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Farming systems of the Loess Plateau, Gansu Province, China

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Abstract

Gansu Province in north western China contains a large portion of China's rural poor. Within this province we compared extant farming systems in lower and higher rainfall areas of the Loess Plateau. The farming systems were dominated by subsistence winter wheat production in the higher rainfall more productive area (Qingyang), and subsistence spring wheat in the lower rainfall less productive area (Dingxi). Once household grain production is satisfied, remaining land is allocated to cash crop and livestock enterprises. Similar farm sizes (ca. 1 ha) in both areas meant that farmers in the more productive Qingyang area were easily able to meet household food needs and produce more cash income from sale of produce. They have reinvested this into their farms and are now developing new enterprises, particularly livestock and co-operative trading arrangements. This has allowed many of these farmers to move away from subsistence grain production, such that 72% of household income is now derived from sale of farm produce. However, many farmers in Qingyang indicated a lack of technical agronomic support and limited access to reliable markets as barriers to diversification. In Dingxi, many farmers struggle to grow sufficient grain for household use and generate very little cash income, often insufficient to provide basic needs such as education. Potatoes, pea and oilseeds are the most common cash crops here, but livestock enterprises are poorly developed. In this area only 28% of household income is generated on farm, and young males often leave the farm to work in larger cities, leaving farming decisions to the elderly, women, and children, who are left behind to manage the farm. High illiteracy rates in this group reduce assimilation of new information. Farmers in Dingxi indicated that restricted access to capital, lack of technical agronomic support and little access to trading markets were serious impediments to the development of more profitable enterprises.

Keywords: Subsistence agriculture; Livestock; Adoption; Poverty

1. Introduction

Despite China's booming economy, income disparity between rural and urban populations (effectively western and eastern provinces) is amongst the highest in the world (Chang, 2002). The bulk of the rural poor come from the north western provinces, where an estimated 53% of the Chinese rural population (totalling 900 million) live on less than US$ 2 per day (World Bank, 2005). Gansu Province in north western China, is home to approximately 40% of China's rural poor. Across the Province, household income averages only Y1946 (US$ 243) per year, 70% of which is gained from agricultural activities with the remainder from wages earned off farm (MOA, 2001). A lack of land and capital resources, combined with high population densities has led to widening disparity between rural and urban incomes. This is particularly evident in one of Gansu's poorer counties, Dingxi, where the average per capita income for urban residents in 2002 (Y5015, US$ 627) was more than triple the earnings of local rural populations (Y1412, US$ 176 (Anon., 2004)).

Gansu Province sits on the Loess Plateau, a geographical feature located in the middle reaches of the Yellow River, the

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plateau covers >400,000 km^2 over five provinces. Some parts of the region have been cultivated for 6000 years. Soil type, slope, rainfall patterns and cultivation mean that soil erosion here (3720 t km^{-2} year^{-1}, rising to maxima of 20,000 t km^{-2} year^{-1} (Liu, 1999)) is the highest in China, and indeed amongst the highest in the world (Fu, 1989). Erosion is principally caused through run off during the rainy season (July–September), resulting in gully erosion and high sediment loads to the Yellow River. While erosion is reduced by perennial forest or grass cover, most of these areas have diminished due to increased subsistence arable agriculture and overgrazing (Rui et al., 2002). This has further eroded the natural resource base and resulted in low crop yields and low farm incomes over much of the region.

Addressing poverty and improving the environment across the Loess Plateau has become a priority of government policy. In Gansu, Provincial strategies aim to reduce farmer reliance on grain production, increase the production of cash crops and livestock and relocate farming villages to more fertile lands (MOA, 2001). Supporting this policy is a heavy investment in rural infrastructure and transport networks by government, and a recent revegetation campaign that encouraged farmers to replant slope land with forage legumes in exchange for grain (Feng et al., 2003). This policy has proved to be popular with most farmers while the grain and cash subsidies have reached the farmers, but as with all such policies, there are concerns over what will happen if and when this program has been withdrawn. Indeed in the study areas there is already evidence that farmers are reverting to previous cropping practices. While there is evidence of progress in some areas (Shi and Shao, 2000; Rui et al., 2002; Zhang et al., 2004), little is known about the way farmers in different agro-climatic zones are able to respond to government policy and market signals. Some regional statistics show that farmer incomes are improving, but it is difficult to gauge whether this is due to farmer innovation, improvement in commodity prices, off farm income sources or the success of government policies.

While erosive processes (e.g. Fu, 1989; Shi and Shao, 2000) and some aspects of crop agronomy (Li et al., 2000b; Huang et al., 2003) have been well studied, there has been little published on extant farming systems of the region. One study (Hardiman et al., 1990) in eastern Gansu's Qingyang County identified three different subsistence farming systems, based on landscape (slope), farm size and labour units household^{-1}. The most common farming system was located on productive tablelands, experiencing high grain yields, with livestock enterprises focussed on rabbit skin and wool production. Of the other two farming systems, one occupied sloping land, resulting in high erosion rates and poor grain yields and was therefore more focussed on livestock enterprises. The other occupied the small amounts of land within wide river valleys and consisted of a productive wheat–maize based system with no reports of other cropping enterprises.

The aim of the present study is to provide insight into extant farming systems and farmer opinions in two climatically contrasting environments in Gansu Province (Qingyang and Dingxi Counties), using a combination of available data, extensive farmer surveys and interviews in 125 households. We hypothesize that differences in farmer ability to change in response to government and market forces will be strongly moderated by local biophysical and socio-economic constraints.

