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RESEARCH ARTICLE

Integrating global socio-economic influences into a regional land use change model for China

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Abstract With rapid economic development and urbanization, land use in China has experienced huge changes in recent years; and this will probably continue in the future. Land use problems in China are urgent and need further study. Rapid land-use change and economic development make China an ideal region for integrated land use change studies, particularly the examination of multiple factors and global-regional interactions in the context of global economic integration. This paper presents an integrated modeling approach to examine the impact of global socio-economic processes on land use changes at a regional scale. We develop an integrated model system by coupling a simple global socio-economic model (GLOBFOOD) and regional spatial allocation model (CLUE). The model system is illustrated with an application to land use in China. For a given climate change, population growth, and various socio-economic situations, a global socio-economic model simulates the impact of global market and economy on land use, and quantifies changes of different land use types. The land use spatial distribution model decides the type of land use most appropriate in each spatial grid by employing a weighted suitability index, derived from expert knowledge about the ecosystem state and site conditions. A series of model simulations will be conducted and analyzed to demonstrate the ability of the integrated model to link global socio-economic factors with regional land use changes in China. The results allow an exploration of the future dynamics of land use and landscapes in China.

Keywords global socio-economic influence, land use change model, integrating, China

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1 Introduction

Land use and 1and cover change (LUCC) is a major part, and also a main cause, of global environmental changes. LUCC has recently emerged as an important area of focus for land change studies (Turner II et al., 2007). The impact of LUCC on the climate, ecosystems, society, and economy are well acknowledged in the scientific community (Foley et al., 2005; Liu and Diamond, 2005; Wu et al., 2007). Optimal land use planning is a primary issue for terrestrial ecosystem management in the world (Brody, 2003; Bousquet and le Page, 2004; Pourebrahim et al., 2011). The multiple objectives of land use decisions can lead to substantially different consequences (Haberl et al., 2001; Krausmann, 2001; Krausmann et al., 2003; Verburg et al., 2004; Lee et al., 2011). Policy makers and stakeholders have the right to decide on how to use the land currently and in the future (FAO, 1995). Thus, they require improved understanding of the opportunities and limitations to regional development and environmental protection associated with LUCC.

The use of simulation models to study dynamic changes in land use has become a widely used technique, and will be used in the current study to examine land use decisions and environmental economic impact (Kline et al., 2007; Schulp et al., 2008; Verburg et al., 2009). A number of land use models have been developed in the last decade based on methods of systems analysis (de Wit et al., 1988; Rabbinge and van Latesteijn, 1992; Kruseman et al., 1995; Kuyvenhoven et al., 1995; Penning de Vries et al., 1995). Many studies focus on specific land use change processes where one conversion is dominant, such as urbanization, deforestation and agricultural intensification (Engelen et al., 1995; Hilferink and Rietveld, 1999; Brown et al., 2000; Lambin et al., 2000; Mas et al., 2004; He et al., 2008).

These models simulated land use change either as a function of land use, or based on the empirical relationship between land use and driving factors (Pijanowski et al., 2000; Pontius et al., 2001). However, different processes are taking place at the same time, mutually influencing each other.

Integrated modeling approaches are essential for the complex analyses of land use change. These integrated modeling approaches can address both the development of individual land use types, as well as spatial interactions and competition between land uses. Land use change results from interactions between numerous influencing factors. Single factor models are often incapable of accurate simulations of the actual land use change process. Integrating multiple processes within one model is challenging, since different processes determine the dynamics of various land use types. A clear distinction is made between the spatial allocation of land use to individual locations (the spatial location of change) and the determination of the aggregated area of change (the quantity of change).

The LUCC and global land project (GLP) promote the development of land use change and land cover research. Land use change has been thought of as the comprehensive result of both society and the natural world. The major challenge of such studies is to deal with multiple processes interacting at different tempo-spatial scales. There have been some integrated land use models (Pijanowski et al., 2006; Soares-Filho et al., 2006; Verburg et al., 2006, 2008, 2013; Dietzel and Clarke, 2007; Overmars et al., 2007; Sohl et al., 2007; Tao et al., 2009) .

Significant changes in land use and land management have taken place in China over the last decade, as the country embarked on market reforms and active participation in the global economy (Lin and Ho, 2003; Liu et al., 2009). China, as the most populated country in the world, tries to meet its food needs by improving domestic agricultural production (Brown and Funk, 2008). However, with such a large population, China has to make up any shortfall in domestic production through trade with other countries, and in this way influences global agricultural markets. Considering global socio-economic driving factors is necessary when studying land use changes in China.

So the key questions about land use models include two aspects. The first is the coupling of multiple factors and multiple processes. The second is scale interactions. In this study, we attempt to develop a global-regional coupled model system, in order to link socio-economic factors and land use changes, and to investigate scale interactions. Global economic changes are accumulated as the total effect of region level land use changes, and can be analyzed and predicted according to human decisions and behaviors. The integrated regional level land use model will take the total land use demands on the regional level and then allocate them to sublevel spatial units until the smallest geographic units are reached. The modeling approach, which integrates global economic changes with regional level land use changes, is illustrated using a simulation of a scenario for future land use in China, under conditions of environmental protection and global economic development.

