Agriculture, Ecosystems and Environment 138 (2010) 249–256

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Intensive agropastoralism: dryland degradation, the Grain-to-Green Program and islands of sustainability in the Mu Us Sandy Land of China

Zunguo Dai*

Graduate School of Geography, Clark University, 950 Main Street, Worcester, MA 01610-1477, United States

ARTICLE INFO

Article history:
Received 28 May 2009
Received in revised form 4 May 2010
Accepted 19 May 2010
Available online 15 June 2010

Keywords:
Grain-to-Green Program (GTGP)
Desertification
Agricultural intensification
Agropastoralism
Mu Us Sandy Land

ABSTRACT

The Grain-to-Green Program (GTGP) was initiated in China in 2000 to address environmental degradation. In northern China, the central goal of the program is to entice sustainable transitions in resource uses through subsidizing cropland afforestation and grassland exclosure. This study, based on a household survey in Shabianzi, an agropastoral community in the Mu Us Sandy Land, examines farmers' responses to and the environmental outcome of the GTGP. Results show that through intensification of maize production, farmers were able to assimilate the impact of grassland exclosure, and the new resource use system fosters closer linkage between crop and livestock production. As a result, sheep population in the community shows a steady recovery after the program, hogs experience a sharp increase, while goats register an abrupt decline. Improved household economy resulted from increased livestock offtake rates diminishes pressure on subsistence cultivation, and average household landholding has been stabilized at ~1.0–1.2 ha. Grassland exclosure is almost universally violated through surreptitious herding; but grazing intensity has been reduced, which leads to vegetation recovery and an improvement in the local environment. Similar transitions are observable within the Mu Us Sandy Land, demonstrating these successful stories are not site-specific, but represent a general pattern. These "islands of sustainability" stress the importance of pathway(s) undertaken by local farmers in understanding the environmental outcomes of the GTGP. They also suggest that even in an endangered environmental region, opportunities for sustainable resource use are still present.

1. Introduction

Environmental degradation as the antithesis of sustainability has drawn increasing attention (Barrow, 1991; Reynolds and Stafford Smith, 2002; Geist and Lambin, 2004; Geist, 2005; Johnson and Lewis, 2007). Among its many manifestations, desertification became a global issue since the 1970s following severe drought and devastating famine in the Sahel (Grainger, 1990; Middletown and Thomas, 1997). Over the last three decades, the perception of desertification as a simplistic, linear degradation pattern has been gradually replaced by that of a dynamic, non-equilibrium, spatial-heterogeneity process (Westoby et al., 1989; Milton et al., 1994; Dougill et al., 1999; Illius and O'Connor, 1999; Sullivan and Rohde, 2002; Gillson and Hoffman, 2007). The shift in ecological thinking stresses the importance of a place-based approach to desertification to understand the causal relationships within specific physical and social settings (Blaikie and Brookfield, 1987; Adams and Mortimore, 1997; Warren, 2002; Reynolds et al., 2007).

Desertification is widespread and severe in northern China (Zhu, 1989; Fullen and Mitchell, 1994; Zhu and Chen, 1994; Muldavin, 1997; Dong et al., 1999; Wang et al., 2004; Liu and Diamond, 2005). Recent remote sensing result (Wang et al., 2004) reveals the rate of desertification in northern China is accelerating despite tremendous mitigation efforts. In certain regions (e.g., the Minqin Oasis in the Gansu Corridor), rampant desertification has threatened the well-being of people living there (Kang et al., 2004).

Desertification in China is largely understood as resulted from the overworking of drylands by local farmers (Zhu and Liu, 1981; Zha and Gao, 1997). This perception underpins the traditional technical approaches to desertification control. Since the late 1990s, however, the Chinese central government began to address the problem from the social domain with a series of environmental programs. Among them, the Grain-to-Green Program (GTGP), which subsidizes farmers for afforestation on marginal croplands, is unprecedented in China's environmental history in terms of geographic extent, government budget and social mobilization (SFA, 2007; Liu et al., 2008).

Under the program, farmers in northern China, once designated by the local government, would receive 100 kg of grain (in kind or cash) and 20 yuan (at present, $1 US = 6.83 yuan) for every mu (1/15 ha) of cropland re-vegetated (the duration of subsidies varies

* Tel.: +1 508 250 6226.
E-mail address: zdai@clarku.edu.

0167-8809/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.agee.2010.05.006

depending on the types of vegetation used). In return, livestock herding on grassland is banned and violators punished, usually with a fine. To fit into local conditions, the program also includes guidelines on rules and criteria for the scrutiny of croplands. One caveat is irrigated croplands are excluded from the GTGP; nor does the program prohibit the expansion of irrigated agriculture where possible.

Unlike traditional technical approaches to desertification, the GTGP aims to entice through subsidies a sustainable transition in rural livelihood. Direct intervention into local resource uses, however, implies that success of the program relies on the questionable premise of cooperation from farmers, especially considering the importance of grassland and livestock keeping to peasant economy in northern China.

Responses to external intervention in local resource use can be cooperation, resistance, or assimilation (Peluso, 1992; Muldavin, 1997; Bebbington, 2000; Jiang, 2004), contingent upon the interactions among stakeholders and the physical and social settings within which these interactions occur. The environmental consequences are as well complex, defying any a priori assumption of either degradation or improvement (Robbins, 1998). One implication is that both drivers and inhibitors of degradation might coexist within the social system. But the pathway undertaken has yet to be understood sufficiently to project with accuracy (Lee, 1986; Turner and Ali, 1996). In northern China, the significance of this antinomy is reflected through the joint role between government policies, particularly the GTGP on one hand, and the environmental problems these policies attempt to address on the other.