2. Study area

2.1. Biophysical environment

The Loess Plateau is mostly 1000–1500 m in altitude, extending to >3000 m and consists of highly erodible hills, slopes and tablelands. Chinese farmers first began to build terraces in the region for crop production on sloping land more than 500 years ago, and while mechanisation has greatly increased the rate of terracing in the last 50 years, much is still done by hand (Zhengsan et al., 1981). Although the soils are deep, free draining and able to hold appreciable plant-available water (130 mm m^{-1}) for long periods of time (Zhu et al., 1983), a combination of low clay content and cultivation methods results in poor organic matter retention, structural instability (erosion) and low fertility for crop production (Catt, 2001).

Two localities, Qingyang County and Dingxi County, are chosen to represent the principal land systems and contrasting environments of the region. In biophysical terms, the areas differ in their position in the Loess landscape, with Qingyang (35.40′N, 107.51′E, elev. 1298 m a.s.l.) on tableland in eastern Gansu and Dingxi (36.03′N, long 103.53′E, elev. 1517 m a.s.l.) occupying Loess hills in central Gansu. Dingxi comprises of a number of small farming villages typically situated within narrow valleys that are surrounded by terraced mountains, where the majority of farmland is located. Soils are infertile sandy loams with a high silt content.

2.2. Climate

The region experiences cold dry winters and warm wet summers (Figs. 1 and 2), with annual rainfall ranging from 600 mm in the south east of the province to <100 mm in the north west (Li et al., 2000a). Rain falls sporadically over a short summer period but is highly variable from year to year with variability in monthly rainfall (CV) between years ranging from 45 to 100% for both Dingxi and Qingyang. The additional 155 mm of annual rainfall in Qingyang (551 mm) than in Dingxi (396 mm) provides the basis for greater fallow water storage (Li et al., 2000b) and much higher crop growth and grain yields than in Dingxi. In 2003, the year of our study, rainfall in Qingyang was 794 mm, more than double that of Dingxi (380 mm). Winter wheat (*Triticum*

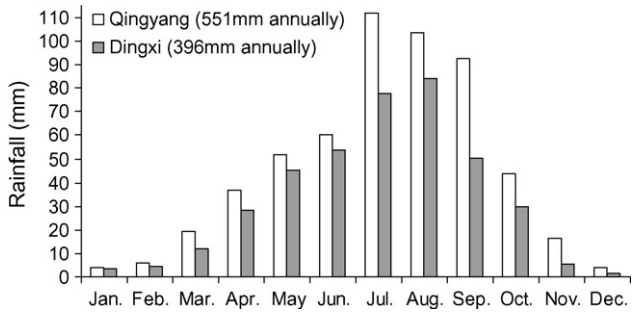

Fig. 1. Average monthly rainfall for Qingyang (1961–2003) and Dingxi (1970–2003). Annual variability is great with monthly coeffcients of variation ranging from 44 to >100% at both sites.

aestivum L.) is grown in Qingyang but this is not possible in Dingxi where there is less snow cover and more severe radiation frosts in winter. The growing season at both sites approximates the period when minimum temperatures above 0 °C (Fig. 2) coincide with significant rainfall (approximately April–October; Fig. 1). These combinations of factors result in a longer, more benign, growing season at Qingyang compared to Dingxi.

3. Methods

3.1. Surveys

Data from surveys were used to describe local farming systems and help identify farmer inputs to cropping systems and yields obtained. Developed with volunteer farmers in Qingyang during July 2003, finalised surveys were conducted in Shi She and Waxie townships in Qingyang Prefecture during August, before being adapted to the different cropping systems in Dingxi. Surveys were bilingual and contained standardised questions on household socio-economic data and conventional farming practices.

The majority of surveys were completed on local market days with farmers who were purchasing or selling goods at the market. Farmers were selected primarily to represent the broad range of age, products sold, and socio-economic status

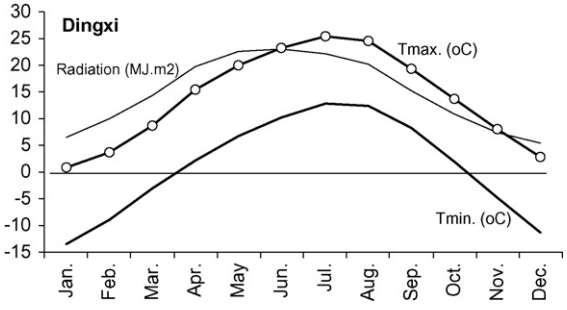

Fig. 2. Average daily maximum (T_{max}) and minimum (T_{min}) temperature (°C) and average daily radiation (MJ m^{-2}) for each month for Dingxi (1970–2003). Data for Qingyang are closely similar.

apparent. At the conclusion of the study, a total of 125 households had been surveyed from five villages in Qingyang and Dingxi. The results of the surveys thus provide a snapshot of farming systems in localised areas within Qingyang and Dingxi Prefectures.

3.2. Interviews

Farmers were interviewed to obtain information about their farming practices and incomes, attitude to new farming technology and the effect of government policy on their farms. Participants were chosen to represent a range of ages, farming enterprises and socio-economic standing. In most cases, farmers were happy to participate in this study. They were then interviewed one-to-one or in groups in their homes or at the Qingyang Research Station, depending on convenience and interest in the study. Group interviews were very beneficial in generating discussion amongst farmers about topical issues and to cater for substantial farmer interest in the study. Each interview asked farmers a range of standardised open-ended questions, with points of interest followed up where the need arose.

Five group interviews were conducted in Qingyang between April and June 2003, with 30 farmers participating from three farming villages. Similar numbers of farmers were involved in interviews in Dingxi between October and November in 2003.