2 Materials and methods

2.1 Global socio-economic model

The global socio-economic model used in this study is the newly developed Global Food System model (GLOB-FOOD) (Jiang et al., 2013), within the SIMILE declarative modeling framework (Muetzelfeldt and Massheder, 2003; http://www.simulistics.com). Figure 1 shows the global socio-economic model structure. The socio-economic model includes 145 country units in which three aspects (consumption, production, and land use quantity) are simulated, respectively.

In our socio-economic model, population growth is the primary force driving the development of agricultural food production. Pressures on food supply comes not only from growing populations, but also from food consumption per capita and food preferences, such as dietary habits, societal structure, religious beliefs, and individual wealth. Consumption is divided into three major types. These are consumption of cereal, consumption of meat, and milk consumption.

The relationship for meat consumption per capita can be described as

$$M_t = M_0 \times \left(\frac{P_t}{P_0}\right)^m,$$

where M_t and M_0 stand for meat consumption per capita at time t, and a reference baseline, respectively; P_t and P_0 stand for GDP per capita at time t, and a reference baseline; and m is a changing parameter.

Milk consumption can be described similarly as

$$N_t = N_0 \times \left(\frac{P_t}{P_0}\right)^n,$$

where N_t and N_0 stand for milk consumption per capita at time t and a reference baseline; P_t and P_0 stand for GDP per capita at time t and a reference baseline; and n is a changing parameter.

A global trade method is used to calculate the balance of agricultural commodities between production and consumption at the global level through trade flows between countries (Tongeren et al., 2001; Tebaldi and Lobell, 2008; Tongeren, 2008).

Crop yield is affected by climate change and technological sophistication, which vary in impact across different regions.. The production model translates consumption

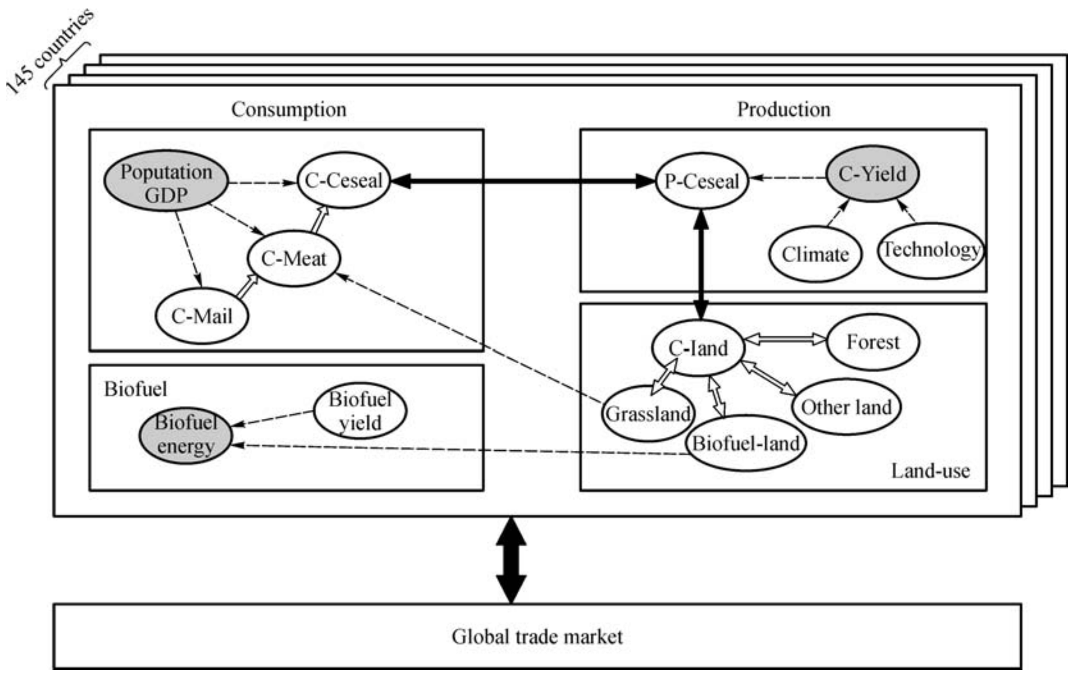

Fig. 1 The diagram map of GLOBFOOD (abstracted from Jiang et al., 2013).

demand into agricultural land use that can be used to meet the demandin each country. Different types of food demand determine major transitions in land use between agricultural arable land and other land sectors, (e.g., forest, grassland, and land used for biofuel production).

2.2 Land use spatial allocation model

Our land use spatial allocation model is an extension of the CLUE model (Veldkamp and Fresco, 1996; Verburg et al., 1999, 2002, 2006; Castella and Verburg, 2007; Verburg and Overmars, 2009), which is based on the spatial allocation of demand for different land use types to individual grid cells. Based on the CLUE model, we coupled ecosystem processes with land use change processes. The ecosystem processes dominated land use spatial patterns. The rational and detailed evaluation of the coupling model TES-LUC (Terrestrial Ecosystem Simulation-Land Use Change) is summarized in other studies (Gao et al., 2007; Xu et al., 2009).

