Hindawi Publishing Corporation
Advances in Meteorology
Volume 2013, Article ID 908307, 9 pages
http://dx.doi.org/10.1155/2013/908307

Research Article

Projection of the Spatially Explicit Land Use/Cover Changes in China, 2010–2100

Yongwei Yuan,[1] Tao Zhao,[2] Weimin Wang,[3] Shaohui Chen,[4] and Feng Wu[5]

[1] *Faculty of Resources and Environmental Science, Hubei University, Wuhan 430062, China*
[2] *Bureau of Science and Technology for Development, Chinese Academy of Sciences, Beijing 100864, China*
[3] *Shenzhen Environmental Monitoring Center, Shenzhen, Guangdong 518049, China*
[4] *Institute of Geographic and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China*
[5] *State Key Laboratory of Water Environment Simulation, School of Environment, Beijing Normal University, Beijing 100875, China*

Correspondence should be addressed to Yongwei Yuan; yuanyw.simlab@gmail.com

Received 18 July 2013; Accepted 31 August 2013

Academic Editor: Xiangzheng Deng

Copyright © 2013 Yongwei Yuan et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Land use/cover change (LUCC) is an important part of the global environmental change. This study predicted the future structure of land use/cover on the basis of the Global Change Assessment Model (GCAM) and an econometric model with the socioeconomic factors as the driving forces. The future spatial pattern of land use/cover in China was simulated with the Dynamics of Land System (DLS) under the Business as Usual scenario, Rapid Economic Growth scenario and Cooperate Environmental Sustainability scenario. The simulation results showed that the land use/land cover in China will change continually due to the human activities and climate change, and the spatial pattern of land use/cover will also change as time goes by. Besides, the spatial pattern of land cover in China under the three scenarios is consistent on the whole, but with some regional differences. Built-up area will increase rapidly under the three scenarios, while most land cover types will show a decreasing trend to different degrees under different scenarios. The simulation results can provide an underlying land surface data and reference to the methodology research on the prediction of LUCC.

1. Introduction

Land use/cover change (LUCC) is an important part of the global environmental change, which has always been the focus of academia [1]. In 1995 the International Geosphere-Biosphere Programme (IGBP) and International Human Dimensions Programme on Global Environmental Change (IHDP) jointly launched the land use/cover change research project, and LUCC is still one of the core contents of the Global Land Project (GLP) jointly launched by IGBP and IHDP in 2005 [2, 3]. Research shows that LUCC not only affected the terrestrial ecosystem biodiversity, energy balance, and water cycle but also exerted influence on climate and social economy [4, 5]. LUCC plays an important role in the regional and global environmental change, and its effects can be beyond the time scale through the global land-ocean interaction [6].

The core part of researches on LUCC includes the driving force, driving mechanism, effects, and model simulation of LUCC [7, 8]. In the past decades, scholars of different fields have paid great attention to LUCC, mainly focusing on the spatiotemporal change, driving mechanism, eco-environmental impacts, and simulation of LUCC [8, 9]. The research on the spatiotemporal analysis of LUCC mainly focuses on the change in quantity and spatial pattern [10], while the research on the driving mechanism of LUCC plays an important role in revealing the basic processes of LUCC and its driving factors, predicting the future change and formulating the corresponding policies. Currently, there have been various models to reveal the mechanism, explore the driving factors, and simulate the dynamic process of LUCC [10–15].

The researches on the simulation of LUCC mainly focused on the models used to forecast the future LUCC,

Table 1: Projected change rates of GDP and population (POP) in China, 2011–2100.

		2011–2015	2016–2020	2021–2025	2026–2030	2031–2040	2041–2050	2051–2075	2076–2100
GDP/%	BAU	7.90	7.00	6.60	5.90	5.60	5.50	3.90	2.40
	REG	8.30	7.35	6.93	6.20	5.88	5.78	4.10	2.52
	CES	7.51	6.65	6.27	5.61	5.32	5.23	3.71	2.28
POP/%	BAU	6.24	4.10	1.67	−0.14	−1.04	−3.99	−5.54	−5.12
	REG	6.55	4.30	1.75	−0.13	−0.99	−3.79	−5.26	−4.87
	CES	5.93	3.89	1.59	−0.15	−1.10	−4.19	−5.82	−5.38

Note: the data come from references [25–27], and the change rates of GDP were expanded to 2100 according to the historical changing trend. Under the CES scenario, the rates of population growth rate and GDP increase are 5% lower than that under the BAU scenario, while they are 5% higher under the REG scenario than the BAU scenario.

which mainly include the empirical statistical model, agent-based model, methods based on the neighboring relationship of grids, and dynamic simulation of the land system [11, 16]. The empirical statistical models can be used to extract the major driving factors of LUCC and explore the reasons for its spatiotemporal processes. The Conversion of Land Use and its Effects (CLUE) model and Conversion of Land Use and its Effects at Small Region Extent (CLUE-S) model are two representative empirical statistical models [17, 18]. However, there is generally a very large spatial scale and low resolution used in the simulation with the CLUE model, while the CLUE-S is mainly applied in the dynamic simulation of regional land use at small scales [11, 19]. The simulation of the structural change of land use with the Agent-based Model (ABM) has many advantages, but it generally concentrates on the small study area [20]. The Cellular Automaton (CA) simulates the processes of cellular evolution rules, but it requires a variety of spatial statistical methods to assist in the detection [21]. Many scholars have tried to explore the land use change with other methods and models, such as the land-use dynamic degree model [22], the model for identification of driving forces [23], and the Dynamics of Land System (DLS) model. The DLS model is capable of simulating the spatial dynamics of LUCC, and case studies indicate that it is an effective tool to simulate the process of land use change [11, 24].

