JARQ 39 (3), 181 – 190 (2005) http://www.jircas.affrc.go.jp

Better Access to New Technologies and Credit Service, Farmers' Land Use Decision, and Policy for Poverty Alleviation and Rangeland Conservation

Minjun SHI[1,3]*, Qiaoyun ZHANG[1] and Tao WANG[2]

[1] Graduate School of Life and Environmental Sciences, University of Tsukuba (Tsukuba, Ibaraki 305–8572, Japan)
[2] Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences (Lanzhou, Gansu, 730000, China)

Abstract

This paper focuses upon the incompatibility between poverty alleviation and environmental conservation and the solution to the incompatibility in an agro-pastoral area of China. The effects on income and grazing pressure of restricting herd size, prohibiting rangeland reclamation, introduction of sedentary beef production, and credit provision were examined using linear programming in a cropping system and a pastoral system in Inner Mongolia, China. Eight scenarios on land use regulations were compared: unrestricted grazing with or without prohibition of rangeland reclamation, four grazing restrictions (1 or 2 sheep equivalent/ha; 5 or 10 sheep equivalent/person), and two grazing prohibitions (half-year or all year). Complete prohibition of rangeland reclamation and grazing reduced income, but with different effects in the two systems. Rangeland reclamation prohibition reduced income more in the cropping system (–26%) than in the pastoral system (–9%), while grazing prohibition reduced income more in the pastoral system (–55%) than in the cropping system (–14%). Grazing restrictions had little effect on income (0 to –9%) in the cropping system, but more severe restrictions (1 sheep equivalent/ha or 5 sheep equivalent/person) had major negative impact on income (–31% and –30% respectively) in the pastoral system. Introduction of sedentary beef production increased income under all three grazing restriction scenarios in both systems, by 30–42% in the cropping system and 3–18% in the pastoral system, relative to unrestricted grazing without land reclamation. Compared with no credit service, providing credit for poor households of the cropping system to introduce sedentary beef production increased their income by 51%, and increased income for poor households in the pastoral system under the grazing restriction of 1 sheep equivalent/ha by 416%.

Discipline: Agricultural economics
Additional key words: credit supporting, grazing pressure, sedentary livestock

Introduction

Recent literature on the links between poverty and environment in rural areas of developing countries concentrates mainly on debate on the hypotheses of poverty as a major cause of environmental degradation[11,12]. The findings related to causes and consequences of environmental degradation provided an insight into policy design for poverty alleviation and environmental conservation. The effective way to simultaneously reduce poverty and enhance resource base is to understand what factors are driving households' behavior and cause poverty and environmental degradation, and then to focus efforts on these[12].

Rangeland degradation and desertification are the most severe environmental problems in the northwestern areas of China. It is estimated that 50% to 70% of rangeland is degraded in the northwestern areas of China and 60% in Inner Mongolia[16,17]. It is recognized that rangeland degradation and desertification is significantly affected by overgrazing and reclamation. (In this paper, we use the term 'reclamation' to refer to the conversion of rangeland to cropland). Deterioration of resource base poses a threat to poverty alleviation. In Inner Mongolia, rural income per capita is 1,973 Yuan (unit of Chinese

Present address:
[3] Graduate University, Chinese Academy of Sciences (Beijing, 100049, China)
*Corresponding author: fax +86–10–88256370; e-mail mjshi@gscas.ac.cn
Received 21 May 2004; accepted 31 January 2005.

currency) about 50% of that in the coast areas of China. Since 2000, a policy to prohibit grazing activity has been introduced in order to promote rangeland conservation and to combat against desertification and dust storm. With the implementation of the policy of grazing prohibition, here rise some questions. What impacts will environmental conservation practices place on poverty alleviation? Is there any alternative policy measure that can contribute to simultaneously reduce poverty and promote rangeland conservation?

This paper contributes to the design of effective policy instruments to simultaneously reduce poverty and promote rangeland conservation based on a case study from Inner Mongolia of China. At first, the tradeoff relation between poverty alleviation and rangeland conservation is verified through analysis of the effects of environmental conservation practices on poverty. Next, the authors simulate farmers' land use decisions and their effects on poverty alleviation and rangeland conservation with changes of socio-economic circumstances, with an emphasis on technical introduction and improvement of credit supporting service. Then, the importance of reconsidering a combination of environmental policy and rural development policy, such as improving access to new technologies and credit service, is discussed based on the empirical results.