Land use in China is grouped into the following six types: crop fields (CROP), grassland (GRAS), forest land (FORE), buildings (BUIL), water bodies (WATE), and other land use (OTHE), using the following equation:

$$\begin{aligned} LU(r) &= LT_j, \text{ if } \max_{k=1,2,3,4,5,6}(F_{site,k} + F_{\exp\ t,k} + F_{loss,k} + D_k) \\ &= F_{site,j} + F_{\exp\ t,j} + F_{loss,j} + D_j, \end{aligned}$$

where $LU(r)$ is the land use variable, r is the spatial location variable (r^{th} grid cell), and LT_j is the value of LU (r), specifying the type of land use. In the present study, LT_j = CROP, or GRAS, or FORE, or BUIL, or WATE, or OTHE, for j = 1, 2, 3, 4, 5 and 6. $F_{site,j}$ is a site suitability factor, statistically derived from the relationship between current land use and site variables, such as climate, topography, people and economy. $F_{\exp\ t,j}$ is the weighted average of the expert fuzzy membership functions. $F_{loss,j}$ is a factor derived from past land use change data to quantify the likelihood of j^{th} land use type's being transferred to other land use types. Thus, $F_{loss,j}$ characterizes the reciprocal of land use stability. D_j is a series of constants determined by socio-economic demands for a specified land use structure. The subscript j here indicates they are factors for the j^{th} land use type. Hence land units (grid cells) will be allocated to types that have the maximum suitability and stability, adjusted by the demand.

Site suitability $F_{site,j}$ was calculated using a function of mule variables.

$$F_{site,j} = \frac{\exp\left(a_j + \sum_{\xi=1}^{m} b_{j\xi} X_\xi\right)}{1 + \exp\left(a_j + \sum_{\xi=1}^{m} b_{j\xi} X_\xi\right)},$$

where X_ξ for $\xi = 1, 2, 3, \ldots, m$ is a series of site variables. In our case, these variables were site slope, site elevation, mean annual temperature, cumulative daily mean temperature during the growing season, annual mean precipitation, and precipitation during the growth season. All of these special variables were quantified from long-term climate data and population data. Coefficients a_j and $b_{j\xi}$

were estimated by applying linear regression to the land use variable on all of the site variables within China. The land use variable equals 1 if a site is currently occupied by land use type *j*, or zero otherwise. Only those coefficients that were significant were used in the land use model.

$F_{\exp\ t,j}$ was calculated using the following equation:

$$F_{\exp\ t,j} = \sum_{i=1}^{n} w_i f_i(x_i),$$

w_i is the weight determined by the relative correlation between land use and the i^{th} influence factor x_i.

The calculation of loss likelihood ($F_{loss,j}$) requires that there are at least two maps of land use for different time periods, so that a Markov transfer matrix of land use changes can be derived. In particular, element μ_{ij} in the $q\times q$ Markov matrix is the conditional probability that land use type *j* transfers to land use type *i* in the next period. μ_{ij} is equal to the approximate number of sites transferred to land use type *i* in the later map, divided by the total number of sites of land use *j* in the earlier map. $F_{loss,j}$ is then calculated as

$$F_{loss,j} = \sum_{i=1,i\neq j}^{q} \mu_{ij},$$

where q is the total number of land use types in the region. In this study $q = 6$.

2.3 Linking the global socio-economic model and the land use spatial allocation model

As illustrated in Fig. 2, we linked global socio-economic processes, ecological processes, and regional land use change processes in China. Socio-economic processes in our model were simulated using a newly developed global food system model GLOBFOOD (Jiang et al., 2013) which simulates the global socio-economic drivers for land use change. The GLOBFOOD model optimizes the allocation of different land use requirements under different conditions of balance between food supply and demand, caused by dynamic changes in socio-economic structure. For a given socio-economic situation, such as population growth, gross domestic product (GDP) per capita, global trade, consumption structure, and yield changes, the global socio-economic model simulates competition and an equilibrium point in several land-intensive sectors, and quantifies the demand for areas of different land use types.

Then, land use spatial allocation processes were simulated using a land use spatial allocation model (modified CLUE model) (Veldkamp and Fresco, 1996; Verburg et al., 1999, 2002, 2006; Castella and Verburg 2007; Verburg and Overmars, 2009). The land use spatial allocation model was capable of simultaneously simulating competition among multiple land use types. This was accomplished by employing a weighted suitability index,

