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Sustainability of Agricultural Diversity in the Farm Households of Southern Tibet

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Abstract: Farming systems in Tibet are undergoing significant change as farm households are encouraged to shift from more subsistence-oriented staple cereals to more intensive, diverse, and integrated forage crop livestock systems reliant on engagement with external input and product markets. This is occurring at a time of rapid agrarian transition with more and more of the livelihoods, income, and expenditures of farm households dependent on off-farm sources. Modernizing an agricultural sector that can sustain the livelihoods of smallholder farmers and meet the demands of an ever more discerning customer base all within the confines of a limited resource base has proved a major R&D and policy challenge for Tibetan and Chinese officials, let alone the farmers and market actors impacted by these developments. In this paper, key drivers impacting diversity in Tibetan farm households, including agrarian transition and demographic, infrastructure, and food price developments, are outlined. The impact on household economics and on the environment of the more intensive and diverse farming systems are then discussed, along with the attitudes of farm households to the changing farming systems and to their future in farming. The paper finds significant labor and environmental challenges that farm households and policy makers must grapple with if the farming system and agrarian transition trajectories are to be sustained.

Keywords: agricultural diversity; Tibet; farming systems; agrarian transition; livestock development

1. Introduction

In the valleys of southern Tibet, agriculture has been integral to Tibetan households for centuries. Staple crops such as spring barley and winter wheat supplemented by yaks and a few local cows and small ruminants have sustained the food production needs of these subsistence and semi-subsistence households. Toward the end of the 20th century, government initiatives sought to increase the productivity of cereals to improve the welfare of these farm households. However, by the end of the 20th century, per capita cereal production in Tibet (370 kg per person) was at the levels for China as a whole (364 kg per person) [1,2], while the push into livestock production and so-called 'agricultural sector rebalancing' so prevalent elsewhere in China in the 1990s was gaining traction in Tibet (see, in particular, Waldron et al. [3] for a discussion of the 'livestock revolution' in China and efforts at rebalancing the agricultural sector). Other drivers, including broader agrarian transition and changing institutional and policy settings, climate and production conditions, and market developments, were leading to more diverse agricultural structures and farm households. The push into livestock not only involved more livestock, but also a modernization and intensification of livestock systems, while off-farm activities of farm household members were also increasing.

These macro developments are reflected in the official statistics. In 1980, animal husbandry accounted for 60% of the gross value of agricultural output, with farming accounting for most of the remaining 40% [4]. The push to increase cereal production saw the proportion of gross value of agricultural output attributable to cropping increase to 51.5% by the turn of the century, while the share to animal husbandry fell to 45.9% [4]. However, the subsequent promotion of livestock production led to a reversing of these shares, with animal husbandry increasing its share of the gross value of agricultural output to 48% by 2010, with the share to cropping falling to 45.9% [5]. This trend has since consolidated with cropping having a 44% share in 2017 and animal husbandry 50.9% [1].

Tables 1 and 2 highlight some of these developments at a more individual crop and livestock level. Specifically, Table 1 highlights how there was a significant percentage increase in sown crop areas during the 1990s. Although fodder crops also realized a percentage increase, this was from a low base. With the cereal targets in Tibet largely met, sown cereal areas declined by around 36% in the first decade of the 21st century, offset by increasing canola areas as well as fodder crops. Since 2009, fodder areas have continued to increase, albeit at a slower rate, while cereal areas have also risen partly at the expense of canola. The figures in brackets in the right hand column of Table 1 indicate that not only have fodder crop areas increased, but also their productivity.

Table 1. Percentage changes in crop areas.

Time Period	Cereals (Wheat and Barley)	Canola	Fodder [1]
1990–1999	25.3	59.0	62.0 (21.7)
2000–2009	−36.2	51.9	245.5 (479.6)
2010–2017	20.9	−8.1	42.9 (77.6)

[1] Fodder includes lucerne, vetch, oats, and other fodder crops. Figures in brackets are percentage changes in fodder production.

Figure 1. The map of Tibet and surveyed sites. (In Tibet Autonomous Region, there are seven prefectures (such as Lhasa, Shannan, and Shigatse) which each contain a number of counties (such as Nagarze, Naidong, and Gyantse). The administrative units below counties are townships and villages.).

Table 2. Percentage change in livestock numbers: 2000–2009 and 2010–2017.