The study site

For the purpose of this study, two villages, Yaoledianzi Village and Sharitala Village in Naiman Banner, were chosen as study sites. Naiman Banner, located in the eastern part of Inner Mongolia, is a typical agro-pastoral area with an average annual rainfall of 367 mm, 70% of which falls in summer. As the spring is extremely arid with strong winds in this area, desertification is likely to occur, especially where vegetation cover suffers deterioration due to over-grazing and widespread reclamation of rangeland. In the past decades, the number of livestock animals has increased by 3.8 times, which means that grazing pressure has risen at least 3.8 times even without considering the decrease in the area of rangeland. In the 1960s and early 1970s, annual reclamation was more than 7,000 ha. Widespread reclamation led to rapid decline of rangeland. As a result, about 90% of rangeland is in the process of degradation at varying rates. Consequently, the vegetation cover of rangeland has fallen from 60–70% to 10–30%. The area of land in the process of desertification has reached 66% of the total area.

Land use in Naiman Banner is characterized as a crop-livestock system, and is quite different in cultivated regions and pastoral regions. The adjacent two villages represent two different types of land use in the region. Yaoledianzi village is typical of upland cropping regions, where most residents are Han Chinese, and Sharitala village is typical of pastoral livestock regions, where Mongolians cluster. Hereafter cropping system is used to refer to Yaoledianzi and pastoral system is used for Sharitala in the subsequent discussion.

Table 1 gives the background data of the two villages. In Yaoledianzi village, there is about 122.9 ha cultivated land. Among the cultivated land, approximately 30 ha is rice field and 72.2 ha is irrigable upland. The rest is non-irrigable field. Maize is the main crop, cultivated as a cash crop. Part of the maize is also used to

Table 1. Background data on sample villages

	Yaoledianzi	Sharitala
Household	84	37
Population	343	147
Labor	222	96
Total area (ha)	1,283	1,235
Cultivated land (ha)	122.9	54.0
Rangeland (ha)	530.2	859.6
Livestock per household (sheep equivalent)	10.5	41.7
Income per capita (Yuan)	2,050	2,264
Sources of income		
Farm income (%)	86.6	87.8
Crop income (%)	76.1	31.5
Livestock income (%)	10.5	56.3
Off-farm income (%)	13.4	12.2

Calculations are based on authors' household survey from July to August in 2003.

Table 2. Differentiation of households in two villages

Village	Household group	Income level (Yuan)	Households		Average income per capita (Yuan)	Cultivated land (ha)	Grazing animal (Sheep equivalent)
			Count	%			
Yaoledianzi	A	<1,000	10	11.9	669	1.08	—*
	B	1,000–2,000	40	47.6	1,515	1.23	—
	C	2,000–3,000	20	23.8	2,414	1.56	—
	D	3,000–4,000	8	9.5	3,547	2.12	—
	E	>=4,000	6	7.1	4,708	2.70	—
	Total		84	100	2,050	1.46	—
Sharitala	A	<1,000	12	32.4	440	1.04	21.01
	B	1,000–2,000	9	24.3	1,093	1.74	32.11
	C	2,000–3,000	4	10.8	2,790	1.30	68.75
	D	3,000–4,000	5	13.5	3,569	1.79	50.50
	E	>=4,000	7	18.9	5,665	1.68	67.71
	Total		37	100	2,264	1.46	41.69

Calculations are based on authors' household survey from July to August in 2003.
* A complete grazing ban is implemented in Yaoledianzi, so data are absent.

feed livestock. Most households grow wheat for their own consumption. Some households grow watermelons on the wheat plots after the grain harvest. More than half of the households have rice fields along a river. In Yaoledianzi there is about 530.2 ha of rangeland which is under management of the village. Sharitala village has about 54 ha cultivated land, of which approximately 61% is irrigable upland. Maize is the main crop and is cultivated as forage. In Sharitala, there is about 859.6 ha of rangeland which is allocated to the individual households. The number of herds per household in Sharitala is 41.7 sheep equivalent, which is four times of that in Yaoledianzi. Although traditionally nomadic pastoralists in Sharitala have been settled and crop cultivation has been performed, pastoralism still plays a major role in management.

Pastoral livestock is the major stream of existing livestock in this area. The number of animals depends mainly upon rangeland productivity. The average yield of usable grass of rangeland is 1,832 kg per ha[18]. According to Zhao et al., residue of vegetation cover should be kept to a ratio of 50% after grazing activities for renewal of rangeland productivity[19]. A grazing experiment shows that when grazing pressure for half year exceeds 2 sheep equivalent per ha, vegetation cover will be deteriorated[10]. One sheep equivalent per ha can be considered as the reasonable grazing pressure in this area. Due to shortage of forage in winter, crop straw is used as supplementary fodder. Compound feed is rarely purchased for supplementary forage.