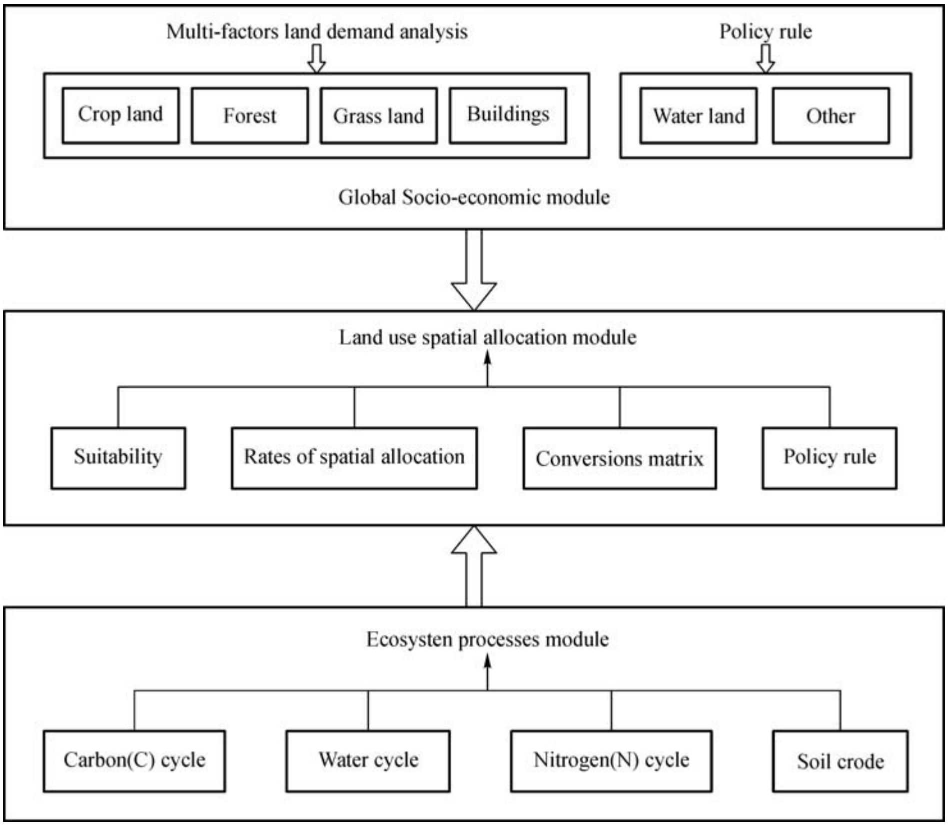

Fig. 2 Integrative model combining the three modified models.

derived from expert knowledge about the state of the ecosystem, and site conditions. Concurrently, a modified terrestrial ecosystems simulation model (TESim) was used to simulate the ecosystem state and site conditions. Simulations using TESim were coupled with simulations using the land use spatial allocation module. Coupling the land use spatial allocation model with the ecosystem processes model was summarized and reported previously by Xu et al. (2009).

Linking the regional land use model with the global socio-economic model was realized via an iterative procedure. The global socio-economic model was driven by an initial socio-economic driving factor. The output values, using the global socio-economic model for the quantitative demand of different land use, were then used as input for the land use spatial allocation model. The land use spatial allocation model then was applied to allocate areas of different land use types to each cell of the spatial grid. Concurrently, the ecosystem processes model calculated the ecological and environmental effects of the allocation. Then, based on selecting the largest suitability index, individual cells in the grid were allocated to a particular land use type. After all of the cells of the spatial grids were allocated, it was expected that we would get the desired amount of crop fields, forest land, grassland, and buildings, and spatial patterns of land use. This completes the first round of simulation. If the newly adjusted land use cannot meet the demand set after the first round of simulation, we edit the iterative constant D_j; and the land use spatial allocation model is run for a second round, allocating land use demand again. The land use spatial allocation model allocates land use demand to individual grid cells until the demand has been satisfied, by iteratively comparing the allocated area of the individual land use types, which signals the convergence of the procedure and stops the iteration. If all of the suitable grid cells will not satisfy the demand for a specific land use type, then, we edit the land use demand of GLOBFOOD based on the largest suitable area. The data flow is shown in Fig. 3.

2.4 Data preparation

The data used included two land use maps of China quantifying land use changes from 2000 to 2005 from the Chinese Academy of Resources and Environment Science Data Center. $F_{loss,j}$ was derived from these land use maps by using the transfer probability of the Markov matrix between the two land use maps. Regional DEM with 50 m resolution coming from the State Bureau of Surveying and Mapping was used to calculate all topographical variables. All of these spatial variables were re-sampled using ArcGIS at a linear resolution of 1 km. Daily weather records from 685 weather stations from the National Weather Service covering the time period from 2000 to 2007 were interpolated into the regional maps with the same resolution. The interpolated daily climate data was then used to drive the model simulation. The site controlling factor $F_{site,j}$ and the weight in the joined expert membership function w_j were also calculated from these data. The GDP, production per unit, population of every country, and the trade surplus between countries came from the statistics department. These data were used to drive the global socio-economic model and to generate different scenarios.

2.5 Scenario design

The scenario approach is widely used in many sciences (physical, economic, and social) in varied circumstances and for different purposes. Scenarios represent one of the main tools in climate change analyses and has been used in series of IPCC assessment reports characterized by different considerations of storylines. Currently, there are new initiatives to encourage new scenario design approaches to include more socio-economic developments interactively, the so called Shared Socio-Economic Pathway (Moss et al., 2010). In the current context of rapid economic development, environmental issues have become increasingly important. So, based on the two components of economic development and environmental protection, we used two scenarios to illustrate the different development pathways in terms of land conversion and degradation, yield increase, and consumption changes. Scenario A represents policies of implementing regional environmental protection, while scenario B stands for sustainable economic development in a global context. The parameter of the GLOBFOOD model under the two scenarios is shown in the Table 1.

3 Results

3.1 Conversion matrix of land use

Land use change was quantitatively calculated based on the transition features of different land use types between 2000 and 2005. According to the statistical analysis of land use change frequency, the transition rules of different land use types were determined; and the transition indices were shown in Table 2. The larger the transition indices, the more probability that a certain land use type will change into some other and vice versa.

