INTERNATIONAL CONFERENCE OF AGRICULTURAL ECONOMISTS
ICAE
29th | Milan Italy 2015
UNIVERSITÀ DEGLI STUDI DI MILANO AUGUST 8 - 14
AGRICULTURE IN AN INTERCONNECTED WORLD

Individual and Social Optima of Rural Land Allocation by Stakeholders: A Case Study on Eco-fragile Areas of Northern China

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This paper analyses the degree of divergences among different groups of stakeholders in allocation of the four types of rural land: cultivated, range, forest and other land, and the optimal allocation from the social perspective of balancing economic and ecological benefits. The preference of stakeholders stemming from stakeholders' different ecological and economic interests on four types of rural land was quantified by the Analytic Hierarchy Process. Weights for stakeholders in the social welfare function were derived for three social-economic scenarios. Welfare economics was employed then to determine the 'individual' or 'private' optimal allocation of each stakeholder by maximizing its utility function, and social optimal allocation by maximizing the social welfare function. A county located in the eco-fragile areas of Northern China was taken as a case to present the empirical analysis. Our results provide policy insights on how to regulate the divergences and achieve an efficient allocation of rural land.

1. INTRODUCTION

Rural land is used for production and subsistence to satisfy immediate human needs for food, fuel and ecosystem services (DeFries et al. 2007; Millennium Ecosystem Assessment 2003). However, as a result of economic development, technological progress, environmental change and policy and market forces, the total area of rural land is decreasing worldwide (Liu et al. 2010; Verburg et al. 2008). This inevitably raises the question of how to efficiently allocate the decreasing amount of rural land. Moreover, there are increasing divergences and conflicts on the allocation of rural land in many parts of the world, especially for populous countries such as China (Petit 2009; Williams and Schirmer 2012). The scientific research on the changes in rural land cover and efficient rural land allocation has received increased attention since the 1990s because of prominent problems due to overuse of natural resources and environmental deterioration (Turner Ii et al. 1993; Qasim et al. 2013). There is, however, lack of quantitive research on how to optimize the allocation of rural land comprehensively (Cocks and Ive 1996), considering the different interests of various people, groups and organisations that have a stake in rural land use – so called stakeholders (Barker and Selman 1990; Rambonilaza and Dachary-Bernard 2007; Zeng and Edwards 2010; Yang et al. 2012; Pacione 2013). Investigating the optimal allocation of rural land from the perspective of various stakeholders is necessary in light of the decrease of rural land and increasing divergences in rural land allocation. Therefore, this paper will start with identifying stakeholders and their interests in allocation of rural land, and employ empirical analysis to explore their individual and social optima that incoprorate their diverging preferences.

According to the stakeholder theory detailed by Freeman (1984), stakeholders are any groups or individuals who can affect or are affected by the achievement of an organization's objectives. In the case of rural land allocation in China, the main stakeholders include rural households who are using and benefiting from the rural land directly, and public authorities who decide the macro-level land use strategies. For example, several national programs have been introduced since the 1990s that attempt to steer rural land allocation in order to satisfy not only human needs for economic development but also the provision of ecosystem services. One of the main programs is the Sloping Land Conversion Program (SLCP, also known as the ‘Grain for Green’ program), initiated by the Chinese national government in 2000 in order to convert sloping cropland into forest or grassland (Liu et al. 2010). Such national programs that are directed at ecological conservation, may constrain the economic activities of local residents, while the majority of rural households in China rely on rural land for their livelihoods and economic benefits (Liu and Lan 2015). As such, the divergences of stakeholders on rural land allocation stem from the different extents of economic and ecological interests on rural land.

Divergences in allocation of rural land among stakeholders are particularly obvious in eco-fragile areas where ecological issues and widespread poverty are being confronted simultaneously (Ran et al., 2001). This is reflected in the poor implementation and high supervision costs of eco-environmental policies, ecosystem deterioration and illegal grazing of livestock on natural grasslands by rural households. Protective use is urged by the society because the eco-fragile areas play a crucial role in the ecosystem of China, but productive use is decisive to the livelihoods of rural households. We, therefore, take a county located in the eco-fragile areas of Northern China as a case to investigate the divergences and potential optima of rural land allocation considering the ecological and economic benefits of various stakeholders.

In the existing literature, optimal allocation of land is mainly studied either from the macro perspective referring to the regional strategy (Verburg et al., 2013), or aiming at local land use decisions at the rural household level (Kokoye et al., 2013). However, the interests of allocation by different stakeholders have not been investigated jointly. Moreover, most research analysed land allocation based on remote sensing data (Turner Ii et al. 1994; Zhan et al. 2007) and discussed the driving forces of land allocation based on qualitative analysis, econometrics or game theory (e.g. Angelsen 2001; Kokoye et al., 2013). Others have tried to determine an optimal landscape (Heijman and Mouche 2013). This paper will explore the optimal allocation of rural land by considering representative stakeholders in the study area and by maximizing a social welfare function which considers the utility of the different stakeholders. This approach is in line with other studies that have modelled environmental problems through welfare analysis (Gerlagh and Keyzer 2004; Gerlagha and Keyzer 2003; Zhu 2004).

The remainder of this paper is structured as follows. First, we present a conceptual framework of the process of rural land allocation to identify and categorize the stakeholders. Next, we derive the theoretical model starting with the utility function based on the preferences over desired rural land allocation for each stakeholder group, and then deducing the social welfare function considering the weights that are assigned to various stakeholder groups. In the empirical analysis, the Analytic Hierarchy Process (AHP) is used to quantify preferences for each stakeholder group for different types of land; three social-economic scenarios are considered to measure the weight of each stakeholder group; and eventually the individual and social optima of rural land allocation are derived based on the estimated parameters of preference in the utility function and weights in the social welfare function. This paper concludes with a discussion on the divergences of individual optima and differences between current rural land allocation and the social optima. It is hoped to provide some policy insights to regulate divergences of stakeholders in allocating rural land and achieve efficient allocation of rural land considering different stakeholders' ecological and economic benefits jointly.

2. CONCEPTAL FRAMEWORK

Both public authorities and rural households are identified as the stakeholders, because they can affect or are affected by the allocation of rural land. To further specify these stakeholders and understand their relationships, we employ the concept of the social-ecological system (SES) that was introduced by Ostrom (2007; 2010) to depict the process of rural land use allocation. The theory of SES is a diagnostic framework for the study of complex social-ecological system, considering the resource units, resource system, governance system and users as four core subsystems to link social, economic and regulatory settings and related ecosystems (Ostrom 2009). Figure 1, based on Ostrom's SES framework, demonstrates the conceptual framework of our study.

FIGURE 1. Schematic representation of rural land allocation process and relationships among stakeholders

In the process of rural land allocation, the crucial resource unit is land, categorized as cultivated land, forest land, rangeland and other rural land[1]. The resource system is the system of rural land allocation. As defined by Ostrom (2009) , the governance system is represented by the rules and regulations set at the level of the government and other organizations to regulate the resource. Hence, the governance system in our study is established by the public authorities that make and implement the rules to manage rural land allocation. Rural households, as the users of the rural land, are affected by these rules directly in terms of their land use decisions. These four core subsystems of the social-ecological system hereto present the linkages of social, economic and regulatory settings and related ecosystems in rural land allocation.

Considering that public authorities aim at economic development as well as ecological conservation in rural land allocation, they can be divided into public actors with an economic objective (economic authority) and public actors with an ecological objective (ecological authority). In fact, this is a simplified representation of reality which assumes that these public objectives can be separated. Rural households primarily focus on the economic benefits of rural land. However, some rural households may also pay attention to ecological benefits. For instance, herders who are solely dependent on the use of grasslands for livestock production have more awareness of grassland conservation than farmers who engage in both crop production and animal husbandry. As such, we divide the rural households into farmers and herders. In short, according to the positions in the social-ecological system and different interests in rural land use, four stakeholder groups are differentiated, including ecological authority, economic authority, herders and farmers. Furthermore, the resource units - various types of rural land - have different degrees of economic benefits as well as ecological benefits. For example, cultivated land is a combination of less ecological function and more economic function, but forest land provides more of an ecological function and less economic function. Moreover, different stakeholders have different estimations on the economic and ecological benefits of each type of land.