Farmers generate income mainly from on-farm activities due to limited off-farm opportunities. Income from on-farm activities makes up 87% of total household income. The sources of farm income are different between Yaoledianzi village and Sharitala village. Crop income accounts for 76% of total household income in Yaoledianzi, while livestock income accounts for 56% of total household income in Sharitala (Table 1). There is significant differentiation of household income in both villages. The poorest households (Group A) receive a net income per capita of 669 Yuan in Yaoledianzi and 440 Yuan in Sharitala. In contrast, the richest households (Group E) have an average net income of 4,708 Yuan in Yaoledianzi and 5,665 Yuan in Sharitala (Table 2). Table 2 also indicates that higher income household groups cultivate a larger area of farmland in Yaoledianzi and that higher income groups are grazing more herds in Sharitala. Using household level data, a significant correlation was found between household income and area of farmland in Yaoledianzi and between household income and the livestock holdings in Sharitala (Table 3).

Table 3. Correlation between income and cultivated land / livestock

	Income-Cultivated land	Income-Grazing animal
Yaoledianzi	0.677 **	—
Sharitala	0.323	0.658 **

** Correlation is significant at the 0.01 level (two-tailed).

In order to reduce rangeland degradation and desertification, an environmental regulation to restrict grazing activities has been introduced in Inner Mongolia since

2000. In upland farming areas, an all-year grazing ban is implemented. In pastoral areas, instead of prohibiting grazing completely, a policy to prohibit grazing for half year during January to June is implemented. Ahead of implementation of the government policy of prohibiting grazing, regulation to restrict reclamation has been implemented as a community rule to prevent desertification in the villages.

Model

Heerink et al. (2001)[4] provide a conceptual framework for analyzing effects of policy reform on land degradation. Farm household decisions on land use activities and technological choices affect the soil quality and play an important role in aggravating or reducing the land degradation process. Farm household decisions are dependent on relative prices of output, input and production factors, and other socio-economic circumstances that are influenced by macroeconomic and agricultural policies. Agricultural policies affect soil degradation by influencing the socio-economic environment under which farm households operate. To measure such impact, several bioeconomic household models that incorporate a bioeconomic model with a household model have been developed[1,3,6,7,9,14,15]. In this paper a bioeconomic household model that incorporates household behavior and an agro-ecological process has been developed as the base of the analytical framework.

Three modeling approaches of bioeconomic household models have been developed, including the econometric estimation approach, the decision rules approach and the mathematical programming approach[2,5]. The econometric approach is based on statistical analysis of historical and/or cross-sectional data and is usually very demanding in terms of data, which are rarely available in developing countries. The decision rules approach regards household behavior as the outcome of the interplay between its 'disposition to act', its resources and external context. It cannot provide insight but only estimates a statistical relationship between exogenous variables and relevant endogenous variables. The mathematical programming approach allows determination of an optimal allocation of land, labor and capital, given a set of goals and constraints. A major advantage of the mathematical programming approach is that it may combine economic behavior and biophysical process in an integrated framework, while a disadvantage of the mathematical programming model is that it generates a vast amount of results with 'what-if' analysis when some of the parameters of the model are not known with great accuracy[8]. In this paper a linear programming model (LP) is applied to describe the relationship between changes in policy and socio-economic circumstance and the land degradation process.

1. Model description

The model is designed to maximize net income, simultaneously incorporating both of the crop and livestock activities, subject to constraints on land, labor and budget resources. The model simulates expected behavior for the year following the base year of the study. The model is run separately at village level and household level. Considering that the basic unit of land management is the village in China, the model is run at village level to verify the impacts of land use regulations and technological introduction. As there is an income gap between poor households and better-off households, the model is run at the household level to treat credit service. Several features of the LP model introduced in the paper are as follows.

