Chapter 112
Simple Simulation of Abandoned Farmland Based on Multiagent Modeling Approach

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Abstract In recent years, the agent-based model (ABM) has been widely applied and popularized in land-use and land-cover change (LUCC). It expresses the spatiotemporal heterogeneities of a model with individuals and ultimately obtains the emergence of individuals' behaviors on a macroscopic scale. This paper takes Taipusi Banner in the Inner Mongolia farming-pastoral zone as the study area based on local questionnaire data. The model synthesizes climate factors, the Grain for Green policy, direct subsidies of grain, and socioeconomic factors and simulates household farmland use behaviors in the next 30 years based on the Repastj toolbox in the Java language and in Eclipse. This model precisely reflects the LUCC process and its corresponding factors' interactions, provides deep insight into the integration process of these factors, and gives advice to governments on how to make land-use and food-security policies long-lasting and reasonable.

Keywords Agent-based model • Artificial intelligence • Inner Mongolia farming-pastoral zone • Abandoned farmland • Climate

112.1 Introduction

Farmland use plays an irreplaceable role in the development of agriculture and national economy [1]. Few studies focus on the relationship of livelihoods and land use in China. Integrating households' livelihood to study changing trends in farmland and ways of adapting to those changes is a frontier area of research that can be explored to realize the sustainable development of ecologically fragile regions [2].

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W.E. Wong (ed.), *Proceedings of the 4th International Conference on Computer Engineering and Networks*, Lecture Notes in Electrical Engineering 355,
DOI 10.1007/978-3-319-11104-9_112

A land system is a coupled system comprised of a human society and the natural environment. The Global Land Project asserts that we need to improve our understanding of how human activities influence the natural processes of the terrestrial biosphere [3]. However, traditional models, for example, System Dynamics, CLUE-S, Cellular Automata, and Markov chain, often ignore human activity. The agent-based model (ABM) can simulate individuals in complex systems from a bottom-up perspective. It defines behavior rules and interactive mechanisms of individuals and pays more attention to human influences. More and more applications and spreads have been adopted using ABM in the area of land-use and land-cover change (LUCC) [4]. In an early application of ABM in another country, Balmann developed a simulation of agricultural land change based on ABM in 1977. This simulation concerns the competitive relationships of farms under different policies [5]. In China, Chen [6] explored households' decision-making processes on different scales. Pan [7] studied different types of household land-use behaviors under natural-environment, government, and enterprise-subsidy mechanisms.

In recent years, farmers in the Inner Mongolia farming-pastoral zone have experienced land degradation, frequent drought, government subsidies, working in the city, among other things. Households' livelihood strategies and farmland use modes in this location change frequently. Farmers and related management institutions try new farmland uses, so an exhaustive study should be conducted to offer support for adaptive and sustainable farmland use.

112.2 Overview of Study Area

Taipusi Banner (Fig. 112.1) is located in the south of the Xilin Gol League. It is a fragile area in the north farming-pastoral zone. This banner is located in a fast-growing, high-yielding region, is part of a grain subsidy project, and falls within the Grain for Green project, so studying the effects of government policies can assist government in making improvements in policies. Recently, as the drought has intensified and the social economy developed, an increasing number of agricultural labors have gone to the big cities and more and more farmland has been abandoned. Because currently China's land system is one that gives responsibility to households, households' land-use decisions (especially for abandoned farmland) are directly related to farmland-use changes. The study of farmland-use changes necessarily entails understanding the households' farmland using behaviors.