[1] We follow the rural land classification by AQSIQ (General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China) whereby rural land is divided into cultivated land, forest land, rangeland and other rural land (such as land used for raising animals, agricultural facilities, agricultural roads, pit-ponds, fishponds, irrigation, drying grains and forming ridges among croplands) according to the functions of land use in 2002.

3. MODEL SPECIFICATION

The above conceptual framework is formalized into the theoretical model based on welfare economics in this section. It involves the individual optima to maximize each stakeholder group's benefits and social optima to maximize all stakeholders' benefits as a whole. The former aims to explore the divergences of rural land use between stakeholder groups, and the latter is to investigate the efficient rural land allocation.

According to the theory of welfare economics, different agents have different demands on the consumption of various goods/services. This has led to the study of individual utility and social welfare optimisation for combinations of different goods characteristics (Heijman and Mouche 2013; Perman et al. 2011). In the process of rural land allocation, we consider the hypothetical society consisting of four individuals and four goods, that is, four stakeholder groups (herders, farmers, ecological public authority and economic public authority) and the four types of rural land (cultivated land, rangeland, forest land and other rural land). These four stakeholder groups derive utility from combined using the four types of land. In addition, a Cobb–Douglas form of utility function has been applied to study the optimal consumption, leisure, investment and voluntary retirement problem for an agent (e.g. Koo et al. 2013), and discuss the trade-off between goods and leisure of workers (e.g. Train and McFadden 1978). This paper hereby employs Cobb–Douglas utility function to represent individual utility and social welfare.

3.1. Utility function of each stakeholder group

Assuming that the economic and ecological interests of stakeholders on rural land are demonstrated by their preference on the four types of rural land. And then their utility function in the Cobb-Douglas form is:

$$U_i = l_{cul(i)}^{a_i} l_{ran(i)}^{b_i} l_{for(i)}^{c_i} \, l_{oth(i)}^{d_i}, \qquad [1]$$

where $i = 1, 2, 3 \; and \; 4$ represent the four stakeholder groups: herders, farmers, ecological public authority and economic public authority, respectively. U_i indicates the obtained utility of stakeholder group i in allocation of rural land. $l_{cul(i)}$, $l_{ran(i)}$, $l_{for(i)}$ and $l_{oth(i)}$ denote the area of four types of rural land that are allocated by stakeholder group i, and they are cultivated land area, rangeland area, forest land area and other rural land area, respectively. a_i, b_i, c_i *and* d_i represent stakeholder group i's preference over four types of rural land. Remarkably, the land constraint needs to be met, presented as follows:

$$l_{cul(i)} + l_{ran(i)} + l_{for(i)} + l_{oth(i)} = L, \qquad [2]$$

$$with \;\; l_{cul(i)}, l_{ran(i)}, l_{for(i)}, l_{oth(i)} \geq 0;\; 0 \leq a_i, b_i, c_i, d_i \leq 1;\;\; a_i + b_i + c_i + d_i = 1.$$

where L is the total area of the rural land. Equation [2] illustrates that the sum of the cultivated land, rangeland, forest land and other rural land that are allocated equals the total area of rural land. Moreover, the area of each type of rural land is not negative. The preference of each stakeholder group over four types of rural land is not negative and their sum is 1.

Further, the individual optima is able to be derived through the utility function. As suggested, the allocation of land may achieve the optimum when the aggregate interests from its various uses are maximized (Lopez et al. 1994). Thus, we maximise the utility function of each stakeholder group to reveal the individual optima of rural land allocation. With the help of the Lagrange optimisation procedure, this gives (see Annex A for the detailed derivation):

$$l^0_{cul(i)} = a_i \times L\,, \qquad [3]$$

$$l^0_{ran(i)} = b_i \times L, \qquad [4]$$

$$l^0_{for(i)} = c_i \times L, \qquad [5]$$

$$l^0_{oth(i)} = d_i \times L. \qquad [6]$$

$l^0_{cul(i)}, l^0_{ran(i)}, l^0_{for(i)}$ *and* $l^0_{oth(i)}$ are the resulting individual optima of stakeholder group i in allocation of rural land, indicating the individually rational optimum depending on the preference of stakeholder group i for the different types of rural land and taking into account land constraint.

3.2. Social welfare function

Bergson and Samuelson introduced the social welfare function, which sums up the utility functions of all the individuals in the society (Pollak 1979). We assumed that the four stakeholder groups represent all of the social agents of rural land allocation, therefore our social welfare function is presented by the weighted sum of the four stakeholder groups' utilities, subject to the land constraint. Thus, the Cobb-Douglas form of the social welfare function is:

$$W = \prod_{i=1}^{4} U_i^{\beta_i} \, , \qquad [7]$$

subject to:

$$l_{cul(s)} + l_{ran(s)} + l_{for(s)} + l_{oth(s)} = L \, , \qquad [8]$$

$$\text{with } \sum_{i=1}^{4} \beta_i = 1 \; and \; \beta_i \geq 0 \, , \; l_{cul(s)}, l_{ran(s)}, l_{for(s)}, l_{oth(s)} \geq 0,$$

where $i = 1, 2, 3 \; and \; 4$ represent our four stakeholder groups. W is the social welfare of rural land allocation that equals to the weighted sum of the four stakeholder groups' utilities. U_i is the obtained utility by stakeholder group i. β_i is the weight of stakeholder group i in the process of rural land allocation. $l_{cul(s)}, l_{ran(s)}, l_{for(s)} \; and \; l_{oth(s)}$ are the areas of cultivated land, rangeland, forestland and other rural land considering social welfare. The constraints are the area sum of four types of rural land equals to the total area of rural land, and each of them is not negative. The total weights of four stakeholder groups on rural land allocation are 1 and no one is negative.

To reveal the social optima of rural land allocation, we maximise the social welfare function. With the help of the Lagrange optimisation procedure, this gives (see Annex B for the detailed derivation):

$$l_{cul(s)}^{*} = L \times \sum_{i=1}^{4} \beta_i a_i \, , \qquad [9]$$

$$l_{ran(s)}^{*} = L \times \sum_{i=1}^{4} \beta_i b_i , \qquad [10]$$

$$l_{for(s)}^{*} = L \times \sum_{i=1}^{4} \beta_i c_i \, , \qquad [11]$$

$$l^*_{oth(s)} = L \times \sum_{i=1}^{4} \beta_i d_i. \qquad [12]$$

$l^*_{cul(s)}, l^*_{ran(s)}, l^*_{for(s)}$ *and* $l^*_{oth(s)}$ are the resulting social optima of rural land allocation, which illustrate the optimum for social welfare considering the preference of each stakeholder group on four types of rural land and their weights in the process of rural land allocation.

4. RESEARCH REGION AND DATA COLLECTION

4.1.Research region

The empirical application of the theoretical model will focus on the case of Tai Pusi County. Tai Pusi County is located in the eco-fragile areas of northern China and faces both economic backwardness and ecological degradation (Chen et al., 2007). Its total population is 211,146, and there are 171,500 and 39,646 residents living in rural and urban areas, respectively. Rural residents include 168,514 farmers and 2,986 herders. Tai Pusi County's total area measures 341,473 hectares, including 322,100 hectares of rural land, 14,613 hectares of urban and industrial land and 4,760 hectares of unused land. Since it is on the southern edge of Otindag Sandy Land, the nearest crucial sand source of sandstorms in Beijing, it plays a significant role in preventing sandstorms from reaching Beijing. A series of eco-environmental policies with restraints on rural land use have been introduced by the public authorities to protect the vulnerable ecosystem here. On the other hand, Tai Pusi county is one of the poverty-stricken counties of China and two thirds of local rural households' income is derived from agricultural production relying on the use of rural land. As such, an efficient rural land allocation is indispensable concerning not only its ecological importance but also the local households' livelihoods.

