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Individual and social optima of rural land allocation by stakeholders: a case study on eco-fragile areas of northern China

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Abstract. Divergences in preferences over the allocation of rural land among stakeholders are getting stronger with the decrease of rural land area. This paper analyses the degree of divergences among different stakeholders over the allocation of four types of land: cultivated land, grassland, forest and other land, and explores the optimal allocation from the social perspective of balancing economic and ecological benefits. Considering the heterogeneity of stakeholders that are concerned with land-use decisions, we distinguish four types of stakeholders, namely, ecological authorities, economic authorities, herders and farmers. The diverging preferences of these four stakeholder types over the different types of land use were quantified using the Analytic Hierarchy Process. Weights for each stakeholder type were derived for three scenarios: equal weights, weights based on income distribution and weights based on labour force distribution. Welfare analysis was employed then to determine the individual optimal allocation by maximising the utility function of each stakeholder type. Social optimal allocation was derived by maximising the social welfare function, which is the weighted sum of individual utilities. Tai Pusi County, located in an eco-fragile area of northern China, was taken as a case to present the empirical analysis. Individual optima revealed the degree of divergences among stakeholders and the social optima revealed the optimal allocation based on social welfare. Our results provide policy insights on how to achieve an efficient allocation of rural land, balancing the ecological and economic benefits of different stakeholders from different types of land.

Additional keywords: Analytic Hierarchy Process, stakeholder preferences.

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Introduction

Rural land is used for production and subsistence to satisfy immediate human needs for food, fuel and ecosystem services (European Commission 2012). However, as a result of economic development, technological progress, environmental change, and political and market forces, the total area of rural land is decreasing worldwide (Verburg *et al*. 2008; Liu *et al*. 2010*b*). This inevitably raises the question of how to efficiently allocate the decreasing amount of rural land. Moreover, there are increasing divergences and conflicts on land allocation in many parts of the world due to various interests in land use among different individuals or organisations, especially in populous countries such as China (Petit 2009; Williams and Schirmer 2012).

Research on the changes in land cover and efficient land allocation has increased since the 1990s because of prominent problems stemming from overuse of natural resources and environmental deterioration (Turner Ii *et al*. 1993; Qasim *et al*. 2013). Many studies employed the geographic information system, spatial models and mathematical programming to investigate land allocation (e.g. Turner Ii *et al*. 1994; Zhan *et al*. 2007; Santé and Crecente 2007; Santé-Riveira *et al*. 2008; Zarei *et al*. 2015), and discussed the driving forces of land allocation based on qualitative analysis, econometrics and game theory (e.g. Angelsen 2001; Kokoye *et al*. 2013). Optimal allocation is mainly studied either from the macro perspective as a regional strategy (Verburg *et al*. 2013), or from the rural household perspective for local land-use decisions (Kokoye *et al*. 2013). However, the interests of land allocation by different individuals, groups and organisations that have a stake in land use – the so-called stakeholders – have not been well investigated. This paper explores the individual optimal allocation of rural land by considering the different interests of representative stakeholders of land use, as well as the social optimal allocation by considering the trade-offs between interests of different stakeholders. The research approach is based on welfare economics, which enables us to take into account the interests of stakeholders over different types of land use (Barker and Selman 1990; Rambonilaza and Dachary-Bernard 2007; Zeng and Edwards 2010; Yang *et al*. 2012; Pacione 2013). This approach is in line with similar studies that have modelled environmental problems through welfare analysis (Gerlagha and Keyzer 2003, 2004; Zhu 2004).

The different interests of stakeholders are particularly obvious in eco-fragile areas where ecological issues and widespread poverty are observed simultaneously (Ran *et al*. 2001). This is reflected in the poor implementation and high supervision costs of eco-environmental policies, ecosystem deterioration, over-grazing and over-cultivation in these regions (Han *et al*. 2008). On the one hand, sustainable use is demanded by society because the eco-fragile areas play a crucial role in the provision of ecosystem services. On the other hand, productive use is important to the livelihoods of rural households. The empirical analysis in this paper, therefore, used data from a county located in an eco-fragile area of northern China to investigate the divergences of different stakeholders and the potential optima of rural land allocation considering both ecological and economic benefits of land use.

