Energy balance characteristics of crop/rangeland-livestock production systems in eastern Gansu, China

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Abstract

The Loess Plateau is a typical rain-fed agricultural area. Agricultural practices vary with precipitation. Three typical regions in the north, middle and south of the Loess plateau in eastern Gansu were studied for energy analysis of agricultural systems. From north to middle to south, the annual precipitation increases from 330 to 440 to 565 mm, respectively. The cultivated land was 2.78, 1.49 and 1.07 hectares/farm, respectively. The number of breeding livestock was 34.0, 19.5 and 11.5 sheep unit (SU)/farm respectively. Average annual energy input from crop production systems was 68.5, 146.6 and 73.3 GJ/farm, and the energy output was 98.6, 67.1 and 156.0 GJ/farm, respectively. For livestock-production systems, annual energy input was 140.1, 75.9 and 193.1GJ/farm and the energy output was 86.8, 79.2 and 87.9 GJ/farm, respectively. The annual energy input for integrated crop-livestock systems were 41.0, 21.2 and 34.1GJ/farm and energy outputs were 63.6, 48.5 and 70.3 GJ/farm, respectively. The results indicated that the conversion and input-output ratio of energy for crop-production systems were lower in the north than that in the south, while the conversion and input-output ratio of energy for livestock-production systems were higher in the north than in the south. A linear programming model indicated that enhancing forage crop production in south would help improve livestock production in north. The coupling of agricultural resources could increase productivity and efficiency of agricultural systems.

Key Words

Crop-livestock systems, energy efficiency, China

Introduction

Integrated crop-livestock systems dominate the Loess Plateau, Gansu , China (Hou et al. 2008). Energy balance analysis is a useful approach for assessing the sustainability of farming systems as it combines energy flow and matter cycle. Using data from 2006 and 2007, this paper presents the results of an energy balance analysis from three typical farming systems on the Loess Plateau.

Methods

Three township sites located on the Loess Plateau were selected and studied between 2006 and 2007: Tianshui in the north, Huancheng in the centre and Shishe in the south. The average annual temperatures are similar among the three sites while the rainfall varies greatly. From north to south, the annual precipitation is 330, 440 and 565 mm, respectively.

In both 2006 and 2007, 30 farms were surveyed in each township site to determine farm-level energy use. This included energy that is used for production inputs (for example, fertiliser, labour and seed) and production outputs (for example, grain, meat and wool). The farm systems were divided into crop and livestock sub-systems for the energy-balance analysis. A rangeland system was added to the livestock sub-system to acknowledge that some animals graze permanent rangeland and others get most of their nutrients from crops. Energy efficiency was measured as the ratio of energy output to energy input. Higher ratios imply a greater level of energy-use efficiency. Energy profitability was the difference between output and input of energy and higher differences often indicated more income to farmers. Data on crop area, yields, crop inputs, livestock breeds and numbers, livestock live weights, supplementary feeding, labour usage and grazing management, such as time of grazing and stocking rates, were obtained.

The energy parameters followed Hou (2007) and Wang (2008) (Table 1). In energy-balance analysis, the energy of crop and livestock products is what is used for production (land preparation, seeding, applying fertilisers and chemicals, harvesting crop, immunization and grazing livestock, etc.), primary processing (cleaning seed, slaughtering livestock and fabricating, etc.), package and distribution (storage, transportation, etc.). Energy of wool, lamb and cattle are 20.90 MJ/kg, 11.01MJ/kg and 13.88 MJ/kg, respectively (Hou 2007; Wang 2008). Energy input of labour usage was calculated on basis of intensity of work and gender of labour. A female will input 0.331 MJ/hr for light work (e.g. grazing sheep), 0.383 MJ/hr for moderate work (e.g. driving tractors in cropland) and 0.523 MJ/hr for heavy work (e.g. harvesting crop by hand), whilst male labour inputs are 0.418 MJ/hr, 0.488 MJ/hr and 0.679 MJ/hr, respectively. Both energy inputs and outputs of each farm were identified and calculated in terms of gigajoules of energy (GJ).