FIGURE 2. The eco-fragile areas in northern China (left) and Tai Pusi County (right)

Source: Ouyang (2013) and Farming and Grazing Bureau, Tai Pusi County.

Figure 2 presents the eco-fragile areas of northern China and our research area, Tai Pusi County. It has seven townships and includes pasture area and agricultural area. In the pasture area, where the herders are living, the local livelihoods depend primarily on grazing and very few herders engage in crop farming. The farmers living in the agricultural area are involved in both crop farming and livestock breeding. The latter is merely allowed with barn breeding by ecological authorities through eco-environmental regulations. In recent years, with increasing population and continuing ecological deterioration, divergences in allocation of rural land among local farmers, herders and public authorities have intensified.

4.2. Data collection

Individual interviews with representatives of each of the four stakeholder groups that were identified in section II were conducted to assess the groups' preferences over four types of rural land. In our survey, 15 herders, 15 farmers, 6 officers of economic authority and 6 officers of ecological authority were interviewed. Herders and farmers were selected considering their different income levels and sufficient knowledge about rural land allocation. The public officers are key informants of rural land allocation strategy about their affiliated public authorities. It is noted that 30 public authorities are in charge of local affairs in Tai Pusi County. The Local Finance Bureau and the Farming and Grazing Bureau were selected as the representatives of economic authority which pay more attention to local economic development than other public authorities. Moreover, the Environmental Protection Agency and the Forestry Bureau aim at ecological conservation and represent the ecological authority. The interviewees were firstly noted to represent their groups' benefits, and then scored their interests on the ecological benefit and economic benefit of rural land. Specifically, the interviewees translated their preferences on four types of rural land into pairwise comparisons given a criterion (ecological benefit or economic benefit) (see Annex C for the detailed questionnaires). The interview procedure and content are based on the theory of Analytical Hierarchy Process (AHP), which will be further described in next section.

Besides the individual interviews, additional data on social-economic indicators is based on statistical information collected by local governments. This includes data on population, income, public expenditure on economic development and ecological conservation.

4.3. Data description on actual rural land allocation

Before we investigate the optimal rural land allocation, the actual change of rural land allocation in Tai Pusi County from 1995 to 2012 is described in figure 3.

FIGURE 3. Dynamic change of rural land allocation in Tai Pusi County

Source: Land Resources Bureau, Tai Pusi County.

The total area of rural land decreased from 1995 to 2012. Rangeland has the largest proportion in total rural land but reduced as well. Especially, there was a rapid decrease from 2007 to 2008 after a smooth decrease between 2002 and 2006. The area of cultivated land has the second largest proportion and decreased from 1999 until 2006. Conversely, the area of both forest land and other rural land increased slightly during this period. Although a change in rural land allocation occurred, there was little variation in the order of the dominant type of rural land. Next, we will study the theoretical optimal rural land allocation based on different stakeholders' interests. This will then be compared with the actual land use allocation.

5. Estimation of the model parameters

5.1. Stakeholders' preference ($a_i, b_i, c_i, and\ d_i$)

Based on the individual interviews, the stakeholders' preference on rural land allocation presented by $a_i, b_i, c_i\ and\ d_i$ in our conceptual model, is evaluated through Analytic Hierarchy Process (AHP). The AHP method was introduced by Thomas Saaty (1980) as one of the most effective tools for dealing with complex decision-making. Numerous studies in different fields have used AHP, such as planning, resource allocation, conflict/divergence resolution and optimisation (Vaidya and Kumar 2006). AHP includes two phases: hierarchic design and evaluation (Vargas 1990). In the design phase, the problem is structured in a hierarchical model descending from an overall goal to criteria and alternatives in successive levels (Saaty 1990). Based on our research target, iterative interviews with interviewees led to a consensus on the hierarchic design, as presented in figure 4.

FIGURE 4. Hierarchical structural model on rural land allocation

In our case, the goal cluster is efficient rural land allocation. The criteria cluster indicates the benefits of rural land, including economic benefit and ecological benefit. The alternatives under the criteria cluster involve cultivated land, rangeland, forest land and other rural land. According to this hierarchical model, interviewees expressed their desired rural land allocation through a series of pairwise comparisons that derive numerical scales of measurement for the nodes. The criteria (economic benefit and ecological benefit) are compared against the goal for importance. And the alternatives (four types of rural land) are pairwise compared against each of the criteria for preference. With the help of Super Decisions software, every stakeholder's preference on rural land allocation is estimated. As presented in table 1, the numerical value of each stakeholder group's preference is the average value of all representatives of each stakeholder group[2].

TABLE 1. Preference of each stakeholder group on rural land allocation (a_i, b_i, c_i and d_i)

We expect each stakeholder group's interests in rural land use are as follows: farmers mostly prefer cultivated land for its economic benefits of agricultural production; herders mostly prefer rangeland for its economic benefits of livestock production; ecological authority, who takes the responsibility of protecting the ecosystem on behalf of the ecological target of national government and ecological demands of the society, prefers the forest land and rangeland for their more ecological benefits than other two types of rural land; and economic authority, who aims at developing local economy, prefers the cultivated land and rangeland for their economic benefits. The numerical value of preference in table 1 is consistent with these assumption. That is, herders have the highest preference for rangeland (0.5286); farmers prefer cultivated land (0.4317) and then rangeland (0.2695); ecological authority has more interest in forest land (0.3746) and rangeland (0.3173); and economic authority has more interest in cultivated land (0.4304) and rangeland (0.3133). The degree of divergences on rural land allocation among stakeholders is

[2] In the same stakeholder group, the variance of different representatives on the rural land allocation is smaller than 0.01. Taking the average value to represent the stakeholder group's preference is appropriate.

shown in table 1 through the differences of stakeholder groups' preference on the four types of rural land.

5.2. Weights for stakeholders in the social welfare function (β_i)

Weights that are assigned to the stakeholders in the social welfare function are quantified in three social-economic scenarios.

Scenario 1: we assume that the weight of each stakeholder group in allocation of rural land is the same, i.e. $\beta_1 = \beta_2 = \beta_3 = \beta_4 = 1/4$. Scenario 2: we assume that the weight of each stakeholder group in allocation of rural land is determined by income distribution. That is, β_i is the income share of stakeholder group i in total stakeholder groups' income. This weight is considered as the Negishi weight (Negishi, 1972). Zhu and van Ierland (2006) showed that the Negishi weight is the income share of each region in the total economy if the Cobb-Douglas utility function is used. In this study, the income of stakeholder groups in 2012 was measured as follows: the total income of the farmers is the population of farmers multiplied by the annual net income of each farmer in 2012; the total income of the herders is the population of herders multiplied by the annual net income of each herder in 2012; the eco-environmental expenditure on rural land is regarded as a proxy income of ecological authority from the rural land, assuming that the ecological authority balances its real income and expenditure; and the economic expenditure on rural land is regarded as a proxy income of economic authority from the rural land, assuming that the economic authority balances its real income and expenditure. Scenario 3: we assume that the weight of each stakeholder group in allocation of rural land is determined by labour force distribution. That is, β_i is the labour force share of stakeholder group i in total stakeholder groups' labour force in 2012. The weight of each stakeholder group in allocating rural land (β_i) is shown in Table 2 in three scenarios (see Annex D for more details).