Table 2 shows that the transition indices for buildings and forestland were larger than others, 52.66% and 41.63%, respectively. The main cause was rapid economic development and the rising level of urbanization. The expansion of forestland was attributed to the increasing awareness of the value of protecting the ecological environment. The transition indices for grassland and water land were smaller, 23.46% and 22.28%, respectively. Considering the local conditions, the transition index of

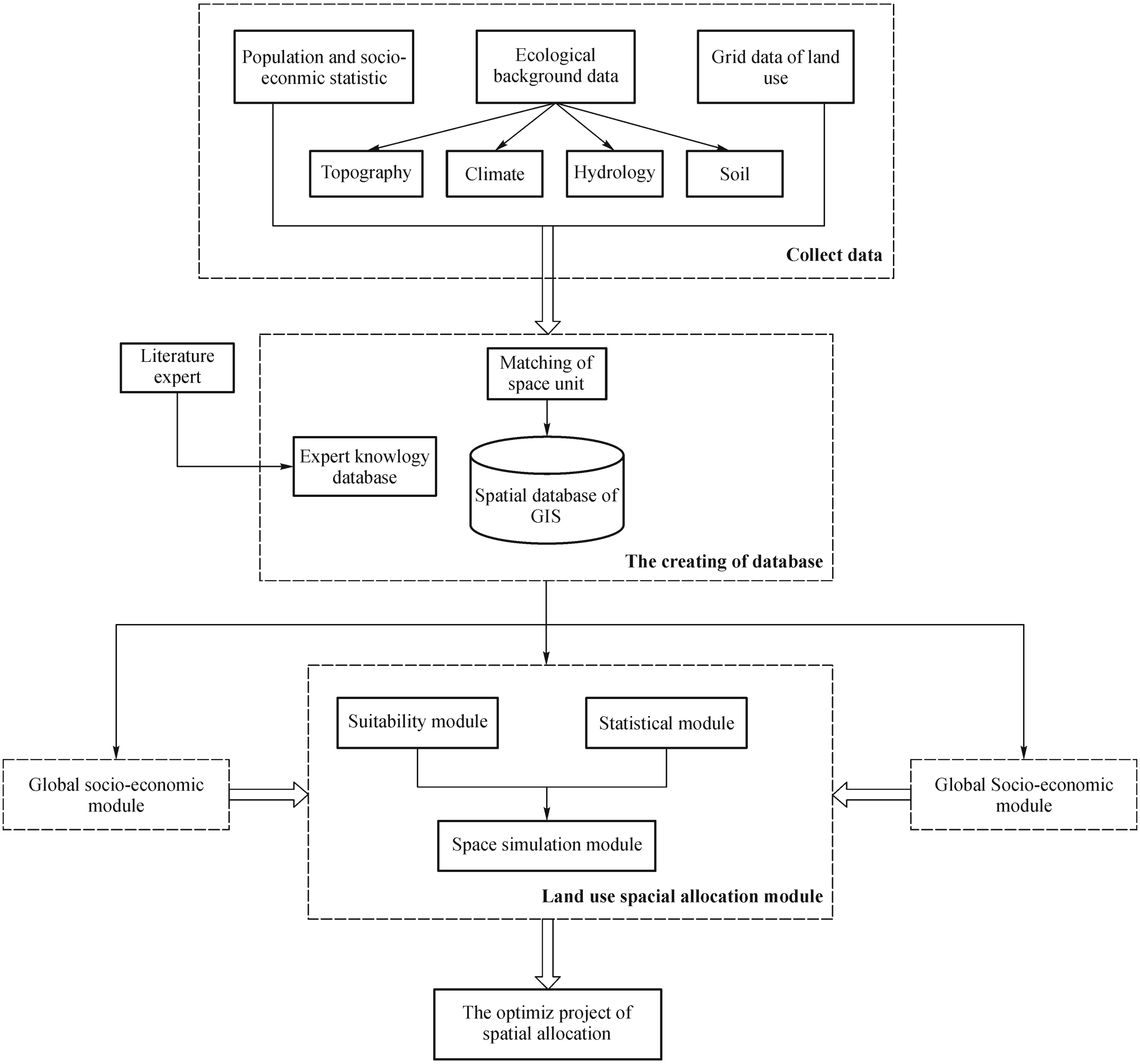

Fig. 3 Sketch map of data flow (modified from Xu et al., 2009).

ecology protective land, such as water land, was set at 0 during the space allocation process. Ecology protective land would not be allowed to be transferred to any other type of land use.

Table 3 shows inter-transition possibilities between the different land use types. From Table 3, the main performance of the land use conversion was the mutual transition among cropland, forestland, and grassland. The possibility of cropland's being transformed to grassland or forestland is 98.16% when the transition of cropland takes place. The value for grassland to cropland is 54.87%, and grass land to forest is 43.33%. The other main change is the expansion of building areas, which will change the existing land for buildings in the process of urban construction and economic growth.