(1) Objective function

The objective function is to maximize net income as follows:

$$
\begin{aligned}
MaxM &= \sum_{c=1}^{C}\left\{P_c\left[\sum_{g=1}^{G}A_{cg}y_{cg}(x)-b_c-s_c\right]-\sum_{g=1}^{G}\sum_{i=1}^{n}A_{cg}e_{icg}x_{icg}\right\} \\
&+\sum_{v=1}^{V}\left\{p_v(L_vy_v(x)-b_v-s_v)-\sum_{i=1}^{n}L_ve_{iv}x_{iv}\right\}-\sum_{j=1}^{J}p_jf_j \\
&+\sum_{o}^{O}w_oz_o-\sum_{k}^{K}w_kh_k \qquad (1)
\end{aligned}
$$

subject to

$$A = \sum_{c}^{C}\sum_{g}^{G}A_{cg}+A_r \qquad (2)$$

$$Z_h = z_f+z_o \qquad (3)$$

$$Z_f = z_f+\sum_{k}^{K}h_k \qquad (4)$$

$$\sum_{v=1}^{V}365\alpha_vL_v \le A_ry_r+S \qquad (5)$$

$$365\gamma P \le \sum_{c=1}^{C}\beta_cb_c+\sum_{j=1}^{J}\beta_jf_j \qquad (6)$$

$$
\begin{aligned}
&\sum_{c=1}^{C}\sum_{g=1}^{G}\sum_{i=1}^{n}A_{cg}e_{icg}x_{icg}+\sum_{v=1}^{V}\sum_{i=1}^{n}L_ve_{iv}x_{iv} \\
&+\sum_{j=1}^{J}P_jf_j+\sum_{k}^{K}w_kh_k \le M_0+N \qquad (7)
\end{aligned}
$$

$$\sum_{c=1}^{C}\sum_{g=1}^{G}\sum_{i=1}^{n}A_{cg}e_{icg}x_{icg}+\sum_{v=1}^{V}\sum_{i=1}^{n}L_{v}e_{iv}x_{iv}$$
$$+\sum_{j=1}^{J}P_{j}f_{j}+\sum_{k}^{K}w_{k}h_{k}+\sum_{v=1}^{V}p_{vo}L_{v}$$
$$\leq M_{0}+N+R_{0} \tag{8}$$

The definition of variables in the above equations is given in Table 4.

(2) Production activities

Six categories of activities are included in the model: crop and animal production, sale, self-consumption, self-supply and purchase. Crop production activities are constituted by combinations of three types of cultivated land and six kinds of crops. Cultivated land includes rice fields, irrigable upland and non-irrigable upland. The area of rice fields and irrigable upland is fixed, but the area of non-irrigable upland may be changed by converting rangeland to non-irrigable fields which often occurs in spring. Crops include maize, wheat, watermelon, rice, millet and beans. Yields depend on land type, input level of labor, fertilizer, seeds, pesticides and manure.

Existing livestock production is grazing of sheep, goats, cattle and horses, as well as hog husbandry. Horses are raised as draught animals. Pigs are raised with crop seed and kitchen waste. Sheep, wool, goat, cashmere, cattle, milk and pig are the livestock products. Sedentary beef cattle are introduced as an alternative technology, which is incorporated in the model as an adding production activity. In total, livestock activities include six kinds of animals: sheep, goats, pastoral cattle, sedentary beef cattle, horses and pigs.

Introduction of sedentary livestock technologies has been considered as a possible solution to the tradeoff between poverty alleviation and rangeland conservation, as it is assumed that sedentary livestock may reduce grazing pressure without a decrease in household income[13]. Sedentary livestock in this area includes beef cattle, small-tailed sheep and milk cow. Beef cattle husbandry involves buying calves and fattening them through feeding crop products, straw and grass, without grazing. Small-tailed sheep are one kind of high-breeding sheep. Milk cow refers to a highly-productive hybrid milk cow, not a native breed of cow. As small-tailed sheep do not bring a significant income increase, and milk cows face limited demand in the local market as well as a transportation constraint, beef cattle became the most realistic choice for farmers to prefer.

Some tradeoffs exist in land use choice, labor allocation between on-farm labor and off-farm employment, feed allocation among livestock animals, and other resource allocation. Tradeoffs in land use choice include

Table 4. Variable definition

Variables	Explanation	Variables	Explanation
M	Net income	N	Amount of available loan
M_0	Cash income in the base year	R_0	Value of livestock in the base year
c	Crop	p	Price of crop, livestock output or purchased food
g	Land type of cultivated land	p_{v0}	Price of purchased livestock for feeding
A	Land endowment	y_{cg}	Yield function for production of crop c
A_{cg}	Area of crop c produced on land type g	y_v*	Yield function for livestock v and livestock product
A_r	Area of rangeland	y_r	Grass yield of rangeland
v	Livestock	x_i	A vector of inputs used in production of crop c or livestock v
L	Stock level of livestock v	e_i	Per unit input cost for input x_i
w_k	Wage for labor employed off-farm	b	Crop or livestock output y used for self-consumption
w_o	Wage for hired labor	f	Purchased food
Z_h	Total family labor	α	Daily fodder requirement of livestock v
z_o	Family labor used off-farm	β	Nutrition content of food
z_f	Family labor used on-farm	γ	Daily subsistent nutrition requirement of human
Z_f	Total farm labor input	S	Supplementary fodder from crop residue
h	Hired labor used on-farm	P	Human population
s	Crop or livestock output y used for self-supply, such as seed, feed, draft animal		