TABLE 2 The weight of each stakeholder group (β_i) in three scenarios

6. RESULTS

6.1. Individual optima in allocation of rural land

According to the individual preferences of each stakeholder group on the four types of rural land (see table 1) and the maximised forms of stakeholder utility function (equation (3),(4),(5) and (6)), we obtain the individual optima of each stakeholder group on rural land allocation. Moreover, the total rural land area of Tai Pusi county in 2012 is used as the land constraint that is the available rural land area for allocating (322.3 hectares). The results of individual optima and actual allocation of rural land in 2012 are presented as follows:

TABLE 3 Individual optima of each stakeholder group and actual allocation of rural land in 2012

The results in Table 3 present the differences between individual optima and actual rural land allocation in 2012, as well as the divergences among individual optima of four stakeholder groups on rural land allocation. Compared with the actual areas of cultivated land (94.7), rangeland (158.1), forest land (62.4) and other rural land (7.1) in 2012, herders prefer more rangeland (170.4) and other rural land (33.0), but less cultivated land (67.2) and forest land (51.7); farmers prefer more cultivated land (139.1), forest land (71.0) and other rural land (25.3), but less rangeland (86.9); ecological authority prefers more forest land (120.7) and other rural land (30.9), but less cultivated land (68.4) and rangeland (102.3); and economic authority prefers more cultivated land (138.7) and other rural land (45.4), but less rangeland land (101.0) and forest land (37.2). In short, the actual rural land allocation does not correspond with any of these four stakeholder groups' individual optima, and these individual optima are different from each other. Table 3 shows the degree of divergences in allocation of rural land among stakeholders.

6.2. Social optima in allocation of rural land

The divergences among stakeholders can be possibly solved by the tradeoff of stakeholders' benefits on rural land, i.e. the social optima of rural land allocation. According to the weight of each stakeholder group in three social-economic scenarios (see table 2) and the maximised forms of social welfare function (equation (9),(10),(11) and (12)), we obtain the social optima considering the interests of all stakeholders on rural land allocation. The total rural land area of Tai Pusi county in 2012 is used as the land constraint (322.3 hectares). The results of social optima are presented as follows:

TABLE 4 Social optima of all stakeholder groups and actual allocation of rural land in 2012

The minimum and maximum of cultivated land area in three scenarios are regarded as the lower and upper bounds of the range of social optima for allocating cultivated land. The range of social optima for rangeland, forest land and other rural land is derived in the same way. It demonstrates that if we consider all of the stakeholder groups' interests on rural land, then the largest part of rural land will be allocated as cultivated land (103.3--136.7), the second largest part for rangeland (90.9--115.1), followed by forest land (58.5--70.2) and the smallest part for other rural land (27.6--34.1). Comparing the actual rural land allocation in 2012 with the range of social optima, only the actual area of forest land is within the range of social optima but the actual areas of cultivated land, rangeland and other rural land are out of the range of social optima. In particular, the mean of the range of social optima is the largest for cultivated land while the actual allocation tends most towards rangeland. There is also an apparent difference between actual other rural land area and the mean of its range of social optima.

In addition, different scenarios provide different social optima for the allocation of rural land, but there are no big differences among the three scenarios, especially not between secnario 2 and 3. The largest part of rural land is expected to be allocated as cultivated land if the allocating weights depend on the income distribution (scenario 2) or labour force distribution (scenario 3). But the largest part of rural land is expected to be allocated as rangeland if we assume equal weight to every stakeholder group (scenario 1). Scenarios 2 and 3 provide the same order for the four types of rural land allocation, but they are different from the order for actual allocation. It indicates that the actual allocation might not meet the social-economic requirements on how to allocate the rural land, which could be considered as the reason of divergences of rural land allocation.

6.3. Comparison of individual optima, social optima and actual allocation of rural land

Table 5 presents an overview of individual optima, social optima and actual allocation of rural land based on above results, which is presented by the ratio of each type of rural land area in total rural land area.

TABLE 5 Individual optima, social optima and actual allocation of rural land

For cultivated land, actual allocation and all of the individual optima are out of the range of social optima. Herders and the ecological authority expect to allocate less cultivated land than social optima, while farmers and the economic authority expect to allocate more cultivated land than social optima. Actual allocation needs to increase cultivated land area to go into the range of social optima. For rangeland, the optima of ecological and economic authorities are within the range of social optima, but the optima of herders and farmers are not. Herders expect to allocate more rangeland than in the social optima, but farmers expect to allocate less rangeland than in the social optima. Actual allocation needs to decrease rangeland area to go into the range of the social optima. For forest land, actual allocation is within the range of the social optima. However, farmers and the ecological authority expect to allocate more forest land than in the social optima, while herders and the economic authority expect to allocate less forest land than in the social optima. For other rural land, i.e., land that is used for raising animals, agricultural facilities and agricultural roads, the optima of herders and ecological authority are within the range of the social optima, but the optima of farmers and economic authority are not. Farmers expect to allocate less other rural land than in the social optima, but economic authority expects to allocate more other rural land than in the social optima. Actual allocation needs to increase other rural land area to go into the range of social optima. In short, table 5 presents the degree of divergences of individual optima and the differences among individual optima, social optima and actual allocation of rural land.

7. CONCLUSION

This paper takes a welfare economics perspective to investigate the divergences of individual optima among stakeholders and social optima in allocation of rural land, combining the interests of public authorities and rural households on rural land allocation. The social-ecological system approach introduced by Ostrom (2007; 2010) is employed to identify stakeholders and categorize them into four groups: herders, farmers, ecological authority and economic authority. AHP is used to quantify the preference of four stakeholder groups on the four types of rural land: cultivated, range, forest and other. And three social-economic scenarios are used to measure the weights of four stakeholder groups in the process of allocation of rural land. Tai Pusy county, located in the eco-fragile areas of Northern China, is studied as a case to present the empirical analysis. Our results reveal the specific degree of divergences of individual optima and the differences among individual optima, social optima and actual allocation of rural land in our case. We find that a social optimum of rural land allocation would require a shift towards more cultivated land, more other rural land, and less rangeland, compared with the actual rural land allocation in 2012. And only the forest land area was in the range of the social optimum in 2012.

These results should be put in the Chinese policy context. Since the 1990s, the Chinese government has shown increased interest in extending the area of forest land and rangeland for ecosystem protection purposes. Programs such as the SLCP that aim to convert sloping cropland into forestland or grassland are witness to this policy direction (Liu et al. 2010). However, our results show that the social optima of rural land allocation requires conversion in the other direction: from grasslands towards cultivated land, while the area of forest land is already within the range of social optima. The preference for cultivated land over rangeland may be driven by the policy restrictions on rangeland. For instance, the policies of grazing bans or seasonal grazing for ecological conservation restrict the econimic benefits of grassland (Li et al., 2007; Dorji et al., 2010). In this case, farmers can use cultivated land more freely than rangeland. While the insight of increasing cultivated land instead of rangeland might seem controversial in view of the current policy context, our results could also be driven by the overall pressure on rural land, and limited cultivated land in particular, in China. This pressure is likely to be especially strong in the eco-fragile areas where most of the local residents depend on farming, but where agricultural productivity falls far behind the national average level. This promotes the demand for more cultivated land. With respect to the demand of more other rural land, it reflects that the rural area of China lacks of the land used for raising animals, agricultural facilities, agricultural roads and irrigation. Furthermore, our results may also reflect the misalignment between preferences of the national government – as included in the national policy programs that focus on environmental protection – and preferences of local governments – whose performance evaluation is based primarily on economic growth indicators (Liu & Diamond, 2005).

Finally, we would like to point out a number of limitations of our research. While the research method is generic and likely to be valid for other regions facing land use divergences, the specific outcomes presented in this paper are based on stakeholder interviews in one Chinese county and are therefore not generalizable. Furthermore, the application of the model includes only 4 different categories of rural land, 4 stakeholder groups and 3 senarios, which is a simplification of reality.

Acknowledgements

Funding for this research was supported by the Chinese academy of engineering with the project: Ecological security and food security in the grasslands of China (2012-ZD-7). The authors would like to thank Xiangzheng Deng, Wenhui Kuang and Zeng Tang for their help and suggestions during the field work in China.