Great achievements have been made in the researches on LUCC, but it is still far from being able to meet the need to alleviate and adapt to the global environmental change. One of the major issues to settle is that there is still no temporal data and the current research on the driving force of LUCC is only from simple perspectives; therefore, it is urgent to obtain the long-term temporal data of LUCC parameters. To solve this problem, this study simulated the structural change of land use in China with the Global Change Assessment Model (GCAM) and an econometric model with the socioeconomic factors as the driving forces. Then an econometric model was set up and used to forecast the built-up area change, and the changing trend of land use was simulated based on different scenarios of socioeconomic development. Thereafter the DLS model was used to forecast the future spatial pattern of LUCC in China, which can provide temporal underlying surface data for relevant researches.

2. Scenario Design and Downscaling Simulation Method

2.1. Scenario Design. In this study, three scenarios were designed according to the characters of historical socioeconomic development of China, including the Business as Usual (BAU) scenario, Rapid Economic Growth (REG) scenario, and Cooperate Environmental Sustainability (CES) scenario. The BAU scenario mainly reflects the future changing trends of population and economy, which provides the baseline trend of land use change. Based on the BAU scenario, the REG scenario and CES scenario were designed according to the main risks and the adjustment direction of China's medium and long-term development plan. It is assumed that under the BAU scenario the urbanization and industrialization will continue, the total factor productivity (TFP) which is on behalf of the scientific and technological progress will develop following the historical development trend, and China's population will peak in the 2030s, but the population growth rate will gradually reduce. The REG scenario assumes that the industrial structure adjustment would be smoothly carried out, and the resource allocation and industrial structure would be more reasonable, while the speed of economic growth will keep steady. Under the CES scenario, the population growth rate is lower than it is under the BAU scenarios, the urbanization rate is relatively lower, and GDP would increase with a lower rate (Table 1).

2.2. Data. The input data used in this study include the baseline structure land use/cover data and the historical socioeconomic data used in the GCAM model, the historical socioeconomic data used in the econometric model, and the baseline land use/cover data and some driving factors data used in the DLS model.

The baseline data of land use/cover change are derived from the dataset of National Basic Research Program of China. With these spatial distribution data, the initial land use allocation data in 2000 used by GCAM model could also be obtained. The dataset is originally established with a 1 km × 1 km grid scale using the land use/cover classification system of the United States Geological Survey (USGS) based on the remote sensing image and ground information of 2000 (Figure 1). The socioeconomic data include the population,

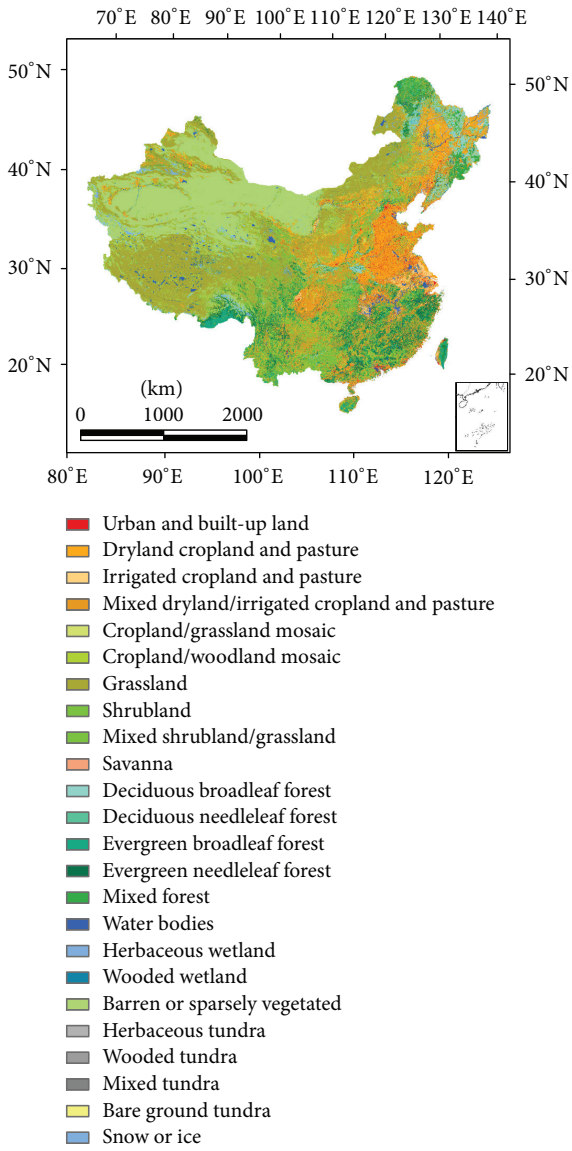


Figure 1: Land use/cover data with USGS classification system in 2000 in China.

population density, and growth rate of per capita income, the proportion of agricultural population, urbanization ratio, GDP, and price index of oil, gas, coal, and hydropower, which are obtained from the Statistical Yearbook and other statistical data. As essential input parameters, they are used in the GCAM model.