The remainder of this paper is structured as follows. We first identify the specific types of stakeholders and types of land use that will be considered in the analysis. Next, we derive the utility function based on the preferences over desired land allocation for each type of stakeholder. The social welfare function is then derived, considering the weights that are assigned to various stakeholders. In the empirical analysis, the Analytic Hierarchy Process (AHP) is used to quantify preference of each type of stakeholder for different types of land. Three scenarios are considered to define the weight of each type of stakeholder in the social welfare function. 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. Finally, we present a discussion of the divergence in individual optima and between current rural land allocation and the social optima. We conclude with preliminary policy insights to achieve the optimal allocation of land while jointly considering different stakeholders' ecological and economic benefits.

Methodology

Conceptual background

To identify the main elements that need to be considered in the welfare analysis presented in the next section, we draw on the concept of the social-ecological system, introduced by Ostrom (2007). The social-ecological system is used as a diagnostic framework for the study of complex systems, which are composed of four core subsystems: resource units; resource system; governance system; and users (Ostrom 2009). The resource unit in the context of this paper is rural land. Rural land can be used in four different ways: as cultivated land; as forest land; as grassland; or as other rural land according to the land classification system of China. This rural land classification was introduced by AQSIQ (General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China) whereby rural land is divided into these four types of land according to the functions of land use in 2002. Other rural land includes land used for raising animals, agricultural facilities, agricultural roads, pit-ponds, fishponds, irrigation, drying grains and bridges among croplands.

The resource system considers the different economic and ecological benefits that can be derived from the land. The governance system includes the rules and regulations set at the level of the government and other organisations to regulate the resource (Ostrom 2009). In this paper, the governance system will be represented by the public authorities that make and implement the rules to manage land use. The users of the land are the households that are affected directly by the governance system when making land-use decisions. The main elements that will be incorporated in the mathematical model and the empirical analysis will therefore be: the different types of land use; the benefits derived from land use; public authorities; and households. The latter two categories are considered the stakeholders in land allocation decisions.

Following Freeman (1984), stakeholders are defined as 'any group or individual who can affect or is affected by the achievement of the organisation's objectives'. In the case of rural land allocation, the main stakeholders include households who are using and benefiting from the land directly, and public authorities who decide on macro-level land-use strategies. More specifically, households utilise land for agricultural production and recreation, whereas public authorities consider societal demands for the implementation of regulations or policies concerning rural land management. For example in the case of China, several national programs have been introduced that attempt to steer land allocation 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 (also known as the 'Grain for Green' program), initiated by the Chinese national government in 1999 to convert sloping cropland into forest or grassland (Liu *et al*. 2010*a*). Such national programs that are directed at ecological conservation, however, have impacted grain supply at the national level and constrained the economic activities of local households on land use (Feng *et al*. 2005; Uchida *et al*. 2005). However, the Chinese government also introduced regulations targeting food security such as the requirement to uphold a minimum of 120 million hectares for cultivated land in 2006 (Yang and Bi 2009). This heterogeneity in land-use policies is a reflection of the divergences between stakeholders over land allocation.

To incorporate the heterogeneity in stakeholders in our model, we consider four different types of stakeholders in rural land use in the remainder of this paper: households that use land mainly for agricultural production purposes (farmers); households that use land mainly for (extensive) grazing of livestock and that are therefore also concerned with grassland conservation (herders); public authorities that are mainly concerned with ecological objectives (ecological authorities); and public authorities that are concerned with economic objectives (economic authorities).

Distinguishing between only four stakeholder types is a simplified representation of reality. For instance, it assumes that public objectives over economic and ecological targets can be separated and that the interests of citizens – as stakeholders – are perfectly represented by public authorities. Furthermore, only rural households are considered although urban households may also derive benefits from rural land use through recreational activities. Possible interactions between stakeholders are also ignored. These simplifications were, however, needed to keep the mathematical modelling as well as the data collection process manageable.

Model specification

Our theoretical model based on welfare economics determines the individual optima by maximising each stakeholder's benefits and the social optima by maximising combined stakeholders' benefits. The former explores the divergence in land allocation among different stakeholder types, whereas the latter investigates the optimal land allocation.

According to welfare economics, each agent derives utility from the use of land. The question is how to allocate limited land resources in an optimal way (Perman *et al*. 2011; Heijman and Mouche 2013). We consider four types of stakeholder (herders, farmers, ecological public authorities and economic public authorities) and four types of land use (cultivated land, grassland, forest land and other rural land). Stakeholders are representatives of the society and have different weights and interests in land allocation. Each representative stakeholder type obtains utility from the combined use of the four types of land.

