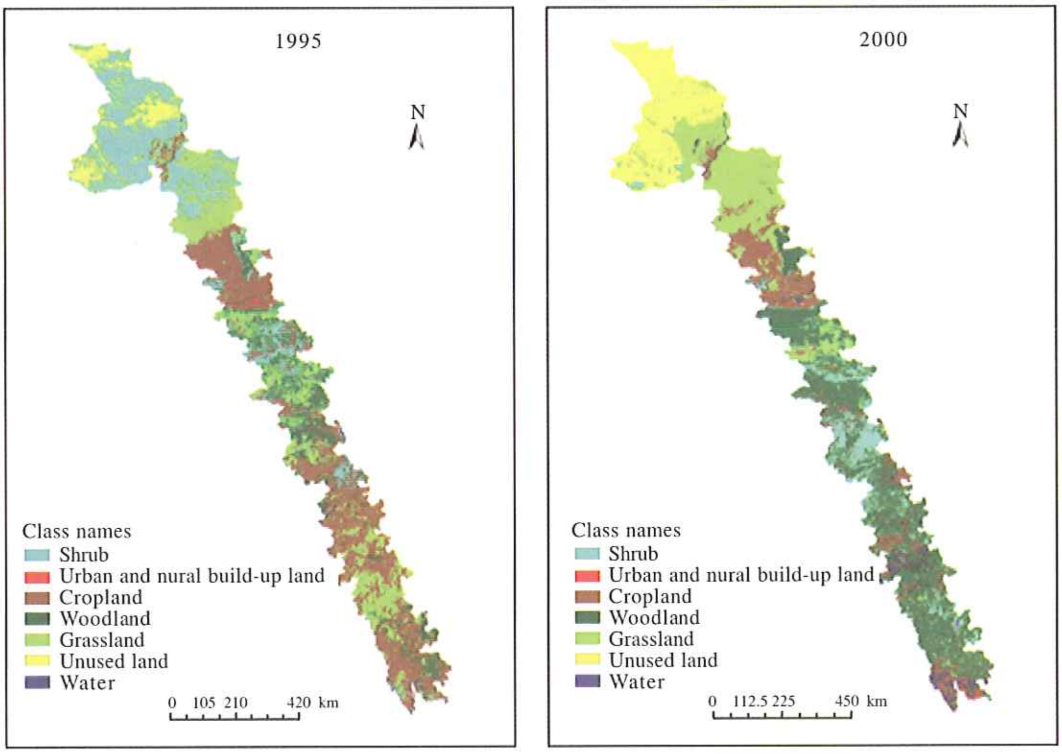

Figure 6. Land use maps of Shenzhen-Bayanhaote belt transect in 1995 and 2000

Table 6. Land use types and their proportion of Shenzhen-Bayanhaote blet transect

Land use types	1995		2000	
	Areas(km²)	Percentage	Areas(km²)	Percentage
woodland	40880.58	10.62%	121267.19	31.50%
shrub	96084.17	24.96%	38539.63	10.01%
grassland	83632.31	21.72%	78960.67	20.51%
water	3218.16	0.84%	8725.93	2.27%
cropland	131689.04	34.20%	66432.85	17.26%
Urban land	362.19	0.09%	1088.8	0.28%
unused land	29133.6	0.0757	69984.9	18.18%

Table 7. Land use conversion matrix of Shenzhen-Bayanhaote belt transect from 1995 to 2000

	woodland	shrub	grassland	water	cropland	urban land	unused land
woodland	66.94	24.58	3.94	0.07	4.42	0.05	0
shrub	9.34	3.51	37.01	0.45	5.36	0.08	44.25
grassland	40.62	11.39	31.78	1.78	12.99	0.15	1.3
water	24.24	7.53	9.07	16.86	38.62	1.85	1.82
cropland	38.12	11.19	9.64	4.59	35.8	0.61	0.06
urban land	0.31	0	0.12	0	0	99.57	0
unused land	0	2.2	7.31	0.15	0.22	0.01	90.11