The input variables of driving factors in the DLS model include the natural environment data and social economic data. The natural environment data include basic geographic information dataset of climate, location, terrain, and soil property. The meteorological data used in this study, including the near-surface temperature and precipitation, were all from meteorological stations of China Meteorological Administration, which were interpolated into 1 km resolution grid data with the Kriging interpolation algorithm, and got the annual average value of which between 1998 and 2002. Location data include grid distance data and neighborhood land use/cover structure data. Among them, the grid distance data are the distance data of each grid center to the nearest road (including highway, state roads, provincial roads, county roads, and other roads), the provincial capital city, cities, water body, and the port, which were extracted and calculated based on 1 : 250000 basic geographical information data. The data neighborhood of land use/cover structure was calculated as the area percentage of the same land use/cover type with the target grid in the rectangular ranges of the 11×11 grids surrounding the target grid. Terrain data include slope, aspect, plain area ratio, altitude, topography, and other data. The slope and elevation data were extracted based on the 1 : 250000 digital elevation models. The soil attribute dataset was from the spatial soil attribute data of 1 : 1000000 soil database built in the second general survey of soil in China and interpolated with the Kriging interpolation algorithm. This dataset includes data of loam proportion, organic content, Nitrogen content, phosphorus content, potassium content, the content of rapid available phosphorus, the content of rapid available potassium, and pH value.

2.3. Models. In this study, the GCAM model, econometric model, and DLS model were used to simulate the land use/cover data from 2000 to 2100 under the three scenarios. The former model was used to simulate the land use structure data of 5 categories and the latter one was used to simulate the spatial distribution of the land cover data of 24 categories based on the simulated structure data from 2000 to 2100.

The Agriculture and Land Use (AgLU) module of GCAM and simulated land use change trend data under three scenarios in the future were used to complete the structure land use simulation. AgLU module is a dynamic partial equilibrium economic model, and at the core of the AgLU model is a mechanism that allocates land among cropland, grassland, forestry area, and other land and the economic return from each land use type in each region is maximized. The three primary drivers of land use change are population growth, income growth, and autonomous increases in future crop yields.

As there is no simulation function for built-up area in the GCAM model, an econometric model was set up and used to simulate the built-up area. In order to optimize the simulation results, the coefficients in the econometric model were calibrated according to the variation of population, GDP, and urbanization ratio year by year.

The major driving factors in GCAM model are GDP and population with no urbanization ratio involved in; thus, urbanization ratio variable should be added. American urban geographer Northam (1969) has researched the process of urbanization in various countries in the world [28, 29]. His studies indicated that the process of urbanization was expressed as an S. Therefore, the equation was built as follows:

$$y = \frac{1}{\left(1 + \partial \cdot e^{-\beta t}\right)}, \tag{1}$$

where y represented the urbanization ratio, t represented time, and ∂ and β were parameters. It could be deformed as follows:

$$\ln\left(\frac{1}{y-1}\right) = \ln\partial - \beta t \quad (\text{or } y_1 = a_0 + a_1 t). \tag{2}$$

The urbanization ratio over the years was obtained from statistical yearbook, and according to which the parameters ∂ and β in the formula were obtained from the simulation. Hence, the calculated equation of urbanization was worked out as follows:

$$y = \frac{1}{\left(1 + 4.5748\, e^{-0.04t}\right)}. \tag{3}$$

Afterwards, the impact on built-up area of population, GDP, and urbanization ratio as socio-economic indicators was estimated by econometric model as follows:

$$Y_t = a_0 + a_1 X_{1t} + a_2 X_{2t} + a_3 X_{3t} + \varepsilon_t, \tag{4}$$

where Y_t stands for the area of built-up area, X_{1t} represents population, X_{2t} is GDP, X_{3t} is urbanization ratio, and α_0 is intercept. ε_t is random error term, which is an independent random variable from other explaining variables, and it is assumed to obey normal distribution with zero expectation and homoscedasticity.

The DLS model is a useful tool to simulate the change of spatial pattern of regional land use [26, 30]. It was used to forecast the spatiotemporal pattern of LUCC across the country in this study. The DLS model presumes that the change of the land use pattern is influenced by both the historic land use pattern and the driving factors within the pixel and neighboring pixels [11].

The DLS model used in the simulation includes three modules: driving force analysis module, scenario analysis module, and spatial allocation module. The DLS model analyzes the balance between supply and demand of land resources at the grid scale through the spatial allocation module, which can be used to realize the spatial allocation of the structural data of land use so as to simulate LUCC under different scenarios [11, 24]. The DLS model provides the response function about the change of land system structure. And based on the suitability evaluation of land use type distribution, the DLS will express the spatial dominant of the possible scenarios on regional change of land system structure by estimating the response function. DLS expresses the difficulty level of the conversion from one land type to other land types through defining transformation rule. Spatial allocation module calculates the number of grids to allocate. As for the grids needing distribution, the model would calculate the distribution probability of the different land use/cover types and allocate those.