Utility function

The Cobb–Douglas form of a utility function has been applied in earlier research to study optimal consumption, leisure, investment and voluntary retirement decisions (e.g. Koo *et al*. 2013), and to analyse the trade-off between the consumption of goods and leisure of workers (e.g. Train and McFadden 1978). This paper employs the Cobb–Douglas utility function to investigate the optimal rural land allocation. The utility function incorporates the economic and ecological preferences of stakeholders over the four types of land. Stakeholder utility functions are represented as follows:

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

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 subscript i = 1, 2, 3 and 4 represents the four stakeholder types: herders, farmers, ecological public authorities and economic public authorities, respectively. U_i indicates the obtained utility of stakeholder type i. $l_{cul(i)}$, $l_{ran(i)}$, $l_{for(i)}$ and $l_{oth(i)}$ denote the area of the four types of land: cultivated land, grassland, forest and other rural land. Parameters a_i, b_i, c_i and d_i represent stakeholder type i's preference over the four types of land use. The land constraint is presented as follows:

$$l_{cul(i)} + l_{ran(i)} + l_{for(i)} + l_{oth(i)} = L \tag{2}$$

where L is the total area of available rural land.

The allocation of land is considered optimal when the aggregate interests from its various uses are maximised (Lopez *et al*. 1994). Thus, we maximise the utility function of each stakeholder type to identify the individual optima of rural land allocation. With the help of the Lagrange optimisation procedure, this gives (see Appendix 1 for the detailed derivation):

$$l_{cul(i)}^{0} = a_i \times L \tag{3}$$

$$l_{ran(i)}^{0} = b_i \times L \tag{4}$$

$$l_{for(i)}^{0} = c_i \times L \tag{5}$$

$$l_{oth(i)}^{0} = d_i \times L \tag{6}$$

where $l_{cul(i)}^{0}$, $l_{ran(i)}^{0}$, $l_{for(i)}^{0}$ and $l_{oth(i)}^{0}$ are the resulting individual optima of stakeholder type i in the allocation of rural land, considering the preferences of stakeholder type i over the different types of land and taking into account the land constraint.

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 have assumed that the four types of stakeholders 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 types' utilities, subject to the land constraint. Thus, the Cobb–Douglas form of the social welfare function is:

$$W = \prod_{i=1}^{4} U_i^{\beta_i} \tag{7}$$

subject to:

$$l_{cul(s)} + l_{ran(s)} + l_{for(s)} + l_{oth(s)} = L \tag{8}$$

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 types. W is the social welfare of rural land allocation that equals the weighted sum of the four stakeholder types' utilities. U_i is the utility obtained by stakeholder type i. β_i is the weight of stakeholder type i in the optimisation of social welfare. $l_{cul(s)}$, $l_{ran(s)}$, $l_{for(s)}$ and $l_{oth(s)}$ are the four types of land.

To identify the social optima of rural land allocation, we maximise the social welfare function. With the help of the Lagrange optimisation procedure, this gives (see Appendix 2 for the detailed derivation):

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

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

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

$$l_{oth(s)}^{*} = L \times \sum_{i=1}^{4} \beta_i d_i \tag{12}$$

where $l_{cul(s)}^{*}$, $l_{ran(s)}^{*}$, $l_{for(s)}^{*}$ and $l_{oth(s)}^{*}$ are the resulting optima in land allocation, considering the preference of each stakeholder type and their weights in the process of rural land allocation.

Research region and data collection

Research region

The empirical application of the theoretical model focussed on the case of Tai Pusi County. Tai Pusi County is located in an eco-fragile area of northern China and faces both economic backwardness and ecological degradation (Chen *et al*. 2007). According to the Local Bureau of Statistics of Tai Pusi County (2013), its total population in 2012 was 211 146 with 171 500 residents living in rural areas and 39 646 in urban areas. Rural residents included 168 514 farmers and 2986 herders. The total area measured 341 473 ha, including 322 300 ha of rural land, 14 613 ha of urban and industrial land and 4760 ha of unused land. The rural area consisted of 94 700 ha of cultivated land, 158 100 ha of grassland, 62 400 ha of forest land and 7100 ha of other rural land. As 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 in the region. However, Tai Pusi County is one of the most poverty-stricken counties of China and two-thirds of rural households' income is derived from agricultural production (Local Bureau of Statistics of Tai Pusi County 2013). As such, an optimal rural land allocation is indispensable concerning not only its ecological importance but also local households' livelihoods.