* The yield of livestock refers to the proportion of transaction (sales, self-consumption) of livestock;
Livestock product refers to milk, wool and cashmere.

allocation between maize and wheat in use of irrigable fields, and allocation among maize, millet and bean in use of non-irrigable fields. Another type of tradeoff exists in use of farm products, such as allocation between sales, self-consumption and self-supply for seed or feed in use of crop products.

(3) Market imperfection

As a price band of agricultural products exists between farm gate prices and purchasing prices, the model introduces non-tradable use of produced products that are self-consumption and self-supply, with a distinction between sale and purchase of produced products and inputs.

(4) Model constraints

The main constraints incorporated in the model include: land, labor and budget resources, cropping rotation, feed supply and demand balance, and food supply and demand balance based on subsistent food intake requirements. As there is rare mobility of land management rights between households and a land market is absent, the total area of land is no more than the land endowment, as defined as equation (2). Labor resource constraints are defined as equations (3) and (4). Total family labor is allocated to on-farm activities and off-farm employment. Farm labor input consists of on-farm family labor and hired labor for farm activities. As off-farm employment opportunities for rural residents are limited, a constraint of off-farm opportunities is incorporated in the model. Similarly, hired labor for farm management is limited.

The number of animals is limited by feed supply, especially by the area and productivity of rangeland. The feed supply and demand balance, defined as equation (5), consists of the feed requirements of animals and the feed supply from grass, crop straw and part of crop seed. The food supply and demand balance consists of food consumption requirements and food supply activities, defined as equation (6). Food supply activities include self-consumption of produced products and purchased food. Food consumption requirements are calculated according to subsistence nutrition intake requirements with a linear consumption preference.

A budget constraint is incorporated in the model, defined by equations (7) and (8). Total expenditure, the sum of production inputs purchased and food consumption expenditures, is limited by the sum of cash income and available loan. Equation (8) specifies that total expenditure including investment in expanded reproduction, such as initial investment in livestock, is limited by the sum of livestock stock, cash income and available loan.

(5) Grazing restriction

Grazing pressure is defined as $GP = L \times (1 - F)/A_r$ in this paper, where GP is grazing pressure, L is sheep equivalent of livestock, F is the rate of supplementary fodder in fodder requirement, and A_r is the area of available grazing land. In the above equation,

$$F = S/\sum_{v=1}^{V} 365 a_v L_v \text{, where } \sum_{v=1}^{V} 365 a_v L_v$$

is total fodder requirement. Equation (5) determines the number of animals. A grazing prohibition or a half-year prohibition is incorporated in the model by changing the available grass yield of rangeland. Restriction on herd size as alternative regulations is directly dealt with through adding a constraint in the model.

Table 5. Scenario definitions for environmental regulation and new technology

Environmental regulations		
	Grazing	Land reclamation
GR	Free grazing	Free reclamation
G	Free grazing	Prohibition
G(10)	Restricted to 10 sheep equivalent per capita	Prohibition
G(5)	Restricted to 5 sheep equivalent per capita	Prohibition
G(2)	Restricted to 2 sheep equivalent per ha	Prohibition
G(1)	Restricted to 1 sheep equivalent per ha	Prohibition
G(1/2 y)	Grazing half year	Prohibition
C	Complete prohibition	Prohibition
New technologies		
0	Using existing farming technologies	
1	Introducing sedentary beef cattle technology	

2. Scenario design

In order to simulate the effects of regulations on grazing and reclamation, several scenarios are designed. Regulations on grazing in practice include: complete prohibition and half year prohibition of grazing. As a control, the scenario of free grazing is also introduced. As an alternative regulation, a scenario of restricting herd size is designed. Regulations on reclamation include two scenarios: reclamation prohibition in practice and free reclamation as a control. Combinations of regulations for grazing and those for land reclamation consist of scenarios for land use regulations, listed in Table 5. Restrictions on herd size include two types: one is to restrict it by the number of residents, and the other is to restrict it by the area of rangeland. G(10) and G(5) are scenarios restricting herd size per person (calculated as number of animals/number of household members), and G(2) and G(1) are scenarios restricting herd size per ha of rangeland. Different restriction levels are simulated to determine a reasonable level of restriction.