3. Simulation of the Pattern of LUCC in China

3.1. Simulation Scheme. The simulation scheme is as follows. The structural data of LUCC were simulated on the basis of GCAM combined with the econometric model. Then based on the correspondence table of USGS classification and GCAM classification (Table 2), the data of demand for each land use/cover type of USGS classification in each year during 2010–2100 were obtained through allocating the land area in the structural data of LUCC, with the original area percentage of each land use/cover type in last year as the weight:

$$ld_{i,t+1} = \frac{ld_{k,j,t}}{\sum ld_{k,j,t}} \times ldg_{j,t}, \tag{5}$$

where $ld_{i,t+1}$ is the predicted area of the ith land use/cover type of USGS classification in year $t+1$; $ldg_{j,t}$ is the predicted area of the ith land use/cover type of USGS classification in year t; $ld_{k,j,t}$ is the predicted area of the kth land use/cover type of USGS classification, which corresponds to the jth land use/cover type of GCAM classification in year t.

3.2. Results. The structural data of LUCC in China in the future were simulated on the basis of GCAM combined with the econometric model according to the BAU scenario, REG scenario, and CES scenario. Then the LUCC in China during 2001–2100 was simulated with the DLS model in this study. In the future, the land use/cover in China will continually change with the human activities and climate change, and the spatial pattern of land use will change as time goes by.

(1) The simulated changes of LUCC. In the study, we simulated the changes of LUCC in China in the future using GCAM model combined with the econometric model under the three scenarios (Figure 2). The simulated results show the changing trends of different land use/cover in three different scenarios.

On the whole, built-up area, and forestry area will show an increasing trend under the three scenarios. On the contrary, cropland, grassland, and water area will show a decreasing trend under the three scenarios. However, grassland and forestry area change at the fastest rate under CES scenario, at the lowest rate under REG scenario, while other types change at the lowest rate in CES scenario and fastest rate in REG.

Statistical analysis of the simulation result indicated that land cover will change as follows. The area of built-up area will increase most rapidly during 2000–2100, with the 10-year increasing rate reaching 3.86%, 5.05%, and 2.98% under the BAU scenario, REG scenario, and CES scenario, respectively. The area of built-up area will increase rapidly during 2010–2060 under the BAU scenario and CES scenario, under which the 10-year increasing rate reaches 0.54 and 0.44 million ha, respectively. But during the latter period, the 10-year increasing rate tends to slow down, reaching only 0.15 and 0.08 million ha, respectively. Under the REG scenario the increasing trend of built-up area tends to be rapid on the whole during 2010–2100, with the 10-year increasing rate reaching 0.5 million ha and the total area of built-up area reaching 5.05 million ha. By contrast, cropland and water area both show a decreasing trend under all the three scenarios, especially the REG scenario, under which their 10-year decreasing rates reach 0.23% and 1.28%, respectively. Under the BAU scenario and CES scenario, the change of these two land cover types tends to slow down, with their 10-year decreasing rates reaching 0.19% and 0.15%, 1.17% and 1.03%, respectively. Forestry area shows us that the area increases to 19.77, 17.74, and 22.79 million ha under the BAU scenario, REG scenario, and CES scenario, respectively.

Table 2: Mapping table of land use/cover types of USGS and GCAM classification systems.

ID	USGS_Code	USGS_Name	GCAM_Code
1	100	Urban and built-up land	50
2	211	Dryland cropland and pasture	10
3	212	Irrigated cropland and pasture	10
4	213	Mixed dryland/irrigated cropland and pasture	10
5	280	Cropland/grassland mosaic	10
6	290	Cropland/woodland mosaic	10
7	311	Grassland	30
8	321	Shrubland	20
9	330	Mixed shrubland/grassland	30
10	332	Savanna	30
11	411	Deciduous broadleaf forest	20
12	412	Deciduous needleleaf forest	20
13	421	Evergreen broadleaf forest	20
14	422	Evergreen needleleaf forest	20
15	430	Mixed forest	20
16	500	Water bodies	40
17	620	Herbaceous wetland	40
18	610	Wooded wetland	40
19	770	Barren or sparsely vegetated	30
20	820	Herbaceous tundra	30
21	810	Wooded tundra	30
22	850	Mixed tundra	30
23	830	Bare ground tundra	30
24	900	Snow or ice	40

Note: in the column "GCAM_Code", 10: cropland; 20: forestry area; 30: grassland; 40: water area; 50: built-up area.

Grassland shows a decreasing trend under the BAU scenario, REG scenario, and CES scenario, with the decreasing rates of 3.12%, 2.67%, and 3.80%, respectively.

