The role of alfalfa and forage resources in crop-livestock systems in a rain-fed region of north-western China

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Abstract. Western China has been facing the challenges of both environmental sustainability and economic development. Current government policies and interventions support the development of integrated crop-livestock production systems for enhancing food security and environment sustainability. Compared with traditional grain-based faming systems, integrated systems have better resource utilisation, however annual forage supply deficits estimated at 1.37 t DM forage/farm are experienced in the region, especially in late winter and early spring. Accordingly, optimising the use of available forage resources is a priority for regional researchers and extension officers, with research seeking pathways for better fodder conservation and greater and more effective use of fodder sources to close the spring feed gap. This paper presents relevant research activities relating to alfalfa (*Medicago sativa* L.) and winter wheat (*Triticum aestivum* L.) management in integrated crop-livestock production systems. As the planting of alfalfa is strongly encouraged in northern China, alfalfa species selection and optimised harvesting management are essential to ensure the full benefits of alfalfa are available for livestock intensification. The capacity for a prevalent grain crop, winter wheat to be managed as a dual-purpose fodder and grain source shows potential as a means to alleviate deficits of animal feed supply. The present information expands our understanding of integrated forage-livestock production in rain-fed areas, exploring options that can improve productivity in small-farm households leading to income generation.

Keywords: Loess plateau, dryland, rotation, integrated system.

Introduction

The traditional rain-fed farming system in north-western China, well known for severe erosion and high rainfall variability, is typically grain-based, with wheat crops being most prevalent and livestock production representing a small proportion of total agricultural output, approximately 20%. The net income per capita is US$320, half that of the China's coastal area. Demands for economic development and environmental restoration in north-western China have led to the promotion of integrated crop-livestock production systems, which are recognised as beneficial to both food security and environmental sustainability. With the subsequent rapid increase of regional sheep and goat numbers driven by ambitious administrative targets, improving the management of forages such as alfalfa (*Medicago sativa* L.) is essential to the sustainability of these new systems (Shen *et al*. 2009). Researchers and extension officers have made tremendous efforts in the promotion of forage production, with the aim of meeting the growing demand from livestock (Komarek *et al*. 2012).

Accordingly, this paper discusses the role of alfalfa and the dual-purpose use of winter wheat within integrated farming systems in the rain-fed region of north-western China. The present information expands our understanding of integrated forage-livestock production in rain-fed areas, exploring options that can improve productivity in small-farm households, within current environmental constraints.

Alfalfa within crop-livestock systems

Cultivars

Alfalfa planting area reached 580,000 ha in Gansu province in 2010, accounting for one third of the nation's total alfalfa planting area. As high-quality forage, alfalfa has a long growing history in the western Loess Plateau. Qingyang is the most productive rain-fed alfalfa growth zone in China. Adopted cultivars are Gannong No. 1, Golden Queen, Longdong (local variety; name means eastern Gansu), longzhong (local variety; means mid Gansu), Alqonquin ,Sanditi and Ameristand, with autumn-dormancy grades between 2 and 4. The Longdong cultivar has superior drought tolerance; WUE (water-use efficiency) of Longdong under 25% FC was 30% higher than imported cultivars, attributed to a photosynthetic advantage (Table 1) and greater resilience, whereas imported cultivars, selected for high yield in the initial growth years and greater leaf to stem ratio, suffer under Qingyang's conditions.

Production and management

Alfalfa was most often used in hay-carrying systems, harvested three times per year in late May, mid July and mid September. Annual DM yield ranged from 15 t/ha to 22.4 t/ha for the second and third years; the first harvest yielded 50% of annual DM (Fig. 1). Alfalfa is usually harvested in small amounts each day to meet daily

Table 1. Comparison of WUE and photosynthetic rate on three alfalfa cultivars Longdong, Alqonquin and Daye in a greenhouse experiment.

Water content FWC %	WUE (μmol/mmol)			Pn/Ci(mol/m^2.s)		
	Longdong	Alqonquin	Daye	Longdong	Alqonquin	Daye
25	2.25	1.73	1.44	0.086	0.059	0.063
50	2.43	1.61	1.61	0.084	0.077	0.135
75	2.13	1.88	1.33	0.102	0.093	0.128