Two scenarios are designed for simulation of the effects of the introduction of alternative technologies: existing livestock production and sedentary beef cattle as a new technology.

Simulation results

1. Impacts of rangeland conservation regulations

Simulation results indicate that if farm households can graze livestock and clear rangeland freely, average income per capita may reach 3,021 Yuan in Yaoledianzi and 2,526 Yuan in Sharitala (Table 6). If grazing is not restricted, in comparison with free reclamation (GR), reclamation prohibition (G) may lead to 26% income decrease in Yaoledianzi and 9% in Sharitala. Restriction of reclamation poses a more severe negative effect on farm household income for the cropping system than for the pastoral system. Compared with free grazing (G), average income per capita will decrease 14% in Yaoledianzi and 55% in Sharitala under the policy to prohibit grazing completely (C). The policy of prohibiting grazing causes a major negative effect on household income, especially for pastoral areas. A half year grazing prohibition (G(1/2 y)) poses a relatively less negative effect on household income (4% for Yaoledianzi and 16% for Sharitala) than complete grazing prohibition. This may be the explanation for the current regulations: complete grazing prohibition in Yaoledianzi and half-year grazing prohibition in Sharitala. Rangeland conservation regulations have posed negative impacts on poverty alleviation.

Although there are less negative effects on household income from prohibiting grazing for half year, the grazing pressure exceeds the recommended level (1 sheep equivalent per ha) in both villages. The simulation results suggest that alternative regulations are needed to promote simultaneously rangeland conservation and poverty alleviation. Restriction of the herd size (G(5) in Sharitala) or grazing pressure (G(1) in both villages) might be considered as alternative regulation measures, especially in pastoral areas, as they may keep grazing pressure at the recommended level with less negative impact on household income rather than prohibiting grazing completely (C).

2. Effects of new technology: sedentary beef production

Table 7 shows that introducing sedentary beef cattle will generate 52% increase of income in Yaoledianzi under a complete grazing ban (from C-0 to C-1) and 78% income increase in Sharitala under a half year grazing ban (from G(1/2 y)-0 to G(1/2 y)-1). This increase results in income 30% greater than free grazing with land reclamation prohibition in the cropping system case.

Table 6. Impacts of rangeland conservation regulations

Scenario	Yaoledianzi (cropping)			Sharitala (pastoral)		
	Income per capita (Yuan)	Grazing pressure (Sheep equivalent /ha)	Reclamation (ha)	Income per capita (Yuan)	Grazing pressure (Sheep equivalent /ha)	Reclamation (ha)
GR	3,021	2.41	85.1	2,526	2.41	34.9
G	2,229	2.25	0	2,305	2.41	0
G(1)	2,026	1.00	0	1,559	1.00	0
G(2)	2,144	2.00	0	2,076	2.00	0
G(5)	2,217	2.25	0	1,611	1.10	0
G(10)	2,229	2.25	0	2,180	2.20	0
G(1/2 y)	2,149	1.58	0	1,931	1.68	0
C	1,907	0.00	0	1,042	0.00	0

Table 7. Simulation results on technical introduction

Scenario*	Yaoledianzi (cropping)		Sharitala (pastoral)	
	Income per capita (Yuan)	Grazing pressure (Sheep equivalent /ha)	Income per capita (Yuan)	Grazing pressure (Sheep equivalent /ha)
C-0	1,907	0.00	1,042	0.00
C-1	2,892	0.00	1,852	0.00
G(1/2 y)-0	2,149	1.58	1,931	1.68
G(1/2 y)-1	3,079	1.58	2,723	1.68
G(1)-0	2,026	1.00	1,559	1.00
G(1)-1	3,011	1.00	2,369	1.00
G(5)-0	2,217	2.25	1,611	1.10
G(5)-1	3,160	2.25	2,421	1.10

* The part of the scenario label before the bar refers to land use regulation, number 0 and 1 after the bar refers to technology.

However, the increase does not bring income up to the level of free grazing in the pastoral system (20% less). If the restriction of 1 sheep equivalent per ha was implemented as an alternative policy to keep grazing pressure at a reasonable level, the introduction of sedentary beef cattle may bring a 49% increase in income in Yaoledianzi and 52% in Sharitala. The simulation results are evidence that improving farmers' access to new technologies may not only overcome income decrease with the implementation of rangeland conservation regulation, but also bring income increase relative to unrestricted grazing while reducing rangeland degradation.