This paper, taking a place-based approach to desertification, explores how peasant farmers in *Shabianzi*, an agropastoral community within the Mu Us Sandy Land, responded to the GTGP and the environmental outcomes of these responses. In order to do so, resource uses at household-level prior to and after the GTGP are examined using socioeconomic data from 1996 to 1997 and 2003 to 2005. Changes in agricultural land-use structure and livestock husbandry and the interactions between the two are analyzed to demonstrate how local farmers were able to intensify maize production after the GTGP, and assimilate with mild resistance the impact of grassland exclosure. The new resource use system reduces the grazing intensity and leads to improvement in local environment. This and similar responses within the Mu Us Sandy Land indicate that even within an endangered environmental region, islands of sustainable intensification still exist. The lessons learned from these successful stories for the GTGP in specific and for environmental degradation in northern China in general are also discussed.

2. Study area and data source

2.1. The Mu Us Sandy Land

The Mu Us Sandy Land falls within the border of Inner Mongolia, Ningxia and Shaanxi. It covers one third of the Ordos Plateau encircled by the elbow of the Yellow River and the Great Wall, and has an area of about 40,000 km^2. Average annual rainfall decreases from above 400 mm in the southeast to 250 mm towards the northwest, 70% of which falls between June and August. As part of the agropastoral transitional zone in northern China, resource uses in the Mu Us Sandy Land are characterized by the coexistence of agriculture and livestock husbandry; because of marginal rainfall, drought is a major obstacle to rain-fed agriculture, and crop yields are generally low.

The Mu Us Sandy Land is particularly vulnerable to desertification. Its expansion and contraction during historic time make it an ideal place to study environmental changes, and not surprisingly, it has been the "incubator" and "hotspot" of desertification research in China since the 1960s. The discovery deep in the Mu Us Sandy Land of *Tongwan*, the abandoned capital of the Great *Xia* empire (407–427 A.D.), provided convincing evidence of desertification in the region during the past two thousand years (Hou, 1973; Hou and Yu, 1973). Recent research also reveals severe desertification in the Mu Us Sandy Land (Fullen and Mitchell, 1994; Mitchell et al., 1998; Wu and Ci, 2002; Kobayashi et al., 2005; but see Runnström, 2000, 2003). For these reasons, the Ordos Plateau has also been recognized as a critical environmental region in an assessment of such regions worldwide (Kasperson et al., 1995, 1996; Jiang, 1999).

Two types of landforms dominate the Mu Us Sandy Land: sandy uplands (locally known as *liang*) and lowlands (*tan*). The differences in local relief between the two are usually within a few dozen meters, which largely account for variations in groundwater depths and vegetation types. For the proposes of agriculture, however, the significance of variations in groundwater depths could not be overestimated since farmers usually limit irrigation water use to shallow aquifers because of economic and technical constraints.

2.2. Characteristics of the community

Shabianzi, as its name in Chinese indicates, is a village "bordering desert," specifically the Mu Us Sandy Land. It is an agropastoral community in Yanchi County, Ningxia some 14 km north of the township of Huamachi, the county seat (Fig. 1). Average annual rainfall in the region is 293 mm (1956–2005) with high interannual variability (coefficient of variation, or C.V. = 0.31). Situated near the provincial border with Inner Mongolia to the north, the village lies in an extensive lowland and nearly all lands are within 30 meters above the lowest point (1295 m) in Yanchi County.

The village had 80 households and a population of 405 in 1997, which increased to 114 and 457, respectively in 2007. These households distribute sparsely, extending for miles along a dirt road, the only connection with the outside world. Based on the relative closeness of the households, the community can be further divided into five subgroups, or natural villages, which are Yikeshu, Macanghao, West, Middle, and East Shabianzi.

The village controls a total land area of 48.2 km^2, creating a population density of less than 10 persons/km^2, among the lowest in Yanchi County but representative of neighboring Inner Mongolia banners (e.g., Runnström, 2000; Jiang, 2004). Total croplands in the village registered 1890 mu in 1997; among these, 1327 mu were classified as irrigated, although all cropland can be irrigated if the farmers so choose. Fallow was practiced before the GTGP because of the paucity of moisture and economic constraints. This leaves well over 95% of the total land resources in the community as grassland, accessible to livestock grazing throughout the year.

Households in the community engage in a mixed livelihood of subsistence cultivation and livestock herding. Crops are produced mainly for household provisioning although surplus also goes to the market. Major crops include wheat, maize, millet, broomcorn millet, soybean, oil seeds and various vegetables. Livestock not only provide the primary sources of animal protein, but also generate the majority of household cash income. The livestock include goats, sheep, and hogs, with certain households, especially before the GTGP, also kept draft animals, such as oxen, donkeys, and/or mules.

The GTGP has been in effect in the community since October 2000. As a result, grassland has been officially closed to livestock herding. However, since all croplands in the community have been classified as irrigated by the local government, none was enrolled in the GTGP. Therefore, farmers are not entitled for government subsidies while denied access to grassland.

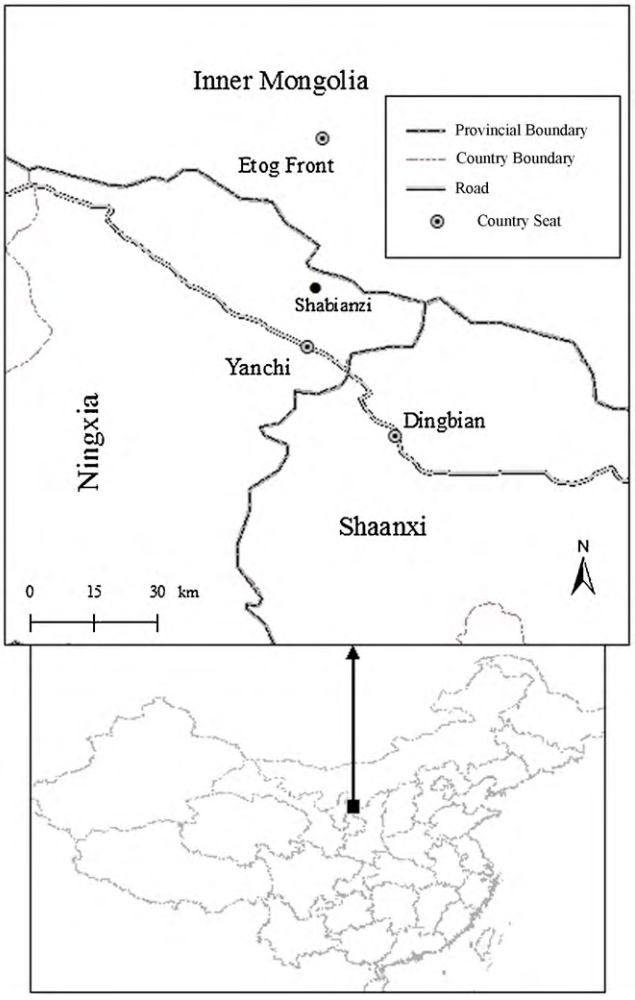

Fig. 1. Shabianzi of Yanchi County in Ningxia, China.