4. Results

4.1. Regional crop statistics

From the 3,649,900 ha under cultivation across Gansu Province in 2002, approximately 29% was used for the production of wheat for household use, giving rise to a traditional wheat monoculture rotated periodically with maize (*Zea mays* L.) or crop legumes (Gansu Statistic Bureau, 2003). Across the Province spring wheat (378,000 ha) accounts for 35% of total wheat sowings, the remainder being winter wheat. Provincial data indicates cash crops are sown on ca. 12% of the total arable land in both study areas, but the type grown varies between sites (Table 1), with apples (*Malus domesticus* Bork.), vegetables, soybean (*Glycine max* (L.) Merr.) and oilseed crops (canola, rapeseed (*Brassica rapa*/*B. napus* L.)) being important in Qingyang, and potatoes (*Solanum tuberosum* L.), chinese herbs and linseed (*Linum usitatissimum* L.) in Dingxi. In general, agricultural activities employ approximately 85% of the adult labour force (Yao, 2002).

4.2. Extant farming systems

Data from the farmer surveys (Table 2) indicates that farms average almost 1 ha in size, and are predominantly sown with wheat (30–50% of area), maize (Qingyang 23%

Table 1
Areas of principal sown crops (10^3 ha) in Gansu Province and in Dingxi and Qingyang Prefectures within Gansu for 2002 (source: Gansu Statistic Bureau, 2003)

	Gansu Province	Dingxi Prefecture	Qingyang Prefecture
Wheat	1074.0	102.4	192.0
Maize	497.9	25.2	57.0
Linseed	140.1	33.0	23.4
Rapeseed	136.5	8.6	20.6
Sunflower	15.2	0.0	6.5
Millet	91.9	4.5	45.7
Soybean	81.8	0.1	40.9
Millet (*Setaria*)	34.0	6.3	7.9
Sorghum	18.8	0.4	5.8
Forage crops	181.0	18.8	13.2
Potato	484.9	193.7	36.4
Orchards	262.2	10.0	36.0
Vegetables	200.7	15.3	25.6
Chinese herbs	132.8	75.0	3.8
Tobacco	9.4	0.0	8.0

of area) or legumes (Dingxi field pea 17% and some lucerne (*Medicago sativa* L.). The larger farm size in Dingxi may result from a greater proportion of sloping land and the lower productivity due to the lower rainfall. While wheat occupies a similar land area per farm at both sites, in Qingyang winter wheat is typically grown for 2–3 seasons before the yield declines and a break crop (predominately maize) is incorporated. In Dingxi, spring wheat is grown in yearly rotations with field pea (*Pisum sativum* L.), with an occasional break crop of potatoes, linseed or lentil (*Lens culinaris* Medik.) In both areas crop stubbles (often including roots) are almost always removed after harvest and fed to livestock or used as household fuel for cooking and heating. This leaves the soil bare and exacerbates erosion problems.

Cash crops in Qingyang account for 28% of the cultivated area and include fruit, vegetable and feed crops. In Dingxi, cash crops are grown on approximately 20% of the cultivated area and are dominated by potatoes, lentils and linseed. Fruit and vegetables, which are grown as a cash crop for sale in regional centres, are more common at Qingyang than in Dingxi due to the higher rainfall. Average yields from crops in Qingyang from the farmer survey in 2003 were 3.5 t ha^{-1} for winter wheat, 6.5 t ha^{-1} for maize and 1.8 t ha^{-1} for soybean. Crop yields in Dingxi in the same year were a half to one third, averaging 1.0 t ha^{-1} for wheat and 0.8 t ha^{-1} for pea.

Farmers in Qingyang also have more livestock, with well developed sheep (*Ovis aries*) or goat (*Capra hircus*) enterprises and an average of 1.7 pigs (*Sus scrofa*) $household^{-1}$. Dingxi farmers have fewer sheep/goats and pigs. Cattle (*Bos taurus*) are used for draught in Qingyang whereas donkeys (*Equus asinus*) are used in Dingxi.

4.3. Cropping system inputs

Inputs for staple food crops include fertilisers (organic and inorganic), seed, pesticides, herbicides and in some

Table 2
Summary of data on farming systems from farmer surveys in two contrasting environments on the Loess Plateau, Gansu Province

	Qinyang ($n = 80$)		Dingxi ($n = 55$)	
	Average (ha)	Comments	Average (ha)	Comments
Area of holdings	0.73	Range 0.4–2.1 (ha)	0.99	Range 0.2–1.5 (ha)
Winter wheat	0.36	Range 0.1–1.3 (ha)	Not suited to the area, killed by radiation frosts	
Spring wheat	Not grown in region, winter wheat more productive		0.31	Range 0–1 (ha)
Maize	0.17	Range 0.1–0.5 (ha), used for feed and food	–	Minor crop here
Legumes	–	Soybean is a minor crop	0.17 (pea)	Range 0–0.8 (ha)
Other cash crops	0.21	Sorghum, soybean, watermelon, millet, flax, peaches, apples, tobacco, vegetables, rapeseed/linseed, medicinal herbs	0.19	Potato, lentils, millet, forage sorghum, maize, lucerne
Typical rotation	Wheat–wheat–wheat/fallow–maize–soybean or linseed		Field pea–wheat–potato, lentil or linseed	
Slopeland/wasteland	Limited in Qingyang, slopes in very steep gullies may be grazed in some instances		0.3	Most farmers have some slopeland allocated, used for grazing, occasionally sown to lucerne
Livestock	80% of farmers have livestock		96% of farmers have livestock	
	Units/farm		Units/farm	
Cattle	1.0		0.26	
Sheep/goats	4.5		0.46	
Donkey	–		1.0	
Pigs	1.7		0.76	
	Rabbits and horses are also common in Qingyang area			