(2) The spatial pattern of land use/cover change. The simulation results indicated that the spatial patterns of land cover in China under the three scenarios are consistent on the whole, but with some regional difference (Figure 3). The spatial pattern of land cover in China in the future is as follows. The urban and built-up land has special requirement for location, and the spatial pattern of the built-up land in the future will show significant regional differentiation under the joint influence of natural factors, socioeconomic factors, topographic conditions, and so forth. In the eastern part of China, the urban and built-up land will continue to gather in the three major plain regions (i.e., Northeast China Plain, North China Plain, and Middle-Lower Yangtze Plain), Yangtze River Delta, and Pearl River Delta, and it will show an expanding trend on the original basis. In the western part of China, the urban and built-up land will mainly concentrate in the regions such as Sichuan Basin, Guanzhong Basin, Hetao Plain, Hexi Corridor, and oases in Xinjiang Province. While with the implementation of policies to exploit the land resources on the low hill and gentle slope, the land in hills with gentle slope, mountains, and plateaus may also become urban and built-up in the future.

The cropland, such as dryland cropland and pasture, irrigated cropland and pasture, mixed dryland/irrigated cropland and pasture, cropland/grassland mosaic, and cropland/woodland mosaic, will still be contiguously distributed in the three major plain regions (i.e., Northeast China Plain, North China Plain, and Middle-Lower Yangtze Plain), Sichuan Basin, Hexi Corridor, oases in Xinjiang Province, and so forth. Besides, it will also gather in some alluvial plains and regions of the low hill and gentle slope. In addition, in the marginal areas between cropland, grassland, and forestland, there may be some farming-grazing or farming-forestry ecotones, which include various land cover types.

Grassland will be mainly located in Inner Mongolia, Qinghai-Tibet Plateau in the western part of China. While in the eastern part of China, grassland will be mainly distributed in the regions of the low hill and gentle slope, and it will generally be mixed with cropland or forestland. There will be great regional heterogeneity of the distribution of land cover types that mainly include the forestland, such as shrubland, mixed shrubland/grassland, deciduous broadleaf forest, deciduous needleleaf forest, evergreen broadleaf forest, evergreen needleleaf forest, and mixed forest. In the northern part of China, the forestland will be mainly located in Northeast China, for example, Greater Khingan Mountains, Lesser Khingan Mountains, Changbai Mountains, and Liaodong Basin. While in the southeast part (e.g., Lingnan area, Taiwan), southwest part (e.g., the Yunnan-Guizhou Plateau, Sichuan Basin and Guangxin Province), and