Figure 1 presents the eco-fragile areas of northern China and our research area, Tai Pusi County. Tai Pusi has seven townships and includes pastoral areas and agricultural areas. In the pastoral area more than 90% of land is natural grassland and the livelihoods of the local population – mainly herders – depend primarily on grazing livestock. In the agricultural area more than 60% of rural land is cultivated land and local livelihoods involve both crop farming and livestock breeding. Rural households in the agricultural area are not allowed to graze their animals on the natural grassland since the implementation of the grazing ban policy. In recent years, with an increasing population and continuing ecological deterioration, conflicts about the allocation of land among local farmers, herders, ecological public authorities and economic public authorities have intensified.

Data collection

Interviews with representatives of each of the four stakeholder types were conducted to assess preferences over the four types of land. Fifteen herders, 15 farmers, 6 officers from economic authorities and 6 officers from ecological authorities were separately interviewed face to face. The population of farmers and herders is much larger than that of public officers, which leads to more variations in the opinions of farmers and herders than the officers on rural land allocation. We therefore interviewed more representatives from farmers and herders. 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 strategies of their affiliated public authorities. Thirty 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 authorities because they pay more attention to local economic development than other public authorities. The Environmental Protection Agency and the Forestry Bureau aiming at ecological conservation were selected to represent the ecological authorities. The interviewees were asked to represent their agency's interests, after which their preferences over the ecological and economic benefits of rural land were scored. Specifically, the interviewees translated their preferences on the four types of land into pairwise comparisons given a criterion (ecological benefit or economic benefit) (see Appendix 3 for the detailed questionnaires). The interview procedure and content are based on the theory of AHP, which will be described further in the next section.

Besides the individual interviews, secondary data on socioeconomic indicators was collected from local government statistics. This included data on population, income, public expenditure on economic development and ecological conservation.

Data description on actual rural land allocation

The total area of rural land decreased between 1995 and 2012 (Fig. 2). Grassland had the largest share in total rural land area but was reduced as well, with an especially rapid decrease in the period 2007–2008. The area of cultivated land had the second largest share and decreased from 1999 until 2006. Conversely, the area of both forest land and other rural land increased slightly during this period. In general, although a change in rural land allocation occurred, there was little variation in the order of the dominant type of rural land. That is, grassland was always ranked in the first place, cultivated land in the second place, forest in the third and other rural land in the last.

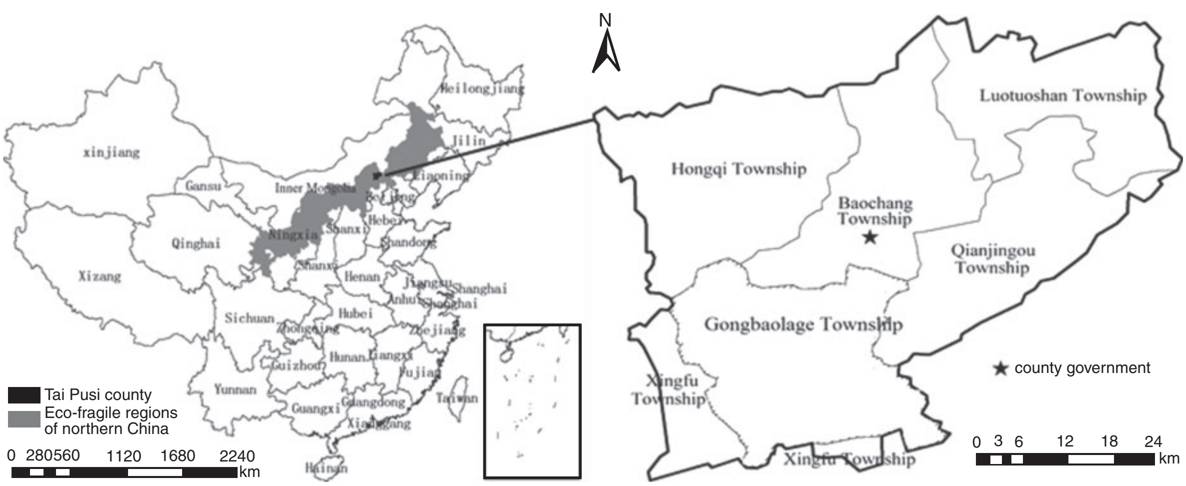

Fig. 1. The eco-fragile areas in northern China (left) and Tai Pusi County (right). Source: Ouyang (2013) and Farming and Grazing Bureau, Tai Pusi County.