Year	All Tibet			Lhasa, Shannan, and Shigatse Prefectures [1]		
	Bovines	Sheep and Goats	All Ruminants (Sheep Equivalents) [2]	Bovines	Sheep and Goats	All Ruminants (Sheep Equivalents) [2]
2000–2009	24.1	−4.8	12.9	16.7	−2.3	8.8
2010–2017	−9.3	−31	−16.4	−8.3	−25.8	−14.9

[1] In China, prefectures are the administrative unit below autonomous region/province. Tibet has seven prefectures, including Lhasa, Shannan, and Shigatse (see Figure 1). [2] One bovine is equivalent to five sheep or goats.

Table 2 reports how bovine numbers and all ruminant numbers on a sheep equivalent basis increased in the 2000–2009 period, although the number of sheep and goats fell. In the southern prefectures of Lhasa, Shigatse, and Shannan, much of the bovine increase was associated with an increase in dairy cow numbers. The prefectures of Lhasa, Shannan, and Shigatse comprise agricultural, semi-pastoral, and pastoral areas. However, most of the agriculture in Tibet, with the exception of some parts of Qamdo and Nyingchi prefectures, are located in the agricultural valleys in these three prefectures. Much of the decrease in sheep and goat numbers in Lhasa, Shannan, and Shigatse in the 2000–2009 period was in the more pastoral areas of these prefectures, with numbers still rising in the agricultural townships. However, the number of livestock (bovine, sheep, and goats, and all ruminants) fell in the 2010–2017 period. Increased productivity of livestock (improved breeds and feeding and faster growth and turnoff rates) meant that livestock production (meat and milk, in particular) continued to increase. This was particularly the case in the shift from local to improved cows.

While the farming, agrarian, and household systems have been changing and diversifying in the 21st century, in part due to technical and government interventions, it is not clear whether these changing systems are sustainable. Indeed, the shift to more diversified agricultural systems in the first decade of the 21st century has partly been pared back since then (Tables 1 and 2). Modernizing and diversifying an agricultural sector that can sustain the livelihoods of smallholder farmers and meet the demands of an ever more discerning customer base all within the confines of a limited resource base has proved a major R&D and policy challenge for Tibetan and Chinese officials, let alone the farmers and market actors impacted by these developments. The aim of this paper is to explore the diversity occurring in Tibetan farm households in the agricultural valleys of southern Tibet, with the intent of providing insights on how likely these systems and structures are sustained into the future. Key research questions within this overall aim are: Do the new systems improve or worsen the incomes and livelihoods of Tibetan farm households? What are the perceptions of Tibetan farm households to the new systems, and are they likely to continue in these systems or in agriculture in general? And will the new systems exacerbate or improve environmental conditions in these farming areas? While agrarian transition and changing agricultural systems are not unique to Tibet, what makes the Tibet case so fascinating from a sustainability perspective is the rapidity of the change and the potential impact on the important yet fragile resource base of Tibet.

The remainder of the paper is organized as follows. Section 2 provides the context and background for the analysis by reviewing the literature and information that highlights key drivers to agrarian transition and diversifying agricultural systems. The methods employed in the paper to do the analysis are then outlined in Section 3. The results and discussion in Section 4 are organized to highlight the sustainability of the diversity from different perspectives, namely economic, social, and environmental. Section 5 draws key insights from the different perspectives together to reflect on the sustainability of the changing and more diverse agricultural systems in China.

2. Background and Literature Review

The literature review focuses on the drivers to agrarian transition as context for understanding the diversifying agricultural systems and the sustainability of these systems.

2.1. Demographic Developments and Resettlement

Migration from rural to urban areas so prevalent elsewhere in China has also been occurring in Tibet. Between 2000 and 2017, the proportion of total population in rural areas declined from 80.7% to 69.1%. Nevertheless, rural population over this period still increased 11.1% from 2.1 million to 2.3 million. Thus, although it did not match the increase in population in urban centers, which doubled over the period, there was a substantial increase in population in rural areas.