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TABLE 1. Preference of each stakeholder group on rural land allocation (a_i, b_i, c_i and d_i)

	Cultivated land (a_i)	Rangeland (b_i)	Forest land (c_i)	Other rural land (d_i)	Total
Herders	0.2084	0.5286	0.1606	0.1024	1
Farmers	0.4317	0.2695	0.2202	0.0786	1
Ecological authority	0.2121	0.3173	0.3746	0.0960	1
Economic authority	0.4304	0.3133	0.1154	0.1409	1

TABLE 2 The weight of each stakeholder group (β_i) in three scenarios

	Scenario 1 (β_i equal weights)	Scenario 2 (β_i income distribution)	Scenario 3 (β_i labour force distribution)
Herders	0.2500	0.0110	0.0304
Farmers	0.2500	0.5295	0.8640
Ecological public authority	0.2500	0.0389	0.0031
Economic public authority	0.2500	0.4206	0.1025
Total	1.0000	1.0000	1.0000

TABLE 3 Individual optima of each stakeholder group and actual allocation of rural land in 2012

	Cultivated land (10^3 hectares)	Rangeland (10^3 hectares)	Forest land (10^3 hectares)	Other rural land (10^3 hectares)	Total (10^3 hectares)
Herders	67.2	170.4	51.7	33.0	322.3
Farmers	139.1	86.9	71.0	25.3	322.3
Ecological authority	68.4	102.3	120.7	30.9	322.3
Economic authority	138.7	101.0	37.2	45.4	322.3
Actual rural land allocation in 2012	94.7	158.1	62.4	7.1	322.3

TABLE 4 Social optima of all stakeholder groups and actual allocation of rural land in 2012

Land allocation (10^3 hectares)	Cultivated land	Rangeland	Forest land	Other rural land	Total
Scenario 1 (β_i is equal weight)	103.3	115.1	70.2	33.7	322.3
Scenario 2 (β_i is income distribution)	135.4	94.3	58.5	34.1	322.3
Scenario 3 (β_i is labour force distribution)	136.7	90.9	67.1	27.6	322.3
Range of social optima	103.3--136.7	90.9--115.1	58.5--70.2	27.6--34.1	
Actual rural land allocation in 2012	94.7	158.1	62.4	7.1	322.3

TABLE 5 Individual optima, social optima and actual allocation of rural land

	Cultivated land (%)	Rangeland (%)	Forest land (%)	Other rural land (%)	Total (%)
Herders' optima	20.9	52.8	16.1	10.2	100
Farmers' optima	43.2	26.9	22.0	7.8	100
Ecological authority's optima	21.2	31.7	37.4	9.6	100
Economic authority's optima	43.0	31.3	11.5	14.1	100
Range of social optima	32.1--42.4	28.2--35.7	18.2--21.8	8.6--10.6	
Actual rural land allocation in 2012	29.4	49.1	19.4	2.2	100

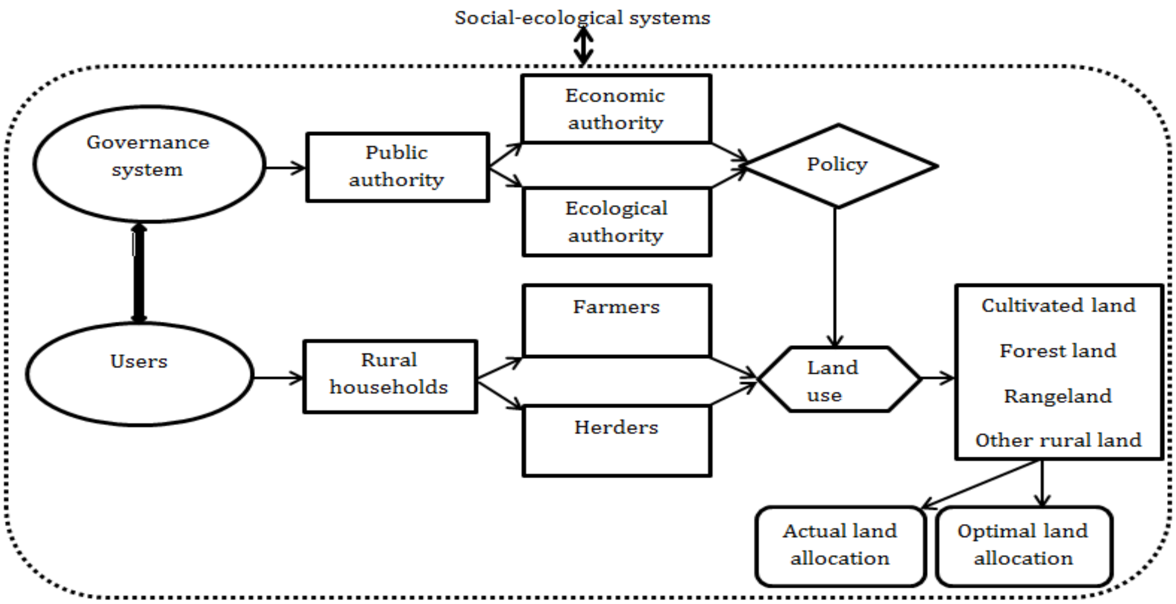

FIGURE 1. Schematic representation of rural land allocation process and relationships among stakeholders

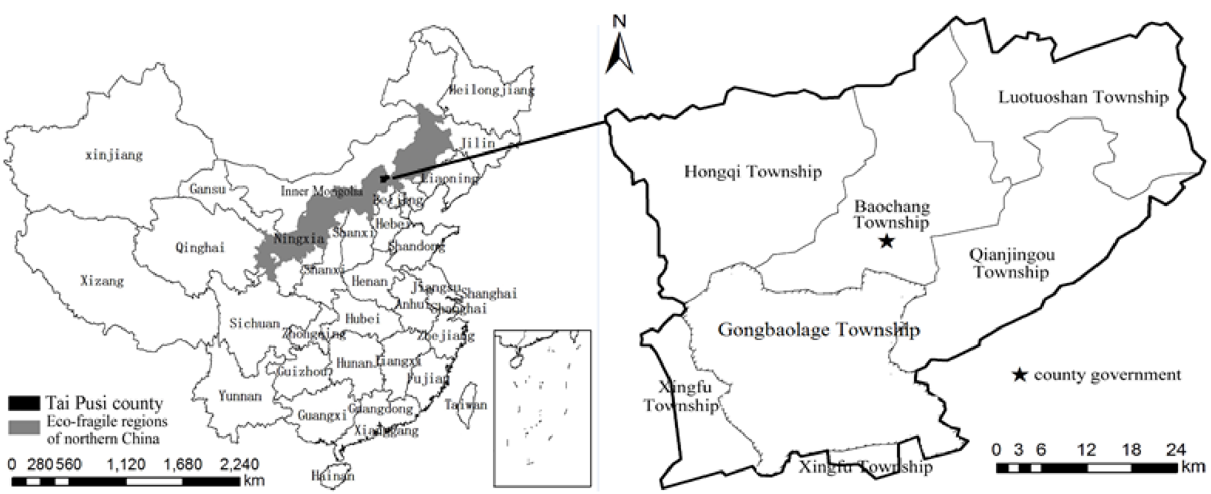

FIGURE 2. The eco-fragile areas in northern China (left) and Tai Pusi County (right)

Source: Ouyang (2013) and Farming and Grazing Bureau, Tai Pusi County.

