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Conference name: 55th Annual AARES National Conference

Year: 2011

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Role of agriculture in the livelihoods of farm households in Tibet

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1 Introduction

In its ongoing efforts to identify more socially inclusive forms of development that target households in rural areas of Tibet, the Chinese central government has begun to focus more attention and resources on agricultural modernisation and development. Although agriculture continues to play a pivotal role in rural areas of Tibet, the nature of agriculture and rural society is changing.[3] This paper first highlights some of the macro-level changes that are occurring and some of the underlying drivers behind these changes. It then describes a model used to understand farm household systems at a micro-level for the main agricultural areas of the Yalong river and its tributaries . The models explore the impact of agricultural innovations and changing agricultural practices on household consumption, resources, and economic returns. Although the model and analysis are still in a preliminary stage, they reveal detailed insights about the role of agriculture in the livelihoods of Tibetan farm households.

2 Agrarian transition, macrodevelopments and drivers of change[4]

Traditionally agriculture has been the cornerstone of rural Tibet. Rural households have relied on agriculture for food security in subsistent food systems on the remote high altitude Tibetan plateau. Although barter trade occurred and continues today, commercial exchanges were modest and markets rudimentary. Agrarian change has not taken place in Tibet on the massive scale observed in many others parts of China or Asia. However, powerful drivers of agrarian change—including industrialization, urbanization, migration, off-farm and non-farm employment opportunities, the development of markets and cash economies, and agricultural intensification—are all prevalent and gathering momentum in agricultural areas of Tibet.

Numerous studies have explored the process of agrarian transition. For instance, Rigg (2005) identifies six agrarian types in South-east Asia ranging from subsistence, semi-subsistence,

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[1] Paper presented at 55th AARES Conference, Melbourne, February 2011.

[2] Colin Brown is an Associate Professor and Scott Waldron a Research Fellow within the China Agricultural Economics Group in the School of Agriculture and Food Sciences, the University of Queensland. The authors would like to acknowledge the contributions of the project scientists on ACIAR project LPS/2006/119 entitled "Integrated crop and dairy systems in Tibet Autonomous Region, PR China" on which the research for this paper was based and, in particular but in no particular order, Nyima Tashi, Se Zhu, Jin Tao, Tsam Yu, Bemba Drolma, Pubu Drolma, Tim Heath, John Wilkins, Ann McNeill, John Piltz, Nick Paltridge, Nicole Spiegel, David Coventry, Jay Cummins and Carol Rose. The authors would also like to thank and acknowledge the households, officials, enterprise managers and others involved in the study. Of course any omissions or errors in the paper are the sole responsibility of the authors.

[3] See, for instance, Goldstein et al. (2003) for a discussion of some of these changes and development challenges.

[4] The aggregate statistical data in this section comes from the Tibetan statistical yearbooks (Tibet Statistical Bureau 2010).

pluriactive, professional, and remnant smallholders. The agrarian types also relate to the source of household livelihoods and so are closely related to the rural livelihoods literature (see Ellis 2000 and especially in the context of different types of migration). The World Bank (2007) also classifies rural households according to livelihood strategies ranging from "subsistence-oriented farmers", "market oriented farmers", "labour oriented households", "migration-oriented households" and diversified households".

The discussion of agrarian change is also linked with the discussion of poverty alleviation in rural areas. In its 2008 World Development Report, the World Bank (2007) outlines three "pathways out of poverty" for rural people namely: commercialization of agriculture and greater integration with markets; agricultural wage employment or non-agricultural self employment; and out-migration from the rural economy. Individual households may employ their own diversified pathway or combination of these pathways depending not only on household resources and systems, but on the macro-level environment in which they operate, while pursuit of any particular pathway is no assurance of poverty alleviation.

The following sections highlight some of the key macro-level drivers of change in rural Tibet.

2.1 Pressure on farm land resources

Natural rates of population growth in Tibet of 10.3% are around twice the national average. In 2009, there were 460 thousand rural households compared with 313 thousand households in 1980. Over the same period the number of agricultural workers increased from 818 thousand to 1.2 million. Three quarters of these workers were employed in farming, animal husbandry, forestry, and fisheries. The increased population growth rates especially in rural areas have been offset somewhat by the general migration from rural into urban areas, but the movement has been less than in other parts of China. The proportion of rural population in the total population decreased gradually from 1990 to 2005 from 84% to 80% although it has since fallen to 76% in 2009.

The increasing numbers of households and population in rural areas combined with relatively limited agricultural areas has placed increasing pressure on using farm land more intensively. The pressure has been exacerbated in some agricultural areas by the resettlement of households from pastoral regions either to implement grazing restrictions or reduce grazing pressure, or to provide a base for households to access health, education, accommodation and other services. There has been considerable debate over the merits and nature of these schemes (see, for instance, Richard 2005), which is not taken up in this paper. However many of the schemes are on marginal agricultural land and there is a need to examine what farm systems can best support the livelihoods of these settled households as well as the existing households under increased land pressure.

2.2 Household incomes

Although per capita rural incomes of Rmb3532 in Tibet in 2009 were almost 2.6 times higher than the incomes in 2000 and almost eight times the incomes of 1990, they are only 69% of the national rural per capita incomes and are among the lowest in China. Furthermore the gap between urban and rural per capita incomes in Tibet is among the highest in China. In 2009, rural net per capita incomes were only 26% of disposable urban per capita incomes. Thus there is extreme pressure on all levels of government to help raise investment and incomes in rural Tibet.

2.3 Off-farm incomes

Many farm households in Tibet engage in off farm work and as in the rest of China this covers the full gamut from long term migration, to temporary or seasonal migration, to casual irregular

employment. Given the much less diversified economy, industrial base and opportunities relative to many other agricultural areas in China, however, these off farm income options are more limited.

Figure 1 highlights the broad sources of rural household net incomes from the official aggregate statistics. As mentioned net incomes per capita for rural households in Tibet rose substantially between 1990 and 2000 and even more so between 2000 and 2010. Wage (off-farm income) rose substantially during the 1990s from virtually no income at the start of the 1990s to accounting for around 17% of rural household incomes by 2000. Since then, while wage incomes have increased from Rmb232 per capita to Rmb753 per capita, they still represent only around one fifth of net incomes. Transfer income also increased during the 2000s and accounted for 17% of net incomes in 2009.

Most of the off-farm income for the households and regions visited in this study fell into two main categories. The first category were specialized activities and especially the gathering of "caterpillar" fungus (genus *Cordyceps*) on high slopes. This collection of this high value product is a family activity with children often also involved in the collection. Usually the collection occurs over the period from May to June. As the fungus is only found on slopes in particular locations and at particular altitudes, householders often travel significant distance and incur significant costs for the gathering. Originally it was a relatively unregulated and lucrative activity. However widespread picking has led to significant degradation of these fragile mountain grasslands, and concern over extraction of the resource rents by external parties has seen changes to access and fees that impact on the worthwhileness of the activity for many households.

The second major category, and again universal throughout much of rural China and China as a whole, is construction. This is the preserve of the adult members of the family but has provided an important source on off-farm income for farm households. However, construction work is not an open-ended source of income, as it occurs in Tibet usually only over warmer periods (April to September) and is influenced by the vagaries of the economic conditions (for instance decline associated with the global financial crisis in 2008 and 2009) and government initiated construction programs. The variability in the contribution of construction income to household incomes (either as labourers or as the household providing construction services as a business) across years is also reflected in the aggregate official statistics. Construction is also undergoing modernisation in China with many construction companies employing external teams of semi-skilled labourers rather than unskilled local workers.

Other local off-farm opportunities do exist while there is likely to be a more diverse economy and flow-on opportunities in the future. Nonetheless most of the current opportunities are somewhat constrained and centre on the summer period.

2.4 "Modernisation" of agriculture

Development funds from the central government to Tibet have been primarily in the form of funds for major infrastructure. Although this has had a significant impact on urban growth in Tibet there has been relatively little flow-on effect to Tibetan households in rural areas. Indeed there has been considerable debate that the infrastructure programs have widened the income and development gaps between rural and urban residents and between ethnic Tibetans and non-ethnic Tibetans because ethnic Tibetans in rural areas do not have the skills or resources to compete with outside workers and entrepreneurs in taking advantage of the construction and other business opportunities afforded by the infrastructure programs. However, in recent years, more attention has focused on increasing the flow of resources to agriculture and developing agriculture and agricultural research infrastructure as part of both agricultural modernization and broader development programs in

China. To date the focus has been on facilities and breeding programs[5] with much less attention on supply chains and marketing systems, extension programs, and institutional structures needed to "modernize" the sector.

In terms of productivity gains, since 1980 yields for grain crops have doubled while canola yields have trebled. However the yield increases have slowed since 2000 with yields rising only 10% from 2000 to 2009. Yields relate not only to new technological innovations but also to factor inputs and to weather conditions. However, over this period of modest yield increases, chemical fertiliser utilization increased from 25kt in 2000 to 47kt in 2009.

The extent of commercialization has also increased but only slowly. The proportion of grain sold relative to the grain produced rose from 11% in 1995 to 15% in 2009 while the proportion of canola sold to production remained the same at around 22% over the same period.

2.5 Agricultural structures

Figure 2 highlights the relative share of cropping, livestock and forestry in the gross value of agricultural production through time. Before the 1980s, animal husbandry accounted for two-thirds of the value of agricultural production. However this share fell during the 1980s and 1990s to the extent where livestock accounts for around 47% of the gross value of agricultural output. The fall in animal husbandry share was taken up by cropping which rose to around half of the value of output in the 1980s and 1990s [in response to policy to increase grain production and self-sufficiency in Tibet]. However the share wound back to 42% in 2009 mainly due to an increase in the value of forestry and partly due to an increase in livestock value.