2.3. Data sources

The household survey for this study was conducted by the Bureau of Agriculture, Yanchi. During 1991–1995, Shabianzi hosted an experimental station on desert and desertification control ran jointly by the Institute of Desert Research, Chinese Academy of Sciences, the Commission of Science and Technology, Ningxia and the Bureau of Agriculture, Yanchi. In 1996 the station was taken over by the County Bureau of Agriculture, which has since conducted socioeconomic survey in the community.

The survey was designed as a structured one and collected information on household economy. It inquires information on agriculture, including total areas of croplands, areas and yields of each crop and capital outlays such as on seeds, fertilizers and pesticides. The survey also includes questions on livestock composition and offtake, income generated from livestock production (e.g., wools, hides), feed and fodder inputs and spending on veterinary services. In addition, information on household income (e.g., waged labors) and expenditure (e.g., durables, food consumptions) is also collected. Because of this, during my visits to the community in the summers of 2005 and 2006, my interviews focused mainly on farmers' attitudes towards grassland exclosure and policy enforcement and their perceptions of changes in rangeland quality.

The data for this study were collected during two periods, 1996–1997 and 2003–2005, with 2000, the year the GTGP was implemented, in the middle. The survey was intended to cover all village households. But the actual numbers of households surveyed vary (Table 1). The 75 households (out of 80) surveyed in 1997 represented 94% in the community, which reduced to 52% (57/109) in 2005. Since these surveys were conducted at roughly the same time of the year—early October at the end of the harvest season, I suspect that changes in the percentage of households surveyed might reflect a higher degree of mobility as a result of improved off-farm employment opportunities and the gradual relaxation of the household registration system.

Table 1
Total cropland areas at household-level (unit: mu).

	No. of household surveyed	Average	Min	Max	S.D.
1996	69	15.7	3.0	44.0	7.36
1997	75	16.9	3.0	40.0	7.50
2003	64	18.5	3.0	46.5	9.62
2004	60	16.4	5.0	41.0	6.93
2005	57	16.6	3.0	44.0	8.19

Note: 1.0 mu = 1/15 ha.

3. Results

3.1. Crop production

Cropland areas at household-level in the community show no sign of expansion after the GTGP. On average, household cultivates an area of 1.0–1.2 ha; the highest average of 18.5 mu occurred in 2003 (Table 1). But this expansion was short-lived and regressed back to areas prior to the program during the following 2 years. However, as the number of households in the community increased from 80 to 109 during the period, the expansion of irrigated cropland in the community is still significant: from about 1350 mu in 1997 to over 1800 mu in 2005, an increase of about a third. But this increase is caused by demographic transitions (more and smaller households) in the community, rather than a direct response to the GTGP.

The persistence of average total cropland areas, however, belies significant structural changes in agricultural land-use. By structural change, I mean changes in cropland areas dedicated to different crops. Among the major crops grown in Shabianzi community, three broad categories can be identified: wheat as the staple food crop, maize as livestock feed and fodder and miscellaneous crops, which include soybean, millet, oil seeds and sundry vegetables.

Before the GTGP, farmers in the community undertook a conservative approach to crop production, with each of the three crop categories accounting for about one third of cropland areas (Table 2). Wheat, be it produced annually or biannually, was grown mainly for household consumption; with irrigation sporadic at best, average wheat yield was low by Chinese standard: $\sim$150 kg mu^{-1}, or 2.25 t ha^{-1}. Maize was cultivated as animal fodder, but unlikely to be a major source except seasonally (e.g., during the winter and drought) since grassland was still accessible to livestock grazing. The miscellaneous crops were produced both for subsistence and for market (e.g., watermelon).

The most notable structural changes in agriculture in the community after the GTGP are twofold: an almost vanishing of wheat production and a significant gain in maize's share (Tables 2 and 3). During 2004 and 2005 less than 10 households grew wheat; for those who continued to do so, the average area was about halved (Table 3). As a result, the areas for wheat after the GTGP are too small to be statistically significant at community level. Likewise, average cropland areas dedicated to miscellaneous crops (except in 2003) also registered slight contractions.

Since the average household landholdings remained stable after the GTGP, the structural changes resulted in a steady expansion

Table 2
Agricultural land use structure in Shabianzi (unit: mu).

	Average total area	Wheat	%	Maize	%	Miscellaneous					
						Watermelon	%	Broomcorn millet	%	Alfalfa	%
1996	15.7	5.4	34.4	4.8	30.6	2.3	14.6	1.2	7.6	0.0	0.0
1997	16.9	5.5	32.5	4.7	27.8	1.7	10.1	1.7	10.1	0.0	0.0
2003	18.5	–*	–	9.4	50.8	1.6	8.6	1.2	6.5	1.4	7.6
2004	16.4	–	–	11.0	67.5	1.8	11.0	–	–	1.4	8.5
2005	16.6	–	–	12.5	75.3	1.3	7.8	–	–	0.6	3.6

* During 2003–2005, the number of households and croplands engaged in wheat production are too small to be statistically significant.

Table 3
Changes in number of households growing wheat and area (mu).