Shenzhen-Bayanhaote Belt Transect. Flood and drought disasters showed strong differentia in the North and the South. In other words, drought disasters were strongly distributed in the North, and floods mainly in the South. Considering the different conditions of climate and geomorphology, the research belt transect can be divided into eight major regions for research, namely, the Alxa Plateau, the Ningxia Plain, the Maowusu Desert, the Loess Plateau, the Weihe River Plain, the Qinba Mountain-Dongting Lake-Xiangjiang River, the Nanling Mountain and the Pearl River

Delta region. The relationship between the land use patterns and flood/drought disasters was summarized in Table 8. The land use change types can be further categorized to 8 types (Table 9). The results indicated that the counties with complex land use types are more vulnerable to flood/drought disasters, while the frequency of flood/drought disasters in counties with mono-type of land use is relatively low. The floods occur mainly in the south areas with a mixed land-use types, particularly in the areas with higher proportion of build-up land. Drought disasters occurred more frequently in areas that are deficient in irrigation water sources and wherein, the land use was dominated by cropland and grassland.

Table 8. Relation between land use patterns and flood-drought disasters of different physical geography unit in Shenzhen-Bayanhaote belt transect

Region	County number	Main land use types in 1995	Main land use types in 2000	Average flood times	Average affected index of flood	Average accumulate duration time of flood(day)	Average drought times	Average affected index of drought	Average accumulate duration time of drought(day)
Alxa plateau area	1	unused land, shrub	unused land	1	0	5	0	0	0
Ningxia Plain area	8	cropland, shrub	cropland, grassland	1.1	0.02	62.8	0	0	0
Muwusu Sandland area	5	meadow, shrub	grassland	1.2	0.01	?*	2.8	0.37	2096.4
Loess Plateau area	18	cropland	cropland	1.3	0.01	3.3	1.7	0.22	167.4
Weihe plain area	11	cropland, urban land	cropland, urban land	2.1	0.01	2.5	1.5	0.64	78.4
Qinling-Daba Mountains area	33	grassland, woodland, shrub, cropland	woodland, shrub and grassland	3.6	0.06	15.5	1.9	0.14	146
Dongting Lake-Xiang River basin area	27	cropland, and others	woodland, water, cropland	3.7	0.34	19.7	0.4	0.42	17.2
Nanling Mountains area	20	cropland, grassland	woodland	3.9	0.44	16	0.9	0.05	51.5
Pear River delta area	14	cropland, woodland, urban land	cropland, urban land, woodland	5.4	2.1	39	0.9	0.04	25.5

*data error

Table 9. Statistics of flood/drought disasters with different land use types in Shenzhen-Bayanhaote belt transect from 1995 to 2000

Land use change type	County number	Average flood times	Average affected index of flood	Average accumulate duration time of flood(day)	Average drought times	Average affected index of drought	Average accumulate duration time of drought(day)
I	25	1.6	0.18	8.6	1.2	0.76	72.68
II	10	3.5	0.828	11.6	0.6	0.018	84
III	9	2	0.008	62.9	1.2	0.156	807.56
IV	2	4	0.007	12.5	2	0.073	141
V	10	2.7	0.017	16	0.7	0.0489	68.1
VI	37	3.5	0.923	27.2	0.97	0.094	148.35
VII	13	3.8	0.064	12.5	1.301	0.0371	115.61
VIII	31	4.6	0.07	31.9	1.774	0.156	200.29

I: Only cropland or little land use changes; II: from mono-land use (cropland) to woodland or shrub; III: from mono-land use (shrub) or dual-land use (shrub and grassland) to grassland; IV: from mono-land use (grassland) to multi-land use (grassland, cropland and woodland); V: from dual-land use (cropland and grassland or cropland and woodland) to woodland; VI: Dominated by tow land use types (cropland, grassland or cropland, shrub) and the proportion of two land use type changed; VII: from multi-land use to mono-land use (woodland); VIII: multi-land use types.