The area cultivated in Tibet in 2009 was 229 thousand hectares with little variation across years. However there have been significant changes in the crops cultivated. The proportion of grain crops in sown area has fallen from 87% in 2000 to 72% in 2009. Some of this area has been taken up by oilseed crops which have increased their share from 7% to 10%. However there has also been a significant increase in fodder crops. The production of fodder crops increased, from a low base, 30 times from 1986 to 2009 and four-fold from 2000 to 2009. Conversely grain production, despite the increase in fertiliser usage, has declined from 2000 to 2009 reflecting the substitution from grain to oilseeds and fodder crops and as concerns about food security in grains have been allayed and policy restrictions relaxed.

In terms of production, (spring) barley rose from around half to two thirds of grain output in the first half of the 1980s. The barley increase was at the expense of wheat whose share has fallen to around one-fifth. Most of the wheat, around four-fifths, is winter wheat.

On the livestock side, the number of animals has remained constant from 2000 to 2009. However this masks the substitution out of small ruminants and into large ruminants. Bovine numbers have increased by 38% from 1980 to 2009 while small ruminant numbers decreased by 12% over the same period. Bovine meat output as a proportion of total meat output has increased from 45% at the start of the 1980s to 50% at the start of the 1990s to 55% in 2000 and 64% in 2009. Bovine milk also represents 80% of all milk produced. While the number of animals has remained constant from 2000 to 2009, meat output has increased by 71% from 149kt to 255kt, reflecting some commercialization of the livestock sector, albeit from a low base.

[5] Tibet Daily (2009) reported plans by the Tibet Autonomous Regional Government to invest Rmb2.86 billion on agriculture and livestock breeding.

3 Research design, methods and modeling approach

The trends implied in the official macro-data presented above is [mirrored / reflected] in pressures at household level, including increasing land pressure, agricultural commercialization, changing enterprise structures and livelihood strategies, and the influence of various development programs. Within these broader developments, more specific agricultural innovations and changes in agricultural systems and practices have been promoted among farm households. To investigate the impacts of these innovations on households, a detailed, micro-level analysis of the farming systems and economics of farm households was undertaken.

3.1 Research design

The analysis was based on farm households in the agricultural areas which are located in and around the main Yalong river and its tributaries (see

Figure 3). The research design involved developing models of farm households in three agricultural areas that capture some of the variation in agricultural systems in Tibet. The emphasis was on particular farms with both crop and livestock systems and especially those farms with dairy cattle. Although there are many aspects in common among farm households across the agricultural areas of Tibet, variations in agroecological conditions, household structures, location and other factors engender a diversity of agricultural systems. The three areas investigated and modeled were Mozhugongka, Bailang and Naidong and their location is highlighted in Figure 1 while some general statistical information about the three areas appears in Table 1.

Mozhugongka is in Lhasa prefecture but still far enough away from the capital to not be considered as peri-urban. Nonetheless, the proximity to Lhasa city provides scope and a diversity of off-farm opportunities. Mozhugonka farms are also smaller and less specialized than the other regions. In the hills behind the cropping areas on the valley floor, most households graze yattle (or dzo, a hybrid between yaks and cattle) rather than sheep or goats. The dairy cows are mainly local cows rather than improved crosses, while the cattle are generally poorly fed as reflected in low milk yields and liveweights. Cereal yields (both spring barley and winter wheat) are lower than the other areas but canola yields are higher and there is some specialization emerging in canola production.

Naidong is located further east and at a lower elevation along the Yalong river in Shannan prefecture. The households on which the farm model was based are located on the outskirts of the capital of the prefecture and some can be considered peri-urban. Family sizes are relatively small as are crop areas, while livestock are raised in intensive agricultural systems, rather than primarily grazed in adjacent mountain pastures. Many household members have incomes independent of farm activities and are only marginally involved in farm activities themselves and so are not included in the analysis even though their remittances can be an important source of income for the household. In particular, transport (both for tourism and general freight purposes) was a major source of livelihood in this region. The area is also more specialized in winter wheat rather than barley while there is also emphasis on improved cows rather than local cows.

Bailang is located in Shigatse prefecture which lies to the west of Lhasa about 200km along the Yalong river. It is an intensive cropping region located on one of the tributaries of the Yalong. Both household size and land areas are large compared to the other two areas. Spring barley and winter wheat yields are relatively high while much of the canola is grown as a mixed crop with the spring barley. Many households also graze herds of small ruminants, primarily sheep in the surrounding hills/mountains. There has also been a strong push to upgrade local cows to improved dairy cows.

Although relatively remote, Bailang is close to the prefectural capital and there are local markets in dairy products and some other products.

3.2 Information sources

The information used to develop and run the models and undertake the analysis came from five main sources namely:

- The primary source of information, was information collected from detailed case studies and interviews with farms in the three regions. The households were interviewed in detail in 2009 covering many aspects from land use, financial matters, own consumption, cropping systems, livestock systems, feed systems, prices, off-farm activities, labour and household structures. Most of the households were re-visited in 2010 to fill information gaps, to check on the model's robustness, to gain a better appreciation of the dynamics of these systems, and to understand adaptation of these farm households especially as 2010 was a very dry year with impacts not only on crop yields but also on the price and availability of feed resources. Several new households were also interviewed in 2010.
- Apart from the household interviews, local officials were also interviewed to place the households in the context of the region. Enterprise managers (grain and dairy processors and feed companies) and some local traders were also interviewed for a better understanding of local markets and prices.
- Much of the technical information was drawn from agronomists, animal production scientists and extension officers working in the Tibetan Academy of Agricultural and Animal Sciences and other agencies. Apart from the knowledge gained through their research work, the Tibetan scientists work closely with farmers and so have a lot of local knowledge to place the technical information in context.
- Technical and some socio-economic information was drawn from previous studies including work done on associated projects (see, for instance, Paltridge et al. 2009, and Wilkins and Piltz 2008).
- Finally, secondary information and in particular regional statistical yearbooks was reviewed. Although the information could not be used directly because of the masking associated the level of aggregation and some underlying biases within the data, it does provide another source and helps place the specific household information in a broader regional context.

3.3 Modeling approach

A two-fold approach is employed in the modeling as shown in

Figure 4. A mixed integer programming model is developed as a prescriptive tool to identify potentially worthwhile crop, livestock and other household activities as well as feed rations under a range of price and production conditions and prevailing household constraints and conditions. The programming model can also provide useful information on the shadow prices and opportunity costs of various household resources and farm activities. Thus the output provides a useful guide to researchers or extension officers in formulating recommended practices and activities.

The programming approach faces some limits however, in the capacity to capture household objectives, the full complexities of household faming systems, to tailor individual household circumstances, and to identify the household impacts of a specific set of activities. Thus a separate descriptive simulation model was also developed to identify detailed household and farm level impacts of various farming system, enterprise mix, market and policy scenarios. Although the model is primarily a representative farm model designed to illustrate impacts common to many farm

households in these agricultural areas, it has sufficient flexibility to model individual household circumstances and traits.

As shown in Figure 4 there are significant synergies and connections between the two approaches, among other things in sharing much of the core information. The differences between the prescriptive programming model and descriptive simulation model are a matter of degree. For instance, it is possible to highly constrain the programming model while the simulation model can be set up to readily scan the response surface. Nevertheless the development of separate but closely integrated models was regarded as the best way to achieve the research and extension objectives of the study. Because refinement of the programming model is still in progress and to give this paper some focus, the discussion below focus on the simulation model.

In essence, the model is a simulation model of household crop, livestock, feed and other systems. Although designed specifically to investigate integrated crop-livestock systems in Tibet, the model is flexible enough to consider a wide range of agricultural and semi-agricultural systems across Tibet and in other areas. The model, known as *CAEGTibet*, was developed by the China Agricultural Economics Group at the University of Queensland in conjunction with other Tibetan and Australian researchers on a collaborative research project investigating integrated crop and dairy systems in Tibet.[6]

The model is a steady state annual model although multi-year iterations for crop, feed and manure activities are undertaken to identify the steady state. The basic model time unit is a month. Both on-farm and off-farm activities are incorporated into the model. The model is run as a Visual Basic model embedded in an Excel spreadsheet. Data is input to the series of input sheets, with the Visual Basic model generating the output sheets. Although considerable resources have been devoted to the construction of the model and gathering of information, it enables often complex farming system implications of changes in activities or production or market conditions to be determined and, importantly, to be readily communicated.

The left hand column of Table 2 provides details about the information input to the model while the right hand column shows the output generated by the model. After inputting the data, the *CAEGTibet* model performs reconciliations on cash flow, labour, crop products, livestock, livestock products and manure. Apart from the various physical and financial reconciliations, the model also estimates and reports on various returns to household labour, management and capital.

Table 3 provides a summary on how the main output reconciliations are performed while Figure 5 illustrates in more detail the key and inter-related reconciliations of crops and livestock feed. The model uses information on crop areas grown, inputs and response functions to determine yields and production by crop type. This information is then combined with information on own consumption as well as calculated storage losses to determine a monthly crop amount. For non-feed crops, in the harvest month an amount of the crop is sold that just leaves sufficient production for own consumption and carryover seeds after account for storage losses (i.e. a steady state system). Production from feed crops (lucerne, vetch, oats and maize) is not sold but assumed to be used for livestock feed (although provision is made for own consumption of maize). Any surplus of feed crop production above livestock requirements is captured in the profit statement through a valuation of change in feed inventories. Any monthly shortfall in the amount of crop required for either own consumption, livestock feed or both is met by buying in feed. Because harvest does not occur at the

[6] ACIAR project LPS/2006/119 entitled "Integrated crop and dairy systems in Tibet Autonomous Region, PR China".

start of the year, the model runs a 2-year iteration to ensure the steady state. Cereal crop by-products (straw and husk) are also calculated in the model.

