Integrated agronomic and economic analysis of fodder options for Tibetan farming systems

Tim Heath[1*], Jin Tao[2], Colin Brown[3], Scott Waldron[3], John Wilkins[4], John Piltz[4], Jay Cummins[5], Carol Rose[6], David Coventry[1], Ann McNeill[1]
[1]School of Agriculture Food and Wine, University of Adelaide, SA 5064, Australia
[2] Tibet Agricultural Research Institute, Lhasa, Tibet Autonomous Region, China
[3]School of Agriculture and Food Sciences, University of Queensland, QLD 4072, Australia
[4]Department of Primary Industries, Agricultural Institute, Wagga Wagga, NSW 2650, Australia
[5]Department of Primary Industries, Horsham, Vic 3400, Australia
[6]Department of Primary Industries, West Kempsey, NSW 2440, Australia
[*]Corresponding author: email tim.heath@adelaide.edu.au

Abstract
Farming systems in Tibet that are based on spring barley and winter wheat have traditionally provided all the household and livestock requirements for grain. Increasing recognition over the last decade of the importance of forage in the system with strong support from government policy has encouraged Tibetan farmers to include forages in their farming systems, the aim being to improve livestock productivity whilst maintaining current cereal production for staple grain consumption. Recent research and on-farm demonstration trials in Tibet have evaluated agronomic forage options to fit into the current systems including double cropping and winter forage. Current best-bet options identified include: spring sown oats yielding 4.5t/ha dry matter; winter triticale yielding 5t/ha fodder followed by spring barley; and winter barley followed by vetch yielding 4.5t/ha. This paper describes an approach to integrate these agronomic outputs with other relevant information on human and animal requirements in a typical Tibetan household system in order to assess the overall effect of introducing new fodder options. Using a household model (CAEG Tibet), the effects on incomes are evaluated along with labour requirements, feed availability and other aspects important to the livelihoods of these impoverished Tibetan farm households. Results indicate that double cropping options offer potential net returns up to 2.3 times that of traditional single crop systems. However the path to adoption of these agronomic options is not straightforward as decision making by these households is driven by a complex interaction of socio-economic and cultural factors.

Key Words
fodder, household farming systems, modelling, agronomy

Introduction

Livelihoods of farm households in Tibet are dependent on agricultural production from small areas, with the average farm size being 0.8 ha. Spring barley is the main crop, accounting for 80% of the 230,000 ha of crop-dominated land in Tibet (Paltridge et al. 2009). Spring barley is the staple food for households, with the grain being used for human consumption and grain by-products (husk, brewer's waste) and straw used as fodder for livestock (Tashi 2002). Fresh weeds are also fed to animals during the spring growing season (Wilkins & Piltz 2008). Due to the increasing population, tourism, intake/person and demand for western protein-rich diets (dairy and meat products), livestock production is increasing in Tibet but availability of fodder is a major limitation. Research by national and international bodies into the agronomy of fodder crops in Tibet over the past decade (PIRDP 2004, Lane et al 2006, Coventry et al 2008) has demonstrated that spring sown oats, double cropping of winter triticale followed by spring barley or winter barley followed by vetch are viable agronomic options producing high yields of quality forage. This paper describes how these agronomic outputs can be integrated with other socio-economic information into a model that tests the impact on farm households of incorporating new forage options into local farming systems in Tibet.

Methods

Background

There are two main periods when crops are grown in Tibet: the spring season from April– to September of approximately 125 days duration and the winter season where crops are sown in September and harvested after winter from May to July, depending on the winter cereal (wheat or barley) variety and the altitude of the specific location. Within this cycle there are a number of options for integrating forage into the system (Table 1), including options for short season forage crops to be sown around the main crops. Forage production must also align with peak forage demand, which occurs throughout winter and in early spring, or with the ability to viably conserve forage for later use. The following four systems were chosen to be investigated as they are considered from agronomic trials to provide a good representation of suitable options for the majority of the crop dominated zone in Tibet:

1. Single crop spring barley (traditional system with grain by-products and straw for fodder)
2. Single crop spring oats (to replace the spring barley entirely and hence no staple grain crop will be grown; spring oats used entirely for fodder purposes)
3. Double crop winter triticale and spring barley (winter triticale for early fresh fodder harvested in April at tillering and spring barley for cereal grain sown in April with grain by-products and straw for forage)
4. Double crop winter barley and vetch (winter barley for grain production with grain by-products and straw for forage) and vetch relay crop sown after the harvest of the winter barley for fodder production)

Table 1. Timeframe for sowing and harvest of crops for the four options analysed.