	No.	Average	Max	Min	Median
1996	62	5.4	9.5	1.0	5.3
1997	56	5.5	12.0	2.0	5.0
2003	14	2.6	5.0	1.0	2.2
2004	4	2.4	4.0	2.0	2.0
2005	7	2.8	4.0	2.0	3.0

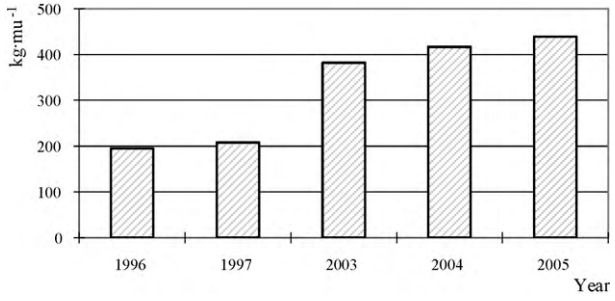

Fig. 2. Changes in average maize yields (kg mu^{-1}) in Shabianzi.

of maize production. Compared with that of 1996 and 1997, the average of 12.5 mu in 2005 represented an increase of about 260%, accounting for 75% of the total cropland area. Among the miscellaneous crops, alfalfa (*Medicago Sativa* L.), a fodder crop which is an excellent source of protein for livestock, is a new addition after the program.

Parallel to the areal expansion of maize production, maize yields also experienced a remarkable increase after the GTGP (Fig. 2). Before the program, maize yields in the community were generally low; for 1996 and 1997, average yields fluctuated around 200 kg mu^{-1}. The GTGP program witnessed an steady increase in maize yields in the community. The average yield of 439 kg mu^{-1} in 2005 was more than doubled that achieved in 1996 or 1997 and comparable to maize yields of China's productive regions.

As a result of the structural changes and intensification process, maize, in terms of both area and yield, has become the single most important crop in household economy after the GTGP in the community. During this process, local farmers also increasingly engage the market as most households choose not to produce the staple food crop. This transition is made possible through an improvement in household economy (e.g., reliable sources of income) and more productive employment of labor invested otherwise into wheat production, which relies heavily on a similar transition in the livestock sector.

3.2. Livestock husbandry

One major change in the livestock sector after the GTGP is an almost collapse of the goat population resulted from a dual reduction in goat-keeping households and the number of goats they keep (Table 4). Before the program, most households kept goats, which made up approximately 40% of livestock in the community, defying government policies discouraging such practice (Brogaard and Zhao, 2002; Wu and Ci, 2002). The GTGP seemed effective, at least initially, in reducing goats in the community through grassland exclosure: at its lowest (in 2004), the total goat population in the community was between 120 and 200, less than one tenth of the pre-GTGP level. This success, however, should not be exaggerated since the year 2005 witnessed a strong recovery in the goat population and the average number was more than doubled. Despite this, the total goat population in the community in 2005 remains less than a third of the pre-GTGP level because of the small number of goat-keepers.

The changes in the sheep population are less dramatic. Almost all households in the community continue practicing sheep-keeping after the GTGP, and the herd sizes (including both sheep and goats) remain generally small, with only one household having herd larger than 120. Likewise, the reduction in the number of sheep was temporary and moderate: the average for 2003 represented a decrease of some 20% from 1996 to 1997 (Table 4). During 2004 and 2005, the average numbers of sheep experienced a steady increase, surpassing in both years the pre-GTGP level.

Hogs register another major change in the livestock sector after the GTGP. Hog was raised in the community before the program. The average number in 1996 and 1997 suggests that it was kept primarily for household consumption, although some surplus also went to the market (Table 5). The program has witnessed a steady buildup in the hog population: while the percentage of hog-raising households varied little, the average hog number increased considerably, reaching 7.4 per household by 2005, more than doubled that of 1996 or 1997.

In agropastoral societies, the selling of livestock generates the major source of cash income, and therefore changes in market

Table 4
Change in livestock before and after the GTGP in Shabianzi.

	Goats			Sheep			Hogs		
	Number of household	% of household surveyed	Average	Number of household	% of household surveyed	Average	Number of households	% of household surveyed	Average
1996	60	87.0	24.4	68	98.6	32.5	65	96.2	3.6
1997	57	76.0	27.6	71	94.7	31.5	64	85.3	3.1
2003	15	23.4	7.6	63	98.4	25.9	60	93.8	3.4
2004	10	16.7	9.4	57	95.0	35.2	56	93.3	4.8
2005	14	24.6	21.8	56	98.2	38.0	55	96.5	7.4

Table 5
Changes in market offtakes of SSUs and hogs before and after the GTGP.

	Sheep and/or goats (SSUs)				Hogs			
	Number of households	% of household surveyed	Mean	S.D.	Number of households	% of household surveyed	Mean	S.D.
1996	39	56.5	8.3	9.1	17	24.6	1.4	0.70
1997	32	42.7	8.5	8.5	14	18.7	1.5	0.65
2003	49	76.6	13.7	12.0	25	39.1	5.2	9.24
2004	35	58.3	15.5	14.6	20	33.3	5.3	8.83
2005	34	60.0	18.5	15.0	22	38.6	10.0	14.06

offtakes are also an important indicator of household economy. Because of the prevalence of small stock in Shabianzi, small stock unit (SSU) is used here, and sheep and goat are assumed to have the same SSU value. Changes in average market offtakes for SSUs and hogs in the community are shown in Table 5. One trend is that for both SSU and hog, the increases in the average market offtake far outpaced that of the percentage of households. In addition, while the C.V. (the ratio between S.D. and mean) of market offtakes for SSUs shows sign of decreasing disparity among households, the standard deviation of market offtakes of hogs indicates that they were nonetheless highly concentrated. In fact, most households that expanded hog-raising are from West and East Shabianzi, suggesting the practice might have been initiated by a handful of households within these two subgroups.