Table 3
Average inputs and input costs for grain crops from a survey of farmers in two contrasting environments on the Loess Plateau, Gansu Province in 2003

Inputs	Qingyang ($n = 75$)			Dingxi ($n = 54$)	
	Winter wheat	Maize	Soybean	Spring wheat	Field pea
Seeding rate (kg ha^{-1})	171	40	50	193	175
N as urea or $(NH_4)_2PO_4$ (kg N ha^{-1})	162	182	51	46	40
P as s-superphosphate (kg P ha^{-1})	9	13	5	19	19
Compound fertilisers (kg ha^{-1})	54	102	0	0	56
Animal manure applied[a] (t ha^{-1})	22	152	0	>7.5	7.7
Pesticide and herbicide cost (Y mu^{-1})	0.9	3.8	0	1	0.4
Cost of plastic (Y mu^{-1})	0	16	0	0	0
Cost per ha (Y)	1386	1722	933	497	477
Cost per ha (US$)	173	215	117	62	60
Grain yield per ha (kg ha^{-1})	3628	6032	1770	976	790
Average percentage of crop kept	90	14	80	95	47

Note: All of these data relate to the crop harvest in 2003. For the purposes of this work a conversion of 1 Yuan to US$ 0.125 has been used. Most values have been rounded to the nearest whole number. The standard unit of area in Chinese agriculture is the mu, of which there are 15 to the ha.

[a] Manure is usually mixed with soil prior to application to land, hence the values seem high, the fraction of this that is actually manure would be small.

situations, plastic mulch for soil moisture retention (see Li et al., 2004). Average usage rates obtained from the farmer surveys are listed in Table 3, along with approximate costs per unit area sown.

Overall, maize requires the greatest fertiliser input but provides the highest yields and the highest returns per unit area. In Qingyang in 2003 we calculated the gross margin of maize to be Y298 mu^{-1} (US$ 559 ha^{-1}). However, in 2003 farmers only sold an average of 86% of their maize crop, and with average sowings of 0.17 ha farm^{-1}, this would equate to an income of US$ 82 maize crop^{-1} farm^{-1}. The most profitable cash crops in Qingyang have been oilseed crops, apples and watermelon, which are grown by the majority of farmers. Orchard fruits provided an average yearly profit of ca. Y2500–Y4000 per mu (US$ 4687–7500 ha^{-1}), but these require substantial capital and thus are usually established at the village level. Profits from cash crops and livestock sales commonly made up 60% of household income in Qingyang, whereas farmers in Dingxi indicated that only 28% of household income was generated on farm, mainly from potato and oilseed crops. In Dingxi, field pea was the principal cash crop sold. However, production of field pea carries the high opportunity cost of loss in wheat production for household use. Furthermore, after the costs of ploughing and broadcasting (estimated to cost >Y30 mu^{-1}, US$ 56 ha^{-1}), profits from food crops in Dingxi are too small to support rural households and 72% of household income is derived from off-farm activities.

4.4. Livestock

Major livestock enterprises are outlined in Table 4 and Fig. 3. While almost all farmers (96%) in Dingxi had some livestock, 20% of farmers in Qingyang had none. However, the livestock data in Dingxi are skewed by the use of donkeys for draught, as although 78% of farmers had donkeys, 35% of farmers had no livestock other than the one donkey. The donkeys are relied on for labour and transporting of produce, and are favoured over cattle in Dingxi due to their lower cost and suitability to the more mountainous terrain. Farmers in Qingyang did not have donkeys and indeed only 30% of farmers there owned draught animals (i.e. cattle). Mechanized sowing and harvesting is more common here due to larger tracts of flatter land and higher farm incomes. Households in Dingxi with one donkey negotiated non-monetary agreements with other farmers during ploughing seasons for a second donkey to draw a plough. Non-monetary agreements were not common in Qingyang, and thus cattle owners obtained income by providing ploughing services to farmers without cattle, at 15 Yuan plough^{-1} mu^{-1} (US$ 28 ha^{-1}).

Important feed sources for sheep, goats and cattle, include grazing on roadsides and other wastelands, crop residues after harvest and lucerne hay if it is available. Grazing and browsing of pastures and forage would be restricted to Dingxi farmers who might have access to sloping lands, but in Qingyang grazing is rarely practised as farmers there are more reliant on cut and carry livestock feeding systems. Maize and sorghum provide important feed for cattle in Qingyang, and other forage and grain crops and crop by-products are valuable there for pig production. Differences in livestock systems become more apparent in Fig. 3, where it can be seen that many more Qingyang farmers had more intensive livestock production enterprises than farmers in Dingxi. For example, in Qingyang, pork enterprises contained up to 30 animals, whereas in Dingxi

Table 4
Percentage of farmers surveyed in Qingyang and Dingxi maintaining different types of livestock or with no livestock

	Qingyang	Dingxi
Cattle	30	20
Sheep/goat	47	17
Pig	50	45
Donkey	0	78
No livestock	20	4