Option ↓	**September**	**April**	**July**	**September**	**October**
1		Spring Barley sown		SB Harvest	
2		Spring Oats sown		SO Harvest	
3	W Trit sown	W Trit Harvest & SB sown		SB Harvest	
4	W Barley sown		W Barley harvest & Vetch sown		Vetch harvest

W= winter, SB= spring barley, SO = spring oats, Trit = Triticale

CAEG Model

The CAEGTibet simulation model performs physical and financial reconciliations—including cash flow, labour, crop products, livestock feed, livestock numbers, livestock products, manure and livestock energy and protein requirements—and reports on various returns to household labour, management and capital. Among other key model parameters, the model is able to endogenously calculate crop yield (based on land productivity, organic and inorganic fertiliser application and irrigation) livestock liveweight (based on livestock type, age, month), milk yield (based on livestock type, liveweight, age and stage of lactation) and feed rations (based on ration type, nutritional content of feedstuffs, and energy and protein requirements). In addition, the model employs a series of behavioural assumptions regarding household decisions and resource utilisation relating to labour, manure, feed, own consumption, land use and enterprise mix. A manual for the model that provides more specific details can be found in Brown and Waldron (2012).

Model simulations for four best-bet scenarios to increase fodder production

In this study the model was run for a representative farm household in Naidong, one of the main agricultural areas in Tibet. The farm has three Holstein-cross dairy cows that are fed a fixed ration of 40% (by weight) straw, 2% husk, 20% cereal grain, 5% brewers waste and the remaining 33% either vetch or oats depending on the scenario. The model then determines the total amount of feed required, based on these rations and the energy and protein requirements of the cows. In addition, the household uses 300kg of cereal grain per annum for beer making and flour production for own consumption. These core model parameters remain the same while the different land use/cropping patterns associated with the four scenarios are explored. The yields were not calculated endogenously since yields and fertiliser rates reported from agronomic trials within the region (Table 2) were available. The scenarios were based on prices in 2010, which was a very dry year with high fodder and cereal grain prices.

Table 2. Average yield and fertiliser input data for the four options analysed.

	1. Single crop spring barley	2.Single crop Spring oats	3.Winter triticale /spring barley	4. Winter barley /vetch relay
Fertiliser applied DAP: total for both crops (kg/ha)	90	90	465	375
Cereal grain production (kg/ha)	3,741	0	3,741	3,002
Dry cereal straw production from harvest (kg/ha) DM	6,734	0	6,735	5,405
Fodder crop production (kg/ha) DM	0	4,496	5,001	4,500

Results

Results from the model simulations (Table 3) highlight the significantly higher net returns from the double cropping options compared to the single cropping options. Although crop variable costs are higher, they are more than offset by the value of the increased fodder. It appears that with the double crop options, virtually all feed requirements can be sourced on-farm in contrast to single spring barley (option 1), where the model indicated that 47% of (the value of) the feed had to be brought in. The value of the livestock feed produced on the farm represents a significant proportion of the value of all farm outputs (over 38% in the case of option 3). Of the two double cropping options, the winter triticale-spring barley option (option 3) has a higher net return than the winter barley-vetch relay (option 4) due to the higher cereal, straw and fodder yields.

Table 3. Key output summaries from model simulation of four different cropping scenarios – a comparison of traditional spring barley system with options to increase fodder production in Tibet.

	1. SC spring barley	2.SC Spring oats	3.Winter triticale /spring barley	4. Winter barley /vetch relay
Returns to management for farm activities (Rmb)*	8975	-3207	20292	14395
Increase in value of feed inventory (Rmb)	3317	5290	9796	7348
Crop sales (Rmb)	5857	0	5859	2189
Crop variable costs (Rmb)	201	1397	1904	1820
Livestock feed purchases (Rmb)	8142	11722	338	338
Value intermediate (self produced) livestock feed (Rmb)	10526	6167	17550	18331
Value own consumption as % of value of outputs (%)	47	48	38	45
Crop labour (person days)	60	57	119	101
Returns to management for farm activities based on pre-2010 prices (Rmb) †	6750	179	8783	2205

* Returns to management for farm activities are the value of farm outputs including the value of own consumption and changes in the value of livestock or feed inventories minus the value of inputs used to produce these outputs (net farm income) and including an imputed value of household labour and capital to produce the outputs.
† Pre-2010 prices were much lower than the prices for grain and forage used in the analysis.

The net returns suggest a strong economic incentive, under the prices prevailing in 2010, for the double cropping options given that the net returns for option 3 are 2.3 times those of option 1, while option 4 net returns are 1.6 times those of option 1. However, the implementation of double cropping options depends on the availability of fodder seed as well as suitable land. Furthermore, compared with the single cropped spring barley, the double crop options virtually double the labour required (an increase from 60 to 119 person days). Most of this extra labour requirement is during the busy spring/summer period, which is a period of tight household labour constraints where both livestock labour (due to higher milk yields and so butter/cheese making labour) as well as off-farm opportunities (that occur only during this period) are at their highest. Specifically, the extra labour increases the average amount of additional labour above own household labour from 9.5 person days per month in the May to August period for option 1 to 14.2 person days per month in the April to August period for option 3.