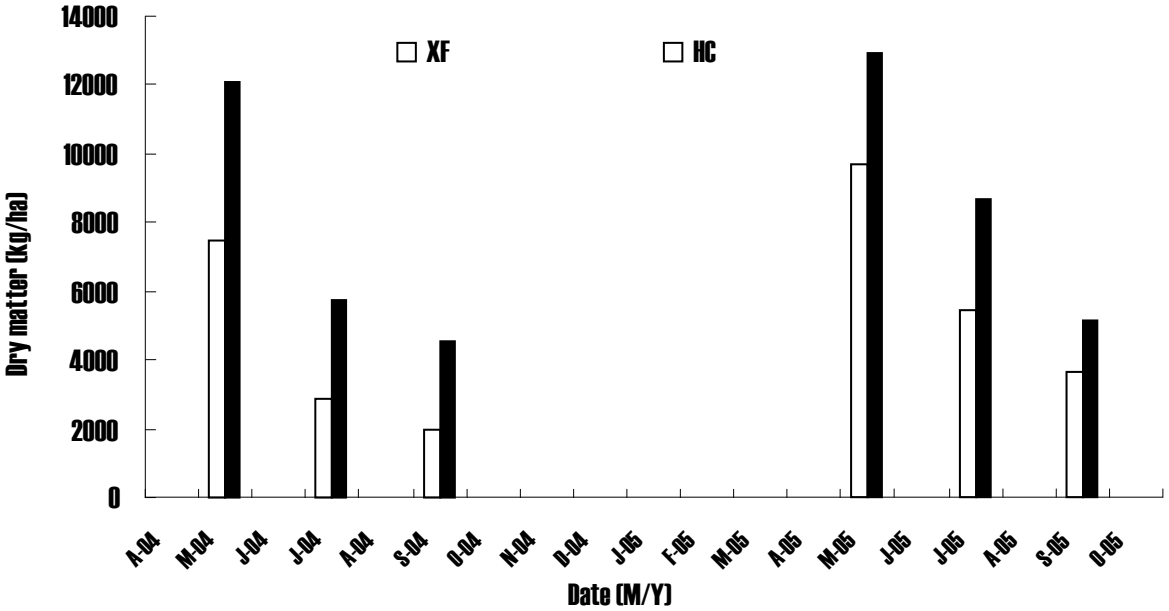

Figure 1. Alfalfa yield for each three cuts at Xifeng site (XF 35°44´N, 107°38´E, 526 mm rainfall), Huanchi site (HC, 36°27´N,107°59´E, 480 mm rainfall), Qingyang in 2004 and 2005.

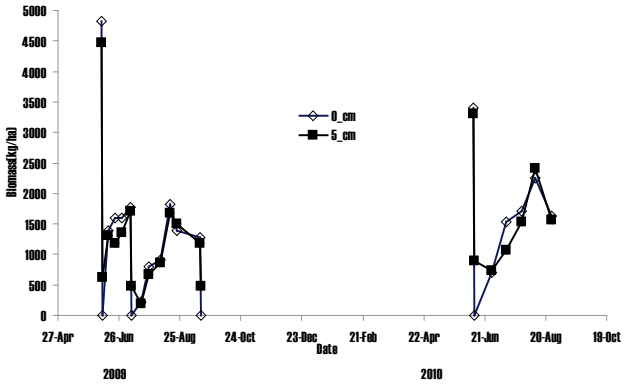

Figure 2. Biomass production (kg DM/ha) for alfalfa harvested with 0-cm and 5 cm cutting height at Xifeng, Qingyang in 2009 and 2010.

livestock requirements. Larger areas are harvested at peak biomass, occurring at the time of flowering, and then conserved for later feeding. Farmers also tend to harvest by hand at ground level, which is a labour-demanding practice. Raising the cutting height from ground level to 5 cm did not penalise harvested total or leaf biomass for the season (Fig. 2), with the added advantage that the residue could provided reasonable ground cover.

For better management, small-scale harvesting machinery is required to reduce labour inputs and ensure the timely completion of harvesting, especially for alfalfa grown on sloping land. Operating hay and feed-processing enterprises is encouraged by the government. Some existing enterprises possess a production capacity of 100 t per year.

Alfalfa within a rotation system

Soil dryness after alfalfa is a concern for water conservation due to its deep soil-water extraction. A continuous three-year experiment on the hilly Loess Plateau showed that soil water was replenished at the cereal stage after a 9-year alfalfa stand. The crop-yield differences between the conventional system and the alfalfa–crop systems were not statistically significant, however the WUE was greatly improved. The inclusion of alfalfa in the cropping sequence ensured more nutrients were available in the soil due to improved soil aggregation and water infiltration (Table 2).

Potential of dual-purpose winter wheat

There are approximately 20,000 ha of winter wheat grown in rain-fed regions of Gansu province, accounting for 60% of the regional total crop sown area. Winter wheat has potential for use as fodder when cut at an appropriate growth stage that allows regrowth for grain. A commonly sown winter wheat cultivar, Xifeng 24, was used for dual-purpose evaluation. After a continuous ongoing study, winter wheat was found to produce 0.53-1.38 t DM/ha of wheat forage with a high nutritive value when cut prior to stem elongation (GS 26) in spring; grain yields were 20-25% less than the uncut crop(3.2-5.8 t DM/ha (Table 3). Plants cut later than GS 30 had greatly reduced harvest index and spike numbers per m^2 (Tian *et al*. 2012).

Table 2. Crop yield, water use and WUE after 9-year alfalfa stand at Yuzhong site with 310 mm rainfall (Wang *et al*. 2008)

Crop		Yield (kg/ha)	Soil water change (mm)	Rainfall in crop (mm)	WUE (kg/ha.mm)
Spring wheat	Conventional	2937.2	49.5	221.8	10.8
	After alfalfa	2935.3	13.3	221.8	12.5
Pea	Conventional	1425	32	185.7	6.9
	After alfalfa	1524	-5.6	185.7	8.4
Potato	Conventional	3498	81.3	178.8	13.9
	After alfalfa	3603	34.2	178.8	16.4

Table 3. Forage and grain yield of winter wheat (CV. Longyu 216) cutting treatments at elongation (GS26) during 2009-2012 at Qingyang, China (Means±se).