Table 1 Energy in seed and straw (MJ/kg).

Crop	Seed	Straw or hay
Potato	14.70	--
Buckwheat	24.99	15.05
Winter wheat	13.75	15.05
Broom-millet	25.00	13.8
Soybean	33.49	18.3
Alfalfa	108.82	18.8
Maize	104.65	17.5

According to the Chinese Agriculture Industrial Standard (NY635-2002), a sheep unit (SU) is defined as a 50 kg ewe with a lamb of less than 6 months, which will ingest 1.8 kg of standard hay (14% water content) every day. Commonly, a mature cattle beast is equal to 5 SU and a mature donkey is equal to 4 SU.

Results

The structure of integrated crop/rangeland-livestock production system

The area of cultivated land and number of breeding animals per farm decreased from north to south (Table 2). Each site was approximately 120 km apart. The sites have different topographies.

Table 2. The agricultural characteristics of the research regions.

	North	Centre	South

Location	37.1?N, 106.8?E	36.6?N, 107.3?E	35.7?N, 107.9?E
Cropland (ha/farm)	2.78	1.49	1.07
Herd size (SU/farm)	34.0	19.5	11.5
Topography	Gully	Gully with residual plain	Plain

Energy balance of the crop sub-system

For the crop sub-system, fertiliser was the main input for grain crops, which was 84.0-97.5% (average 90.8%) of the total energy input. Labour was the main energy input for alfalfa as the forage crop and the ratio to all energy input was 66.6 - 91.2% (average 78.9%). Alfalfa was the best in energy efficiency of all crops in the three sites owing to the lowest energy input. The average crop area per farm in the north was 2.6 times of that in the south due to a significant area of alfalfa (Table 2). As a result, the energy inputs were similar between the north and the south. Crop yields in the north were low and variable which resulted in low energy output. The energy efficiency was the highest in the south due to the higher proportion of crop (Table 3). Crop production in the central site had reduced forage crop and increased grain crop, which potentially could expose household incomes to more risk from variable climates. In the research region, grain self-sufficiency is the main objective of households. This objective explains why the crop sub-system is maintained, despite its negative energy profitability. In the central site, the yield of winter wheat was nearly zero in 2006 and 2007 (Wang 2008).

Table 3. Energy balance analysis of crop production in three sites.

Sites	Input GJ/farm	Output GJ/farm	Output/Input	Energy profitability GJ/farm
North	68.5	98.6	1.4	30.1
Central	146.6	67.1	0.5	-79.5
South	73.3	156.0	2.1	82.6

Energy profitability = Output - Input

Energy balance of livestock sub-systems

Though the number of breeding livestock in the north was approximately three times greater than that in the south, grazing during the summer growing season and selling lambs before they needed hand-feeding resulted in lower energy inputs in the north compared to the south (Table 4). Pen feeding is common in the south as sufficient straw and lucerne hay are produced. During winter and spring, animal requirements for energy considerably exceed supply, resulting in animals losing weight even after some livestock have been sold. Livestock energy efficiency was highest in the central site due to lower levels of energy inputs, reflecting the use of on-farm resources rather than purchased inputs. However, farmers still gain economic profitability under conditions of negative energy profitability, because they freely use communal rangeland for grazing in the northern site or produce feed by themselves in the southern part. The livestock sub-system was the main source of cash income.

Table 4. Energy balance analysis of livestock production in three sites.

Sites	Input GJ/farm	Output GJ/farm	Output/Input	Energy profitability GJ/farm
North	140.1	86.8	0.6	-53.3
Central	75.9	79.2	1.0	3.3
South	193.1	87.9	0.5	-105.2

Energy balance of integrated crop-livestock production systems

Farms raise livestock for cash income and plant grain crops to meet consumption needs, while using stover from grain crops as a livestock feed source (Figure 1).The natural resources available were different in the three regions and resulted in different relationships between crop production and livestock production.