In sum, the GTGP induced in the community not only a transition in the ways livestock are kept, but also livestock composition as well. While certain households continue including goats in their livestock, for most households, traditional goat and sheep herding on grasslands has increasingly been replaced by stall-feeding of sheep. In the new resource use system, hogs also secure a niche and expand in number, generating another source of household income.

3.3. Agropastoralism: the integration of agriculture and livestock husbandry

The expansion and intensification of maize production, achieved at the expense of subsistence cultivation, dominate changes in the agricultural sector in the community after the GTGP; likewise, pressure from grassland exclosure creates the demand for alternative sources of animal fodder when livestock are stall-fed. It is possible that through intensive maize production, farmers in the community were able to foster a strong linkage between agriculture and livestock production; similarly, this improved fodder source is also likely responsible for the recovery of sheep, and, for certain households, the goat population as well.

To test this hypothesis, regression analysis was conducted with households' total maize yields as the independent variable, and the number of sheep, and sheep and goats as the dependent variables. The results reveal a general increase in R^2 values and thus greater explanatory power of maize yields on variations in sheep and/or goats (Table 6). During the 2 years prior to the program, maize yields explained less than 20% of variation in the number of sheep and/or goats each household kept; in contrast, the years after the program had a correlation coefficient of 30% or more.

Table 6
Regression analysis result (R^2) (independent variable: household total maize yields).

	Sheep	Sheep and goats
1996	0.102*	0.178
1997	0.170	0.126*
2003	0.383	0.313
2004	0.452	0.444
2005	0.217	0.294

* $p = 0.05$, all else, $p = 0.01$.

It is unlikely, however, that farmers based their decisions on stock numbers on "anticipated" future maize yields. Since herd sizes are usually established in spring and maize is not harvested until late September or early October, variations in stock numbers might be better explained by maize yields from the previous year. When sheep and/or goats were regressed against total maize yields of the previous year, the correlation coefficients improved (Table 7). During 2004 and 2005, about 50% of variations in the number of sheep and/or goats at household-level can be explained by total maize yields from previous years.

Besides strengthened interactions between crop and livestock production, the new agropastoral system is also notable for its high efficiency in system output measured by market SSU offtake rates. Before the program, on average less than 10% of SSUs went to the market: 9 and 7% for 1996 and 1997, respectively. The unusually high rate in 2003 (38%) might be caused by the "liquidation" of goats by most households due to pressure from grassland exclosure, and inflate the actual value. But for 2004 and 2005, a period of post-GTGP recovery for both sheep and goat, the rates (26% for both years) were also consistently high, indicating livestock keeping becomes more market-oriented.

The proper capture and application of animal wastes, in turn, contributes to the high yields in maize production. Animal wastes did not become a reliable source of fertilizer for crop production prior to the program since livestock grazing on grasslands made the collection of animal wastes less likely, and hogs, small in number, were minor as a source. The transition to stall-feeding of sheep and expansion in hog-raising after the program generates a major source of animal wastes, which can be captured and applied in quantity onto croplands. This has since become a dependable source of fertilizer, and therefore begins the process of soil property improvement.

4. Discussion

4.1. Time-for-space: agricultural intensification

Consistent with peasant economy theory (Chayanov, 1966) and induced intensification thesis (Turner and Ali, 1996), the production behavior revealed through crop and livestock production in Shabianzi before the GTGP demonstrates resistance to "drudgery of labor" (Chayanov, 1966). In alignment with the favorable population–land ratio, resource use was characterized by subsistence cultivation and extensive livestock grazing; engagement in market was minimal; the technologies employed in production (i.e., the use of draft animals, low fertilizer input) were low,

Table 7
Regression results of livestock against previous years' maize yields (R^2).

Independent variables	Dependent variables	R^2
Maize yields 2003	Sheep 2004	0.513
Maize yields 2003	Sheep and goats 2004	0.499
Maize yields 2004	Sheep 2005	0.482
Maize yields 2004	Sheep and goats 2005	0.567

Note: $p = 0.01$.

and apparently did not reflect the capacity known to the community. The central aim of such a resource use system was to ensure household provisioning while minimizing risk and labor (Chayanov, 1966; Turner and Ali, 1996). For this same rationale, the system resists pathways of intensification without major changes in population–land ratio. The environmental implication of the resource use system is that without external forces, it discouraged exploring alternative fodder sources since doing so usually entails risks and/or increases in labor, even though grassland might be in a degraded condition.

The responses to the GTGP observed in Shabianzi community can be best captured by "time-for-space:" to adjust to a sudden increase in land pressure as a result of grassland exclosure, farmers invest more labor (usually measured in working time) to intensify crop production. The GTGP additionally ruled out the expansion of extensive crop production without irrigation, which has been proved to be more labor-efficient (Boserup, 1965; Netting, 1993). Hence, Farmers were reduced onto 2.5% of the village land resource. This increase in population–land ratio induced a Boserupian process of agrarian change: a switch in technologies and strategies of production – most of which long known to the community but not employed – such as irrigation, the use of tractors, chemical fertilizer and herbicides. Fodder shortfalls, the major challenge confronting livestock production after the GTGP, are met through intensive production of traditional fodder crop (maize) and the search for "new" ones (i.e., alfalfa).

The new resource use system differs from the one prior to the GTGP in production goals. While maintaining agropastoral practices, farmers increasingly engage the market as hybrid subsistence and commodity producers. The kinds of livestock products that go to the market remain the same but increase in quantity; most farmers now depend on the market for staple foods, and for seeds, fertilizers et al as well.

The upgrade in technologies and strategies of production leads to a reallocation of labor among productive activities, which in turn, alter agricultural land-use structure. Without expansion in average landholdings, the gain in maize production is at the expense of wheat and, to less extent, miscellaneous crops. This suggests that for most households, dedicating the same labor to value-adding maize production (as animal feed and fodder) is likely to be more economically sound than to wheat cultivation for subsistence. Although the data I have do not permit a test of such a hypothesis, the agrarian transition marginalizes wheat production with improved household economy, and helps stabilize the average household landholding at 1.0–1.2 ha.