Estimation of the model parameters

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 parameters a_i, b_i, c_i and d_i in our model, was evaluated using the 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). The AHP method 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).

Iterative interviews with interviewees led to a consensus on the hierarchic design, based on our research target, as presented in Fig. 3. In our case, the goal cluster is optimal rural land allocation. The criteria cluster indicates the benefits of land, including economic benefit and ecological benefit. The alternatives under the criteria cluster involve the four types of land. According to this hierarchical model, interviewees expressed their desired land allocation through a series of pairwise comparisons to derive numerical scales of measurement for the nodes. The criteria (economic benefit and ecological benefit) were compared against the goal for importance. And the alternatives (four types of land use) were pairwise compared against each of the criteria for preference. With the help of Super Decisions software, every stakeholder's preference on rural land allocation was estimated. As presented in Table 1, the numerical value of each stakeholder type's preference is the average value of all representatives from the same stakeholder type. In the same stakeholder type, the variance of different representatives on rural land allocation was smaller than 0.01. Taking the average value to represent the stakeholder type's preference is therefore appropriate.

We observed that stakeholder type's interests in land use were as follows: farmers mostly preferred cultivated land for its economic benefits from agricultural production; herders mostly preferred grassland for its economic benefits from livestock production; ecological authorities preferred forest land and grassland; and economic authorities preferred cultivated land

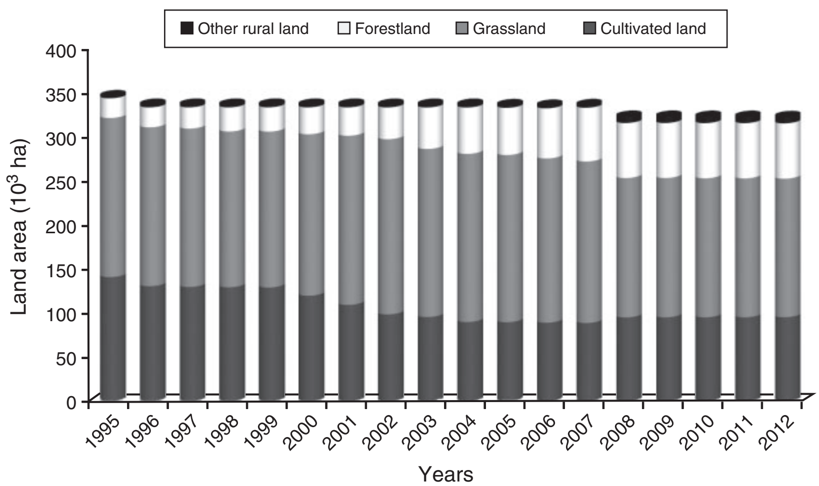

Fig. 2. Actual rural land allocation in Tai Pusi County from 1995 to 2012. Source: Local Bureau of Statistics of Tai Pusi County (2013).