With respect to the single cropping options, the traditional spring barley option (option 1) provides sufficient barley for own consumption (beer and flour making) as well as cereals, straw and husk for livestock feed. It also has a much higher return than the spring oats (option 2). Indeed, the spring oats option 2 has a significant negative return. This is partly due to the relatively low yield for oats used in the scenario (4.5t/ha DM), which means that the oats does not fill the households' own livestock feed gap in the way that the double crop options can. Similarly, the value of the extra oats fodder does not compensate for the food and livestock feed cereals and straw in the single spring barley option and so the returns are a lot less. However, if oats yielded 7.5t/ha, as has been reported for some on-farm demonstration trials in Tibet (Jin Tao, unpublished data), rather than the 4.5t/ha used in the scenario, returns to management for farm activities for this option would increase by Rmb 7,554 to Rmb 4,347. Thus the economic incentives for households to specialize into a single oats crop depends critically on the yields that can be achieved, even before consideration of the significant changes in the household systems that such a specialization would entail.

Part of the reason why the double crop options exhibit substantially higher net returns compared to the single crop options relates to the high price of fodder and cereals used in the scenarios, based on the very dry year of 2010/11. The net returns based on pre-2010 cereal and fodder prices (shown in the final line in Table 2) demonstrate that if prices return to pre 2010 levels, the relative merits of these options changes significantly. Specifically, the returns to management for farm activities for the single cropped barley are only slightly lower than the returns for the winter triticale-spring barley option (option 3) while they exceed the returns for the winter barley-vetch relay (option 4). Conversely, the net returns for the single crop oats (option 2) actually increase, although the returns are still well below the other options. The returns to option 2 increase because whilst the lower crop and fodder prices reduces the value of the oats grown, this is more than offset by the lower value of all feed (including the oats) fed to the livestock. For the double crop options (options 3 and 4), the lower cereal and fodder prices reduce the value of the feed fed to livestock, but because of the much greater cereal and fodder production in these options, this is more than offset by the lower value for cereals and fodder produced. Thus the volatility and relativity of prices, and households' perceptions of these, will have a crucial impact on the incentives for households to adopt particular crop or fodder options.

Conclusions and future work

There are feasible options for incorporating fodder into these Tibetan household farming systems and this study has clearly highlighted that double cropping for cereal-forage or continuous cereals can increase farm returns. However, other critical factors need to be investigated, such as the agronomy and long term effects of growing continuous cereals without break crops. In this model analysis, there are no yield penalties for such a practice; however, extra inorganic fertiliser is applied to replace the nutrients that are being removed from the system. Cash flow and labour requirements are key contributing factors. By growing double crops, and fodder crops the households are taking on the risk of the extra out lay required to purchase seeds and the fact that money will not be received from fodder crops until they are sold later in the season or when required by the livestock internally. The market channels for fodder and general farm produce in Tibet are not as well developed and produce cannot be sold and transported as easily as in other parts of China or in other parts of the world. Because the extra labour requirements occur at peak times for other labour requirements, both on and off the farm, they are reflected in higher costs either in terms of higher opportunity cost of farm household labour or in casual labour required.

The household modelling based on best-bet agronomic options for forage production in these Tibetan systems indicates that double cropping does increase net farm household returns. However given that valuations of own labour, own feed and own consumption are critical in these returns and that households value these items in different ways, the double crop options will need to clearly demonstrate how they align with household livelihood activities and how they can improve livelihoods before they will be adopted .

Acknowledgements

Australian Centre for International Agricultural Research (ACIAR) is gratefully acknowledged for project support, as is the team at CAEG, University of Queensland for developing and running model analyses.

References

Brown, C., Waldron, S. (2012) China Agricultural Economics Group Tibet Manual, version 1.

Coventry, D., Paltridge, N., JinTao. (2008) Project final report: Intensifying production of grain and fodder in central Tibet farming systems. ACIAR, Canberra, ACT. Available at www.aciar.gov.au/publication (accessed February 2012)

Lane, IR (2006) Fodder conservation. In 'Fodder production and double cropping in Tibet: Training manual'. (ed. IR Lane) (FAO: Beijing)

Paltridge, N., Tao, J. et al. (2009). "Agriculture in central Tibet: an assessment of climate, farming systems, and strategies to boost production." *Journal of Crop and Pasture Science,* 60: 627-639.

PIRDP (Pannam Integrated Rural Development Project) (2004) 'Annual report 2004: Applied research, demonstration and extension.' (Pannam Integrated Rural Development Project: Shigatse, Tibet Autonomous Region)

Tashi, N, Liu Yanhua, Tej Partap (2002) Making Tibet food secure: Assessment of scenarios. International Centre for Integrated Mountain Development, Kathmandu.

Wilkins, J. and Piltz, J. (2008) Project final report: Increasing milk production from cattle in Tibet. ACIAR, Canberra, ACT. Available at www.aciar.gov.au/publication/FR2008-37 (accessed January 2012)