3.2 Quantifying change of land use

Table 4 lists the future possible changes of major land use types generated by the global socio-economic model. Compared with land use in 2005, in general, both scenarios show clearly the rapid growth of buildings areas, which may be the result of high-speed economic growth. Under the regional environmental protection scenario, areas of cropland and grassland decrease by 1.43% and 0.72%; and the area of forestland increases 1.05%, in line with China's Grain for Green Program.

Under the global economic development scenario, the areas of cropland, grassland, and buildings show significant increases, by 11.55%, 52.38%, and 19.66%, respectively. This is bound to take up a lot of forestland

Table 1 The parameter of the GLOBFOOD model under two scenarios

Parameter	A	B	Notes
Population	* [– 1,1]	* [– 1,1]	SERS at country level
GDP	* [– 2,2]	* [– 5,5]	SERS at country level
Cereal consumption	* [– 2,2]	* [– 5,5]	Cereal consumption per capita
Meat consumption	0.46 [– 10,10]	0.55 [– 10,10]	Extend the current elasticity relationship between consumption per person and GDP to future scenario
Milk consumption	0.30 [– 10,10]	0.35 [– 10,10]	Extend the current elasticity relationship between consumption per person and GDP to future scenario
Yield changes due to technology, climate change etc.	10% 30%	50% 75%	We combine all the factors into one value to simplify the different impacts, divide countries into different groups with GDP, which will take different levels of yield advance
Land degradation or natural loss	– 0.2% [– 10,10]	– 0.5% [– 10,10]	Natural land lost considered here for all types of land use types Over-grazing degradation is not included here
Trade (integrated market level)	30% [– 50,50]	50% [– 50,50]	This determines the rate of trade to meet demand
Feed rate	0.005 [– 10,10]	0.01 [– 10,10]	This shows the technological development of conversion from cereal to meat and milk. The same rate applies for all countries

Notes: We quantify the parameters in the two scenarios A and B with a mean value and an uncertainty level, for example 5 [– 10,10] means we will assign a (4.5, 5.5) to a factor. Exceptions are that GDP and Population are used as absolute values. All other factors in the model are considered as relative changes compared to year 2005. The * means real data at country level and can be used directly by the model.

Table 2 Conversion rate of different land use types (%)

Conversion	Cropland	Forest	Grassland	Buildings	Water land	Other
2000–2005	34.96	41.36	23.46	52.66	22.28	38.82

Table 3 Conversion rate between different land use types (%)

Conversion	Cropland-forest grassland	Grassland-crop	Forest-crop	Forest-grassland
2000–2005	98.16	54.87	23.86	19.85
Conversion	**Grassland-forest**	**Other-water land**	**Other- buildings**	**Water land-other**
2000–2005	43.33	63.53	98.65	39.65

Table 4 Different land use type areas under two scenarios. A represents the regional environmental protection scenario and B stands for the global economic development scenario (Unit: 10,000 hm^2)

Scenario	Cropland	Forest	Grassland	Buildings	Other
2005	12208.27	24729.01	26214.38	3192.24	29656.10
2020A	12033.33	24992.02	26025.43	3724.00	26324.80
2020B	13618.75	17624.14	39944.93	3819.92	20992.26

and other land use areas. It also shows the pressure on land for food production, and the background of rapid urbanization. This indicates that we must put effort toward protecting the environment while pursuing economic growth. In scenario B, declines in areas designated as "other", and forest lands were greater by 25.4% and 41.8% respectively, compared to those in scenario A. Areas of cropland, grassland, and buildings under scenario A show significant increases, 11.6%, 34.8%, and 2.5% respectively. This shows that simply seeking the most economical return with less environmental concerns will lead to a lot of excessive land use transitions into cropland, pasture, and buildings.

3.3 The spatial allocation of land use

Figure 4 shows the spatial distribution patterns of land use in China during 2005. The spatial distribution of different

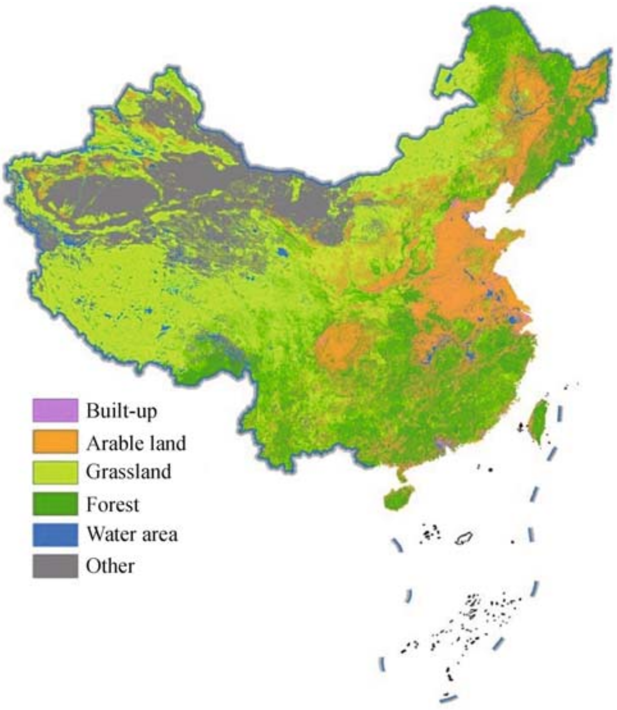

Fig. 4 The spatial pattern of land use of China in 2005.

land use has significant regional differences. Cropland is mainly distributed in the eastern humid climate, with flat topography, and the population relatively concentrated in an area where natural conditions are superior. Forest land is primarily in China's northeast area, the subtropical zone, and the southern subtropical zone. Grasslands are in the Qinghai-Tibet Plateau district, northwestern Xinjiang, and Inner Mongolia. Buildings areas were concentrated in the eastern densely populated areas, intersecting with cropland.