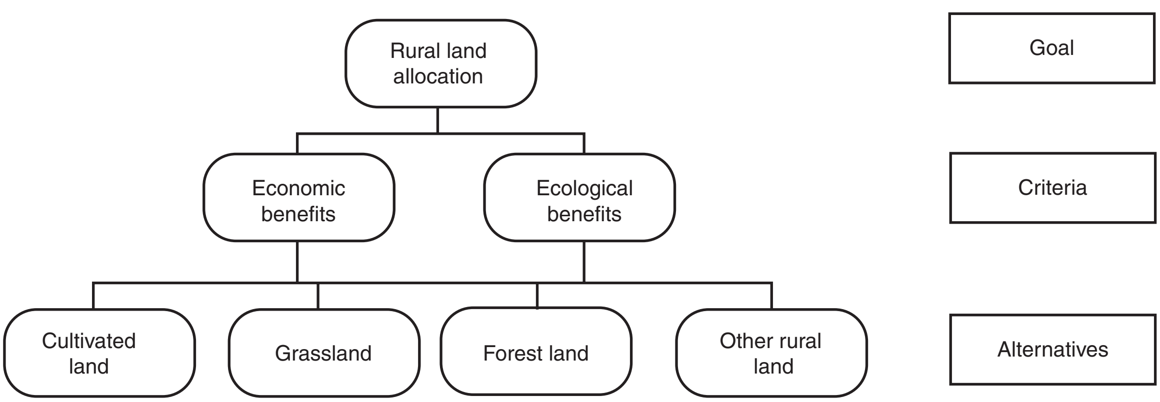

Fig. 3. Hierarchical structural model on rural land allocation.

and grassland. Moreover, different stakeholders had various demands for other rural land as well, due to the requirement of space for animal shelters, agricultural roads, and irrigation. For example, herders and farmers require auxiliary land for supporting their agricultural production, ecological authorities are interested in water areas to support local ecosystems, and economic authorities prefer a diversity of land use to develop the local economy.

Weights for stakeholders in the social welfare function (β_i)

Weights that were assigned to the stakeholders in the social welfare function are quantified in three socioeconomic scenarios. Scenario 1 assumes that the weight of each stakeholder type is the same, i.e. $\beta_1 = \beta_2 = \beta_3 = \beta_4 = 1/4$. Scenario 2 assumes that the weight of each stakeholder type is determined by the income distribution. That is, β_i is the income share of stakeholder type i in the combined income of all stakeholders. This weight is considered as the Negishi weight of a social welfare function (Negishi 1972), as applied in Zhu and van Ierland (2006). In this study, the income of farmers and herders was measured as the population of farmers (herders) multiplied by the annual net income of each farmer (herder) in 2012. The eco-environmental and economic expenditures on rural land were regarded as proxies for the income of ecological and economic authorities respectively, assuming that the public authorities balance their real income and expenditure. Scenario 3 assumes that the weight of each stakeholder type is determined by the labour force distribution. That is, β_i was the labour force share of stakeholder type i in the total labour force in 2012. The weight of each stakeholder type in allocating rural land (β_i) is shown in Table 2 for the three scenarios (see Appendix 4 for more details).

Results

Individual optima in allocation of rural land

Using the individual preferences of each stakeholder type on the four types of land use and the maximisation of stakeholder utility functions, we obtained the individual optima of each stakeholder type on rural land allocation (Table 3).

Compared with the actual allocation, herders prefer more grassland and other rural land; farmers prefer more cultivated land and forest land; ecological authorities prefer more forest land and other rural land; and economic authorities prefer more cultivated land and other rural land. In short, the actual rural land allocation is not consistent with any of these four stakeholder types' individual optima.

Social optima in allocation of rural land

Results in Table 3 show the divergence in stakeholder optima. A trade-off between stakeholder benefits is therefore necessary to maximise social welfare. Depending on the different weights of each stakeholder type in the social welfare function under three socioeconomic scenarios we obtained the optimal allocation of land in Tai Pusi County (Table 4).

The range (the minimum and maximum bound under the different scenarios) of social optima for the four types of land demonstrates that if we consider all of the stakeholder interests on rural land allocation, the most land will be allocated as cultivated land, then grassland, followed by forest land and other rural land. Comparing the actual rural land allocation in 2012 with the range of social optima, we observe that only the actual area of forest land is within the range of social optima. Furthermore, the actual allocation of cultivated land seems much below its optimal allocation, whereas the actual grassland area is much larger than what would be considered as socially optimal. Finally, it should be noted that the different scenarios provide somewhat different social optima. Moreover, a higher importance is given to grassland in the scenario where equal weights are assigned to all stakeholders, whereas the other scenarios give more importance to the area of cultivated land.