For farmers in the agricultural valleys of southern Tibet, several migration and demographic developments have impacted their livelihoods. First, as part of the agrarian transition and rural to urban migration so prevalent in the rest of China, there has been a migration of some farmers and members of rural households to urban centers. Second, there has been some resettlement of herders from pastoral areas of Tibet to agricultural areas as part of grassland and regional development policies placing pressure on limited agricultural land and water resources in agricultural areas, as discussed in Section 3. Part of the grassland policies implemented in the 12th Five-Year-Plan involved grazing restrictions and eco-compensation payments to reduce grazing pressures and rejuvenate degraded grasslands with some resettlement of herders from the most severely degraded grasslands [6]. Furthermore, some resettlement schemes were associated with facilitating the delivery of health, education, and other services to herder households [7]. Third, the increase in population in Tibet, and especially in urban areas such as Lhasa as outlined above, has increased the demand for local agricultural and livestock products. Furthermore, a significant part of this increase in population in urban centers has been an influx of Han Chinese from elsewhere in China to urban centers such as Lhasa partly as a result of the infrastructure developments and associated business opportunities outlined below. Not only has this created a big demand for local agricultural and livestock products, but has also changed the types of products being demanded.

2.2. Agrarian Transition

Rural economies in Tibet have diversified over the last two decades, with implications for agricultural households. Where off-farm income opportunities were largely constrained to picking of caterpillar fungus and local construction work over the summer period [8,9], there is now a more diverse but demanding, skill-wise, set of off-farm opportunities. Part of the more diverse set of off-farm income opportunities is a result of the rural–urban migration and increase in urban and total population. Household expenditures are now also more diverse, covering a range of education, health, work, and entertainment expenses. This has increased the cash expenses of farm households, forcing them to generate more cash sources of income either from external sales of farm products or from off-farm activities.

2.3. Infrastructure Developments

As in the rest of China, transport infrastructure has increased dramatically—although of more recent origin in Tibet. The infrastructure has not only increased integration with the rest of China, but also within Tibet. Where the plateau and remoteness provided a natural barrier to developments occurring elsewhere in China, the Qinghai–Lhasa train line, expanded air services, and new connecting roads have broken down these barriers, increasing trade with the rest of China. New eastern corridors off the plateau, airport, and further motorway construction will enhance the integration. Between 2000 and 2017, freight ton kilometers increased by 1392% [1].

Within Tibet, formerly 'remote' locations primarily self-sufficient in their food systems have become peri-urban with new roads, bridges, and other transport infrastructure. For instance, Waldron et al. [9] describe the case of Duopozhang, a township in Naidong county of Shannan prefecture. While relatively close to the prefectural and county capital, its location on the opposite bank of the Yarlung Tsangpo river (see Figure 1) and poor roads meant that there was little trade in farm products between Duopozhang and Naidong or engagement in off-farm activities, a scenario typical of a number of townships located

in small tributaries and valleys of the Yarlung Tsangpo river. However, the recent construction of new bridges over the Yarlung Tsangpo and new motorway on the northern bank of the river to Lhasa has changed the remoteness of the township, with Naidong only a half hour drive away and Lhasa around one and a half hours. This has created various opportunities for farm households to expand their dairy production, livestock, and cash crops and sell any household surplus to these urban markets. Thus, as elsewhere in China, this has the scope to increase engagement of farmers with external markets, both product markets and input markets, as well as to increase levels of specialization based on comparative advantage (such as fattening operations in peri-urban areas closer to markets and sources of feed with feeder livestock grown out in more remote locations).

2.4. Food Price Developments

Apart from an increase in demand for agricultural products as a result of the in-migration discussed below, price patterns for agricultural and livestock products have changed dramatically in China over the last two decades. Prices for ruminant meat products (beef and sheep and goat meat) were stable in the first part of the 2000s, but increased dramatically in 2010/11 and again in 2013/14 to almost three times that of the early 2000s [10]. Grain and feed prices also rose dramatically at the time of the global food crisis and have maintained their higher level since. Dairy prices and production rose markedly in China during the 2000s, punctuated by the melamine scandal in 2008 and a more recent wind back in prices, given rapid expansion of the dairy industry. Cashmere prices have always been volatile and continue to be so, but in general, are lower in real terms than they were in the 1990s. Wool prices are less volatile than cashmere prices, but the coarse wool farmers grow is of low value, while the cashmere and wool are less important in the livelihoods of farmers in agricultural and semi-pastoral areas.

For Tibet, price developments elsewhere in China have impacted on local prices. Cereal prices in particular show close integration with the pattern of prices elsewhere in China, although local feed in terms of hay and straw are impacted by local (production) conditions and livestock feed demand. Price transmission in ruminant meat between the rest of China and Tibet is also evident, albeit with some delay in the transmission. It is more difficult to determine price transmission in raw milk or farm gate prices between Tibet and the rest of China, given the relative paucity of milk price data in Tibet. However, in general, farm gate milk prices in Tibet have increased in line with increases observed in northern China, although with less volatility, partly reflecting the high level of own consumption of dairy products in Tibet.