A central part of the model is the reconciliation of feed supply and demand again on a monthly basis. Feed demand is determined from livestock rations and the number of livestock by type as determined in the model. Feed availability is determined by the cropping systems with provision to buy in feed supplies to meet any feed deficit or for feed not produced on the farm. Feed can be carried across months with provision to allow for storage losses. For cereal livestock feed, the model calculates the surplus amount of cereal grains produced by the household (after accounting for own human consumption, carryover seed and storage losses). If there is sufficient total surplus cereal grain produced to meet the livestock feed requirement, the cereals are sourced according to their proportion of the overall cereal surplus (any surplus cereal grain is then able to be sold by the household). If there is insufficient surplus cereal grain to meet the total cereal livestock feed requirements, the shortfall is purchased in as barley. Cereals are also used by the households to make beer for their own consumption and this brewer's waste is also a feed source. Similarly, the extracted meal from the processing of canola to make oil for own consumption is another feed source for livestock. However the small amounts of canola meal and brewers waste deriving from own consumption means that it forms a small part of the overall ration for households with larger livestock numbers, and significant further quantities will have to be bought in.

4 Regional analysis / base household survey runs

In the first series of model runs, base household models for each of the three regions were run to provide insights on the household and farming systems. A brief synopsis of these runs appears in Table 4.

4.1 Bailang

For the representative Bailang household shown in column 2, the return to management, labour and capital for the farm household from the farm activities is Rmb 16,918, made up of revenues of Rmb29,058 and costs of Rmb 11,532. Of the revenues, more than half (54%) are associated with the value of own consumption of which two thirds relate to own dairy product consumption alone. Another 28% of the revenues are associated with increases in the value of inventories, especially livestock inventories which accounted for 93% of all the increase in inventories. Only 18% of the revenues are sales of crop and livestock products. The major cost item (accounting for over half of costs) is livestock feed purchase while depreciation accounts for just under one fifth of the costs.

Interest costs or the opportunity cost of capital is a relatively small item. The opportunity cost of labour, however, is a major item and the valuation of household labour is crucial to the estimation of returns. At Rmb16,127, the opportunity cost of labour (used in both farm and off-farm activities) accounts for virtually all of the returns to management, labour and capital from farm activities. If household labour is valued at casual labour rates, this would result in a significant negative returns to household returns to labour and capital]. However household labour is also used for off-farm activities. The income from off-farm activities amounts to Rmb5,850 which is less than a quarter of the value of farm outputs. The return to management including the off farm income and after account for the opportunity cost of household labour and capital is Rmb6,641. The other source of income not directly associated with the farm production are subsidies provided by the government. However agricultural subsidies are relatively modest accounting for around Rmb1,885 of which around 30% are crop input subsidies (mainly fertiliser) and 30% are crop land subsidies.

Although agricultural activities may improve the net worth of the household, because much of the increase in the value of outputs is associated with own consumption as well as the increase in the value of livestock inventories, the feasibility of the farm plan in terms of cash flow also needs to be investigated. *CAEGTibet* provides a detailed and disaggregated monthly cash flow statement. This cash flow statement is highly dependent on individual household non-farm expenditures and revenues which vary considerably across households. Table 4 presents minimum and maximum monthly cash flow balances assuming no opening balance and some standard expenditures (such as medical and general consumption expenditures). It reveals that for the Bailang household there will be considerable pressure on cash flows to sustain the farm plan especially in the first part of the year (end April cash balance of Rmb3286) unless the household has access to external sources of funds. Furthermore agricultural activities do not generate significant surplus monthly cash balances to cover any major household contingencies. Off farm wage income accounts for one third of total cash receipts although these payments are concentrated in the May to July period. Crop sales and dairy product sales account for only around one sixth of total cash revenues and crop sales for one eighth of the cash revenue. Livestock feed purchases account for one third of total cash costs, while general and major household expenses (food expenditure, education, medical, other) and loan repayments account for half of cash payments.

Although economic viability and feasibility are of concern to rural Tibetan households, there are other aspects of the farm and household systems of concern including the balances (surpluses and deficits) of other physical inputs and outputs including labour, feed, livestock, manure and crops. *CAEGTibet* presents this information on a disaggregated monthly basis, although only a key synopsis of this information is provided in the remaining rows of Table 4. In terms of the household labour requirements and availability, only small amounts of casual labour from outside the household are required in June and July partly because of the relatively large family sizes in Bailang. The period of May to July also corresponds with peak demand for off-farm labour and also livestock labour when cows produce the most milk that must be processed by the household into butter and cheese in a labour intensive process. Labour for cropping activities is highest in the planting and harvesting months of April, September and October but is still less demanding than for livestock labour. A substantial surplus of labour accounting for well over half of household labour occurs over winter (November to March), along with sizeable surpluses around Autumn (August to October and April).

Four crops are grown namely winter wheat, spring barley, canola and oats (some households also have a small vegetable garden but these are not included in the analysis). Despite the relatively large crop land areas, only around one tenth of the winter wheat and spring barley production (148 and 534 kg respectively) is sold. Some is used for carryover seed and 400kg of spring barley is for own consumption mainly for tsampa (flour) and barley beer. However most of the cereal is used to feed the livestock. Of the 396kg of canola produced, around half is sold and half self consumed. Around 2.16 tonnes of oats is produced but this is sufficient only for the oats livestock feed requirements from October through to early February.

Livestock numbers decline steadily over the year in line with mortalities along with own consumption of 2 sheep and the sale of a piglet in winter. However these are more than offset by the improved calves (3), lambs (14), kids (4) and piglets (2) born over the year, resulting in an increase in the value of the livestock inventory. Sufficient manure is produced by the livestock to meet both household heating and organic fertiliser needs. The manure is applied at planting in October but in April only around one-third of the desired amount is what is desired for the April plantings is available.

In terms of livestock feed, all cereal grain feed requirements—which make up around one-eighth of the weight of the cattle feed rations—are grown on the farm. However there are insufficient cereal by-products (straw and husk) to meet the livestock requirements with monthly purchases of

over 1 tonne of straw from January to July and around 40kg of cereal husks in June and July. Cut grass of around half a tonne from May to October is required with considerably more needed from November to March when the yattle are also primarily pen fed rather than grazed. As mentioned, the oats grown on farm is sufficient for the colder, more feed-intensive periods (October through to part of April) but not enough is grown to meet the requirements all year round meaning that around 120kg per month is bought in over the April to August period.[7] Canola meal, a by-product from canola oil processed for the household own consumption, is produced in sufficient quantities to meet canola meal livestock feed requirements in all but July and August (when only small amounts would be required to be bought in). Brewers waste from own production/consumption of barley beer meets about 30% of requirements.

The cows produce 219kg of butter and 351kg of cheese per year. Around 85% of the butter and 76% of the cheese is self consumed with annual sales of 40kg of butter and 91kg of cheese. All of the sheep and goat milk is self consumed. Most of the eggs produced are self consumed but there are annual sales of 120 eggs.

4.2 Mozhugongka

Although Mozhugongka is also an agricultural area, there are key differences with Bailang including being lower altitude and households have smaller family sizes and land areas. Being closer to the capital Lhasa there is more scope to engage in a wider range of off-farm opportunities. In the hills behind the cropping areas, households graze yattle rather than sheep or goats. The dairy cows are mainly local cows rather than improved crosses, while the cattle are generally poorly fed as reflected in lower milk yields. Cereal yields (both spring barley and winter wheat) are lower than the other areas but canola yields are higher and there is some specialization emerging in canola production.

These features are reflected in the profit statement of the representative Mozhugongka household. Total revenues of Rmb16,571 are Rmb12,000 less than for Bailang. Costs are also Rmb4,600 lower but returns to management, labour and capital are considerably lower at Rmb9,254. However because less household labour is utilized, and hence a lower overall opportunity cost of labour, along with the greater off farm income (Rmb8,800), the returns to management including the off farm income are still Rmb3,960. The smaller, less intensive farm production as well as significant off-farm income means that there is less cash flow pressure on these households than in Bailang or Naidong.

Although household size is smaller, the reduced and less intensive farm activities mean that labour demand/supply is nearly balanced in the busy (off-farm and farm) season from April to September but outside these periods there is a large surplus of almost 30 person days per month. The reduced dairy production reduces labour demands for butter and cheese making. Livestock labour, cropping labour in busy months and general household labour each account for around one-sixth of the labour. Off-farm labour in the April to September period can account for more than half of the household labour.

Although crop areas are smaller, because of the reduced livestock feed requirements (in terms of number of animals and the types and breeds of animals), livestock feed is sourced predominantly from within the household. Enough barley is produced on farm for both human consumption and livestock feed in the September to May period, although 200kg of cereal per month as well as cereal

[7] Oats is a relatively new fodder crop and not all farms grow oats. However these farms would need to have other fodder crops such as lucerne or vetch in their feed rations or purchase in more green feed or substitute more cereals into their ration in the absence of growing oats. Thus the net impact on overall feed costs or net returns may be marginal.

husks has to be bought in from June to August. Vetch production is sufficient to meet feed requirements over the October to April period, but straw production (because of the small area of cereals grown) is only sufficient for the September to mid-January period. Despite the small area of canola grown, yields are relatively high and family sizes and human consumption levels are low, This means around 54% of the households' canola is sold, while the meal from the processing of own consumed canola oil is sufficient for the smaller livestock feed requirements on these farms.

In terms of livestock products, the less well fed local cattle still produce enough milk for butter and cheese for the household but unlike Bailang there are no net dairy sales. However egg production is more than double household needs allowing the opportunity for sale of eggs.

4.3 Naidong

Naidong is located further east and at a lower elevation along the Yalong river in Shannan prefecture. The households on which the farm model was based are located near the prefectural capital. They have small household numbers as well as crop areas with fewer animals grazing on adjacent mountain pastures. Many household members have incomes independent of farm activities and are only marginally involved in farm activities, and so are not included in the analysis even though their remittances can be an important source of income for the remaining members of the farm household. In particular, transport (both for tourism and general freight purposes) was a major source of livelihood in this region. The area is also more specialized in winter wheat rather than barley while there is also emphasis on improved cows rather than local cows.