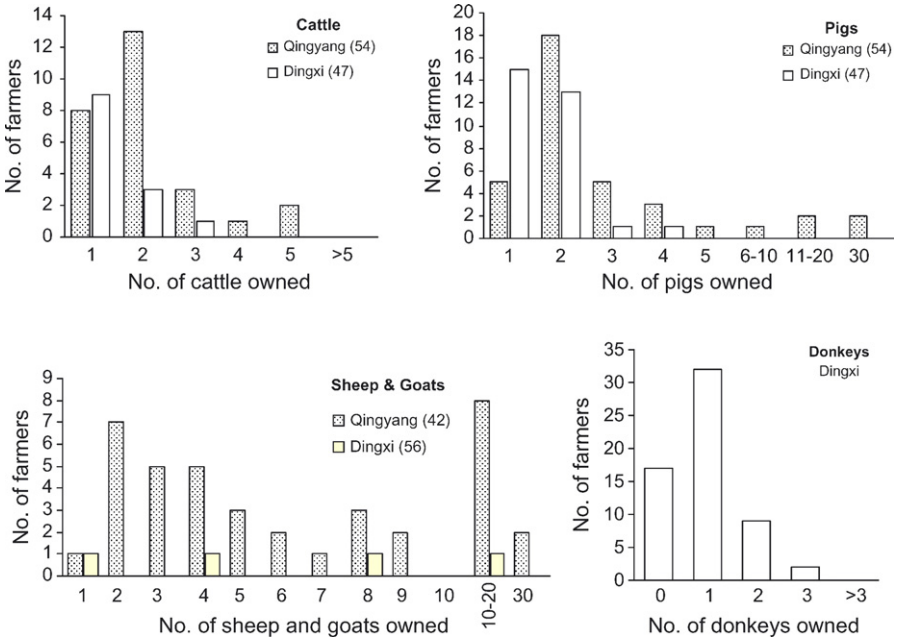

Fig. 3. Number of cattle, pigs, sheep (or goats) and donkeys owned by farmers surveyed in Qingyang and Dingxi districts. Values in brackets beside site names are the number of farmer respondents who had none of those livestock units. No farmers in Qingyang had donkeys.

farmers owned 0–2 pigs, with only exceptional farmers having three or four pigs. In Dingxi livestock are typically only sold in the case of crop failure or emergency. Introduced varieties of sheep (mainly Australian merino) and goats were common in Qingyang, with 10 farmers owning herds numbering 10–30 animals. In terms of profit, farmers indicated that 25 sheep can provide an income through the sale of lambs and wool of up to Y2400 (US$ 300) per year (based on July 2003 prices). This is ca. 23% more than the average yearly income for Gansu Province, and more profitable than breeding cattle, the traditional livestock enterprise in the region. Pigs were owned by half of all farmers at both sites, most often being kept in pens close to the home where they survive on household food scraps.

At both sites a number of small-scale enterprises were reported using specialist types of livestock imported from overseas. Representing large investments, these animals are bred to take advantage of growing niche market opportunities in city centres that favour quality meat, milk, wool and skin products. Specialist breeds included alpacas, chinchilla rabbits (similar to Hardiman et al., 1990), mohair and South African goats, yellow beef cattle (Europe) and dairy cows. The cost of establishing these types of enterprises is prohibitive for many farmers in Qingyang and most in Dingxi. For example, purchasing one productive dairy cow costs between 5000 and 10,000 Yuan depending on age (US$ 625–1250, based on July 2003 prices). This is 1.5–5 times the average yearly household income in Gansu Province. The most common way for specialist livestock to be introduced into rural villages is through a government or bank loan, or loans from city relatives, allowing the most affluent farmers to purchase one or two livestock for breeding. The majority of farmers however are excluded from such schemes and are unable to borrow against their farms or cash crop produce.

4.5. Barriers to adoption of new enterprises/technology

Farmers were invited to outline the issues that they considered needed improvement in order to remove any barriers to the development of new enterprises. Their responses (Table 5), ranked according to the farmers' priority, encompass economic, social and environmental issues. The issues were mostly common across sites, but the importance given to each varied, reflecting differences in climate and development of infrastructure between the two areas. Not surprisingly, low and variable rainfall and risk of subsistence crop failure was rated much higher in Dingxi than Qingyang. While a lack of starting capital was indicated as a constraint to farm development in both regions, it was seen as a greater constraint in Dingxi than Qingyang. Conversely, Qingyang farmers indicated problems with infrastructure, and support for new enterprises (trading networks, technical knowledge, veterinary support) was of higher concern than starting capital.

During the course of the interviews and surveys it became apparent that in both areas there were some innovative farmers that had been able to respond positively to opportunities (early adopters), and others that had not (conservative). Based on the survey data we allocated the farmers to each of these groups (Table 6). Early adopting farmers earned above average profits from cash crop and livestock enterprises through the adoption of new varieties and technologies. When questioned, they had implemented change on their farms in the past 2 years gaining information on how to do so from newly available resources, such as

Table 5
Barrriers to further development of agricultural enterprises as nominated by farmers surveyed in Qingyang and Dingxi

	Qingyang	Dingxi
General		
Aging labour base	*	*
Cropping		
Lack of starting capital	*	**
Declining land areas	*	**
Risk—low rainfall and yield (crop failure)	o	**
Risk—moving away from grain production	*	**
Lack of market and trading network for new varieties	**	*
Lack of knowledge for management of new varieties	**	*
Lack of suitable new varieties	*	*
Livestock		
Lack of starting capital	*	**
Access to veterinary advice	**	*
Animal nutrition, husbandry, diagnosing problems	**	o
Lack of market and trading network for new varieties	**	o
Lack of knowledge for management of new varieties	*	o
Risk—moving away from traditional cattle/donkey systems	o	**
Lack of suitable new varieties	o	*

Asterisks (**) indicate that this point was raised as an area of high concern amongst farmer participants, (*) of moderate concern and (o) of little concern.

farmer workshops, demonstration sites and through agricultural literature. These farmers were typically literate and actively participated in provincial trading. Conservative farmers were classified as those more traditionally minded who typically had a 'wait and see' approach toward new practices. In this group knowledge about farming practices is often intergenerational and localised, with farming advice typically sought through social networks, principally other farmers or the interpretation of first hand information. Livestock are considered important to the conservative systems for ploughing (cattle and donkey), organic manure production and their ability to feed on wheat straw and stubble.