4.2. Landscape of assimilation and islands of sustainability

The GTGP banned grassland livestock grazing, which accounts for over 95% of land resources in Shabianzi; meanwhile, government subsidies for cropland afforestation have not been extended to farmers in the community. Given the importance of livestock to local peasant economy, it might be expected that were the GTGP to meet the strongest resistance, it would be here. The actual trajectory, however, unfolds as a Boserupian process of agricultural intensification and the lack of apparent resistance, with impressive environmental improvement.

Before the GTGP, unrestricted access to commune rangeland provided little incentives for conservation. Farmers in the community seem to understand this all too well. In hindsight, most informants I talked to cited total stock number as the major reason for rangeland degradation. Their attitudes towards the GTGP are also mixed ones: dislike grassland exclosure while welcome the positive changes in rangeland condition.

The local farmers, however, were quick to adjust their production behavior in alignment with increased population–land ratio. Through the intensive use of 2.5% of the total land resources, farmers have been able to assimilate the impact of grassland exclosure. These processes have apparently been facilitated by the fact that neither the resources (namely, croplands and groundwater) nor the technologies employed are new to the community.

The new resource use system is proved to have positive economic and environmental outcomes. The linkage between crop and livestock production reduced the dependence on grassland, largely diverting the pathway of resistance. Some forms of resistance do exist, however. In Shabianzi community as in elsewhere, surreptitious rangeland herding is almost universally practiced. Sporadic herding, however, reduces substantially grazing intensity. As a result, rangeland degradation has been reversed, and vegetation is recovering. This improvement in local environment is reflected in that in the 2005 summer, after 6 months without meaningful rainfall (180 mm total rainfall for the year, one of the driest since weather records began in 1954), rangelands in the community still supported good vegetation cover.

Were the agrarian changes and the island of sustainability thus created in Shabianzi community to be of any significance to the GTGP and dryland degradation in northern China, the next question would be: are the intensification processes observed in the case study community site-specific or replicable under similar physical and socio-economic settings? Fieldworks for this study reveal that two other agropastoral communities within the Mu Us Sandy Land – *Liushuliang* of Yanchi and *Guangsheng* of Ejin Horo Banner, Inner Mongolia – undertook similar pathways of agricultural intensification in responses to the GTGP, although for the latter case the environmental consequences at larger scale are far more complicated and beyond the scope of this paper. For Liushuliang, another lowland community miles away from Shabianzi, the crop and livestock chosen are amazingly the same—maize and sheep and hogs. As moving and semi-fixed sand dunes in the community reminds us, however, the environmental challenges Liushuliang faces are a far more daunting one.

4.3. Livestock as wealth and/or as commodities

China's northern rangelands are characterized by high rainfall variability (Ellis et al., 2002). Precipitation mostly concentrates in the summer months; droughts are frequent, especially during spring. In such environments, livestock mortality is a major source of vulnerability of livestock husbandry; keeping large herds is both a strategy to maximize the grazing potential of animals and a response to fluctuations in stock numbers. The propensity for large herds is further reinforced by the multiple roles livestock played in traditional agropastoral society, for example, as stores of wealth generated through non-agricultural activities, as marketable commodities in use in exchange for household necessities (Dahl and Hjort, 1976; Turner, 1993).

Transition in the livestock sector after the GTGP in Shabianzi community has been characterized by the commercialization of livestock production. The low offtake rates prior to the program reveal that livestock were viewed more as wealth stores, emphasizing keeping large herds. In contrast, the high rates after the program reflect that livestock are viewed more as commodities in use, with farmers actively engage the market. Among Mongolian farmer-herders within the Mu Us Sandy Land, similar increases in offtake rates have been observed, and Jiang (2004) suggests that such trends are generally associated with a more market-oriented outlook of the livestock sector. In fact, despite the lack of hogs and hence greater dependence on small stock as food sources, the offtake rates achieved by the Mongolian farmer-herders are slightly higher than that of Shabianzi. This might indicate that in the case study community, there is still room for further increase in livestock offtake rates.

What lessons can we learn from agrarian changes in Shabianzi community for livestock production and grassland degradation in northern China? Traditional livestock producers are reluctant to destock, often for good reasons. The transition in this community shows that government efforts and development programs aiming at reducing grazing intensity are more likely to succeed if accompanied by measures to reduce risks associated with the variable environments. Likewise, changes in offtake rates in the community show that at the same stocking rate, the transformation to a market-oriented livestock production can lead to remarkable increases in system output. Therefore, instead of a complete ban of grassland herding, especially considering widespread, sometimes severe, resistance to grassland exclosure, a more flexible approach might be followed. These include, but not limited to, enticing with proper pricing system such a transition in livestock production (for example, Hinton, 1990); the wise use of key resource areas (Illius and O'Connor, 1999; Sullivan and Rohde, 2002) as grazing ground during the dry seasons since these are generally when overgrazing occurs, and the supply of feeds and fodders during droughts from China's grain surplus regions.

4.4. Place-based approach to desertification and scale issues

Agrarian changes in Shabianzi highlight the importance of the physical environment at local scale in facilitating (or precluding) the trajectories of sustainable transitions. With low population densities, agropastoral communities within the Mu Us Sandy Land are generally rich in land resources. For Shabianzi community, it is additionally endowed with a favorable lowland environment and access to shallow aquifers. It is through irrigation that local farmers were able to undertake the pathway of agricultural intensification. In contrast, in upland communities where physical and technical barriers to irrigation are high, the absence of intensification often leads to strong resistance to grassland exclosure, even with subsidies for cropland afforestation.

This influence on human use system of the physical environment, however, does not operate in a deterministic manner. In the case study community, the environmental advantages did not materialize into meaningful economic or ecological benefits until the GTGP significantly increased the population–land ratio. This suggests that for sustainable transitions to occur, certain threshold(s) within the social system must be crossed. The pathways towards such transitions can be accelerated, slowed, diverted, or even blocked by factors within the social system. Understanding the thresholds and the interactions among factors at local and larger scales to catalyze such transitions is therefore not only critical to understanding the environmental outcomes of the GTGP, but also to rangeland degradation in northern China in general.