(iii) Impact of land use/cover change on the hydrological process

Shenzhen City is located in the Guangdong Province of Southern China, and is separated from Hong Kong by Shenzhen River. Shenzhen's rapid urbanization can be traced back to 20 years of the 'Reforming and Opening-up' process. Fuelled by the population boom and economic growth, the landscape experienced continuous change. Medium and high density urbanized areas supersede the natural and agricultural landscape, and become the dominant land use type in this area. This change has immense impacts on the meteorological, hydrological process and the Shenzhen ecosystem on the whole. The Buji river watershed in Shenzhen is chosen as the study area for this research. The land use/cover change is measured and analyzed, and different hydrological process scenarios were simulated using distributed hydrological model. The study of the impact of urbanization on the land use/cover change is a primary concern of this research. Besides, the research outcome aims to support regional water resource management, disaster prevention, and mitigation and land use planning.

The Buji River watershed, a major branch of Shenzhen River, is in the middle of Shenzhen City. Its upstream flows through Buji town, and subsequently crosses the central part of Shenzhen City. The Buji River is about 17.72 kilometers long and the whole area of the watershed is about 63.41 km^2. Owing to its geographical relationship with the downtown of Shenzhen, the Buji River watershed underwent rapid urbanization. In 1980, the urban area accounted only for 1.65% of the whole watershed; while in 2005, the proportion rose to 54.25%.

The impact of LUCC on the surface runoff coefficient and watercourse confluence process in Shenzhen(Peijun Shi, et al., 2007) were measured and analyzed. On this basis, the SWAT model was used to simulate the hydrological process of Buji River watershed. This simulation was performed without hydrological observation data. The appropriate coefficients of the hydrological model were obtained through the verification and calibration of the result. Then, different hypothetic scenarios can be simulated and compared. Finally, with the help of GIS and multivariate statistics, the impact mechanism of LUCC on the integrated water cycle is analyzed and discussed(Jing Zheng, 2007).

From the land use classification results, it is evident that the Buji River watershed also underwent rapid urbanization similar to Shenzhen city. This process was characterized by the rapid increment of urban area and the decrement of cropland and woodland. In 1980, the major land use type in Buji River watershed was woodland andthe second largest was the cropland. In 1988, the proportion of woodland, cropland, and grassland decreased significantly. Although woodland was still the major land use type, the secondary largest land use type was replaced by urban area. In 1994, woodland and cropland were still declining, whilst the urban area was increasing. After 2000, the speed of increasing or decreasing slowed down, which indicates that Buji River watershed entered the late stage of urbanization (Table 10).

(1) Simulation of hydrological process in Buji river watershed SWAT (Soil and Water Assessment Tool) is a distributed hydrological model used by the Agricultural Research Service (ARS), United States Department of Agriculture (USDA). The principal use of this model is to simulate and forecast the impact of land management on surface runoff and underground water quality. In this paper, the SWAT model is used to simulate the hydrological process from 1959 to 1969 in Buji river watershed.

Since the discharge records in Shenzhen are not extensive enough to verify the simulation result, only a rough verification could be done using the research in the book (Municipal Water Affairs Bureau of Shenzhen, 1994). The results of the simulation were compared and the monthly discharge of Buji River in 1962, 1966, 1967 and 1968 in the book were used to verify the results of the SWAT model (Figure 7). Then the modeling result was assessed using the correlation coefficient and the Nash-Suttcliffe simulation efficiency. The simulation result had a high correlation with the data from Shenzhen Water Planning and Designing Institute, the R^2 is 0.8711, and most of the points were distributed around the 1:1 line. The Nash-Suttcliffe simulation efficiency is one of the classic index to assess the effectiveness of hydrological model. The index of SWAT model in the Buji River watershed is 0.8672 which is classified into Class 2 (Class 1 is the best).