5. Discussion

Farms in these two regions vary in their crop and livestock enterprises, and in the productivity of those enterprises. Working in eastern Gansu, Lu et al. (2003) indicated that ca. 30% of the arable area might be needed for subsistence grain production, close to the value (31%) obtained in the Dingxi survey, but lower than the 49% in the Qingyang farmer survey. Qingyang farmers are thus easily able to provide for their own food needs. However, in Dingxi where rainfall is lower and more variable, farmers are much less able to provide for their own subsistence grain needs, and to derive income from cash crops to further develop their enterprises. Indeed in Dingxi, in years of low rainfall, many farmers would struggle to be self-sufficient. Growing more wheat for household use in Dingxi would result in less cash crop income. Recognising the difficulties in accurately assessing gross margins (Chang, 2002; Yao, 2002), we calculated returns from spring wheat (US$ 144 ha^{-1}) and field pea (US$ 145 ha^{-1}) in Dingxi in 2003 that would be similar to those in many areas of the developed world. However, comparison of gross margins on a hectare basis is hardly relevant when the total area of sowings are small, and 100% of the wheat is retained for household use. Some of the inputs to cropping in Gansu may be higher than warranted. For example, in Dingxi, the sowing rates for wheat (193 kg ha^{-1}) and peas (175 kg ha^{-1}) seem inordinately high compared to other regions of the world, and the

Table 6
Characteristics of farmers and farming enterprises between innovative, early adopting and conservative farmer practices at Qingyang and Dingxi

	Early adopters	Conservative farmers
Percentage of farmers		
Qingyang	58	42
Dingxi	22	78
Years of education		
Qingyang	9	7.5
Dingxi	6	5.5
Key information sources		
Qingyang and Dingxi	Television, research stations/demonstration sites, Chinese agricultural journals, newspapers, farmer workshops	Other farmers, local markets, television (some), extension agents, agricultural store workers
Livestock enterprises		
Qingyang	Beef and dairy cattle, Chinchilla rabbits, introduced sheep (e.g. Merino) and goats	Traditional cattle systems
Dingxi	Dairy cattle, long tailed sheep, pigs	Traditional cattle systems
Cash crops		
Qingyang	Apples, watermelon, canola, now investing in lucerne	Mostly grain production and, some cash crops
Dingxi	Potato, linseed, peas, some investment in lucerne	Mostly grain production and, some cash crops

application of 40 kg N ha^{-1} to a N_2 fixing crop legume such as pea may not be required at all (Unkovich and Pate, 2000). It may thus be possible to reduce input costs for some of these crops. Nevertheless, when providing grain for household consumption and meeting village grain quotas, Dingxi farmers receive little cash, and often not enough to adequately feed, clothe and educate rural households. This is illustrated in the two examples below, obtained during the interviews.

One younger male farmer (45) has a wife and 2 grandchildren and grows 3 mu of wheat from a total of 8 mu. To ensure an adequate yearly supply of grain, he must purchase 300 kg of surplus wheat from government sources. He is only able to do this by selling the piglets produced by his 2 pigs and selling the yield from his 1 mu of field pea (Dingxi).

One female farmer (36) is able to grow 9 mu of wheat as she consolidated her land with that of her parents (now totalling 15 mu). She must swap half of her field pea crop (7 mu) for enough grain to feed a family of six. This means that her family only has the yield from 3.5 mu of field pea from which to derive a yearly cash income. In a good year, this would equate to 150 Yuan (US$ 18.75), which is not enough to send one child to the local school for one year (currently 200 Yuan per annum) (Dingxi).

In Qingyang farmers also keep almost all of their wheat for household use, but are able to sell surplus maize and soybean as well as various fruit and vegetable crops and livestock. One option for farmers to increase income is through increases in productivity. Although wheat yields in this region may be similar to comparable areas of the world (Sadras and Angus, 2006), there is good evidence that improved practices in the region can increase grain yields above those currently obtained (Huang et al., 2003; Lu et al., 2003). In Qingyang this is likely to result in considerable increases in farm income. However, for farmers in Dingxi, this is unlikely to be of sufficient benefit to relieve their poverty as less than one third of those surveyed indicated that they could live off income generated on the farm. Rozelle et al. (2002) similarly showed that farmers totally dependent on farm production for income were likely to be below the poverty line. Working in another province, McCulloch and Calandrino (2003) found that poverty in low-income rural households was often transient rather than chronic, and there is no doubt that in years when there are low yields or crop failures, farmers in Dingxi especially, will remain unable to feed themselves. While some farmers did their best to minimise risk by storing 2 years of grain yield and keeping adult cattle or donkeys to sell in case of emergency, in times of sustained crop failure they would have no choice but to rely on food aid programs. Substantive benefits from increased grain productivity in Dingxi would only come if coupled with increased areas of sowing/household. In some districts government policy is actively aimed at reducing the rural population density and so some gains may be made in this arena.