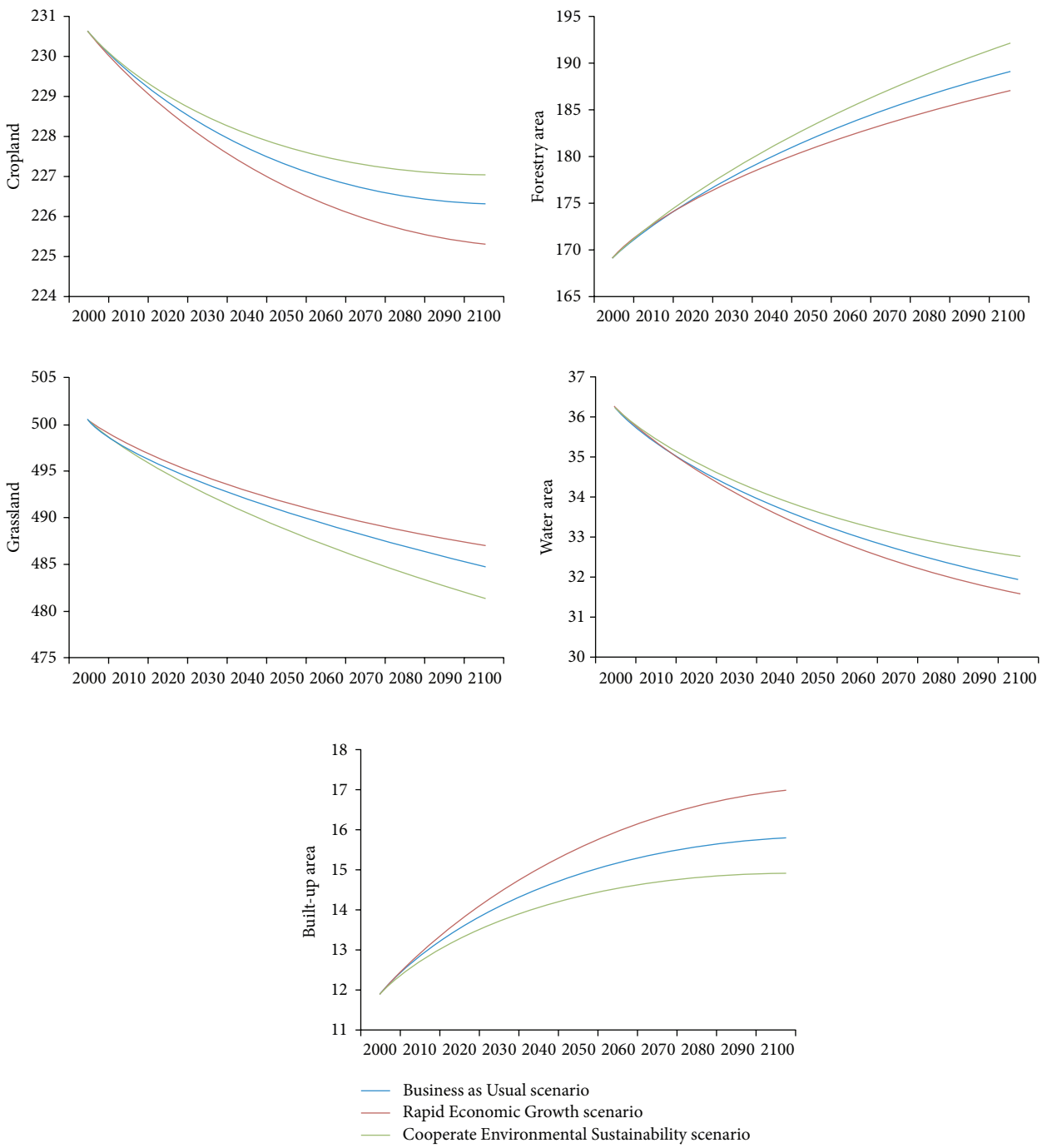


Figure 2: Simulated changes of LUCC area (measured in million ha) in China, 2010–2100.

the forestland will be mainly distributed in the regions of hills and mountains.

Some land use/cover types, including water bodies, herbaceous wetland, and wooded wetland, will still remain in the original regions but will show a shrinking trend on the whole on the original basis. In spatial pattern, there will be more of these land use/cover types in the eastern part and less in the western part; more in the southern part and less in the northern part. Savanna, herbaceous tundra, wooded tundra, and bare ground tundra will be located in the Alpine regions of Himalaya Mountains. There is no mixed tundra in China.

Snow or ice will be mainly distributed in the regions above the snow line in the high mountains (Tianshan Mountains, Qilian Mountains, Kunlun Mountains, and Himalaya Mountains) in the southwest and northwest part of China. Barren or sparsely vegetated land will mainly gather in the arid desert areas centering on Taklimakan Desert in Tarim Basin, Qaidam Basin, and so forth. In the northwest part of