Cutting treatment	Forage yield (t DM/ha)			Grain yield (t/ha)			Spike number/m^2		
	2009/10	2010/11	2011/12	2009/10	2010/11	2011/12	2009/10	2010/11	2011/12
UC	0	0	0	5.8± 0.40	3.2± 0.25	5.4± 0.36	606± 32	398± 10	326± 30
R0	1.38± 0.15	1.25± 0.15	--	4.6± 0.40	2.4± 0.15	--	644± 12	273±3 6	--
R3	--	0.53± 0.04	1.7±0.10	--	2.2± 0.20	6.7± 0.18	--	334± 15	447± 40

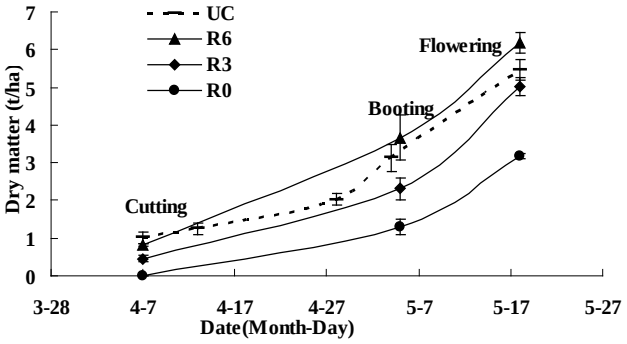

Figure 3. Winter wheat regrowth when cut at mid-tillering stage(GS 25) with 0 cm (R0), 3 cm (R3) and 6 cm (R6) cutting height, uncut(UC) as control at Xifeng, Qingyang, China in 2010.

Table 4. Feed demand and supply at Qingyang, China.

Items	Parameters
Feed demand as % of feed supply	137 %
Live-weight produced per ha	271 kg/ha
Supply deficit (t DM/household)	1.37 t

Cutting prior to stem elongation did not delay crop development in the wetter year. Cutting at 6 cm provided more initial dry matter for regrowth; the dry matter accumulation of plants cut at 6 cm was higher than that of uncut plants, presenting apparent compensatory growth that was maintained until the flowing stage (Fig. 3).

Discussion

Western China faces challenges to both environmental sustainability and economic development, and increasing incomes whilst decreasing income disparity with the eastern region of China remains a significant task. Government policies and interventions promote the revegetation of degraded land to reduce soil erosion and to expand the forage supply for consumption by small ruminants which contribute to farmer incomes. The production and utilisation of key forages, particularly alfalfa, and their use by stall-fed sheep and goats is a key concern. The Qingyang local government established a target to maintain 333,000 ha under alfalfa in total and 66,000 ha of that planted on arable land. Livestock output is expected to reach 3,000 million yuan with 950 yuan per capita. As such, our research is supportive of existing government environmental and poverty alleviation programmes, in addition to the ambitious targets for alfalfa sowing area and meat/cashmere production. Sheep and goat numbers increased from 1.47 million in 2008 to 2.37 million in 2010, however forage supply shortages, especially during winter, have severe implications for farmers that manage them. Estimated feedstuff deficiency was 1.37t DM/ year per household in the region (Table 4). The main bulk feeds used in livestock rations, accounting for approximately 90% of the feed types in the region, were alfalfa, maize or sorghum stover, edible forage in open fields, or tree leaves. Currently, approximately 55% of maize residues are used in feeding. The low nutritive value of many of these available feeds is another factor limiting livestock production, validating the importance of improving alfalfa production to maintain crop-livestock systems.

Use of cereal crops for the dual purposes of grain production and vegetative forage has become common practice in agricultural regions of the world. Dual-purpose use has been stimulated by the development of wheat cultivars with long pre-flowering stages. Winter wheat cut in late autumn and early spring yielded high -quality feed with a 23% crude protein concentration, at the expense of a 20-28% yield reduction at grain harvest. The appeal of the tradeoff is based on the comparative economic returns of livestock and grain. We believe that there is great potential to use winter wheat for both human and animal feeding, although we realize that dual-purpose winter wheat practice requires a high level of management in order to maximise total income.

Conclusions

Alfalfa is a central component of the livestock feed system in north-western China. Alfalfa production is expected to grow strongly, and improving alfalfa harvesting management to increase both biomass yield and quality ensures the full benefits of alfalfa are available for livestock

intensification. Improved management will be facilitated by enhancing awareness of the superior livestock performance obtainable with high-quality conserved alfalfa, by disseminating better fodder-conservation practice and by promoting greater and more effective use of alternative fodder. Harvesting winter wheat before stem elongation could be valuable in this regard, providing a high-quality forage available for use in spring, when feed sources are limited at the expense of extra grain at harvest.

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