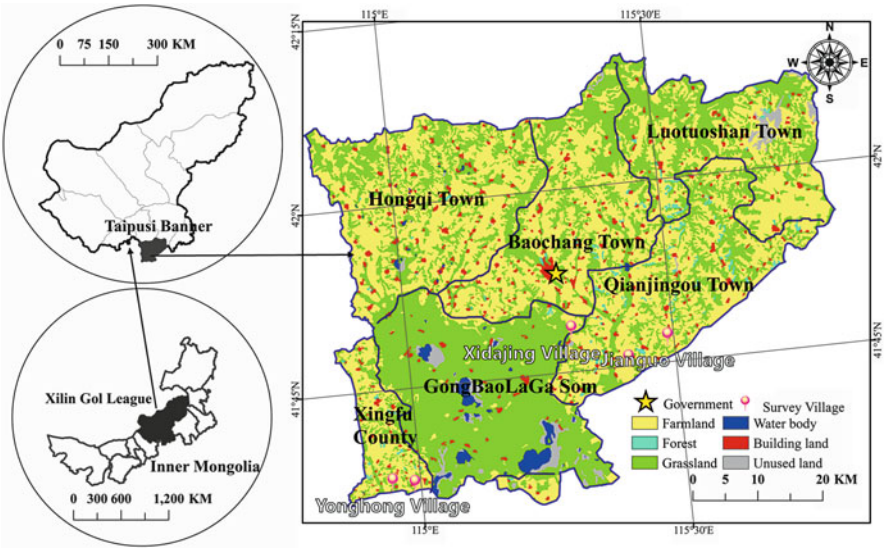

Fig. 112.1 Geographic location and land cover of Taipusi Banner (LUCC data in year 2000 are from the Data Center for Resources and Environmental Sciences, Chinese Academy of Sciences)

112.3 Research Data and Methods

This study uses questionnaire data gathered from households on the spot and statistical data on socioeconomic development. Questionnaire surveys can be used to obtain household information related to population and economic structure, means of livelihood, and farmland use.

Questionnaire surveys were carried out in July of 2011. Study villages' information is listed below (Table 112.1), and 161 households were interviewed. Questionnaires include three parts: (1) basic socioeconomic characteristics of households and their family members, for example, gender, age, job, and educational level; (2) farmland quality, current use and transfer, households' livelihoods' behaviors, sources of family income; (3) natural disasters and households' adaptive abilities.

In this paper, a statistical analysis technique is used to extract households' behavior rules based on questionnaire data. For ABM, the RepastJ toolbox and Java language are used to build a multiagent model platform for simulating households' farmland-use behaviors in a secondary development way.

Table 112.1 Basic information on villages surveyed in questionnaires

Village	Longitude (E)	Latitude (N)	Elevation (m)	Distance to center (km)	Number of questionnaires	Sample rate (%)
Jianguo	115°29′	41°47′	1,439	20	28	9
Jiuyingpan	115°24′	41°45′	1,421	15	36	12
Xidajing	115°18′	41°48′	1,446	10	19	13
Yonghong	114°57′	41°37′	1,418	50	40	17
Chongguang	114°59′	41°37′	1,390	45	39	17

112.4 Framework of Abandoned Farmland Model Based on ODD Protocol

Because theoretical research on ABM lags behind application research, Volker Grimm at the Leipzig-Halle Research Center in 2006 proposed the overview, design concepts, and details (ODD) protocol to describe a standard ABM [8]. He updated this protocol in 2010 [9]. This study describes ABM in abandoned farmland by households according to the ODD protocol (Table 112.2).

112.5 Main Model Components

112.5.1 Configuration of Running Environment

This study takes the RepastJ toolbox as the modeling tool and uses Java to construct an ABM platform in the Eclipse integrated development environment. Repast (Recursive Porous Agent Simulation Toolkit) is an agent modeling tool developed by Social Sciences Computing at the University of Chicago [10]. The initial running environment is land-use/land-cover data of a real geographical environment in the year 2010 with 100 m cell size. In the left panel of Fig. 112.2, the purple cells represent farmland, green cells represent grassland, red cells represent building land, blue cells represent water bodies, and white cells represent no data. In Fig. 112.2, middle, green cells represent planted farmland, pink cells represent abandoned farmland, and yellow cells represent rented farmland. In Fig. 112.2, right, in the parameter configuration window, some running parameters can be set initially by modelers.