Overall, land use distribution had not changed very much. The reason is that the distribution patterns of various land use types is formed by a long historical development process, compatible with the natural and geographical environment in China. It is unlikely that major changes will occur in the short term. In the North China region, Loess Plateau region, Qinling region, and farming-pastoral belt of Inner Mongolia, most croplands were turned into forest and grasslands. In the eastern region of Inner Mongolia, the borderline of the northwest arid, and oasis agricultural regions, grassland, however, was turned into cropland. The land use change in the Tibetan Plateau was quite slight; and only the areas of water land experienced a little expansion. The east and southeast coastal regions of China, including the Beijing, Tianjin, and Hebei Province, Yangtze River delta, and Pearl River delta, are experiencing high levels of urbanization. Land used for construction, most of which was once irrigated land, is increasing due to intensive urban and technological development.. Undue emphasis on increases of GDP has led to great losses of high-quality cropland resources. The invasion of towns primarily occurred in the southern paddy field areas, the Huang-Huai-Hai region, and the southeastern coastal areas.

From Fig. 5, we compare the land-use spatial distribution pattern under the two different scenarios (scenario A minus scenario B), which is very conducive to the further analysis of land use change and its impact on the ecological environment. Under the regional environmental protection scenario A, cropland areas will increase remarkably in Southeast China, the Huang-Huai-Hai Plain, Sichuan Basin, where generally covered with fertile soil of potential high productivity. In the northeast and northwest ecotones around crop-herd, crop-forest, and edge of the desert, crop lands will decline mildly. At the same time, increasing areas of forest and grassland are mainly found in Northeast and Southwest China, corresponding to the declined cropland area. This agrees with the current state land use strategy during the twelfth five year plan in China: maintain the high productivity cropland while converting the low productivity arable land into natural land. Large decreases of grassland are found in the Southeast China where cropland increases.

As long as China is in a rapid development phase of urbanization and industrialization, the demand of built-up land, including urban areas, mining areas, and rural residential areas, will follow an increasing trend. In 2020, the built-up land area will be, respectively, 37.24 million hectares and 38.20 million hectares, under the two different scenarios. The expansion of building areas