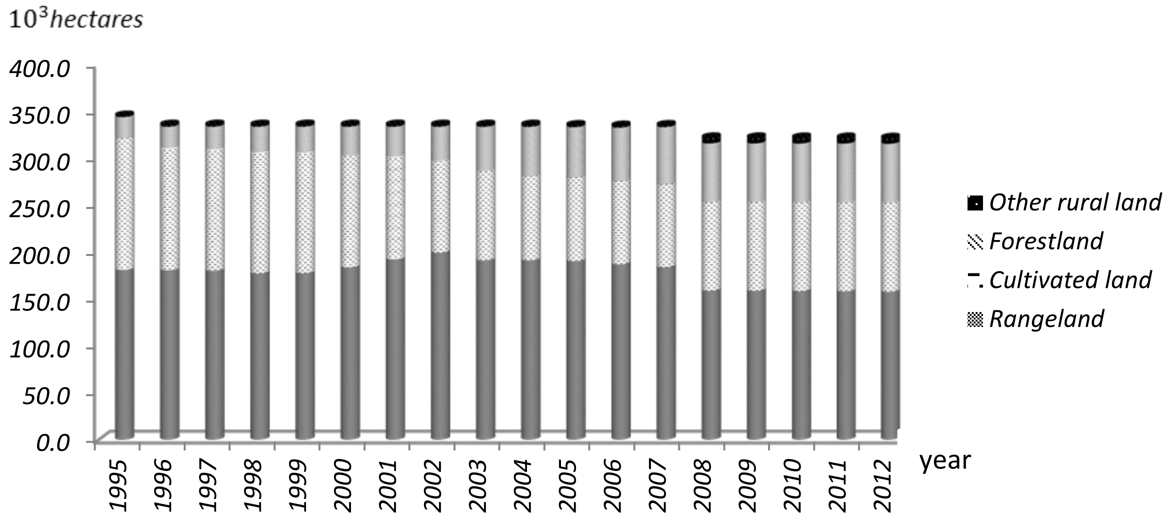

FIGURE 3. Dynamic change of rural land allocation in Tai Pusi County

Source: Land Resources Bureau, Tai Pusi County.

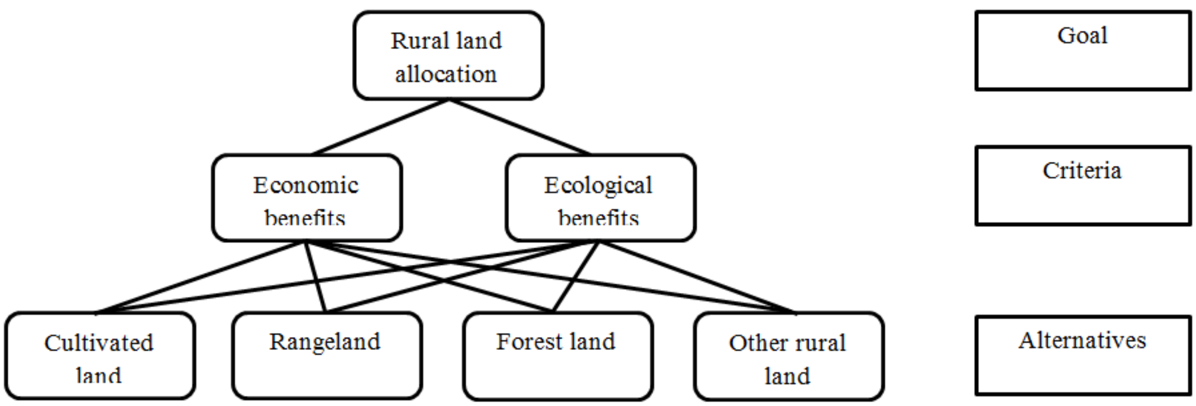

FIGURE 4. Hierarchical structural model on rural land allocation

Annex A: Derivation of the individually optimal allocation of land

For the individual optimal allocation of land, each stakeholder group i ($i = 1, 2\ 3\ and\ 4$ *representing four stakeholder groups, including the herders, the farmers, the ecological public authority and economic public authority) maximizes its utility function by choosing the amounts of land for different purposes. That is:*

$$MAX\ U_i = l_{cul(i)}^{a_i} l_{ran(i)}^{b_i} l_{for(i)}^{c_i}\ l_{oth(i)}^{d_i}\ , \qquad (A.1)$$

Subject to:

$$l_{cul(i)} + l_{ran(i)} + l_{for(i)} + l_{oth(i)} = L, \qquad (A.2)$$

$where \quad l_{cul(i)}, l_{ran(i)}, l_{for(i)}, l_{oth(i)} \geq 0;\ 0 \leq a_i, b_i, c_i, d_i \leq 1;\ \ a_i + b_i + c_i + d_i = 1$

The logarithmic transformation of the utility function gives:

$$u_i = lnU_i = a_i lnl_{cul(i)} + b_i lnl_{ran(i)} + c_i lnl_{for(i)} + d_i lnl_{oth(i)}. \qquad (A.3)$$

The Lagrange function is then:

$$Lu_i = a_i lnl_{cul(i)} + b_i lnl_{ran(i)} + c_i lnl_{for(i)} + d_i lnl_{oth(i)} + \lambda\left(L - l_{cro(i)} - l_{ran(i)} - l_{for(i)} - l_{oth(i)}\right) \qquad (A.4)$$

Taking the partial derivations of Lu_i *with respect to each variable, and setting the first order condition gives:*

$$\frac{\partial Lu_i}{\partial l_{cul(i)}} = \frac{a_i}{l_{far(i)}} - \lambda = 0\ , \qquad (A.5)$$

$$\frac{\partial Lu_i}{\partial l_{ran(i)}} = \frac{b_i}{l_{ran(i)}} - \lambda = 0\ , \qquad (A.6)$$

$$\frac{\partial Lu_i}{\partial l_{for(i)}} = \frac{c_i}{l_{for(i)}} - \lambda = 0\ , \qquad (A.7)$$

$$\frac{\partial Lu_i}{\partial l_{oth(i)}} = \frac{d_i}{l_{oth(i)}} - \lambda = 0\,. \qquad (A.8)$$

Combining (A5) to (A8) gives:

$$\frac{a_i}{l_{cul(i)}} = \frac{b_i}{l_{ran(i)}} = \frac{c_i}{l_{for(i)}} = \frac{d_i}{l_{oth(i)}}\,, \qquad (A.9)$$

Or :

$$a_i l_{ran(i)} = b_i l_{cul(i)}, a_i l_{for(i)} = c_i l_{cul(i)}, a_i l_{oth(i)} = d_i l_{cul(i)}\,. \qquad (A.10)$$

Combining (A2) with (A9), we have:

$$\frac{a_i}{l_{cul(i)}} = \frac{a_i}{L - l_{ran(i)} - l_{for(i)} - l_{oth(i)}}, \qquad (A.11)$$

Rearrange (A10) and (A11) combined with $a_i + b_i + c_i + d_i = 1, we\ obtain$:

$$l^0_{cul(i)} = a_i \times L\,, \qquad (A.12)$$

$$l^0_{ran(i)} = b_i \times L\,, \qquad (A.13)$$

$$l^0_{for(i)} = c_i \times L\,, \qquad (A.14)$$

$$l^0_{oth(i)} = d_i \times L\,, \qquad (A.15)$$

This completes the proof of equation (3) to (6) in the main text.

Annex B: Derivation of the socially optimal allocation of land

For the social optimal allocation of land, maximizing the social welfare is:

$$MAX\ W = \prod_{i=1}^{4} U_i^{\beta_i}\ , \qquad (B.1)$$

Subject to:

$$l_{cul(s)} + l_{ran(s)} + l_{for(s)} + l_{oth(s)} = L\ , \qquad (B.2)$$

$$where\ \sum_{i=1}^{4} \beta_i = 1, . \beta_i \geq 0, 0 \leq a_i, b_i, c_i, d_i \leq 1;\ l_{culs}, l_{rans}, l_{fors}, l_{oths} \geq 0;\ \sum_{i=1}^{4} \beta_i = 1\ \ and\ \ \beta_i \geq 0$$

Plugging equation (A1) into (A16), we obtain:

$$W = \left(l_{cul(s)}^{a_1} l_{ran(s)}^{b_1} l_{for(s)}^{c_1} l_{oth(s)}^{d_1}\right)^{\beta_1} * \left(l_{cul(s)}^{a_2} l_{ran(s)}^{b_2} l_{for(s)}^{c_2}\ l_{oth(s)}^{d_2}\right)^{\beta_2} * \left(l_{cul(s)}^{a_3} l_{ran(s)}^{b_3} l_{for(s)}^{c_3}\ l_{oth(s)}^{d_3}\right)^{\beta_3} * \left(l_{cul(s)}^{a_4} l_{ran(s)}^{b_4} l_{for(s)}^{c_4}\ l_{oth(s)}^{d_4}\right)^{\beta_4} \qquad (B.3)$$