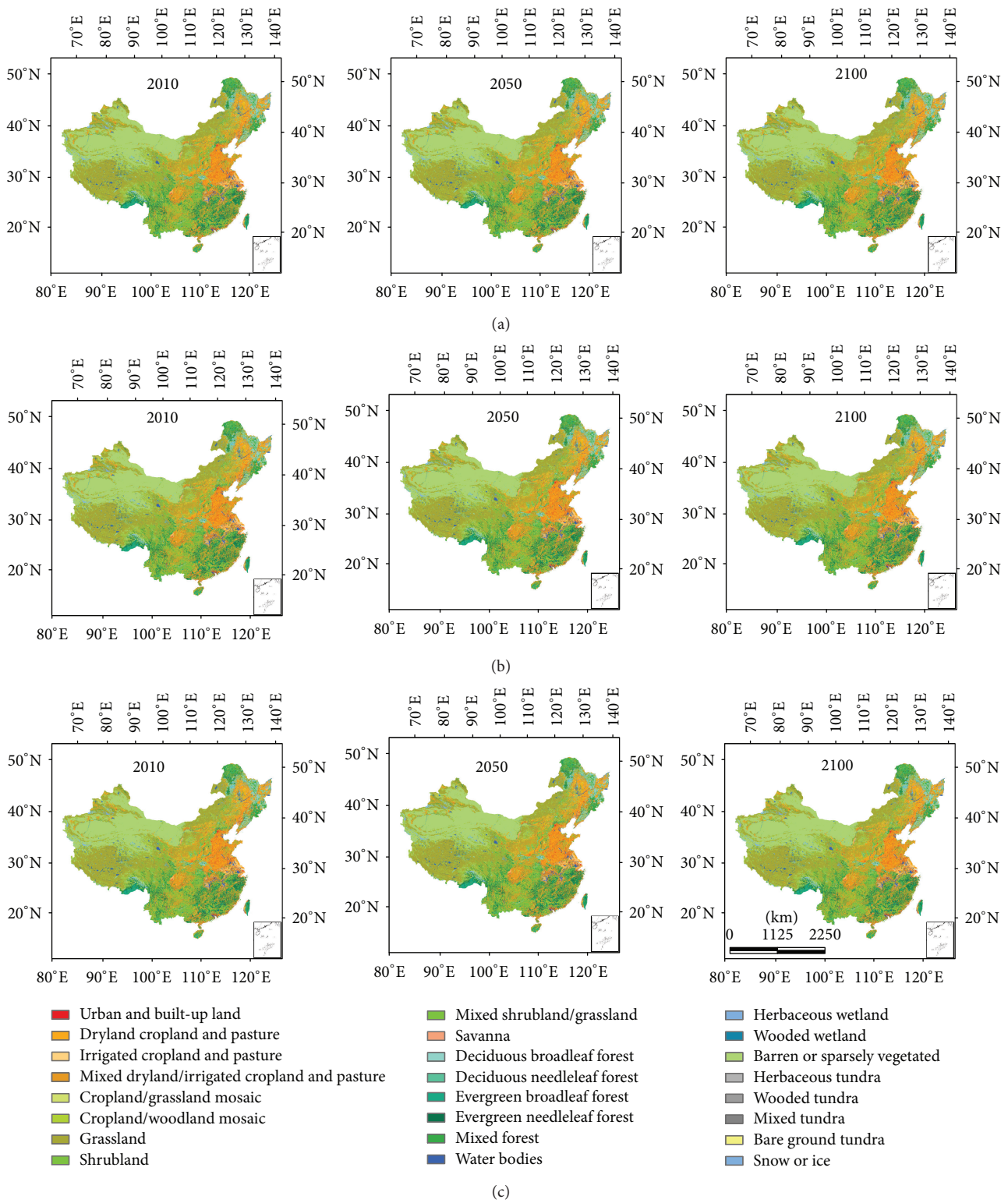


Figure 3: Simulated spatial pattern of LUCC in China in 2010, 2050, and 2100 under the Business as Usual scenario (a), Rapid Economic Growth scenario (b), and Cooperate Environmental Sustainability scenario (c).

China, including the Alpine arid regions in Qinghai-Tibet Plateau, middle part of Inner Mongolia, northwest part of Gansu Province, and so forth.

4. Conclusions and Discussion

In this study, three scenarios of the future LUCC in China were designed on the basis of the trends of the future socioeconomic development and national policies (e.g., Grain for Green). This study predicted the future land use change in China on the basis of GCAM and the econometric model with the socioeconomic factors as the driving forces. The future spatial pattern of land use/cover in China under the three scenarios was simulated with the DLS model and its spatial and temporal change were finally analyzed. The simulation results showed that the spatial pattern of land use/cover in China under the three scenarios is consistent on the whole, but with some regional difference. The result can provide some reference to the methodology research on the prediction of LUCC in the future. Besides, the simulation results based on different scenarios reflect the spatial pattern of land use/cover of China in the future to some extent, which have important policy implications and scientific supporting on land use planning and sustainable development of the society and can provide the input underlying surface data for the climate models.

There are still some uncertainties in the results of the scenario simulation of future land use/cover change due to the uncertain driving factors since the land system is a complex system that is closely associated with the human society and natural conditions. Besides, this study used the land use/cover classification system correspondence from the GCAM model with 5 categories of classification into USGS with 24 categories, which also lead to the risk of uncertainties. Therefore, the simulation results cannot represent the actual change of area of different land use/cover types and their spatial pattern, but they can still make good sense in the reasonable confidence interval to a certain extent due to the robustness of the model. It is necessary to continuously improve the model in the future researches in order to obtain higher simulation accuracy and more reasonable simulation results. In addition, more attention should be paid on the full application of the simulation results in order to make relevant planning more reasonable according to the needs of the socioeconomic development in further researches.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

Acknowledgments

This research was supported by the National Key Programme for Developing Basic Science in China (Grant nos. 2010CB950900; 2012CB955700) and China National Natural Science Funds for Distinguished Young Scholar (Grant no. 71225005). The authors are very grateful to the three anonymous reviewers for their valuable comments that have significantly improved the paper.

References

[1] P. H. Verburg, "Simulating feedbacks in land use and land cover change models," *Landscape Ecology*, vol. 21, no. 8, pp. 1171–1183, 2006.

[2] I. Secretariat, "GLP (2005) science plan and implementation strategy," Tech. Rep. 53, IGBP, Stockholm, Sweden, 2005.

[3] B. L. Turner, D. Skole, S. Sanderson, G. Fischer, L. Fresco, and R. Leemans, "Land-use and land-cover change. Science/Research plan," Global Change Report, IGBP, Stockholm, Sweden, 1995.

[4] A. Berg, C. Papageorgiou, C. A. Pattillo, and N. Spatafora, "The end of an era? The medium-and long-term effects of the global crisis on growth in low-income countries," IMF Working Papers, 2010.

[5] J. Liu and J. Diamond, "China's environment in a globalizing world," *Nature*, vol. 435, no. 7046, pp. 1179–1186, 2005.

[6] J. Y. Liu and X. Z. Deng, "Progress of the research methodologies on the temporal and spatial process of LUCC," *Chinese Science Bulletin*, vol. 55, no. 14, pp. 1354–1362, 2010.

[7] R. S. Yin, Q. Xiang, J. T. Xu, and X. Z. Deng, "Modeling the driving forces of the land use and land cover changes along the upper Yangtze river of China," *Environmental Management*, vol. 45, no. 3, pp. 454–465, 2010.

[8] F. Hasselmann, E. Csaplovics, I. Falconer, M. Bürgi, and A. M. Hersperger, "Technological driving forces of LUCC: conceptualization, quantification, and the example of urban power distribution networks," *Land Use Policy*, vol. 27, no. 2, pp. 628–637, 2010.

[9] R. Patarasuk and M. W. Binford, "Longitudinal analysis of the road network development and land-cover change in Lop Buri province, Thailand, 1989–2006," *Applied Geography*, vol. 32, no. 2, pp. 228–239, 2012.

[10] Y. Liu, J. Wang, and X. Deng, "Rocky land desertification and its driving forces in the karst areas of rural Guangxi, Southwest China," *Journal of Mountain Science*, vol. 5, no. 4, pp. 350–357, 2008.