To introduce sedentary beef cattle needs initial investment. The initial investment in a calf is about 1,600 Yuan. The above results are obtained from village level simulation. The aggregate capital stock makes it possible to afford the initial investment in beef cattle. However, due to the significant difference in household income between poor households and better-off households, for poor farmers, the scarcity of farm assets constrains their ability to introduce sedentary beef cattle. Taking the poorest households (Group A) as an example, average household savings (cash income minus necessary production and living expenditures, from survey data) is minus 678 Yuan for Yaoledianzi and minus 3,371 Yuan for Sharitala in the base year. That is to say, their income is not enough to maintain their livelihood, much less be able to invest in beef cattle.

3. Effect of credit provision

Improving poor farmers' access to credit might help them to increase their profit opportunities and overcome income decrease due to rangeland use regulations. Improvement of poor farmers' access to credit can also be considered as a solution for overcoming the entry barrier to introducing new technologies. In particular, credit service will be essential for poor farmers to introduce sedentary beef cattle. The model is run for poor households to investigate the effect of credit provision.

Simulation results show that under existing technical conditions and rangeland use regulation in practice, providing credit to poor farmers in Yaoledianzi cannot bring them income increase in comparison with no credit service as poor upland farming households face limited profit opportunities under regulation of prohibiting reclamation. But providing credit to poor livestock households in Sharitala may generate a 317% income increase in comparison with no credit service even when a half year grazing ban is introduced under the existing technical conditions (Table 8). That is because farmers will expand livestock that is constrained by their budget with the provision of credit. While restriction on herd size by keeping grazing pressure at 1 sheep equivalent per ha was introduced under existing technical conditions, providing credit service to poor farmers does not generate income increase in Yaoledianzi as poor cropping farmers still face limited profit opportunities under regulation of prohibiting reclamation, but it may bring 183% of income increase to poor farmers in Sharitala. Finally, while sedentary beef cattle are introduced under the regulation to keep grazing pressure at the level of 1 sheep equivalent per ha, providing credit service to poor farmers may generate 51% of income increase in Yaoledianzi and 416% in Sharitala. As poor farmers in both villages may increase their profit opportunities with introduction of sedentary beef cattle, improving access to credit with introduction of sedentary beef cattle may help poor farmers to increase their income sufficiently even when rangeland use regulation to keep grazing pressure at the reasonable level is implemented.

Table 8. Simulation results on credit service to poor households

Village	Scenario	Credit available		No credit	
		Income per capita (Yuan)	Grazing pressure (Sheep equivalent /ha)	Income per capita (Yuan)	Grazing pressure (Sheep equivalent /ha)
Yaoledianzi	C-0	873	0.00	873	0.00
	G(1)-0	981	1.00	981	1.00
	G(1)-1	1,714	1.00	1,137	0.19
Sharitala	G(1/2 y)-0	1,043	1.64	250	0.22
	G(1)-0	707	1.00	250	0.22
	G(1)-1	1,291	1.00	250	0.22

Conclusions and implications

The above discussion examined the incompatibility between poverty alleviation and environmental conservation in agro-pastoral areas of China. The results indicated that rangeland conservation practices have posed negative impacts on the livelihoods of poor households. There is a need for alternative policies to promote simultaneously rangeland conservation and poverty alleviation. Restriction of herd size or grazing pressure might be considered as alternative policy measures in pastoral areas. Introducing sedentary beef livestock technologies could generate a sufficient compensatory increase in household income under rangeland conservation regulation to keeping grazing pressure at a reasonable level, especially in the cropping system. Improving farmers' access to new technologies may not only alleviate income decrease with the implementation of rangeland conservation regulation, but also bring income increase with reducing grazing pressure to rangeland. However, if credit supporting is not available for poor farmers, they cannot introduce sedentary livestock and generate a sufficient increase in income. In order to introduce sedentary beef livestock, improving access to credit supporting service is essential for poor farmers. If sedentary beef cattle technologies are introduced, providing credit to poor livestock farmers may generate several-fold increase in income under rangeland conservation regulation to keep grazing pressure at a reasonable level.

One of the policy implications of this paper is that rural development practices to improve access to new technologies and credit service may contribute simultaneously to poverty alleviation and environmental conservation. It is important to combine implementation of environmental conservation regulation and rural development policy in environmentally degraded areas of developing countries.