The revenue and cost structures for the representative household in Naidong is much more similar to that of Mozhugongka than Bailang. However the use of improved dairy cows means that both revenues and costs are higher than in Mozhugongka. Compared with both Bailang and Mozhugongka, a much higher proportion of the revenues are associated with the value of own consumption (almost three quarters) while sales account for less than 10%. However this also means that there are greater cash flow pressures on the Naidong farms which is relieved through income from non-farm members of the household.

Because of the higher dairy output of improved cows, butter and cheese making account for more than 50% of livestock labour, while livestock labour accounts for more than 20% of total labour and up to 30% in June and July. These months also correspond with months when off-farm income is earned. Because of the small family size, casual labour must be hired from outside the household for 10 person days per month in the May to July period.

Although the Naidong representative household has only a small crop area, the small human and livestock populations means that the household is largely self sufficient in its own consumption and feed needs. Despite low yields and crop areas, canola production still meets three quarters of own consumption while there are even small sales (8% of production) of winter wheat. Vetch and lucerne production are sufficient to meet livestock feed needs for 10 months of the year. Straw is still required to be bought in from early February to July.

The manure from the livestock are sufficient for heating needs but only half of the desired organic fertiliser needs. One third of the eggs produced are sold. Cheese sales account for one tenth of production but there is only sufficient butter produced to meet household own consumption.

5 Specialisation/intensification analysis

As discussed in Section 2, and as part of the process of agrarian change and development, households face pressures and incentives to intensify production, become more integrated into markets, or specialize in particular activities. However, the specific development pathway for households will vary according to differences in systems and regions. Different development options are explored in this section for each of the three regions. These options are by no means the sole option or necessarily the optimal option. However, the options are tailored to the particular regions and household resources, and are interventions that have been either been raised, recommended or trialed by research or policy agencies. Running the options through the *CAEGTibet* model illustrates some of the likely impacts that these interventions or practice changes may have.

The three options considered are outlined in Table 5. The Bailang scenario involves a major scaling up and specialization in dairy production with a consequent shift from food to fodder crops. The Naidong scenario also involves scaling up and specialization in dairy production but the labour to do so requires some household labour to give up some off-farm work[8] and to rely on externally sourced feed. Finally, because of the relatively small household and land size, the greater opportunities for off farm work, low dairy productivity and relatively high canola yields, the Mozhugongka simulation involves some crop specialisation from cereals to canola and a modest scaling back of dairy/livestock production to facilitate households' ongoing reliance on off-farm activities. A summary of the model results are provided in Table 6 in the same format as the summary results for the base region models that appeared in Table 4. Thus a comparison of Table 4 and Table 6 highlights the impact of these interventions and system changes.

The two scenarios of dairy specialization and intensification in Bailang and Naidong show different results even though both involve a shift to a 10 dairy cows. In the Naidong case, the extra cows place a significant increase on labour demands with livestock labour demand accounting for 60% of total labour requirements and butter/cheese making and milking accounting for 60% of livestock labour. However because off-farm labour is foregone, the amounts of casual labour required from April through to October are relatively modest. Overall the scenario does result in a significant increase in the return to management from Rmb3,135 in the base case to Rmb6,901. However it does change the nature of the household systems significantly. The household has changed from one where dairy products were consumed by the household to a "commercial" dairy producer with over 70% of dairy products sold and where dairy receipts account for 73% of household cash inflows. Similarly the share of feed in household cash outlays increase from 18% to 50%. Thus the household becomes much more dependent on the vagaries of the dairy market and productivity levels. Nevertheless the increase in return to management is significant and even where there is a high value placed on the opportunity cost of labour, the returns to management are positive.

Increasing dairy and fodder production impacts on the representative household in Bailang in a very different way. Although revenues increase by 66%, costs increase by 140% and the return to management after account for off farm income is only Rmb570 higher than the base scenario. For this modest improvement in returns, there are again significant changes in household systems and risk profiles. From having modest sales in grains, the household is now a net grain importer while it too has become a "commercial" dairy producer having to sell over two thirds of its dairy products, so that dairy sales account for 62% of all cash receipts. Despite having relatively large and productive crop areas, the household still has to buy in large amounts of feed including straw. This means that

[8] As mentioned in section 3.1, there is significant off farm work in the Naidong region but this work often involves the particular household member in full time, permanent, off-farm employment. Thus while their stream of income is important to the household, they do not contribute to farm household operations.

there may have to be some specialization or exchange of straw and other feeds across households at a local level. For the intensive cropping areas in Bailang, the trade of feed between households without large net imports into the area may be realistic provided all households do not scale up dairy production to the same extent. This compares to the less crop intensive and crop land constrained area of Naidong where large amounts of feed would need to be bought into the region to feed an expanded dairy herd.[9]

In the case of Mozhugongka, the modest changes in household systems in terms of limited crop specialization and a scaling back of dairy production to enable continued focus on off-farm activities increase returns to management by Rmb2,113. This increase is much larger than that for Bailang where much greater changes to the farm and household systems occurred. However cash flows are more volatile, while the household becomes a "commercial" canola producer with 84% of canola production sold. More significantly, off-farm income for the Mozhugongka household accounts for over 50% of cash receipts. The high returns to off-farm labour, however, must be weighed up against the risks (including a volatile construction sector, uncertain or potentially less lucrative fungus picking in the future), which may be even more volatile than crop and livestock yields and prices.

6 Discussion

Section 4 highlighted that the existing farming systems are feasible but only marginally profitable in terms of any increase in net worth to the household and the valuation of all inputs and outputs. However the profitability is critically dependent on the valuation of own household labour. Valuation at casual labour rates would make the farming systems from a profit perspective marginal at best while low valuation of labour would make the systems appear quite productive and remunerative.

Issues associated with the valuation and utilisation of labour have major implications for household incomes, livelihoods and development options. The labour reconciliation highlighted the very seasonal pattern to household labour use with casual labour required in summer periods and significant excess household labour during winter and surrounding months. The opportunity cost of labour used in the model reflects this seasonal pattern with low opportunity costs specified in winter and rates slightly higher than casual labour rates in the peak summer months. The issue is that the peak months for off farm labour coincide with those for livestock although the main cropping labour requirements are at the margins of these peak periods. The main off farm income opportunities are construction—concentrated in summer and restricted in winter when construction ceases—and fungus picking—again restricted to summer months.

Thus the development conundrum is that in seeking to increase household incomes either through greater off-farm employment or through intensification of existing crop and livestock activities will come up against tight household labour constraints. Furthermore it will not take advantage of surplus household resources, namely under-utilised household labour during winter and cold periods of the year. This implies that off-farm opportunities outside of the peak periods and farming systems with a more even distribution of labour requirements will have important development benefits. However identifying and realizing these opportunities and systems in the extreme seasonal variations of the plateau is a major challenge.

The findings also indicate that farm activities are primarily aimed at feeding the household rather than generating cash income. Over 50% of the value of the farm outputs was self consumed

[9] Komarek et al. (2011) report on a model that investigates local level aggregate feed constraints in the case of goat-lucerne systems in agricultural areas of Gansu province.

with much less than 20% sold off-farm (the remaining value being associated with increases in inventory mainly livestock valuations). The relative insulation from the market economy was reflected in interviews with households, researchers and officials in Tibet where the implicit discussion indicated that increases or decreases in production may not necessarily be reflected in more or less cash sales but are more likely to be reflected in changes in own consumption or that of extended family or village community. Indeed the regions and households on which the analysis is based are relatively more specialised than other regions and households where the farm is used primarily to provide sufficient food for the household, and any cash expenditure items are met largely from off-farm income.

Various development implications follow. Increased cash expenditures for both essential and non-essential goods and services increases in the future will need to be met through either more substantial off-farm opportunities and/or more intensive, specialised and less subsistence oriented farming and household systems. This will significantly alter the nature of the risks faced by households as well as the opportunities available to them. Greater farm surpluses, off-farm sales and specialisation will also put pressure on the very localised (often intra- and inter village) market channels. Thus a range of policy considerations and settings arise from ensuring households are able to cope with the new risks through to improving market channels and engagement of smallholders in these markets.

In terms of identifying and implementing new crop and livestock systems, there are two main implications. First, changes in farming systems will tend to impact across all household activities. That is, the semi-subsistent farming systems have largely evolved in line with the household resources. For instance, raising the number of dairy cows will have implications not only for household labour—as butter and cheese making is a labour intensive process—but also for feed—with a need to buy in more feed as requirements extend beyond own feed resource capabilities—and market engagement—as milk/butter/cheese production exceeds own consumption needs. Second, if the intensification and expansion is village or region wide, this will impact on the type, amount and price of feeds available, as well as on the capacity of the local market to absorb the increase in supply of product and associated impacts on prices and need for engagement in external markets.

The analysis in Section 5 highlights that it is possible to formulate changes to farm and household plans that can increase net returns. However in some cases these increases in returns and household net worth may be modest compared to increases in risk profiles and increasing dependence on external markets. This has various implications for adoption to or uptake of practice changes. First, households may be reluctant to uptake changes with only modest and potential net gains if they involve significant changes to their farm and household structures and practices, and exposure to external events and markets. Second, governments may need to ensure the appropriate facilitative environment for a more commercially-oriented systems in particular well functioning credit and insurance markets, inter-regional product and feed markets, and adequate safety net provisions.