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

	Cultivated land (a_i)	Grassland (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 authorities	0.2121	0.3173	0.3746	0.0960	1
Economic authorities	0.4304	0.3133	0.1154	0.1409	1

Table 2. The weight of each stakeholder type (β_i) in three scenarios with (1) equal weights, (2) weights according to income distribution and (3) weights according to labour force distribution

	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 authorities	0.2500	0.0389	0.0031
Economic public authorities	0.2500	0.4206	0.1025
Total	1.0000	1.0000	1.0000

Table 3. Individual optima of each stakeholder type and actual allocation of rural land in 2012

	Cultivated land (10^3 ha)	Grassland (10^3 ha)	Forest land (10^3 ha)	Other rural land (10^3 ha)	Total (10^3 ha)
Herders	67.2	170.4	51.7	33.0	322.3
Farmers	139.1	86.9	71.0	25.3	322.3
Ecological authorities	68.4	102.3	120.7	30.9	322.3
Economic authorities	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**

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

Table 5 shows the degree of divergence of individual optima, social optima and actual allocation of land. For cultivated land, actual land allocation and all of the individual optima are out of the range of the social optimum. Herders and the ecological authorities prefer to allocate less land for cultivation than what is socially optimal, whereas farmers and the economic authorities prefer the opposite. For grassland, the optima of ecological and economic authorities are within the range of social optimum, whereas herders prefer more and farmers prefer less grassland than in the social optimum. For forest land, actual allocation is within the range of the social optima. However, optima for farmers and the ecological authorities would require more forestland, although herders and the economic authorities prefer the opposite.

Discussion

The results reveal the degree of divergences of individual optima among different stakeholder types and the differences among individual optima, social optima and actual allocation of rural land. These results should be put in the context of Chinese rural policies.

Since the 1990s, the Chinese government has shown increased interest in extending the area of forest land and grassland for ecosystem protection purposes. National programs such as the Sloping Land Conversion Program that aim to convert sloping cropland into forestland or grassland are witness to this policy direction (Liu *et al*. 2010*a*). However, our results show that the social optima of rural land allocation require conversion in the opposite direction: from grassland towards cultivated land. The area of forest land is already within the range of social optima, implying no further need to convert rural land into forest land. This apparent contradiction between our research results and the current policy direction may be related to the influence of policies on stakeholder preferences – an interaction that was not incorporated in our model.

The preference for cultivated land over grassland may for instance be driven by the policy restrictions on the use of grassland. For instance, the policies of grazing bans or seasonal grazing for ecological conservation restrict the economic benefits of livestock production from grassland use (Li *et al*. 2007; Dorji *et al*. 2010). In this case, cultivated land can be used more freely and efficiently to get economic benefits than grassland. Moreover, the scarcity of cultivated land in China may be an important element. The average cultivated land area per capita in China was 0.09 ha in 2009, which is far below the world average of 0.22 ha per capita (Nath *et al*. 2015). The demand for cultivated land is especially strong in the eco-fragile areas because most of the local residents rely on farming while agricultural productivity and soil quality fall far behind the national average level. Furthermore, the focus on economic benefits rather than ecological benefits may still be more pronounced in a developing country context, even for interviewees who work in the ecological authorities. As cultivated land is more important for achieving food security than other types of land, society is likely to have a lower preference for forest land and grassland.

As a consequence of the implementation of eco-environmental policies and programs such as the Sloping Land Conversion Program, the area of forest land has already reached the social optimum. The demand for more other land in the social optimum reflects the fact that in the rural areas of China the available land for raising animals, agricultural facilities, agricultural roads and irrigation is limited. 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 and Diamond 2005).

Finally, we would like to point out several limitations of our research. The complicated interaction between the different elements of the conceptual model and in particular the stakeholders is not considered in our analysis. Our research

Table 4. Social optima of all stakeholder types and actual allocation of rural land in 2012

Land allocation (10^3 ha)	Cultivated land	Grassland	Forest land	Other rural land	Total
Scenario 1 (β_i equal weights)	103.3	115.1	70.2	33.7	322.3
Scenario 2 (β_i income distribution)	135.4	94.3	58.5	34.1	322.3
Scenario 3 (β_i 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 (%)	Grassland (%)	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 authorities' optima	21.2	31.7	37.4	9.6	100
Economic authorities' 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**

method is generic and likely to be valid for other regions facing land-use divergences, but the specific outcomes presented in this paper are based on stakeholder interviews in one Chinese county and cannot necessarily be applied to other areas. Furthermore, the model is only applied to four different categories of rural land, four stakeholder types and three scenarios, which is a simplification of reality. We only had one round of interviews, whereas iterative interviews and the possibility for negotiation among the representatives of the four stakeholder types would have been interesting to examine whether the individual optima would converge.