3. Methods

To gather information on diversifying agricultural and household systems, and on the sustainability of these systems, this study focused on six Tibetan villages across three different counties—Gyantse County, Qonggyai County, and Nagarzê County—located in southern Tibet and along the Yarlung Tsangpo River valley. The three counties have different agro-ecological conditions (soil, water, elevation) and economic conditions (remoteness to urban areas and markets), and these were reflected in the household structures in the survey described below. Nonetheless, the households were all representative of farm households in the agricultural valleys of southern Tibet, which differ from households in semi-pastoral and pastoral areas of Tibet.

The study used a mixed methods approach, drawing on semi-structured interviews, village meetings, participatory observation, and questionnaires to gather information for the analysis. Specifically, a stratified random sampling method was used to select 144 households from the three counties mentioned above and shown in Figure 1. Face-to-face interviews were then done with household representatives between May and September 2018. The survey was divided into two parts, with the first one focusing on household and farming system data for use in the economic model used in Section 4.1. The household and farming system modeling was done through the *CAEGTibet* model, which is a household simulation model of integrated crop–livestock systems, especially dairy-feed

systems, tailored to the Tibetan context (see [8] for a detailed outline of the model). The model is designed to provide detailed and disaggregated impacts of changing livestock, cropping, feed, and other scenarios on household returns, cash flow, labor, livestock products, and energy balance. In the second survey, the same set of households were surveyed to gather information on farmers' goals, as well as attitudes and perceptions, to the uptake of new technologies discussed in Section 4.2. In addition, several villagers, especially elderly herders, provided reliable information on historical changes in resource use and their underlying causes. To complement the primary data collected through the surveys, annual yearbooks of Tibet, statistical documents from each of the townships, and technical information and reports from officials were collected from local governments. These provided useful information on herd size and structure, as well as on livestock production.

4. Results and Discussion

Sustainability of the diversified agricultural systems was analyzed from an economic, social, and environmental perspective and the results and discussion are organized in this manner below.

4.1. Household Economics of Changing Farming Systems

Diversifying away from staple crops to more fodder crops and livestock production can be expected, a priori, to have marked effects on farming systems and farm household livelihoods. Brown et al. [11] examined the case of specialization in dairy cow production for similar types of farms. They found that specialization and intensification did improve household returns, with a scaling up from three to ten improved cows increasing returns from farm activities by one-half. However, the returns were dependent on the relative dairy and feed prices prevailing in the 2012 to 2014 period. Sensitivity analysis reported in their paper drawing on 2010 prices (lower dairy prices but high feed cereal and local feed prices due to dry conditions of the time) resulted in lower incomes. The households shifted from a state of food self-sufficiency to one where they need to sell two-thirds of their dairy products and buy three-fifths of their livestock feed. The analysis also examined different household paths to increase scale and specialization in terms of exploring farm households raising their own heifers to build up their dairy herds over time compared with using finance to buy in the extra cows.

The Brown et al. [11] analysis was based on household information from the 2012 to 2014 period. Since then, there have been some significant changes in relative prices and farming systems. Thus, the analysis below draws on an updated version of the same model (CAEGTibet, See Brown and Waldron [8] for a description of the model) but calibrated according to prices from 2018 and updated farming systems and household information based on a 2018 survey of farm households.

Table 3 compares the model-derived indicators for the current farming systems with a fodder/livestock diversification scenario. Specifically, dairy cow numbers (as the livestock type most dependent on supplementary feed) are doubled, as are fodder crop areas (either vetch, lucerne, or feed oats) and oilseed areas (for canola meal from a livestock feed perspective) by substituting for some of the staple cereal areas. This substitution occurs on good quality (irrigated) land and not the marginal (dryland) areas that fodder crops have sometimes been grown in the initial expansion of fodder crop areas in the 21st century. Results are presented for two representative farm types, namely medium-sized farm households in Gyantse County in Shigatse prefecture and in Qonggyai County in Shannan prefecture. Input data on land use, livestock numbers, labor availability, own consumption, prices, and other information for the representative farms in the models were taken from the household surveys described in Section 3. Although representative of medium-sized farms in agricultural valleys throughout southern Tibet and in their respective areas, the farms in Gyantse have much larger land areas (around 40 mu; 1 hectare equals 15 mu) and livestock numbers (around 81 sheep equivalent) than Qonggyai (around 12 mu and 43 sheep equivalent).