7 Final comments

Agrarian change is occurring in the rural areas of Tibet and it is important to be aware of what opportunities this presents to farm households as well as the challenges. The analysis reveals that opportunities to intensify production, specialize in either specific farm or off farm activities, integrate more closely into markets are possible, are able to be tailored to household circumstances, and can bring about net benefits to the household. However uptake of these opportunities may be

constrained given that the net benefits may appear modest relative to the scope of the changes involved and risks confronted. Thus in the Chinese government's desire and push to modernize and intensify agricultural production, consideration needs to be given to ways to facilitate the transition from semi-subsistent household food and agricultural systems to semi-commercial systems, as well as ongoing efforts to identify and formulate interventions and practice changes that increase the magnitude of the net benefits.

Interventions or changes that do substantially increase net benefits may be limited and difficult to identify or formulate given the constrained resources of the farm household. This search may need to extend beyond specialization and intensification on-farm. Various levels of migration and off-farm employment facilitated by ongoing agrarian change may offer a path, but attention to improving rudimentary and often dysfunctional marketing systems, especially those for specialty products, warrants close consideration.[10]

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[10] See Brown et al. (2010) for a discussion and analysis of special product markets in Western China as they relate to household livelihoods. In Tibet, better functioning markets for Tibetan eggs, yak milk and other unique products from the region could generate sizeable benefits for the small, low income, households.

Table 1 Overview of Bailang, Naidong and Mozhugongka counties

	Bailang	Mozhugongka	Naidong
Population	44,880	45,866	58,514
Rural labourers (persons)	21,563	15,665	20,324
of which:			
- Farming, animal husbandry, forestry, fisheries	13,757	11,759	973
- Industry	1,175	27	243
- Construction	3,611	1,130	5,315
- Other non-agricultural	3,020	2,744	5,063
Gross value agricultural production (thousand Rmb)	2,255	1,691	1,300
of which:			
- Farm	936	1,343	653
- Animal husbandry	1,299	321	221
Gross value industrial production (thousand Rmb)	5,022	105	5,747
Sown area (hectares)	8,184	5,250	4,189
Irrigated area	8,184	3,338	3,779
Cereal area	5,771	3,794	2,591
Oilseed area	879	1,052	621
Cereal production (thousand tons)	3,945	2,234	2,134
Oilseed production	234	277	155
Large animals (thousand)	45	137	55
Sheep and goats	214	103	93
Meat output (tons)	1,276	7,468	2,427
of which:			
- Beef output	379	6,621	1,276
- Mutton output	755	582	453
Milk production (tons)	3,898	3,090	2,102
Sheep/goat wool (tons)	116	42	56

Source: Tibet Bureau of Statistics (2010)

Table 2 Outline of information input and output generated by *CAEGTibet* model

Input (information) sheets	Output (sheets) generated
Own consumption: Amount of crop and livestock products produced on farm that are self-consumed specified either on an annual basis or specific monthly basis, while livestock slaughtered for own consumption entered on a specific monthly basis. Service processing fees for crop products and livestock slaughtering entered. Livestock products and crop straw for heating can also be entered as a proportion of amount produced instead of an absolute amount.	***Profit:*** Summary of key revenue, cost (direct and opportunity) and reports various returns to management, capital and labour.
Financial: Information on assets (capacity, cost, depreciation and repairs and maintenance), major cash payments and receipts (such as remittances and education/medical expenses and external to farm operations which are calculated endogeneously within the model; and also opening cash balance) and credit (formal and informal including loan amounts, rates and length of loan)	***Cash Flow:*** Disaggregated monthly cash flow statement with monthly cash flow balances.
Subsidies: Crop subsidies (fertilser, seed, herbicide, pesticide expressed as amount or price/cost subsidy); crop land subsidy; livestock subsidies (direct and indirect); miscellaneous subsidies (loan, welfare, medical, housing)	***Crop reconciliation:*** For each crop by month; production, sales, purchases, livestock feed, carryover seed, carryover balance, straw and husk production and carryover balance.
Prices: Prices for livestock, livestock products, crop products, feed and crop inputs entered as either a monthly price or as an average annual price. Livestock prices also entered on either a per head basis or on a per kg liveweight basis. Transport costs are also included here.	***Labour reconciliation:*** By month: availability by labour type; disaggregated labour use by livestock, cropping and other household activity; casual labour requirements and surplus labour available by type.
Labour parameters: Labour availability by type by month; casual labour rates and opportunity costs of labour by type and month; restrictions/priority on labour type to particular activities; off farm labour usage by type and month and rate; general crop and livestock labour (maintenance activities as labour for specific activities input and calculated elsewhere in the model); specific labour requirements per unit for milking, butter and cheese making, and wine making.	***Livestock reconciliation:*** By livestock type and month and rounded to whole number (for reporting purposes only as feed and other calculations based on)
Land use: Land areas by type/grade of land (including productivity indexes and any land fees); crop areas sown by land type; double or mixed cropping.	***Feed reconciliation:*** By feed type (for those types used) and month: feed required, produced, purchases, sales and carryover balance
Cropping: For each crop: specification of land preparation, planting, organic fertiliser, inorganic fertilser, weeding, pesticide, irrigation, harvesting and storage activities (includes information on timing, rates, and costs); harvest yields and yield response parameters; straw and husk yields for cereal crops.	***Manure reconciliation:*** By month: production, requirements (separate for organic fertiliser and heating), purchases (to meet heating deficits only) and carryover balance.
Livestock numbers: Starting numbers by livestock type and specification of purchases and sales; birth months for female livestock; sale/purchase livesweights by type by month.	***Livestock product reconciliation:*** By month and livestock product: production, own consumption, sales and purchases
Livestock parameters: For livestock types: mortalities, birth and pregnancy rates; egg and fibre production; liveweight productivity indexes; manure production; veterinary and other costs; draught value.	
Milk / dairy products: For each female livestock type: milk yields, fresh milk sales, milk to butter conversion sates, milk to cheese conversion rates and all expressed on an annual or monthly basis.	
Livestock rations: 10 feed types by 25 livestock types. Unit is amount per head per month per type; and can be input either as an average annual amount or specified on a monthly (and so seasonal) basis.	

Table 3 Overview of reconciliations performed in *CAEGTibet*

Reconciliation	Overview
Cash flow	Key cash expenses and receipts specified on the Financial sheet are fed into a monthly cash flow budget along with other cash expenses and receipts determined endogeneously within the model (associated with the livestock, cropping, feed and labour activities). An opening monthly balance, net monthly payments, and closing monthly balance are calculated and appear at the bottom of the sheet. If the closing monthly balance is negative, this figure is highlighted in red.
Labour	Labour household use includes labour activities both on and off the farm. Specific livestock and crop activities (such as milking, fertilizer application) have specific labour coefficients which when integrated with the level of crop and livestock activities determined elsewhere in the model determines labour requirements. There is also provision to enter general unit labour requirements for crop and livestock. Labour requirements also include general household labour, off-farm labour and any family/village labour obligations. Household labour availability is disaggregated into adult and child/senior labour. Labour requirements and availability are reconciled. It is assumed that adult labour is the only labour used for any labour obligations. Both adult and child/senior labour is then allocated to general household labour requirements, crop labour requirements, and livestock labour requirements according to the order/specification that is specified by the user on the Labour parameters sheet (which also enables certain categories of labour to be precluded from the activity). Any labour deficit that arises (labour requirement in excess of availability), is then met by employing casual labour. In the profit statement and economic modeling, the value of the households own labour is incorporated into the non-cash returns based on a user specified opportunity cost of labour.
Cereals	The model uses information on crop areas grown, inputs and response functions to determine yields and production by crop type. This information is then combined with information on own consumption as well as calculated storage losses to determine a monthly crop amount. For non-feed crops, in the harvest month an amount of the crop is sold that just leaves sufficient production for own consumption after account for storage losses (i.e. a steady state system). Production from feed crops (lucerne, vetch, oats and maize) is not sold but assumed to be used for livestock feed (although provision is made for own consumption of maize). Any surplus of feed crop production above livestock requirements is captured in the profit statement through a valuation of change in feed inventories. Any monthly shortfall in the amount of crop required for either own consumption, livestock feed or both is met by buying in feed. Because harvest does not occur at the start of the year, the model runs a 2-year iteration to ensure the steady state situation. Cereal crop by-products (straw and husk) are also calculated in the model. Cereal grains used for livestock feed are determined in a special way as outlined in Section 2.3.
Feed	A central part of the model is the reconciliation of feed supply and demand again on a monthly basis. Feed demand is determined from livestock rations which are specified on either an annual or monthly basis on the Livestock rations sheet as well as by the number of livestock by type as determined in the livestock reconciliation. Feed availability is determined by the cropping systems with provision to buy in feed supplies to meet any feed deficit or for feed not produced on the farm. Feed can be carried across months with provision to allow for storage losses. There is also provision in the model for the feed demand to be met only at a specified level (say 90%) with the feed deficit then accounted for in lower productivity parameters. Cereal grain livestock feed is determined in a special way. First the cereal grain feed requirements are specified in the livestock rations on the Livestock rations sheet. The model then examines the surplus amount of cereal grains produced by the household (after account for own human consumption, carryover seed and storage losses). If there is sufficient total surplus cereal grain produced to meet the livestock feed requirement, then the cereals are sourced according to their proportion of the overall cereal surplus (any surplus cereal grain is then able to be sold by the model). If there is insufficient surplus cereal grain to meet the total cereal livestock feed requirements, the shortfall will be purchased in as barley.
Livestock	The model uses information on start year livestock numbers, mortality rates, birth rates and pregnancy rates as well as sales and purchases to track livestock numbers by month and livestock type through the year. The calculated livestock numbers are then used in other parts of the model such as in determining feed and labour requirements and the outputs of livestock products.
Dairy products	In the first stage, milk production by bovine type (improved cows, local cows, yak and yattle) are determined according to endogenously determined livestock numbers and specified milk yields specified on the Milk/dairy products sheet. These milk yields can be modified according to a feed deficit parameter as well an “average herd age” parameter which can reduce or increase average milk yields by a set percentage according to the age of the herd. For each type of milk, own consumption of the fresh milk is subtracted along with any fresh milk sales which are also specified on the Milk/dairy products sheet. Any excess milk is then used to produce butter and cheese according to transformation coefficients by bovine type specified on the Milk/dairy products sheet. Butter and cheese are assumed to be joint products and not competitive products. Own consumption is then subtracted from each of the butter and cheese consumption with any shortfall made up by butter/cheese purchases and any surplus assumed to be sold.
Manure	Manure production by month is calculated by month based on livestock numbers determined in the livestock reconciliation and by manure coefficients for each livestock type. Manure used for heating is then subtracted to determine a cumulative manure monthly balance. Manure for organic fertiliser specified in the input Cropping sheet in combination with the cropping areas grown is then compared with this cumulative balance. If the organic fertiliser requirement is less than the cumulative balance, then the balance is reduced accordingly. If the organic fertiliser requirement exceeds the cumulative balance, then the organic fertiliser rate is reduced so that the balance can be zeroed. The reduced organic fertiliser rates can then feed into the yield response functions.