Table 112.2 Structure of ABM of abandoned farmland in inner Mongolia based on ODD protocol

	Element of ODD protocol	Model description using ODD
Overview	1. Purpose	Simulating process and trend of farmland use in study area under the influence of socioeconomics, climate, and governmental policies in the next 30 years
	2. Entities, state variables, and scales	Entities: households and government; state variables: external–internal factors of households; scales: households—regional
	3. Process overview and scheduling	Decision making: farmland-use decisions, abandon or plant?; rule: profit maximization; model update: annually
Design concepts	4. Design concepts	Whether households abandon their farmland or not is related to the local environment, socioeconomic factors, and governmental policies. Households adjust their planting behaviors to adapt to changes based on profit maximization
Details	5. Initialization	Land cover of study area, internal factors of households in 2010
	6. Input data	Climatic factors, governmental policies (for related details see Table 112.3)
	7. Submodels	Agent-generating module, agent-classification module, and agent decision-making module

Table 112.3 Main input parameters of ABM and its initial value

Name	Meaning	Initial value	Source	Changing rule
averageLand	Farmland per person	0.39 hm^2	Questionnaire	Do not change
maxDeathAge	Life expectancy	65–100	Questionnaire	65–100
numAgents	Number of households	1,000	Statistical data	Do not change
numPerHousehold	Family size	5	Statistical data	3–8
everEarned	Income from migrant workers per person	11,000 yuan/year	Questionnaire	Increase by 1–10 %
subsidyGFG	Subsidy for green for grain	160 yuan/acre	Questionnaire	Do not change
subsidyFood	Food subsidy	30 yuan/acre	Questionnaire	Do not change

112.5.2 Behaviors and Properties of Agents

This model includes three types of agent. PersonAgent represents family members, householdAgent represent families, and governmentAgent represents a nation which is used to describe government policies.

The properties of PersonAgent include ID, age, gender, education, status (e.g., children, farmer, undergraduate, migrant workers, the elderly). The activities of personAgent include, for example, studying, producing, and going out for job.

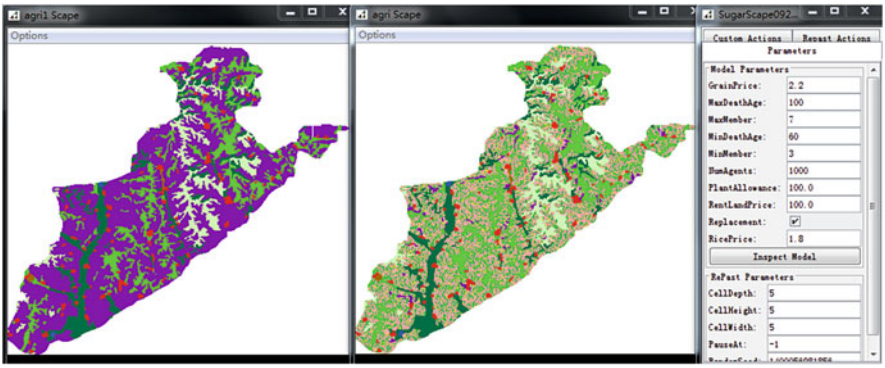

Fig. 112.2 Initial running interface (*left*), running interface at a specific time (*middle*), and parameter configuration window (*right*)

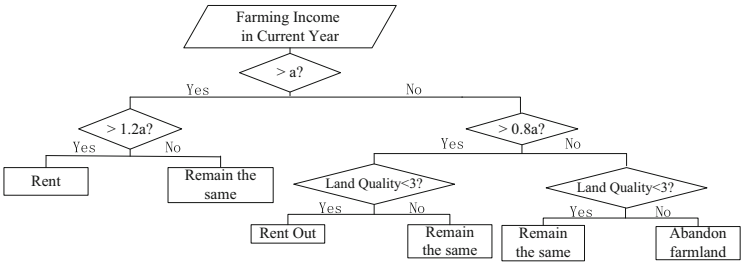

Fig. 112.3 Decision trees of household farmland-use behaviors

The properties of householdAgent include, for example, ID, family member, land, and family income. The activities of householdAgent include planting going out for job. The properties of governmentAgent include subsidy money and number of years of subsidies under the Grain for Green policy and food subsidies.