In Dingxi the low and variable rainfall and mountainous terrain limits the types of produce that can reliably be grown, and as farming cannot return adequate household income, young household members are obliged to work off farm to support their families, providing 72% of household income. With younger males gone, farming decisions are often left to the elderly, women and children that are left behind to manage the farm (see Jacka, 1997). High illiteracy rates in this group reduce assimilation of new information and exclude farmers from accessing information through agricultural literature. Conservative farmers were often reliant on other farmer's interpretation of their problem or information. As highlighted by Zhen et al. (2005), this may result in the misinterpretation of seeding, fertiliser, herbicide rates, etc. Farmers stated that expertise was difficult to access in current extension networks which remain under resourced (Sonntag et al., 2005). Other studies (e.g. McCulloch and Calandrino, 2003) correlate low education rates with poverty, showing that lower schooling rates contribute to a reduction in crop productivity and household income.

Farmers explained that they had little access to veterinary advice and little idea about animal nutrition, husbandry or the diagnosis of disease. The situation was considered critical and most farmers had lost a mature cow or a calf over the past 10 years. However, early adopting farmers were found to have a higher literacy rate than conservative farmers, giving them access to a wider variety of information about new innovations. Sources included agricultural television programs, Chinese agronomy journals and newspapers. These were important for providing advice on problems with new varieties and were also used to anticipate market prices and demand in city centres. This was a key difference to conservative farmers who relied on social networks for information. Two pertinent examples from the interviews are highlighted below.

Two Qingyang farmers commented, 'I don't think the old practices are good, we can do better'. After reading a journal article, the two farmers were using wider row spacing and a lighter seeding rate than traditional methods. Today, they were experiencing much higher yields and are now selling 100% of the crop. They are actively encouraging other farmers to follow and are no longer planting wheat.

One participant had attended an agricultural exhibition at a local university and brought back seeds for a new apple variety that he was trailing with other farmers on his plot. Together they planned to graft the variety with Fuji apples to lessen the risk of selling the new product (Qingyang).

Other sources of information that were considered to be valuable involved visits to local government demonstration

areas showcasing new livestock breeds and cash crops suited to the region. In interviews however, farmers commented that there was rarely anybody at these sites to seek advice from, and farmer workshops were rare. Visits were also made to the local research station in Qingyang whose research director had become a much sought after and trusted source of advice on farming problems. Trust was a priority for early adopting farmers hoping to lower the risk of losing capital in new markets. Given the importance of local social networks and trust for adoption of new enterprises (McWaters and Templeton, 2005) we suggest support for local 'champion' farmers (i.e. early adopters) to participate in on-farm research trials, as farmers at both sites stated that they would feel more comfortable in visiting a local farmer's plot than trials at an unfamiliar research station. If local champion farmers were trained in basic experimental principles, then accurate local technical information could be passed verbally from farmer to farmer.

The capacity of early adopting farmers to generate a sustained income from their farming practices improved the economic resilience of their households. Income was generated through sale of cash crop and livestock produce in large cities, which was occasionally sold through farmer cooperatives. With better information about market opportunities, early adopters were often selling produce in provincial and eastern city markets at prices that were 30–50% higher than those offered by the State. In Qingyang, early adopters were successful to the point that ca. 60% of household income was gained exclusively from cash cropping and sheep enterprises. Profit was commonly reinvested into the farm or saved for emergencies.

Movement into new rural enterprises, requires capital and also carries an element of risk. This study found that while the majority of farmers would like to adopt a form of innovation into their farming systems, entering new markets had proved to be a high-risk venture, with some losing their initial investments through price fluctuations or uninformed management. Barriers to adoption of new enterprises highlighted by the farmers included climatic risk (Dingxi), insufficient technical agronomic information, lack of capital, market access and price volatility.

Farmers attempting to enter new markets in Dingxi, lacked both the knowledge of suitable varieties and the capital required to make initial purchases. Most were ineligible for a bank loan, leaving them reliant on the small amounts of money sent from younger household members working away from the farm, or on informal lending agencies (at very high rates). At present, no formalised micro-finance loans appeared to be available to farmers, leaving them to rely on informal and unregulated money lending networks. In some cases, a lack of capital was found to be extreme and farmers were borrowing against projected crop yields in order to purchase the inputs required for their next crop. Experiences from other countries show that a lack of a regulated rural banking system reduces growth in the rural sector and retards poverty alleviation efforts (Sonntag et al., 2005). Partnerships need to be formed between farmers and government or industry, to share with farmers the risk of entering new markets (see McWaters and Templeton, 2005).

To minimise the risk of entering new markets, some farmers were growing new varieties in small co-operatives, producing consignments large enough to attract traders from the eastern provinces and allowing farmers to negotiate a better price for their produce. Additional benefits included the opportunity to be part of an information-sharing network that also had greater access to extension services. Examples of farmer cooperatives are provided below.

Small numbers of farmers in Dingxi were growing an American variety of potato that met the requirements of large corporations that made French fries.

A group of eight farmers in Qingyang heard about the higher prices of canola oil in the eastern Provinces and had formed a cooperative. Using techniques gained from agricultural television programs, these farmers were now producing a higher quality product and sending consignments to Shanghai.

14 households in a village of 77 have decided to not plant wheat this year for the first time and instead are sharing the risk of establishing an apple orchard for the village by each donating some land. This enterprise will take four to ten years to become productive (Qingyang).

In Qingyang, farmers emphasised that entering new markets was still high risk, as they lacked secure access to trading networks and price guarantees. Returns from new enterprises were never guaranteed. Farmers explained that if a local government policy promotes the production of specific crops or livestock, this drives the price of the commodity temporarily up. While well-placed farmers are able to take advantage of such price increases, the majority (conservative farmers) are left scrambling to purchase at inflated prices. Very quickly, the market becomes over-supplied and prices fall dramatically, as illustrated by one livestock farmer below.