Table 4 Base region model results - overview

	Bailang base	Mozhugongka base	Naidong base
Profit/Net returns			
Total Revenues (Rmb)	29058	16571	18528
proportion value inventory change (%)	28	40	18
proportion sales (%)	19	13	9
proportion own consumption (%)	54	47	73
Total costs (Rmb)	11533	7318	9126
proportion livestock feed purchase (%)	51	46	31
Return to management, labour&capital (Rmb)	17526	9254	9402
opportunity cost of labour (Rmb)	16127 [0]* {22153}**	13894 [0]* {19332}**	9785 [0]* {13777}**
Return to management (incl. off-farm income)	6640 [22767]* {615}**	3960 [17854]* {-1477}**	3135 [12920]* {-857}**
Cash Flow			
Minimum monthly cash balance (Rmb)	-3286 (April)	-1429 (April)	-4755 (December)
Maximum monthly cash balance(Rmb)	756 (January)	991 (January)	1413 (January)
Dairy sales as % of cash receipts	13%	2%	8%
Crop sales as % of cash receipts	16%	6%	4%
Off-farm income as % of cash receipts	33%	56%	38%
Feed purchases as % of cash payments	31%	21%	18%
Labour reconciliation	• Small amount casual labour (5 person days) in June and July. • Off farm labour accounts for around 60% of labour in May to July period. • Cropping labour of about 20% in April, September and October. • Livestock labour generally above 20% and reaching 30% in June to September period. • Butter cheese making of around 10 person days/month in May to September period accounts for around one third of the livestock labour.	• Significant surplus labour casual (> than 30 adult person days per month) in January to March and October to December. • April to September there is a virtual labour balance especially for the adult labour. • Cropping labour in busy months, livestock labour and general household labour each account for around one sixth of the labour utilised. • Off fam labour in the April to September can accoutn for more than one half of labour use. • Butter and cheese making account for a relatively small component of labour use due to small dairy production.	• Up to 10 hours of casual labour required per month in May to July period. • Off-farm labour takes up 55% of labour in May to July period and 27% in March, August and September. • Cropping labour accounts for 20% of labour in April, September and October and 10% in March and from May to August. • Livestoc labour accounts for more than 20% of labour for all months except January and accounts for 30% in June and July. • Butter and cheese making account for more than 50% of livestock labour.
Crop reconciliation	• Spring barley production of 4.6 tonnes of which 12% is sold • Winter wheat production of 1.1tonnes of which 14% is sold • Canola production of 396kg of which 43% is sold • Oats production of 2.2 tonnes meets 71% of livestock feed requirements; purchases of around 120kg per month from April to September	• Spring barley production of 2.2tonnes is only 96% of feed requirements • Canola production of 360kg with 54% sold • Vetch production of 336kg meets 74% of livestock feed requirements;	• Winter wheat production of 3.6 tonnes with 8% of this sold • Canola production three quarters of own consumption • Vetch production of 360kg meeting 80% of production • Lucerne production of 1.2tonnes meeting 88% of production
Feed reconciliation	• Straw production of 6.6tonnes is half of feed requirements • Brewers waste production of 300kg is 30% of feed requirements • Canola meal production of 108kg meets 78% of feed requirements • Cereal husk production of 343kg meets 83% of feed requirements; • 7.4 tonnes of cut grass bought in	• Straw production of 5.5 tonnes is 46% of feed requirements • Brewers waste production 40% of feed requirements • Canola meal production 84% of feed requirements; • Cereal husk production 62% of feed requirements; • 2.2 tonnes of cut grass bought in	• Straw production of 4.1 tonnes is 60% of feed requirements; • Brewers waste production 10% of feed requirements and 2t bought in • Almost sufficient canola meal production to meet feed requirements; • Cereal husk production of 214kg meeting two thirds of feed needs • 3.4 tonnes of cut grass bought in
Livestock reconciliation	• Increase in inventory of 3 improved calves, 14 lambs, 4 kids & one piglet.	• Increase in inventory of 2 calves, 3 yattle calves and 1 piglet.	• Increase in inventory of 2 improved calves and 1 piglet.
Manure reconciliation	• Sufficient manure to meet heating needs but only 39% of desired organic fertilser planting needs in April.	• Sufficient manure for heating but only two thirds of desired organic fertiliser needs in April and one fifth in October.	• Sufficient manure for heating needs but only 28% of desired organic fertiliser needs
Livestock products reconciliation	• 4.4kl milk production • 219kg butter of which 18% sold • 351kg cheese with 26% sold	• 2kl milk production • Butter production of 100kg and cheese production of 160kg and just self sufficient in butter and cheese • Egg production double own consumption with sales of 857 eggs	• 3.6kl milk production • 180kg of butter production and 290kg cheese and essentially self sufficient • 526 eggs of which one third are sold out

* The figures in square brackets are when opportunity costs of all labour are valued at 0.

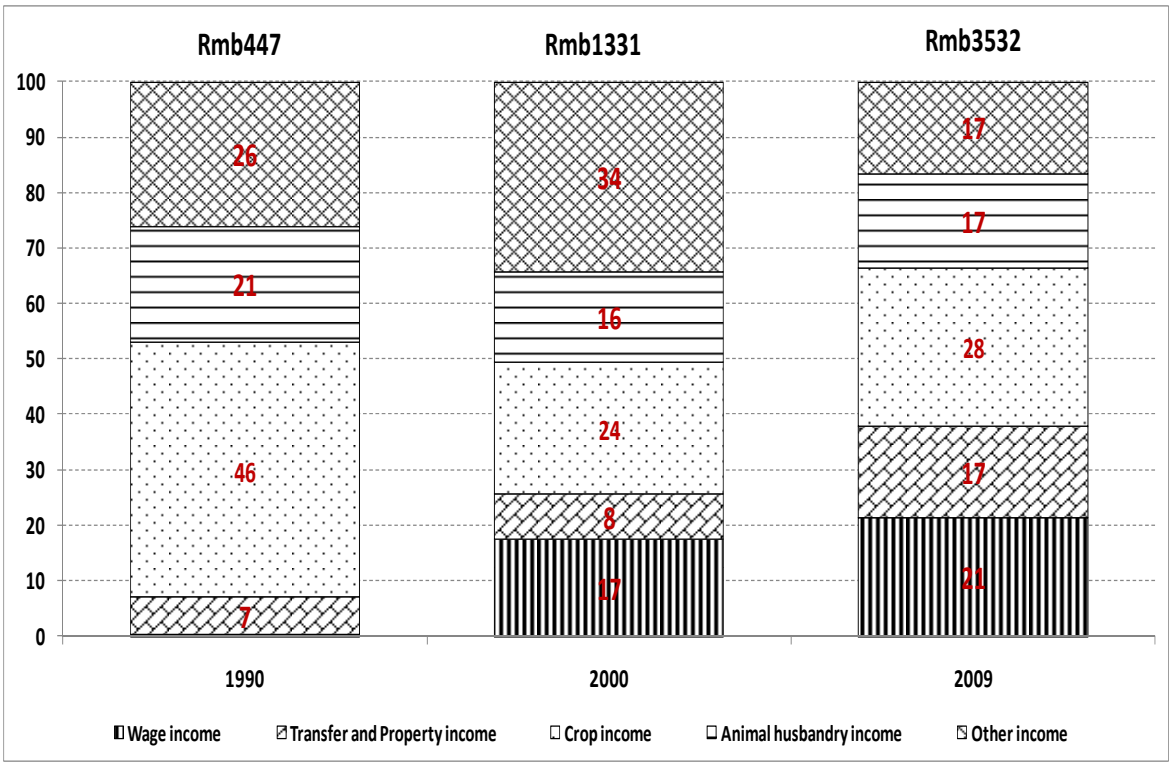
** The figures in square brackets are when opportunity costs of all labour are valued at the casual labour rate.

