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

Lei Xu, Xiaoyan Wang, Fujiang Hou[1], Zhibiao Nan

College of Pastoral Agriculture Science and Technology, Lanzhou University, http://caoye.lzu.edu.cn/
Email xulei07@lzu.cn, cyhoufj@lzu.edu.cn, zhibiao@lzu.edu.cn
[1] Corresponding author

Abstract

The Loess Plateau is a typical rain-fed agricultural area. The structure and function of agriculture showed spatial differences as the gradient with precipitation change from north to south. Three typical regions from north, middle and south in Loess plateau, eastern Gansu were studied for energy analysis of agricultural systems. From north to south, the annual precipitation is 329.7, 438.6 and 565.6 mm, respectively. The farm size was 2.78, 1.49 and 1.07 ha/farm with 34.0, 19.5 and 11.5 dry sheep equivalent (DSE)/farm for farms in north, middle and south in the region, respectively. Average annual energy input was 68.5, 146.6 and 73.3 GJ/farm for crop production systems, and 140.1, 75.9 and 193.1 GJ/farm for livestock production systems, whereas the energy output was 98.6, 67.1, 156.0 GJ/farm for crop production systems, and 86.8, 79.2 and 87.9 GJ/farm for livestock production systems for respective regions. For the integrated crop-livestock system, the annual energy input was 41.0, 21.2 and 34.1 GJ/farm and output was 63.6, 48.5 and 70.3 GJ/farm, respectively. Results showed that the energy efficiency and input-output ratio of energy for crop production system was lower in the north than that in the south, while the energy efficiency and input-output ratio of energy for livestock production system was higher in the north than that in the south. Results also showed that the integrated crop-livestock system can increase productivity and energy efficiency via more efficient use of the resources in space.

Key Words

Integrated crop-livestock systems, crop production, livestock production, energy balance, Loess Plateau

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. This paper presents the results of an energy balance analysis from three typical farming systems on the Loess Plateau using data collected in 2006 and 2007.

Methods

Three townships, Tianshui, Huancheng and Shishe, approximately 120 km apart, were selected as study sites in the north, centre and south on the Loess Plateau. The average annual temperatures are similar but the precipitation varies from 329 mm in the north, 438 in the central and 565 mm in the south. From 2006 to 2007, 30 farms were surveyed in each location each year. Energy input and output was calculated for each farm. The energy for production inputs included those in fertiliser, labour and seed, and production outputs consist of energy in grain, meat and wool.

The farm systems were divided into a crop sub-system and a livestock sub-system for the energy balance analysis. A rangeland system was also added to the livestock sub-system. Energy balance was measured as the ratio of energy output to energy input. Higher ratios imply a greater level of energy efficiency. Data on crop area, yields, crop inputs, livestock breed and numbers, livestock live weights, supplementary feeding, labour usage, and grazing management such as time of grazing and stocking rates were collected. Both energy inputs and outputs were calculated followed Hou (2007) and expressed in gigajoules (GJ).

Results

The structure of integrated crop-rangeland-livestock production system

The farm size decreased from the north (2.78 ha/farm) to the south (1.07 ha/farm). The average crop area per farm in north was 2.6 times of that in the south. The number of animals in each farm also decreases from north to south (Table 1). In general, the topography is hilly in the north and flat in south with gullies in the central region of Loess Plateau.

Table 1. The agriculture structures of 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 (DSE*/farm)	34.0	19.5	11.5
Topography	Hilly	Gully	Plain

*DSE, dry sheep equivalent

Energy balance of crop sub-system

For the crop sub-system, fertilizer was the main input for grain crops, which was about 84.0-97.5% (average 90.8%) of the total energy input. For alfalfa as the forage crop, labour was the main energy input, consisting of 66.6-91.2% (average 78.9%) of total energy input. Alfalfa had the highest energy efficiency of all crops at all three sites due to its lowest energy input. The alfalfa was the major crop in north. However, crop yields in the north were low and variable, resulting in low energy output. The energy efficiency was the highest in the south (Table 2). In the central region, the main objective of household was self sufficient grain production. Farmers intended to grow less alfalfa and more grain crops with greater risk of soil erosion. Despite its negative energy profitability the crop sub-system was maintained. In 2006 and 2007, winter wheat completely failed with no harvest in the central site (Wang, 2008).