On the 22nd of April, he sold 4 newborn lambs and received 900 Yuan. Ten days later the price of sheep had dropped and 4 adult sheep were only worth 150 Yuan each.

This is an important example of Government policy driving up prices, leading to oversupply and low prices that hurt followers. The lucerne on sloping land policy is another example, the price of lucerne hay now having fallen in some areas due to oversupply. The low price is a disincentive for new lucerne plantings and once the Government policy changes the situation is likely to be worse than if they had not had the policy at all, and instead placed emphasis on supporting and regulating the development of markets for new products.

Farmers suggested that agribusiness companies could 'loan' new seeds to farmers, including for initial trial periods and, if successful, recover costs through a percentage of profits from sale. Incentives for farmer participation could include a compensation agreement for failed cropping trials as grain subsidies or cash. Farmers also suggested that to improve rates of mechanisation, machinery needs to be pooled at a village level and hired or loaned to farmers as required. Farmers should be able to pay for the service after sale as the current system of paying up front excludes poorer farmers.

Government policies aimed at facilitating sowing of perennial forages and movement into livestock enterprises and away from grain cropping are likely to have a number of benefits in the longer term, especially in Dingxi. Erosion is likely to be reduced, and cultivation of lucerne (*M. sativa*) for green fodder should improve animal nutrition substantially. By providing animal feed on a cut and carry basis, livestock will not need to be grazed in marginal areas, reducing soil degradation further, and also saving scarce farm labour as animals will not need to be shepherded in marginal areas and wastelands. Furthermore, improved livestock breeds (e.g. Merino sheep and South African goats), which are already introduced in Qingyang, sell for considerably more than traditional breeds and demand for quality produce will increase in line with the rise in disposable incomes (Longworth et al., 2001).

Deng et al. (2005) examined the contributions of irrigation, labour, fertiliser, mechanization and total factor productivity to farm growth in NW China. In Gansu Province they found fertiliser (22%), mechanization (29%) and TFP (28%) contributed to >80% of productivity increase between 1978 and 1998. Irrigation contributed to 9% of growth but this is limited in the region by a shortage of water resources, although significant gains in water use efficiency are probably achievable (farm labour contributed 11%). Levels of mechanisation in Qingyang were modest, but increasing, but in Dingxi almost non-existent. Mechanisation should bring with it environmental benefits if it means that some crop stubbles can be retained in situ, reducing erosion and increasing water infiltration and soil water storage for crop growth (Bissett and O'Leary, 1996; O'Leary and Connor, 1997). However, for this to be achieved, alternative household fuel sources will need to be available and affordable. It has previously been pointed out (Xu et al., 2006) that Gansu's poor natural resource base and social infrastructure (science, education and management) seriously limit agricultural productivity. We would also maintain that the government's *Grain for Green* policy is likely to reduce grain production more in Gansu than other provinces, and more in areas with sloping land like Dingxi than in flat areas like Qingyang, Seventy percent of our study population in Dingxi were required to convert cropping land located on slopes to perennial cover, further reducing the capacity of the poorest farmers to provide for their own food needs. Average wheat yields of flat or gently sloping land (<15°) are estimated to be about three times (3.8 t ha^{-1}) those on sloping (>15°) ground (1.2 t ha^{-1}; Feng et al., 2003). Those households with sloping land relied heavily on government wheat subsidies. However, as this program may be withdrawn in some areas, some farmers are having to revert to crop production on sloping land. In higher rainfall areas of the plateau such land use change has been achieved successfully through the implementation of a combination of social, economic and environmental policies (Zhang et al., 2004).

The present study has described two farming systems in China's poorest rural province. Since the size of the survey was limited to five villages and a total of only 125 farming families the results may only be representative of some local areas of Gansu Province, nevertheless the results presented here provide insight into two contrasting farming systems. One (Qingyang), in a relatively higher rainfall zone, and based on winter wheat, maize, fruit and a range of livestock enterprises, provides sufficient cash flow for farmers to invest in new enterprises, especially livestock, diversifying their portfolio and increasing their capital and reducing risk. Here >70% percent of household income is derived from farming activities. The other farming system, in Dingxi, a lower rainfall area, and including some sloping land, is based around spring wheat, peas, lentil, oilseed crops and potatoes. Here farmers struggle to provide sufficient grain for their own household use, and have insufficient cash flow to invest in new, possibly more profitable enterprises. Rural householders here obtain >70% of income from off-farm sources. In order for farmers in Dingxi to progress away from subsistence farming and rural poverty the following will be required:

(a) starting capital, through microcredit lending schemes or partnerships with industry or government.
(b) greater access to reliable and accurate information about new crop varieties and livestock breeds.
(c) management trading networks and co-operatives to ensure reliable markets and reliable supply from growers.
(d) further consolidation of farm size into larger units.

Government policies aimed at reducing population density in rural areas are also likely to be of considerable benefit. In higher rainfall Qingyang, farm productivity is such that cash crops provide resources for farmers to invest in new enterprises, however, here problems with a lack of technical agronomic and veterinary support, and unreliable markets make many farmers cautious about new enterprises. In this case better agricultural extension networks and partnerships with industry and suppliers is likely to be of great benefit. Increasing crop yields through improved agronomic management will be valuable in both regions, but the social and economic framework required to realise these potential gains needs to be addressed. This is particularly the case for lower income, resource poor farmers of Dingxi.

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