Table 5 Specialisation scenarios

Region	Overview	Details
Bailang	• Specialization into improved dairy cows and away from other livestock • Some shift from food to fodder crops	• Increase in improved milking cows from 4 to 10. • Reduction in other livestock of 26 sheep and goats (which although grazed for much of the year still draw on household feed resources in winter), the local draught bull, and 2 sows. • 4mu of land previously mixed cropped with barley and canola as well as 4mu of single cropped barley is replaced with 8mu of oats.
Mozhugongka	• Crop specialization into canola • Modest scaling back of dairy/livestock production to facilitate ongoing reliance on off-farm activities	• Barley area reduced from 11 to 5 mu and canola area increased from 3 to 9 mu • Local cows reduced from 3 to 2 and draught local bull dispensed with
Naidong	• Scaling up and specialization of dairy production • Shift away from off-farm activities • Reliance on externally sourced feed	• Increase in improved milking cows from 3 to 10. • Reduction in other livestock of 2 sows and 1 egg layer • No change in cropping patterns on own land • 3 mu of low productivity land is rented for vetch production. • Off farm work (total of 135 person days) foregone

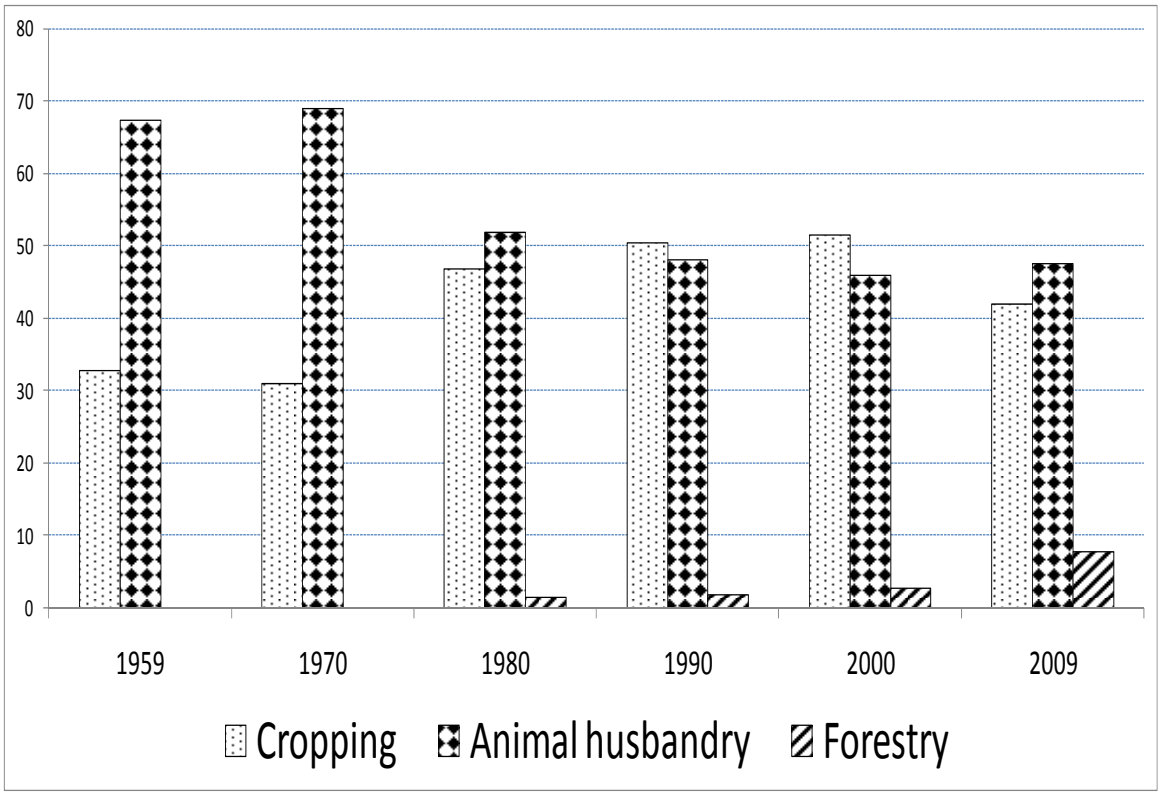
Table 6 Intensification and specialisation results

	Bailang ***Increase from 4 to 10 improved cows***	**Mozhugongka** ***Specialisation in canola and egg production***	**Naidong** ***Increase to 10 improved cows & move out of off-farm work***
Profit/Net returns			
Total Revenues (Rmb)	47774	18799	48821
proportion value inventory change (%)	22	31	20
proportion sales (%)	46	29	52
proportion own consumption (%)	32	40	27
Total costs (Rmb)	28640	8006	27379
proportion livestock feed purchase (%)	71	46	68
Return to management, labour&capital (Rmb)	19134	10793	21442
opportunity cost of labour (Rmb)	17168 [0]* {24119}**	13319 [0]* {18384}**	10874 [0]* {16968}**
Return to management (incl. off-farm income)	7210 [24378]* {257}**	6073 [16866]* {1009}**	10036 [20910]* {3941}**
Cash Flow			
Minimum monthly cash balance (Rmb)	-2416 (December); -1629 (April)	-2538 (April)	-3929 (December); -1969 (July)
Maximum monthly cash balance(Rmb)	1983 (January)	3767 (October)	3728 (January)
Dairy sales as % of cash receipts	62%	0.5%	73%
Crop sales as % of cash receipts	0%	24%	0%
Off-farm income as % of cash receipts	16%	46%	0%
Feed purchases as % of cash payments	53%	22%	50%
Labour reconciliation	• Around 20 person days casual labour required per month from May to July • Adult labour balance in April and October but significant surplus November to March • Livestock labour more than 30% of total labour (including casual labour) from April to November and up to 36% from June to August • Butter/cheese making accounts for 50-60% of livestock labour	• No casual labour required • Significant surplus labour October to March • Livestock labour more than 30% of total labour from October to March and around 15% from April to July	• 7 person days casual labour required in April, May and October and 12.5 days per month from June to September • Significant surplus labour only in December and January (>20 person days) • Livestock labour more than 60% of total labour from April to October • Butter/cheese making and milking labour is over 60% of livestock labour from February to November
Crop reconciliation	• Winter wheat production only 47% of livestock feed requirements; purchases of 155kg per month from January to March and 210kg per month from April to July • Spring barley production only 57% of livestock feed requirements; purchases of around 400kg per month from March to August • Canola production 92% of own consumption needs • Oats production of 6.4 tonnes meets 71% of livestock feed requirements; purchases of around 800kg per month from July to September	• Spring barley production only 57% of livestock feed requirements; purchases of around 160kg per month from February to August • Canola production of 1.08tonnes with 84% sold • Vetch production of 336kg meets 71% of livestock feed requirements;	• Winter wheat production only three quarters of livestock feed requirements; purchases of around 450kg per month from April to July • Canola production three quarters of own consumption • Vetch and lucerne production meets one quarter of livestock feed requirements
Feed reconciliation	• Straw production 17% of feed requirements; 18.7tonnes bought in • Brewers waste production 13% of feed requirements; 2 tonne bought in • Canola meal 36% of feed requirements; 0.2tonne bought in • Cereal husk production 34% of feed requirements; 0.4tonnes bought in • 6 tonnes of cut grass bought in	• Straw production 30% of feed requirements; 3 tonnes bought in • Brewers waste production 75% of feed requirements • Canola meal production 115% of feed requirements; • Cereal husk production 40% of feed requirements; 88kg bought in • 1.3 tonnes of cut grass bought in	• 3.3 tonnes of lucerne and 1.1tonnes of vetch bought in • Straw production 18% of feed requirements; 19.5 tonnes bought in • Brewers waste production 10% of feed requirements and 2t bought in • Canola meal production 26% of feed requirements; • Cereal husk production 36% of feed requirements; 390kg bought in • 11.3 tonnes of cut grass bought in
Livestock reconciliation	• Increase in livestock inventory of 7 improved calves	• Increase in livestock inventory of 1.6 calves, 3 yattle and 1 piglet	• Increase in livestock inventory of 7 improved calves
Manure reconciliation	• Sufficient manure to meet heating needs but only 60% of desired organic fertilser planting needs in April.	• Sufficient manure for heating but only 20% of desired organic fertilser planting needs in April.	• More than sufficient manure for heating and organic fertiliser needs.
Livestock products reconciliation	• 10.97kl milk production • 548kg butter with two thirds sold • 877kg cheese with 70% sold	• 1.7kl milk production • Butter aand cheese production only four-fifths of own consumption • Egg production double own consumption with sales of 857 eggs	• 12kl milk production • 70% of 603kg butter produced is sold • 73% of 965kg cheese produced is sold



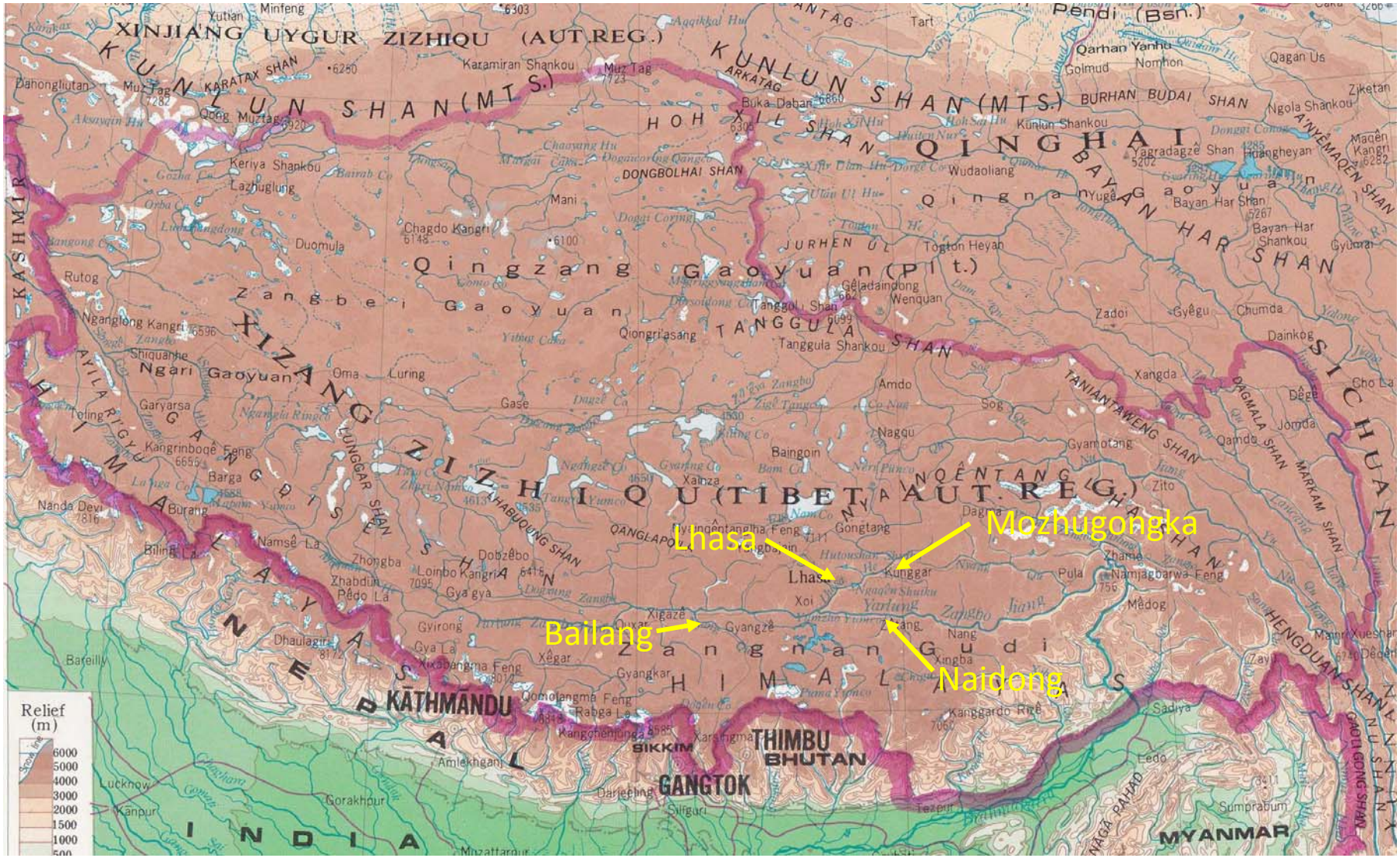
Source: Tibet Bureau of Statistics (2010)