Acknowledgements

This paper reports part of outcomes of the research project "Land Use Planning Method for Combating Desertification and Sand Storm" sponsored by Grant for Environmental Researches of Nihon-seimei Foundation. The research project was carried out since 2003 to 2004. The field works were conducted in the semi-arid areas of Inner Mongolia, China in cooperation with the Cold and Arid Regions Environmental and Engineering Research Institute, CAS and the China Key Research Project "Desertification and its Prevention in North China" (GT2000048700). The authors thank Dr. Tonghui Zhang and Dr. Masakazu Nagaki for their kind help. The authors also appreciate valuable comments from anonymous reviewers.

References

1. Barbier, B. (1998) Induced innovation and land degradation: Results from a bioeconomic model of a village in West Africa. *Agric. Econ.,* **19**, 15–25.
2. Bontkes, T. S. (2001) Agricultural prices and land degradation in Koutiala, Mali: a regional simulation model based on farmers' decision rules. *In* Economic policy and sustainable land use, eds. Heerink, N., Keulen, H. & Kuiper, M., Springer-Verlag, New York, 151–168.
3. Fleming, E. & Milne, M. (2003) Bioeconomic modeling of the production and export of cocoa for price policy analysis in Papua New Guinea. *Agric. Syst.,* **76**, 483–505.
4. Heerink, N., Kuyvenhoven, A. & van Wijk, M. S. (2001) Economic policy reforms and sustainable land use in developing countries: issues and approaches. *In* Economic policy and sustainable land use, eds. Heerink, N., Keulen, H. & Kuiper, M., Springer-Verlag, New York, 376.
5. Kruseman, G. (2001) Assessing the effects of policy measures on household welfare and agro-ecological sustainability: an overview of farm household modelling approaches. *In* Economic policy and sustainable land

use, eds. Heerink, N., Keulen, H. & Kuiper, M., Springer-Verlag, New York, 135–150.
6. Kruseman, G. et al. (1995) Farm household modeling for estimating the effectiveness of price instruments in land use policy. *Neth. J. Agric. Sci.,* **43**, 111–123.
7. Kruseman, G. & Bade, J. (1998) Agrarian policies for sustainable land use: bio-economic modeling to assess the effectiveness of policy instruments. *Agric. Syst.,* **58**, 465–481.
8. Kruseman, G. & van Keulen, H. (2001) Soil degradation and agricultural production: Economic and biophysical approaches. *In* Economic policy and sustainable land use, eds. Heerink, N., Keulen, H. & Kuiper, M., Springer-Verlag, New York, 115–134.
9. Mullen, J. D. et al. (2003) Integrating long-run biological and economic considerations into *Striga* management programs. *Agric. Syst.,* **76**, 787–795.
10. Ohkuro, T. & Nemoto, M. (1996) Vegetation degradation process caused by sheep grazing at sandy grassland in semi-arid regions of Northeast China. *Pap. Environ. Inf. Sci.*, **10**, 31–36.
11. Ravnborg, H. M. (2003) Poverty and environmental degradation in the Nicaraguan hillsides. *World Dev.,* **31**(11), 1933–1946.
12. Reardon, T. & Vosti, S. (1995) Links between rural poverty and the environment in developing countries: Asset categories and investment poverty. *World Dev.,* **23**(9), 1495–1506.
13. Shi, M., Tanaka, Y. & Zhao, H. (1998) Sustainable development of land use and farming system for combating desertification in Horqin sandy area of north China: a case study on Naiman Banner, Inner Mongolia. *J. Agric. Dev. Stu.,* **9**(1), 71–80.
14. Shiferaw, B. & Holden, S. (1999) Soil erosion and smallholders' conservation decision in the highlands of Ethiopia. *World Dev.,* **27**, 739–752.
15. Singh, I., Squire, L. & Strauss, J. (1986) Agricultural household models: extensions, applications, and policy. John Hopkins University Press, Baltimore, pp.335.
16. World Bank (2003) World development report 2003. Oxford University Press, New York, 66–67.
17. Yang, J. (2004) Grassland degradation and rehabilitation in Inner Mongolian steppe regions. *In* Paper presented at international symposium of evaluation and monitoring of desertification, Tsukuba, Japan.
18. Zhao, H. (1993) Evaluation on the grassland resource and its rational use in Yaoledianzi Village, Naiman Banner. *In* Integrated rehabilitation of Korqin sandy land, eds. Liu. X. & Zhao, H., Kansu Technology Press, 3–79.
19. Zhao, H. et al. (1997) Evaluation of productivity and rational utilization of sandy grassland in Horqin Steppe under different grazing intensities. *J. Desert Res.,* **17** (Supp.1), 109–114.