Based on questionnaires of people surveyed on the spot, this study obtains an average planting income for each household in 2010 of 1 yuan. Households adjust their planting decisions (rent, rent out, do not change, or abandon farmland) according to their planting income. The running rules of the model are displayed in a decision tree, as in Fig. 112.3.

112.6 Simulation Results

The model simulates changes in the number of current households that abandoned their farmland and population distribution of in the next 30 years. In this paper, the author analyzed five types of people: local workers, migrant workers, farmers, the elderly, and minors.

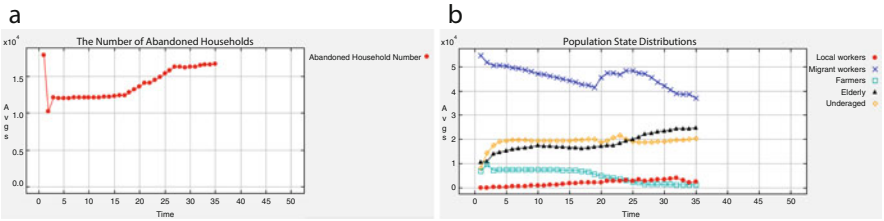

Fig. 112.4 Trends in number of abandoned households (**a**) and population distributions (**b**)

In Fig. 112.4, the *x*-axis represents the year, and the *y*-axis stands for the number of people. Figure 112.4a shows the number of households that abandoned their farmland remaining the same in the next 0–15 years. But in 15–26 years, the number of such households shows an increasing trend. Figure 112.4b shows that, in the next 0–15 years, the number of farmers will remain the same. But in 15–30 years, this number shows a decreasing trend. This changing pattern complements the trend of households abandoning their farmland. The number of migrant workers first shows a decrease and later an increase. The number of local workers does not obviously change, but there is a slightly increasing trend. The number of elderly people and minors shows a clear increasing trend.

On the basis of Fig. 112.4 we arrive at the conclusion that, under current conditions, a large proportion of farmland will be abandoned, and the composition of the population in the study area will be made up of elderly and young people.

The Grain for Green policy provided households with some financial support. This support caused some farmers to minimize their dependence on farmland and, to some extent, minimize the number of farmers. But the direct grain policy did not arouse the enthusiasm of households for planting farmland. This strategy needs to be adjusted; otherwise, more farmland will be abandoned in the future.

Conclusion and Discusssion

The ABM represents a combination of a complex adaptive system and distributed artificial intelligence and has been applied and popularized in the area of LUCC. This paper adopts the ABM as the modelling method, simulates the process of changing land-use behaviors by households under current natural factors, socioeconomic factors, and national governmental policies and predicts changes in trends in decision making regarding farmland use by households in the next 30 years. The simulation results show that if the current situation continues, more farmland will be abandoned. The government's Grain for Green policy has a negative impact on households' willingness to plant, but the policy of direct subsidies for grain has not motivated households to plant. To change this severe situation with respect to farmland

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use, households' awareness of the importance of planting needs to improve, and guidance is also needed on government policies.

The operating rules of this model are simple, for example, neglect state transfer mechanisms of households and family members and climate hazard factors. Households' decisions may have irregularities in this phenomenon, i.e., different households make the same decisions while the same households make different decisions. What's more, topographical factors, which may include spatial heterogeneities, are not included in this simulation. Last but not least, more multivariable and and multiscenario analyses will need to be conducted in the future.

Acknowledgments This work was supported by a special international cooperation program of the Ministry of Science and Technology (ID: 2013DFA91700) and the National Natural Science Foundation of China (41071344).

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