Table 10. Land use classification result of Buji River watershed (1980, 1988, 1994, 2000, 2005)

Land use type	1980		1988		1994		2000		2005	
	Area/km^2	%	Area/km^2	%	Area/km^2	%	Area/km^2	%	Area/km^2	%
High density urban	0	0	0.23	0.42	1.13	2.06	3.68	6.71	7.75	14.15
Medium and low density urban	0.9	1.65	17.06	31.15	22.14	40.41	25.88	47.24	21.97	40.1
Cropland	16.57	30.25	4.83	8.81	2.5	4.56	1.84	3.35	0.91	1.67
Orchard	0	0	9.66	17.64	6.98	12.75	4.81	8.77	4.8	8.77
Woodland	27.21	49.67	18.94	34.57	14.08	25.69	13.99	25.54	13.34	24.35
Grassland/Shrubland	7.46	13.62	0.77	1.4	0	0	0	0	0	0
Water	0.65	1.18	0.54	0.98	0.75	1.36	0.83	1.51	0.3	0.54
Wetland	0.08	0.15	0.01	0.01	0.02	0.03	0.02	0.04	0.07	0.13
Unused	1.91	3.48	2.75	5.02	7.2	13.13	3.74	6.83	5.64	10.3
Total	54.78	100	54.78	100	54.78	100	54.78	100	54.78	100

*The outline of the watershed (54.78 km^2) which is extracted in this paper using DEM is smaller than the actual size (63.41 km^2)

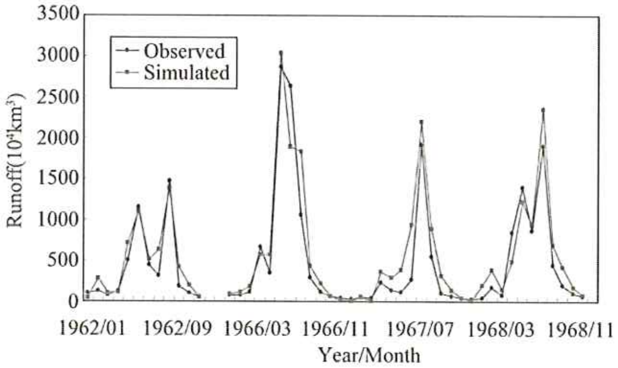

Figure 7. Comparison between the result of SWAT model and the data from Shenzhen Water Planning and Designing Institute

(2) Impacts of LUCC on the hydrological process in the Buji river watershed

To analyze the impact of LUCC on the hydrological process in the study area, five scenarios were generated: assuming that the land use did not change from 1980 to 2005, the results of land use classification in 1980, 1988, 1994, 2000 and 2005 and corresponding meteorological data were used as input, and then the hydrological process was simulated (Table 11). The change curve in those five scenarios was obtained in this manner. To compare the five scenarios, the impact of climate change and land use change on the watershed hydrological process was quantitatively analyzed.

Table 11. Simulation scenarios of Buji river watershed

Scenario No.	Meteorological data	Land use data
S1	Actual meteorological condition from 1980 to 2005	1980
S2	Actual meteorological condition from 1980 to 2005	1988
S3	Actual meteorological condition from 1980 to 2005	1994
S4	Actual meteorological condition from 1980 to 2005	2000
S5	Actual meteorological condition from 1980 to 2005	2005

In order to obtain the impact of LUCC on hydrological process, surface runoff, actual evapo-transpiration, leakage, soil water content, and underground runoff obtained from sub-basin and hydrological response unit (HRU) were used. The conclusion is as follows: 1) LUCC induced by rapid urbanization exerts great influence on the watershed hydrological process. The most affected element is surface runoff, which is lengthened more than 93.75%; then, the underground runoff and leakage, both are reduced by about 68%; the impacts on soil water content and actual evapo-transpiration were much smaller, but distinct: 25.49% and 8.18%, respectively. 2) Though the impact of land use change on the hydrological elements is weaker than the impact of climate fluctuation, the impact of land use change is already evident and cannot be disregarded. Besides the quantities of those hydrological factors , their annual change characteristics were also altered; the annual fluctuations of surface runoff, actual evapo-transpiration and soil water content are aggravated while those of leakage and underground runoff are weakened. 3) The major reason of changes in hydrological process in the Buji River watershed is the increment of urban area and decrement of agricultural and woodland. The increment of impervious area leads to the increase of surface runoff and the decrease of leakage, actual evapo-transpiration, soil water content and underground runoff. 4) The changes of those hydrological factors spatially corresponded with the urban expansion.