[11] X. Deng, Q. Jiang, J. Zhan, S. He, and Y. Lin, "Simulation on the dynamics of forest area changes in Northeast China," *Journal of Geographical Sciences*, vol. 20, no. 4, pp. 495–509, 2010.

[12] D. K. Munroe and D. Müller, "Issues in spatially explicit statistical land-use/cover change (LUCC) models: examples from western Honduras and the Central Highlands of Vietnam," *Land Use Policy*, vol. 24, no. 3, pp. 521–530, 2007.

[13] A. Veldkamp and E. F. Lambin, "Predicting land-use change," *Agriculture, Ecosystems and Environment*, vol. 85, no. 1–3, pp. 1–6, 2001.

[14] R. G. Pontius Jr. and L. C. Schneider, "Land-cover change model validation by an ROC method for the Ipswich watershed, Massachusetts, USA," *Agriculture, Ecosystems and Environment*, vol. 85, no. 1–3, pp. 239–248, 2001.

[15] E. F. Lambin, B. L. Turner, H. J. Geist et al., "The causes of land-use and land-cover change: moving beyond the myths," *Global Environmental Change*, vol. 11, no. 4, pp. 261–269, 2001.

[16] H. Zhao, E. Uchida, X. Deng, and S. Rozelle, "Do trees grow with the economy? A spatial analysis of the determinants of forest cover change in Sichuan, China," *Environmental and Resource Economics*, vol. 50, no. 1, pp. 61–82, 2011.

[17] A. Veldkamp and L. O. Fresco, "CLUE: a conceptual model to study the conversion of land use and its effects," *Ecological Modelling*, vol. 85, no. 2-3, pp. 253–270, 1996.

[18] P. H. Verburg and Y. Chen, "Multiscale characterization of land-use patterns in China," *Ecosystems*, vol. 3, no. 4, pp. 369–385, 2000.

[19] P. H. Verburg, G. H. J. de Koning, K. Kok, A. Veldkamp, and J. Bouma, "A spatial explicit allocation procedure for modelling the pattern of land use change based upon actual land use," *Ecological Modelling*, vol. 116, no. 1, pp. 45–61, 1999.

[20] T. Zhang and D. Zhang, "Agent-based simulation of consumer purchase decision-making and the decoy effect," *Journal of Business Research*, vol. 60, no. 8, pp. 912–922, 2007.

[21] R. White and G. Engelen, "High-resolution integrated modelling of the spatial dynamics of urban and regional systems," *Computers, Environment and Urban Systems*, vol. 24, no. 5, pp. 383–400, 2000.

[22] J. Liu, M. Liu, D. Zhuang, Z. Zhang, and X. Deng, "Study on spatial pattern of land-use change in China during 1995–2000," *Science in China Series D*, vol. 46, no. 4, pp. 373–384, 2003.

[23] H. J. Geist and E. F. Lambin, "Proximate causes and underlying driving forces of tropical deforestation: tropical forests are disappearing as the result of many pressures, both local and regional, acting in various combinations in different geographical locations," *BioScience*, vol. 52, no. 2, pp. 143–150, 2002.

[24] X. Deng, H. Su, and J. Zhan, "Integration of multiple data sources to simulate the dynamics of land systems," *Sensors*, vol. 8, no. 2, pp. 620–634, 2008.

[25] F. Chen and G. Liu, "Population aging in China," in *International Handbook of Population Aging*, vol. 1, pp. 157–172, 2009.

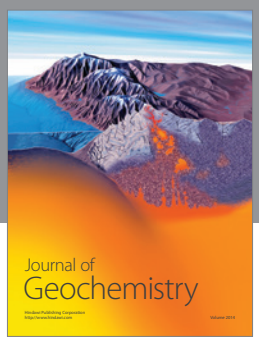
[26] W. Lutz and K. C. Samir, "Dimensions of global population projections: what do we know about future population trends and structures?" *Philosophical Transactions of the Royal Society B*, vol. 365, no. 1554, pp. 2779–2791, 2010.

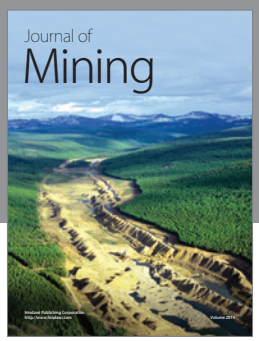
[27] K. C. Samir, B. Barakat, A. Goujon, V. Skirbekk, W. Sanderson, and W. Lutz, "Projection of populations by level of educational attainment, age, and sex for 120 countries for 2005–2050," *Demographic Research*, vol. 22, no. 15, pp. 383–472, 2010.

[28] R. M. Northam, "Population size, relative location, and declining urban centers: conterminous United States, 1940–1960," *Land Economics*, vol. 45, no. 3, pp. 313–322, 1969.

[29] R. M. Northam, "Vacant urban land in the American city," *Land Economics*, vol. 47, no. 4, pp. 345–355, 1971.

[30] X. Deng, *Modeling the Dynamics and Consequences of Land System Change*, Higher Education Press, Beijng, China, 2011.





Hindawi

Submit your manuscripts at
http://www.hindawi.com