The logarithmic transformation of the social welfare function is:

$$w = lnW = \beta_1 ln\left(l_{cul(s)}^{a_1} l_{ran(s)}^{b_1} l_{for(s)}^{c_1} l_{oth(s)}^{d_1}\right) + \beta_2 ln\left(l_{cul(s)}^{a_2} l_{ran(s)}^{b_2} l_{for(s)}^{c_2}\ )\right) + \beta_3 ln(l_{culs}^{a_3} l_{rans}^{b_3} l_{fors}^{c_3}\ l_{oths}^{d_3}) + \beta_4 ln\left(l_{cul(s)}^{a_4} l_{ran(s)}^{b_4} l_{for(s)}^{c_4}\ l_{oth(s)}^{d_4}\right) \qquad (B.4)$$

The Lagrange function is then:

$$Lw = \beta_1 ln\left(l_{cul(s)}^{a_1} l_{gra(s)}^{b_1} l_{for(s)}^{c_1} l_{oth(s)}^{d_1}\right) + \beta_2 ln\left(l_{cul(s)}^{a_2} l_{ran(s)}^{b_2} l_{for(s)}^{c_2}\ l_{oth(s)}^{d_2}\right) + \beta_3 ln\left(l_{cul(s)}^{a_3} l_{ran(s)}^{b_3} l_{for(s)}^{c_3}\ l_{oth(s)}^{d_3}\right) + \beta_4 ln\left(l_{cul(s)}^{a_4} l_{ran(s)}^{b_4} l_{for(s)}^{c_4}\ l_{oth(s)}^{d_4}\right) + \lambda\left(L - l_{cul(s)} - l_{ran(s)} - l_{for(s)} - l_{oth(s)}\right) \qquad (A2)$$

Taking the partial derivations of Lw with respect to each variable, and setting the first order condition gives:

$$\frac{\partial Lw}{\partial l_{cul(s)}} = \frac{\sum_{i=1}^{4} \beta_i a_i}{l_{cul(s)}} - \lambda = 0 \, , \qquad (B.5)$$

$$\frac{\partial Lw}{\partial l_{ran(s)}} = \frac{\sum_{i=1}^{4} \beta_i b_i}{l_{ran(s)}} - \lambda = 0 \, , \qquad (B.6)$$

$$\frac{\partial Lw}{\partial l_{for(s)}} = \frac{\sum_{i=1}^{4} \beta_i c_i}{l_{for(s)}} - \lambda = 0 \, , \qquad (B.7)$$

$$\frac{\partial Lw}{\partial l_{oth(s)}} = \frac{\sum_{i=1}^{4} \beta_i d_i}{l_{oth(s)}} - \lambda = 0 \, , \qquad (B.8)$$

Combining (A21) to (A24) gives:

$$\frac{\sum_{i=1}^{4} \beta_i a_i}{l_{cul(s)}} = \frac{\sum_{i=1}^{4} \beta_i b_i}{l_{ran(s)}} = \frac{\sum_{i=1}^{4} \beta_i c_i}{l_{for(s)}} = \frac{\sum_{i=1}^{4} \beta_i d_i}{l_{oth(s)}} \, , \qquad (B.9)$$

Or:

$$\sum_{i=1}^{4} \beta_i a_i \, l_{ran(s)} = \sum_{i=1}^{4} \beta_i b_i \, l_{far(s)} \, , \qquad (B.10)$$

$$\sum_{i=1}^{4} \beta_i a_i \, l_{for(s)} = \sum_{i=1}^{4} \beta_i c_i \, l_{far(s)} \, , \qquad (B.11)$$

$$\sum_{i=1}^{4} \beta_i a_i \, l_{oth(s)} = \sum_{i=1}^{4} \beta_i d_i \, l_{far(s)} \, . \qquad (B.12)$$

Combining (A17) with (A25), we have:

$$\frac{\sum_{i=1}^{4} \beta_i a_i}{l_{cul(s)}} = \frac{\sum_{i=1}^{4} \beta_i a_i}{L - l_{ran(s)} - l_{for(s)} - l_{oth(s)}} \, , \qquad (B.13)$$

Plug (A26)(A27) and (A28)into (A29), we obtain:

$$l^*_{cul(s)} = \frac{\sum_{i=1}^{4} \beta_i a_i}{\sum_{i=1}^{4} \beta_i a_i + \sum_{i=1}^{4} \beta_i b_i + \sum_{i=1}^{4} \beta_i c_i + \sum_{i=1}^{4} \beta_i d_i} L\,, \tag{B.14}$$

$$l^*_{ran(s)} = \frac{\sum_{i=1}^{4} \beta_i b_i}{\sum_{i=1}^{4} \beta_i a_i + \sum_{i=1}^{4} \beta_i b_i + \sum_{i=1}^{4} \beta_i c_i + \sum_{i=1}^{4} \beta_i d_i} L\,, \tag{B.15}$$

$$l^*_{for(s)} = \frac{\sum_{i=1}^{4} \beta_i c_i}{\sum_{i=1}^{4} \beta_i a_i + \sum_{i=1}^{4} \beta_i b_i + \sum_{i=1}^{4} \beta_i c_i + \sum_{i=1}^{4} \beta_i d_i} L\,, \tag{B.16}$$

$$l^*_{oth(s)} = \frac{\sum_{i=1}^{4} \beta_i d_i}{\sum_{i=1}^{4} \beta_i a_i + \sum_{i=1}^{4} \beta_i b_i + \sum_{i=1}^{4} \beta_i c_i + \sum_{i=1}^{4} \beta_i d_i} L\,, \tag{B.17}$$

Since $\sum_{i=1}^{4} \beta_i a_i + \sum_{i=1}^{4} \beta_i b_i + \sum_{i=1}^{4} \beta_i c_i + \sum_{i=1}^{4} \beta_i d_i = 1$

We have:

$$l^*_{cul(s)} = L \times \sum_{i=1}^{4} \beta_i a_i \tag{B.18}$$

$$l^*_{ran(s)} = L \times \sum_{i=1}^{4} \beta_i b_i \tag{B.19}$$

$$l^*_{for(s)} = L \times \sum_{i=1}^{4} \beta_i c_i \tag{B.20}$$

$$l^*_{oth(s)} = L \times \sum_{i=1}^{4} \beta_i d_i \tag{B.21}$$

This completes the proof of equation (9) to (12) in the main text.

Annex C: Questionnaires and results of Analytic Hierarchy Process

Annex C1: Questionnaires of Analytic Hierarchy Process

1. Which is your stakeholder group in rural land allocation?

a. Herder
b. Farmer
c. Economic authority
d. Ecological authority

2. Comparing the economic benefit and ecological benefit of rural land, which one concerning the efficient allocation of rural land is more important for you, and how much important?

Economic benefit Ecological benefit

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

3. Comparing the cultivated land and rangeland, which one concerning the economic benefit is more beneficial to you, and how many benefits?

Cultivated land Rangeland

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

4. Comparing the cultivated land and forest land, which one concerning the economic benefit is more beneficial to you, and how many benefits?

Cultivated land Forest land

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

5. Comparing the cultivated land and other rural land, which one concerning the economic benefit is more beneficial to you, and how many benefits?

Cultivated land Other rural land

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

6. Comparing the rangeland and forest land, which one concerning the economic benefit is more beneficial to you, and how many benefits?

Rangeland Forest land

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

7. Comparing the rangeland and other rural land, which one concerning the economic benefit is more beneficial to you, and how many benefits?

Rangeland Other rural land

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

8. Comparing the forest land and other rural land, which one concerning the economic benefit is more beneficial to you, and how many benefits?

Forest land Other rural land

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

9. Comparing the cultivated land and rangeland, which one concerning the ecological benefit is more beneficial to you, and how many benefits?