Table 3. Key model-determined economic and household indicators of change from current farming systems to expanded livestock system [a].

	Gyantse County, Shigatse Prefecture [b]		Qonggyai County, Shannan Prefecture [b]	
	Current [a]	**Diversification [a]**	**Current [a]**	**Diversification [a]**
Net farm income [c] (CNY)	73,763	81,190	28,749	40,167
Net farm income per labor day (CNY)	123.0	111.4	96.1	107.0
Own feed as % of all feed	97.3	90.2	84.4	75.0
Off-farm income as % of returns to management and labor for farm activities	45.8	41.6	101.7	72.8
Value of own consumption as % of value of outputs	36.2	29.4	53.3	35.9
Sales and purchases as % of net farm income	51.8	61.9	42.9	72.2
Farm labor used as % of farm labor available in peak April to September period	90.4	106.9	61.1	81.0

[a] "The Current" scenario involves model-based estimates of the current farming systems, with the model calibrated using the farm survey data reported in Section 3. The "Diversification" scenario involves dairy cow numbers (as the livestock type most dependent on supplementary feed) in the model being doubled, along with fodder crop areas (either vetch, lucerne, or feed oats) and oilseed areas (for canola meal from a livestock feed perspective) by substituting for some of the staple cereal areas. [b] Representative medium-sized farm households of agricultural valleys in southern Tibet. While representative of their areas, farms in Gyantse have much larger land areas (around 40 mu) and livestock numbers (around 81 sheep equivalent) than Qonggyai (around 12 mu and 43 sheep equivalent). [c] Net farm income is net of opportunity cost of capital.

Net farm incomes for Gyantse are higher than for Qonggyai, reflecting the larger size of farms in Gyantse. However, the Gyantse farms also use more labor for their cropping and livestock activities and so the net farm incomes per labor day are much closer between the two areas (Gyantse of CNY123/labor day compared with CNY96.1/labor day). These net farm incomes per labor day are lower than the casual labor rates or off-farm income rates. However, the opportunity costs of labor for many farm households and at different times of the year will be much lower than this due to availability of and transaction costs in seeking out work and preferences for work in different seasons. Furthermore, the net farm incomes include a host of non-monetary items, notably the value of own consumption but including other intangibles such as depreciation and value of livestock and other inventory changes. Thus, how households perceive their net farm incomes relative to off-farm incomes varies.

What is notable from Table 3 is what happens to net farm incomes as farms scale up their livestock and diversify their crop land from cereals, on the one hand, to cereals and fodder crops on the other hand. For Gyantse, net farm incomes rise, but only by around 10%. Although dairy production and sales increase markedly, even with the relatively large crop areas and increased proportion of fodder crops, the scaled up livestock require a lot of additional feed to be bought in, as well as labor, including casual labor, to service the greater number of cows. Thus, net farm income per labor day actually falls from CNY123 to CNY111. For Qonggyai, the scale up and diversify strategy increases absolute net farm incomes (from CNY28,749 to CNY40,167), as well as net farm income per labor day (from CNY96 to CNY107). The Qonggyai households, even with the scaled up cow numbers, can draw on their

underutilized and lower opportunity cost own household labor and do not have to bring in expensive casual labor. While livestock feed costs and purchases do increase because of the small fodder crop areas, even with the substitution of some cereal cropping land, this is more than offset by the increased dairy production and value of livestock inventories (new calves).

However, the income changes come with some significant changes in farming systems and their engagement with external markets. Although farms still source most of their feed on-farm in the scaled up livestock scenario (75% in Qonggyai and 90% in Gyantse), they represent significant reductions from the current systems and where farmers have been reluctant or unable financially to buy in feed. Similarly, to generate the higher net farm incomes, sales and purchases as a percentage of net farm incomes, an indicator of engagement with external markets, also increases from 52% to 62% in Gyantse and from 43% to 72% in Qonggyai. Thus, farmers will need to engage more with these external markets and be able to manage the different risks associated with increased engagement with external markets.