Conclusions

This study takes the preference heterogeneity of stakeholders on land use into account to explore the optimal rural land allocation. Four representative stakeholder types were identified among which to allocate the land, namely, herders, farmers, ecological authorities and economic authorities. The rationale is that each stakeholder type represents a large number of socioeconomic agents who can make decisions over rural land allocation in the actual society. Four types of rural land were regarded, including cultivated land, rangeland, forest and other land. Welfare economics was employed to investigate the individual optima of each stakeholder type and the social optima in the allocation of rural land. The AHP was used to quantify the preference of the four stakeholder types over the four types of land. Three socioeconomic scenarios were used to derive the weights of each stakeholder type in the social welfare function. Tai Pusi County, located in the eco-fragile areas of northern China, was studied as a case to present the empirical analysis. We find clear divergences in the individual optima among different stakeholder types. Compared with the actual rural land allocation in 2012, the social optima of rural land allocation would require a shift towards more cultivated land, more other rural land, and less grassland. Only grassland, and only the forest land area was in the range of the social optima. Our results provide interesting insights that can help to steer future land-use policies in rural China.

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Appendix 1. Derivation of the individually optimal allocation of land

For the individual optimal allocation of land, each stakeholder type i (i = 1, 2, 3 and 4 representing four stakeholder types, including the herders, the farmers, the ecological public authorities and economic public authorities) maximises its utility function by choosing the amounts of land for different purposes. That is:

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

Subject to:

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

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

The logarithmic transformation of the utility function gives:

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

The Lagrange function is then:

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

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

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

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

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

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

Combining (A5) to (A8) gives:

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

Or:

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

Combining (A2) with (A9) we have:

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

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

$$l_{cul(i)}^0 = a_i \times L, \tag{A.12}$$

$$l_{ran(i)}^0 = b_i \times L, \tag{A.13}$$

$$l_{for(i)}^0 = c_i \times L, \tag{A.14}$$

$$l_{oth(i)}^0 = d_i \times L, \tag{A.15}$$

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

Appendix 2. Derivation of the socially optimal allocation of land

For the social optimal allocation of land, maximising 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 Eqn (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*:

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

The Lagrange function is then:

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

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:

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

(*continued next page*)

Appendix 2. (*continued*)

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

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

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

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

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

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:

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

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

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

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

This completes the proof of Eqn 9 to Eqn 12 in the main text.

Appendix 3. Questionnaires and results of Analytic Hierarchy Process

3.1. Questionnaires of Analytic Hierarchy Process

1. Which is your stakeholder type in rural land allocation?
a. Herder
b. Farmer
c. Economic authorities
d. Ecological authorities

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 grassland, which one concerning the economic benefit is more beneficial to you, and how many benefits?
Cultivated land Grassland

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 grassland and forest land, which one concerning the economic benefit is more beneficial to you, and how many benefits?
Grassland Forest land

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

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

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 grassland and forest land, which one concerning the ecological benefit is more beneficial to you, and how many benefits?
Grassland Forest land

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

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

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

(*continued next page*)

Appendix 3. (*continued*)

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.

Appendix 3.2. 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 type to represent each stakeholder type's decision in allocation of rural land.

Table 3.1. Values of a_1, b_1, c_1 and d_1 (herders)

	Weights for interviewees in the herder type			
Alternatives	Cultivated land (a_1)	Grassland (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 3.2. Values of a_2, b_2, c_2 and d_2 (farmers)

	Weights for interviewees in the farmer type			
Alternatives	Cultivated land (a_2)	Grassland (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 3.3. Values of a_3, b_3, c_3 and d_3 (ecological authorities)

	Weights for interviewees in the ecological authorities type			
Alternatives	Cultivated land (a_3)	Grassland (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 3.4. Values of a_4, b_4, c_4 and d_4 (economic authorities)

	Weights for interviewees in the ecological authorities type			
Alternatives	Cultivated land (a_4)	Grassland (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

Appendix 4. Estimation of parameter β_i
Table 4.1. Data for welfare weights β_i

Item	Unit	Value
Population of farmers	Person	168 514
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 4.2. Value of β_i based on income distribution and labour force of stakeholder types

	Herders (β_1)	Farmers (β_2)	Ecological public authorities (β_3)	Economic public authorities (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 type in 2012	1962	55 665	200	6601	64 428
Labour force distribution (β_i)	0.0304	0.8640	0.0031	0.1025	1

Source: Statistical Bureau, Tai Pusi County in 2012.