Figure 1 Source of income for rural households in Tibet: 1990, 2000 and 2009



Source: Tibet Bureau of Statistics (2010)

Figure 2 Source of agricultural income in Tibet: 1959 to 2009



Source: China Cartographic Publishing House (1996)

Figure 3 Map of Tibet and study regions

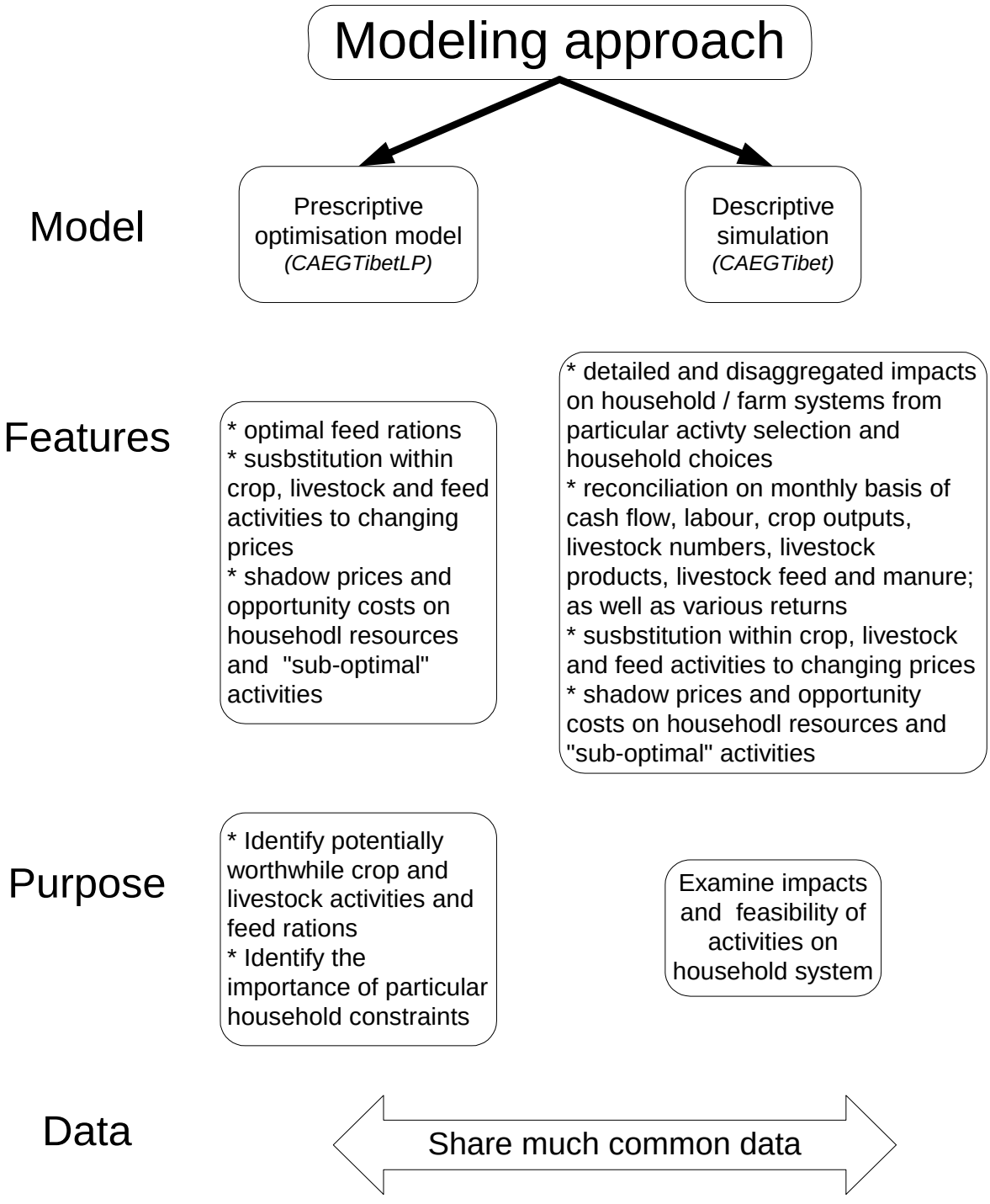


Figure 4 Overview of modeling approach

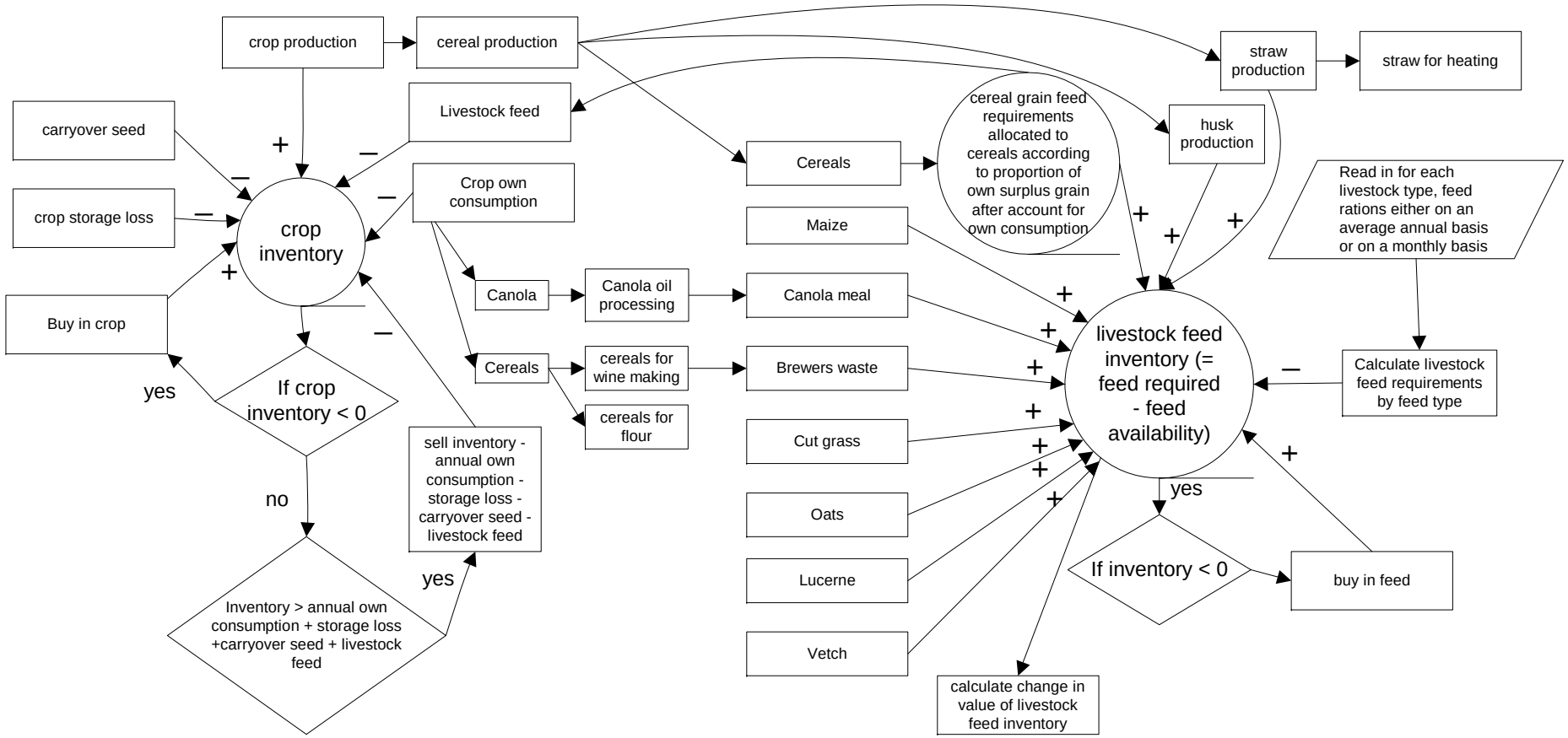


Figure 5 Reconciliations of crops and livestock feed in *CAEGTibet*