Cultivated land Rangeland

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

10. Comparing the cultivated land and forest land, which one concerning the ecological benefit is more beneficial to you, and how many benefits?

Cultivated land   Forest land

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

11. Comparing the cultivated land and other rural land, which one concerning the ecological benefit is more beneficial to you, and how many benefits?

Cultivated land   Other rural land

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

12. Comparing the rangeland and forest land, which one concerning the ecological benefit is more beneficial to you, and how many benefits?

Rangeland   Forest land

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

13. Comparing the rangeland and other rural land, which one concerning the ecological benefit is more beneficial to you, and how many benefits?

Rangeland   Other rural land

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

14. Comparing the forest land and other rural land, which one concerning the ecological benefit is more beneficial to you, and how many benefits?

Forest land Other rural land

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

Note : other rural land indicates land used for raising animals, agricultural facilities, agricultural roads, pit-ponds, fishponds, irrigation, drying grains and forming ridges among croplands.

For above scoring in paired comparisons, the following Fundamental Scale is used to make judgments:1= Equal; 2=Between Equal and Moderate; 3=Moderate; 4=Between Moderate and Strong;5=Strong; 6=Between Strong and Very Strong; 7=Very Strong; 8=Between Very Strong and Extreme; 9=Extreme

Annex C2: Results of Analytic Hierarchy Process

Based on the data from above questionnaires, we employ Super Decisions software to calculate every stakeholder's preference on four types of rural land. And then we take the average value of all representatives of each stakeholder group to represent each stakeholder group's decision in allocation of rural land.

Table C.1. Values of a_1, b_1, c_1 and d_1 (herders)

	Weights for interviewees in the herder group			
Alternatives	Cultivated land (a_1)	Rangeland (b_1)	Forest land (c_1)	Other rural land (d_1)
1	0.1377	0.6311	0.1032	0.1279
2	0.1207	0.6529	0.1120	0.1145
3	0.1232	0.5577	0.1877	0.1314
4	0.2252	0.5715	0.1381	0.0651
5	0.1730	0.5388	0.1653	0.1230
6	0.2014	0.5049	0.2174	0.0763
7	0.2781	0.4993	0.1336	0.0890

8	0.1836	0.3494	0.2909	0.1760
9	0.2409	0.5294	0.1372	0.0925
10	0.2464	0.4913	0.1615	0.1007
11	0.1907	0.5105	0.1716	0.1271
12	0.2679	0.5079	0.1565	0.0676
13	0.1254	0.6754	0.1069	0.0923
14	0.3548	0.4256	0.1487	0.0708
15	0.2573	0.4838	0.1779	0.0811
Average	**0.2084**	**0.5286**	**0.1606**	**0.1024**
Variance	0.0046	0.0070	0.0023	0.0009

Table C.2. Values of a_2, b_2, c_2 and d_2 (farmers)

	Weights for interviewees in the farmer group			
Alternatives	Cultivated land (a_2)	Rangeland (b_2)	Forest land (c_2)	Other rural land (d_2)
1	0.4873	0.2432	0.2003	0.0692
2	0.3031	0.4334	0.1906	0.0729
3	0.4909	0.1336	0.2824	0.0932
4	0.4564	0.2182	0.2531	0.0723
5	0.5433	0.1180	0.2527	0.0859
6	0.4681	0.2129	0.2324	0.0866
7	0.3800	0.2071	0.2929	0.1200
8	0.4695	0.2701	0.1813	0.0790
9	0.4768	0.3130	0.1466	0.0636
10	0.5239	0.1900	0.1831	0.1030
11	0.3352	0.4396	0.1739	0.0513
12	0.4853	0.1285	0.2944	0.0918
13	0.3750	0.3639	0.1942	0.0669
14	0.3661	0.3595	0.2215	0.0529
15	0.3146	0.4114	0.2041	0.0699
Average	**0.4317**	**0.2695**	**0.2202**	**0.0786**
Variance	0.0061	0.0123	0.0021	0.0003

Table C.3. Values of a_3, b_3, c_3 and d_3 (ecological authority)

Weights for interviewees in the ecological authority group

Alternatives	Cultivated land (a_3)	Rangeland (b_3)	Forest land (c_3)	Other rural land (d_3)
1	0.1867	0.3099	0.3808	0.1227
2	0.1963	0.3318	0.3740	0.0979
3	0.1685	0.3894	0.3647	0.0774
4	0.2507	0.2620	0.4008	0.0865
5	0.1985	0.3178	0.3836	0.1000
6	0.2718	0.2930	0.3438	0.0915
Average	**0.2121**	**0.3173**	**0.3746**	**0.0960**
Variance	0.0016	0.0018	0.0004	0.0002

Table C.4. Values of a_4, b_4, c_4 and d_4 (economic authority)

	Weights for interviewees in the ecological authority group			
Alternatives	Cultivated land (a_4)	Rangeland (b_4)	Forest land (c_4)	Other rural land (d_4)
1	0.5768	0.1787	0.1082	0.1364
2	0.4479	0.3403	0.0848	0.1271
3	0.4815	0.2614	0.1194	0.1377
4	0.3849	0.2982	0.1183	0.1986
5	0.3246	0.4247	0.1374	0.1133
6	0.3669	0.3768	0.1242	0.1321
Average	**0.4304**	**0.3133**	**0.1154**	**0.1409**

Variance	0.0083	0.0076	0.0003	0.0009

Annex D: Estimation of parameter β_i

Table D.1. Data for welfare weights β_i

Item	Unit	Value
Population of farmers	Person	168514
Farmer's net income in 2012	RMB per capita	6730
Farmers' total income	Million RMB	1134.10
Population of herders	Person	2986
Herder's net income in 2012	RMB per capita	7898
Herders' total income	Million RMB	23.58
Ecological expenditure in 2012	Million RMB	118.96
Rural ecological expenditure share	%	70
Ecological expenditure on rural area	Million RMB	83.3
Economic expenditure in 2012	Million RMB	1109.42
Rural population share	%	81.2
Economic expenditure on rural area	Million RMB	900.8

Source: Statistical Bureau, Tai Pusi County in 2012.

Table D.2.value of β_i based on income distribution and labour force of stakeholder groups

	Herders (β_1)	Farmers (β_2)	Ecological public authority (β_3)	Economic public authority (β_4)	Total
Income in 2012 (million RMB)	23.58	1134.099	83.3	900.8	2158.669
Income distribution(β_i)	0.0110	0.5295	0.0389	0.4206	1
Labour force in each stakeholder group in 2012	1962	55665	200	6601	64428
Labour force distribution(β_i)	0.0304	0.8640	0.0031	0.1025	1

Source: Statistical Bureau, Tai Pusi County in 2012.

Annex E:Data on actual allocation of rural land

Table E. The areas of total and four types of rural land in Tai Pusi County (10^3 hectares)

Year	Cultivated land	Forestland	Rangeland	Other rural land	Total
1995	140.6	22.4	180.7	2.3	345.9
1996	130.2	22.7	180.4	2.9	336.2
1997	129.3	24.2	179.8	2.9	336.2
1998	129	27.4	176.9	2.9	336.2
1999	128.7	27.6	177.1	2.9	336.3
2000	119.3	30.6	183.4	2.9	336.3

2001	109	32.3	192.1	2.9	336.3
2002	98.2	36.2	199	2.9	336.2
2003	95.2	47.2	190.9	2.9	336.2
2004	89.5	52.7	191	3	336.2
2005	89.2	53.6	189.9	3	335.8
2006	88.7	57	186.6	3	335.2
2007	88.4	61.1	183.4	3	335.9
2008	94.7	62.5	158.3	7.1	322.6
2009	94.8	62.5	158.3	7.1	322.6
2010	94.8	62.7	157.9	7.1	322.5
2011	94.8	62.8	157.8	7.1	322.5
2012	94.9	62.8	157.4	7.1	322.3

Source: Land Resources Bureau, Tai Pusi County.