Dryland degradation can be examined at various scales (Thomas, 1997; Warren, 2002; Reynolds et al., 2007). At regional scale, the Mu Us Sandy Land and the Ordos Plateau have been depicted as experiencing desertification of various forms during the past few decades. At local level, however, the agrarian changes in *Shabianzi* and communities with similar environmental trajectories after the GTGP demonstrate that even within an endangered environmental region, islands of sustainable resource uses do exist. How to replicate their success commands attention from researchers and policy makers alike. Such changes of significance, however, can easily be glossed over by remote sensing-based research at regional scale. This cross-scale discrepancy stresses the importance of a place-based approach to desertification to understand the complex interactions between government policies, human interactions and the physical environment in determining the environmental trajectories without assuming degradation as the sole outcome.

5. Conclusion

The GTGP marks a milestone in China's modern environmental history in its approach to environmental degradation. It represents the first major endeavor of the Chinese central government to entice through subsidies sustainable transitions in local resource uses with the national wealth generated from 30 years of rapid economic growth. While the program has the potential of environmental conservation through massive poverty alleviation, it is based on the problematic premise of collective conformity of millions of farmers in an era when individualism is highly stressed.

Blessed with a favorable lowland environment with easy access to groundwater, farmers in the case study community were able to intensify maize production after the GTGP in search of alternative sources of animal feed and fodder. The new resource use system fosters stronger linkage between crop and livestock production, and is also more market-oriented with significant increase in market livestock offtake rates. Improved household economy reduces pressure on subsistence cultivation, stabilizing the average household landholding at 1.0–1.2 ha. While grassland exclosure is almost universally violated through surreptitious herding, sporadic grazing reduces grazing intensity on grassland, allowing a recovery of vegetation. The trajectory of environmental degradation has largely been diverted with mild resistance to the GTGP.

Similar responses observable in communities in the Mu Us Sandy Land indicate that the environmental trajectories are not site-specific, but represent a general pattern with wider implications. These "islands of sustainability" draw attention to a place-based approach to desertification; they also suggest that even in an endangered environmental region such as the Mu Us Sandy Land, opportunities for sustainable resource uses are still present; therefore, government policy and development initiatives should aim to induce proper agricultural intensification where the physical environment allows to do so.

Acknowledgements

I would like to thank the support of Yuan Qi and the National Natural Science Foundation of China (Grant 40501069) for fieldwork during the 2005 and 2006 summers. I am sincerely grateful to Laurence Lewis for encouragement and critical comments; I also wish to thank Hong Jiang, Douglas Johnson, and Billie Turner II for their suggestions. Special thanks also extend to the editors and two anonymous reviewers for valuable comments on previous versions. Part of this paper has been presented at the 2009 US-IALE Symposium in Snowbird, Utah with the support of a CHANS Fellowship.

References

Adams, W.M., Mortimore, M.J., 1997. Agricultural intensification and flexibility in the Nigerian Sahel. The Geographical Journal 163 (2), 150–160.
Barrow, C., 1991. Land Degradation: Development and Breakdown of Terrestrial Environments. Cambridge University Press, Cambridge.
Bebbington, A., 2000. Reencountering development: livelihood transitions and place transformation in the Andes. Annals of the Association of American Geographers 90 (3), 495–520.
Blaikie, P., Brookfield, H., 1987. Land Degradation and Society. Methuen, London, UK.
Boserup, E., 1965. The Conditions of Agricultural Growth. Aldine, Chicago.
Brogaard, S., Zhao, X., 2002. Rural reforms and changes in land management and attitudes: a case study from Inner Mongolia, China. Ambio 31 (3), 219–225.
Chayanov, A.V., 1966. In: Thorner, D., Kerblay, B., Smith, R.E.F. (Eds.), Theory of Peasant Economy. R.D. Erwin, Homewood, IL.
Dahl, G., Hjort, A., 1976. Having Herds: Pastoral Herd Growth and Household Economy. Department of Social Anthropology, University of Stockholm.
Dong, G., Wu, B., Ci, L., Zhou, H., Lu, Q., Luo, B., 1999. Present situation, cause and control way of desertification of China. Journal of Desert Research 19 (4), 318–332.
Dougill, A.J., Thomas, D.S., Herthwaite, A.L., 1999. Environmental change in the Kalahari: integrated land degradation studies for nonequilibrium dryland environments. Annals of the Association of American Geographers 89 (3), 420–442.
Ellis, J.E., Price, K., Yu, F., Christensen, L., Yu, M., 2002. Dimension of desertification in the drylands of Northern China. In: Reynolds, J.F., Stafford Smith, D.M.