Table 2. 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-system

Though the livestock breeding scale in the north was approximately three times greater than in the south, grazing during the growing season and selling at lambing period makes the energy inputs in the north lower than in the south. Indoor feeding is unique to the south as sufficient straw is produced. During winter and spring, energy demand exceeded supply in the north. Energy profitability is negative in the north and south. Livestock efficiency was highest in central due to lower levels of energy inputs, reflecting the use of on-farm resources rather than purchased inputs. The livestock sub-system was the main source of agricultural income in the central.

Table 3. 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 system

Farmers raise livestock for cash income and grow grain crops to meet consumption needs, while using straw from grain crops as a livestock feed source (Fig. 1). The natural resources availability was different in the three studied regions and formed the specific model between crop production and livestock production.

Livestock are the main component in the northern site, usually by grazing and indoor feeding depending on season. Livestock offered draught power for crop production. Animal manures were used as organic fertilizers for crop production, especially for forage crops. However, the role of manure is less important due to increased use of inorganic fertilizers in the region. The status of crop production and livestock production was equipotent in the central site. In the south, crop production was the main focus of the agricultural systems and and straw from grain crops was the main feed resources for livestock. Indoor feeding was undertaken throughout the year and manure was used as a fertilizer. As animal number in each farm was typically small, by-products of crops were under-utilised in the system. Alfalfa production was limited although yields were highest in the southern site.

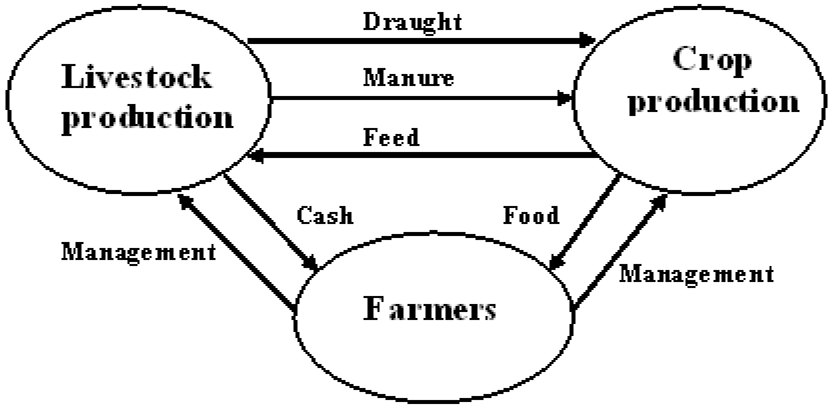

Fig 1. The integrated crop-livestock production system on Gansu Loess Plateau

The integrated crop and livestock production system would use energy more efficiently. The energy efficiency of integrated crop-livestock production system in the north was the lowest and the energy input was the highest (Table 4). In the north, part of input in crop production was switched to livestock production whereas the energy kept by livestock was partly used for planting and ploughing. During drought, when crop failed, the livestock could make use of the crop straw and prepare for crop production in the coming year. In the south, the highest energy profitability at the expense of high energy input from the machine for crop production and the feed input for livestock production.

Table 4. 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 with decreasing rainfall from north to south in the study region, the agricultural systems varied greatly. In the south, the system was high input and high output with high risk whereas in the north, the system was low input and low output with low risk. The risks generally came from both climate and the market. The integrated crop-livestock production system is more sustainable than highly specialised production systems. The benefits of integrated crop-rangeland-livestock production system rely on the relationship of each other and emerge from long-term agricultural practices at the landscape level (Allen, 2006). At the condition of enhancing forage crop production in south to help improve livestock production in north, the integrated crop-livestock system can increase productivity and efficiency of agricultural systems, which can play an important role in improving agricultural household welfare.

Acknowledgements

This paper is supported by National Natural Science Foundation of China (30771529), National Key Project of Science and Technical Supporting Programs (2006BAD16B06) and National Public Service Industry Programs.

References

Allen VG, Hou FJ, Brown CP, Green C and Senarra E (2006). Integrated crop and livestock systems in the Texas High Plains. Invited keynote presentations by the 2nd China-Japan-Korea Grassland Conference. Acta Pratac Sin,15(Suppl.), 33-38.

Hou FJ, Nan ZB, Xie YZ, Li XL, Lin HL and Ren JZ (2008). Integrated crop-livestock production systems in China. Rangeland J., 30(2), 221-231.

Hou FQ (2007). Characteristic of energy, economic and matter of agricultural system in Shihezi oasis. Thesis of Master Degree, Lanzhou University.

Wang XY(2008). Characteristics of energy and matter balance in the integrated crop-livestock production system in Loess Plateau of eastern Gansu. Thesis of Master Degree, Lanzhou University.