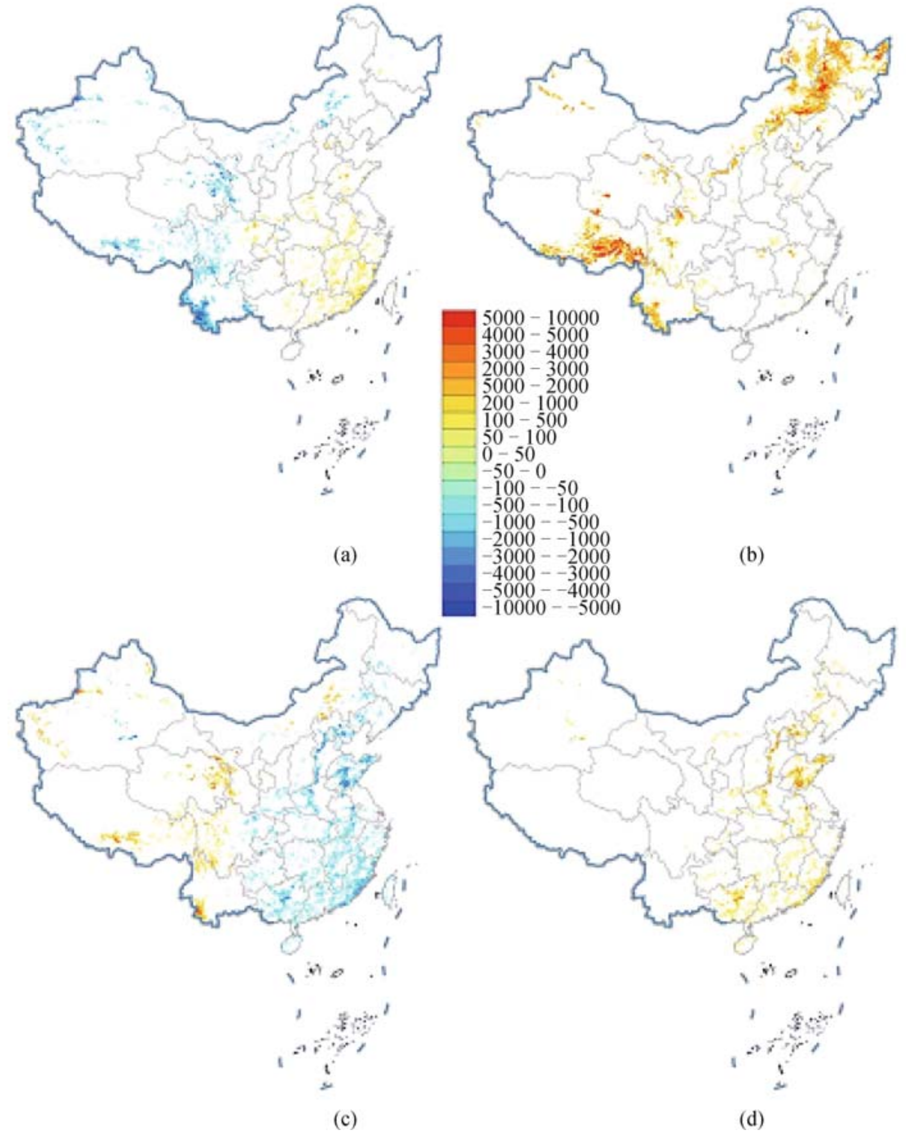

Fig. 5 Difference land use spatial pattern between regional environmental protection scenario A and global economic development scenario B (scenario A minus scenario B) in 2020 for four main land use types: a) Crop land; b) Forest land; c) Grass land; d) Buildings. Unites are hm^2.

occurred mainly in the eastern region of China. The most significant growth areas were the southeast coastal region, the Beijing-Tianjin-Tanggu region, the Huang-Huai-Hai Plain, the Yangtze River delta, the Pearl River delta, and the Sichuan Basin region, occupying major crop land resources of high-quality.

4 Discussion

Land use change is the result of interactions between processes operating at different scales. Different processes determine the dynamics of various land use types. At the same time, if they have different scales, the processes affecting land use change have a greater difference. The linking of global and regional processes within an integration model, as presented in this paper, is a step towards addressing cross-scale interactions in land use modeling more effectively.

Multi-scale interactions are important issues in land use change studies. The importance of cross-scale dynamics for land use change processes has been identified in many land use change studies (Bolliger et al., 2005; Rindfuss et al., 2008). Multi-factor interactions are also important issues in land use change studies. However, the implementation of multi-factor interactions in a model is difficult due to changing social realities and analyses. Social processes, such as the population growth, economic development, changing trade, agricultural policies, energy crop demand, and increasing food demand, will lead to complex, path-dependent dynamics, with cross-scale and multi-factor interactions (Crawford et al.,2005; Rindfuss et al., 2008). Although some land use models incorporate feedback between scales and social and economic factors, the integration of regional and global processes, and the influence of social and economic factors on the land use changes are often largely simplified.

This paper has presented an approach that links global socio-economic influences to a regional land use change model framework for China. The global socio-economic model is designed at the country level, which perfectly suits social or policy practices, and easily handles the scale of economic activity. Output from the global socio-economic model is then used as the driving input for the regional land use spatial allocation module, which simultaneously simulates the competition between multiple land use types by employing a weighted suitability index, derived from expert knowledge about the ecosystem state and site conditions.

The model results for China show clearly the increase of cropland areas, building areas, and decline of natural vegetation areas, in accordance with the results of Liu et al. (2009). The results for China indicate the importance of taking into consideration the process of global socio-economic influences. Especially locations with less favorable conditions for crops are facing land abandonment, with favorable conditions for crop conversion to buildings. The expansion of built-up land areas will be occurring mainly in the eastern regions of China, the Beijing-Tianjin-Tanggu region, the Huang-Huai-Hai Plain, Yangtze River delta, the Pearl River delta, and the Sichuan Basin region, occupying major crop land resources of high-quality. Producers in these areas face competition from other production regions that have a comparative advantage that influences their economic sustainability. So, before we make land use decisions, we must think over food supply systems and assess the uncertainties coming from various environmental and socio-economic factors.

The modeling framework proposed in this study could explore global socio-economic influences on land use changes, and simulate regional land use dynamics. Long low-input agricultural systems will cause soil degradation, which may prevent future productive use of the soil. Therefore, ecosystem processes coupled with fertilization processes need to be taken into account. In addition, the simulation of low-input agricultural systems with fallow periods as part of the crop rotation may be captured by combining an assessment of the overall demand for agricultural production with the processes of soil fertility dynamics. Further integration will be needed. Consistent processes to manage these conversions on a regional level with given regional targets could provide for the systematic assessment of land use decisions.

The simulation results of this study show only a possible picture of future land use change, with great uncertainty, and do not represent actual changes in future land use. First of all, the model assumes that the relationship between land use change and its driving factors is unchanged in the short term. Secondly, the model parameters, such as land use conversion rules, and the stability of the strength of land use types, are set based on expert experience, which includes a certain degree of uncertainty. This study is based on the simulation of planned scenarios. Whether simulation results will be close to the actual future also depends on how successfully objectives can be achieved. Therefore, the results of the study indicate only possible trends in the spatial distribution of land use change. In the future, comparing simulations with and without coupling and feedbacks between land use spatial distribution and socio-economic processes could be useful for decision-making processes in considering alternative policy options.

The integration of global and regional processes in a consistent modeling framework may also be relevant for other processes and in other areas, e.g., where large scale logging results from a global demand for crop commodities, and interacts with the regional processes of an ecosystem. This is a first attempt to link global and regional models and to include global socio-economic driving factors onto regional land use planning. More studies down the line should be encouraged.

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