Livestock are the main component in the northern site, supported by grazing and pen feeding which alternated across different seasons. Composted manures were important fertilisers for crop production, especially for forage crops. Livestock were used for draught power for crop production. Crop and livestock production in the central site were similar in energy balance. The application of fertilisers increased per unit area for crop production and grazing combined with feeding for livestock production. Livestock were still the main driving force for cropping, but are no longer an important source of fertiliser as the use of inorganic fertilisers has increased. Crop production was the main focus of the agricultural systems in the south and produced large quantities of low-quality stover to feed livestock. Pen feeding was undertaken throughout the year and manure was used as a fertiliser. As herd size in this area was typically small, by-products of crops were under-used in the agricultural system. Forage crop production was limited although yields were highest in the southern site.

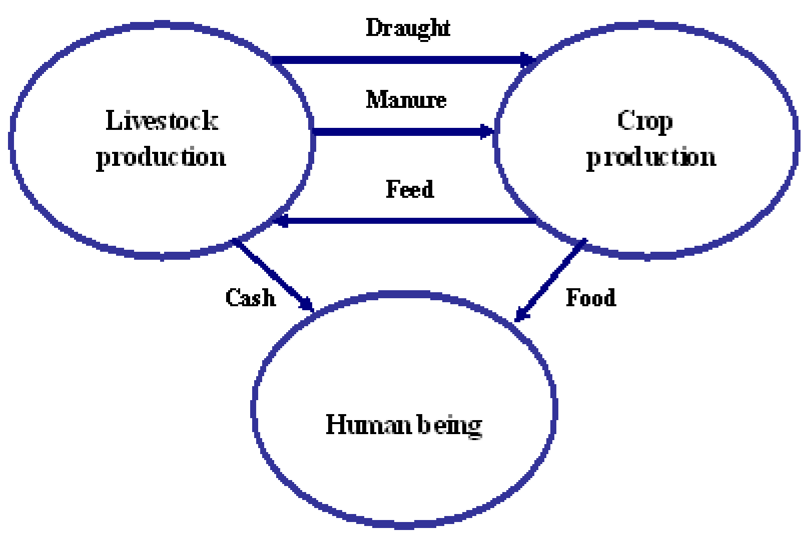

Figure 1. The integrated crop-livestock production system on Gansu Loess Plateau.

Coupling crop production with livestock production retained more energy flows inside the system, though the coupling benefits went with the agricultural structure and natural resource endowment in each site. The energy efficiency of the integrated crop-livestock production system in the north was the lowest and the energy input was the highest (Table 5). In the north, part of the input in crop production was to feed livestock. In contrast, the energy used by livestock was then partly used for planting and ploughing. That has been the traditional approach for system integration. However when there was a drought, grain-crop yields decreased, often to zero and limited the energy flows in the system. Energy was used for crop production without any return. Livestock are a buffer that can make use of the crop straw and prepare for crop production in the coming year. In the south, the highest energy profitability in expense of high energy input of agricultural system coming from the machine input for crop production and the feed input for livestock production.

Table 5. Energy balance analysis of the integrated crop-livestock production system in three sites.

Sites	Input (GJ/farm)	Output (GJ/farm)	Output/Input	Energy profitability (GJ/farm)
North	41.0	63.6	1.6	22.6
Central	21.2	48.5	2.3	27.2
South	34.1	70.3	2.1	36.2

Conclusion

Along the decreasing rainfall gradient from north to south in eastern Gansu, the usage of agricultural energy varies considerably. In the south, high output followed high input, which went with high risk if crops fail. In the north, low output followed low input, which went with lower risk. The risk came from the climate and the market. The integrated crop-livestock production system is more sustainable than highly specialised production systems. The multiple benefits of an integrated crop/rangeland-livestock production system rely on the relationship between the systems and emerge from long-term agricultural practices at the landscape level. A potential option to improve regional energy use would be to couple forage crop production in south with livestock production in north. This coupling of agricultural resources could play an important role in improving agricultural household income.

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