IV. CONCLUSION AND DISCUSSION

This research chose a narrow southeast-northwest geographic belt transect traversing through six cities of Shenzhen, Hengyang, Changde, Xi'an, Yingchuang and Bayanhaote as the study area. The total study area measures 385600km^2 with a width of 100—150km and a length of 2200km. Using the GIS and database technology, this paper integrated the basic geographic information, remote sensing images, statistical data, and special-subject pictures. Subsequently the geographic information system for the Shenzhen-Bayanhaote Geographic Belt Transect was generated. Founded on the database and GIS platform, the related geographic belt transect research on earth-surface interaction mechanism, process and dynamics of Human-Earth system was carried out. This is capable of providing scientific support and the foundation for expressing the impact of human activity on earth-surface system and understanding the differentia of regional geographic process.

The research results show that: 1)Adapting the geographic belt transect method for Human-Earth system interaction mechanism, process and dynamics research of earth surface is a pragmatic and scientific solution. 2)The variations in temperature and precipitation are two essential indicators for meteorological disaster frequency and duration, which is evident from the notable positive correlation between them. Human activities have a great impact on drought disasters, whose occurring numbers and durations have positive correlations with the ratio of the first-industry GDP to the total GDP; With the increase of the first-industry GDP and effective irrigation area, the drought losses can be reduced. The research belt transect was divided into six regions, which are different from each other in terms of natural and human conditions. 3)The land use change is evidently affected by rapid urbanization, industry-structure adjustments and policy driving. During 1995—2000, the percentage of cropland in the total area has decreased from 34.2 % to 17.26 %, while that of woodland has increased from 10.62 % to 31.5 %, which added 89.91 billion RMB to the ecological assets in the research belt transect. Under the influence of land-use pattern adjustment policy, the ecological assets have increased greatly. The increase of the wetland (including water area) in the research belt transect has played a significant and positive role in the ecological assets conservation and improvement. The increase of the urbanization and desertification area has caused a reduction in the ecological assets in some local regions of the research belt transect. 4) The land use structure has a strong influence on the flood and drought disasters in the belt transect. There is higher occurring possibility of the flood and drought disasters in the counties where the land use types are complex, but the counties where the land use type is relatively single, are weakly affected by flood and drought disasters. 5) The Buji River watershed research evinces that land use/cover change (LUCC) induced by rapid urbanization exerts great influence on the watershed hydrological process. The most affected one is surface runoff, which is lengthened more than 93.75%; then is the underground runoff and leakage, both are reduced by about 68%; the impacts on soil water content and actual evapotranspiration are much smaller but also distinct: 25.49% and 8.18%, respectively. Though the impact of land use change on the hydrological elements is weaker than that of physical climate fluctuation, the impact of land use change is already evident and can't be disregarded. Owing to the lack of hydrological observation data, this study took advantage of the SWAT model and employed RS technology to accomplish an innovative integrated hydrological research. The research encompassed surface runoff, leakage, and underground hydrological process, which is an improvement over earlier research efforts and can serve as a reference and foundation for similar research, especially in domains that lack data.

This geographic-belt transect research integrates the area and point (cities and watershed) method, and demonstrates a significant work on both the whole belt transect and the important watersheds and cities, like Xiangjiang River Basin, Shenzhen City, Xi'an City etc. This enriches the integrated belt transect research, and helps to better reveal the regional differentia and build a solid foundation for the integrated earth-surface interaction platform construction, which can be regarded as a good method for this belt transect research. However, still further work remains to be done and in future, notable advancements need to be made. Though the related geographic-belt transect research on earth-surface interaction dynamics of Human-Earth system has been carried out in Shenzhen and other typical station points, that integrated research work in the whole belt transect has not been initiated. The geographic belt transect research on Human-Earth system interaction mechanism and process still needs to be deepened and expanded, including the vulnerability and resilience assessment research. The research modeling and result validation processes should be further enhanced to strengthen the simulation of the Human-Earth system interaction process, accomplish the scale transformation for regional-differentia from the microscopic to the macroscopic view, and provide scientific support for regional sustainable development strategy.

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