(Eds.), Global Desertification: Do Humans Cause Deserts? Dahlem University Press, Berlin.
Fullen, M.A., Mitchell, D.J., 1994. Desertification and reclamation in North-Central China. Ambio 23 (2), 131–135.
Geist, H., 2005. The Causes and Progression of Desertification. Ashgate, Aldershot.
Geist, H., Lambin, E., 2004. Dynamic causal patterns of desertification. Bioscience 54 (9), 817–829.
Gillson, L., Hoffman, M.T., 2007. Rangeland ecology in a changing world. Science 315, 53–54.
Grainger, A., 1990. The Threatening Desert: Controlling Desertification. Earthscan, London, UK.
Hinton, W., 1990. The Great Reversal: The privatization of China, 1978–1989. Monthly Review Press, New York.
Hou, R., 1973. The evolution of the Mu Us Sandy Land from the ancient castles in Hongliu River. Cultural Relics 1973 (1), 35–41.
Hou, R., Yu, W., 1973. The archaeological finds in the Ulan Boha Desert and the changes in geographical environment. Archaeology 2, 92–107.
Illius, A.W., O'Connor, T.G., 1999. On the relevance of nonequilibrium concepts to arid and semiarid grazing systems. Ecological Application 9 (3), 798–813.
Jiang, H., 1999. The Ordos Plateau of China: An Endangered Environment. United Nations University Press, Tokyo.
Jiang, H., 2004. Cooperation, land use, and the environment in Uxin Ju: the changing landscape of a Mongolian-Chinese borderland in China. Annals of the Association of American Geographers 94 (1), 117–139.
Johnson, D., Lewis, L.A., 2007. Land Degradation: Creation and Destruction, 2nd ed. Rowman and Littlefield, Lanham.
Kang, E., Li, X., Zhang, J., Hu, X., 2004. Water resources relating to desertification in the Hexi Area of Gansu Province, China. Journal of glaciology and Geocryology 26 (6), 657–667.
Kasperson, J.X., Kasperson, R.E., Turner II, B.L. (Eds.), 1995. Regions at Risk: Comparisons of Endangered Environments. United Nations University Press, Tokyo.
Kasperson, J., Kasperson, R., Turner II, B.L., 1996. Regions at risk: exploring environmental criticality. Environment 38 (4), 4–11, 25–28.
Kobayashi, T., Nakayama, S., Wang, L., Li, G., Yang, J., 2005. Socio-ecological analysis of desertification in the Mu Us Sandy Land with satellite remote sensing. Landscape and Ecological Engineering 1, 17–24.
Lee, R.D., 1986. Malthus and Boserup: a dynamic synthesis. In: Coleman, D., Schofield, R. (Eds.), The State of Population Theory. Blackwell, pp. 96–130.
Liu, J., Diamond, J., 2005. China's environment in a globalizing world. Nature 435, 1179–1186.
Liu, J., Li, S., Ouyang, Z., Tam, C., Chen, X., 2008. Ecological and socioeconomic effects of China's policies for ecosystem services. Proceedings of the National Academy of Sciences 105 (28), 9477–9482.
Middletown, N., Thomas, D., 1997. World Atlas of Desertification. Edward Arnold, London.
Milton, S.J., Dean, W.R., du Plessis, M.A., Siegfried, W.R., 1994. A conceptual model of arid rangeland degradation. Bioscience 44 (2), 70–76.
Mitchell, D.J., Fullen, M.A., Trueman, I.C., Feardehough, W., 1998. Sustainability of reclaimed desertified land in Ningxia, China. Journal of Arid Environment 39, 239–251.
Muldavin, J.S.S., 1997. Environmental degradation in Heilongiiang: policy reform and agrarian dynamics in China's new hybrid economy. Annals of Association American Geographer 87 (4), 579–613.
Netting, R.M., 1993. Smallholders, Householders: Farm Families and the Ecology of Intensive, Sustainable Agriculture. Stanford University Press, Stanford, CA.
Peluso, N.L., 1992. Rich Forests, Poor People: Resource Control and Resistance in Java. University of California Press, Berkeley.
Reynolds, J.F., Stafford Smith, J.D., 2002. Introduction: do humans cause deserts? In: Reynolds, J.F., Stafford Smith, D.M. (Eds.), Global desertification: Do Humans Cause Deserts? Dahlem University Press, Berlin.
Reynolds, J.F., Stafford Smith, D., Lambin, E.F., Turner II, B.L., Mortimore, M., Batterbury, S.P.J., Downing, T.E., Dowlatabadi, H., Fernández, R.J., Herrick, J.E., Huber-Sannwald, E., Jiang, H., Leemans, R., Lynam, T., Maestre, F.T., Ayarza, M., Walker, B., 2007. Global desertification: building a science for dryland development. Science 316, 847–851.
Robbins, P., 1998. Authority and environment: institutional landscapes in Rajasthan, India. Annals of the Association of American Geographers 88 (3), 410–435.
Runnström, M., 2000. Is Northern China winning the battle against desertification? Ambio 29 (8), 468–476.
Runnström, M., 2003. Rangeland development of the Mu Us Sandy Land in semiarid China: an analysis using Landsat and NOAA remote sensing data. Land Degradation and Development 14 (2), 189–202.
State Forestry Administration (SFA), 2007. http://www.forestry.gov.cn/portal/main/s/436/content-32031.html (last accessed on June 4, 2010).
Sullivan, S., Rohde, R., 2002. On non-equilibrium in arid and semi-arid grazing systems. Journal of Biogeography 29, 1595–1618.
Thomas, D., 1997. Science and the desertification debate. Journal of Arid Environments 37, 599–608.
Turner, M., 1993. Overstocking the range: a critical analysis of the environmental science of Sahelian pastoralism. Economic Geography 69 (4), 402–421.
Turner II, B.L., Ali, A.M., 1996. Induced intensification: agricultural change in Bangladesh with implications for Malthus and Boserup. Proceedings of the National Academy of Science of the United States of America 93 (25), 14984–14991.
Wang, T., Wu, W., Xue, X., Sun, Q., Zhang, W., Han, Z., 2004. Spatial-temporal changes of sandy desertified land during last 5 decades in northern China. Acta Geographica Sinica 59 (2), 203–212.
Warren, A., 2002. Land degradation is contextual. Land Degradation and Development 13, 449–459.
Westoby, M., Walker, B.H., Noy-Meir, I., 1989. Opportunistic management for rangelands not at equilibrium. Journal of Range Management 42, 266–274.
Wu, B., Ci, L., 2002. Landscape change and desertification development in the Mu Us Sandland, Northern China. Journal of Arid Environment 50, 429–444.
Zha, Y., Gao, J., 1997. Characteristics of desertification and its rehabilitation in China. Journal of Arid Environments 37, 419–432.
Zhu, Z.D., 1989. Progress in desertification research in China. Journal of Desert Research 9 (1), 1–13.
Zhu, Z.D., Chen, G.T., 1994. Sandy Desertification in China. Science Press, Beijing.
Zhu, Z., Liu, S., 1981. Desertification Process in North China and Its Regional Control. Chinese Forestry Publishing House, Beijing.