Because of the higher incomes associated with the increased agricultural production in the diversification scenario, off-farm income as a proportion of returns to management and labor for farm activities (a proxy for comparison with off-farm incomes) also falls. In the case of Qonggyai, off-farm incomes currently are of a similar magnitude to the returns to management and labor for farm activities, but the proportion falls to only 73% in the scale version. The effect is less dramatic in Gyantse, where income change is less and overall income is higher.

Historically, many rural households in Tibet have used their farm production to meet their own food and fibre needs. In Qonggyai, more than half (53%) of the value of all outputs produced on the farm have been used for own consumption. Under the new scenario, this falls to just 36%, while in Gyantse the proportion falls from 36% to 29%.

The other broad indicator of interest shown in Table 3 is farm labor used as a percentage of farm labor available during the busy summer or peak labor period. Qonggyai farms, because of their small size, are still able to manage within the existing household labor. However, in Gyantse farms, labor used as a proportion of labor available increases from 90% to 107%. This is an average over the entire April to September period, and there are peak labor months during this period when significant casual labor has to be brought in to service the cows (in lactation and with calf) and cropping (busy planting and harvesting months).

The cases presented in Table 3 are dependent on the particular scenarios, and especially on key parameters such as feed and livestock product prices. Nevertheless, the cases do highlight several key points. In particular, they highlight the importance of both feed and labor constraints in household returns. If diversifying traditional farm structures is to be contemplated, then farms will need to be fully integrated into feed and labor markets, allowing them to make well informed decisions that impact their livelihoods. Second, the shift will have marked impacts on farm household farming systems and household structures. Third, relative feed and product prices and enterprise mix decisions based on these prices are crucial to incomes. Fourth, improving the productivity of fodder crops and feed efficiency and productivity of the livestock will be essential to more specialized systems and the livelihoods of farm households making the changes. Indeed, households are unlikely to consider the changes unless there are substantial and readily understood benefits of doing so. Improving productivity calls for new fodder crops, feeding and livestock technologies, and practices tailored to the needs and capabilities of farm households and underpinned by robust extension packages.

4.2. Attitudes toward Agricultural Production and Future Trajectories of Agrarian Change

With the importance of dairy products in the livelihoods of rural households, it is not surprising that farmers would emphasize dairy production and, moreover, be interested in pursuing methods for increasing production further. Based upon the results of a survey of Tibetan farm households in 2018, overall dairy production is stated to have increased for 61.43% of the farmer respondents compared to five years ago, with the remainder stating unchanged production levels. When asked 'how likely are you to work towards increasing your dairy production in the next few years?', almost 40% said

they were 'extremely likely', with another 48% indicating they were 'quite likely'. These numbers indicate a general interest amongst farmers for pursuing higher levels of dairy production. In terms of their preferred approach for increasing dairy production, improvements on dairy productivity appeared to be more popular relative to increasing herd sizes. According to survey results, slightly under 10% indicated a preference for increasing dairy production by increasing the number of cows, while about 64% said they wished to achieve this through higher productivity. A further 23% preferred to adopt both methods, while about 4% claimed to be uncertain of their preferred method. For those that preferred to improve dairy productivity, just under 20% stated their desire to achieve this goal through improved management practices, such as through improved nutritional feed, while 35% stated a preference for adopting improved breeds. The most popular method, as stated by 40% of respondents, was to adopt both strategies. In order to meet the higher feed demand that is required for increasing dairy production, most farmers were keen on growing their own fodder. Some 77% of respondents stated they would grow their own fodder for this purpose, 10% preferred to purchase the fodder, while about 11% indicated a preference for employing both methods. Similar to dairy production, forage production among the respondents also increased, with 58% stating higher levels of forage compared to five years ago and the remainder indicating no change.

While the interest and intent for increasing dairy production is generally expected from farmers, the extent to which such production increases are desired or are feasible is yet another question. Many rural farmers appear to be making adjustments to their household livelihoods strategies, which are generally in response to changing incentive structures and/or due to limitations in their ability for expanding on agricultural production. While the pursuit of diversified livelihood strategies away from traditional subsistence farming is a known phenomenon of the agrarian transition, what makes the situation in Tibet unique is the pace at which these transitions are occurring. The rapid changes, which have been greatly propelled by the sizable investments under the government's development initiatives for modernizing the economy, have significantly altered the economic and social landscape of the region. The profound effect on household circumstances and structures has, as a result, greatly influenced the attitudes and goals of farmers in relation to their agricultural production.

Increased off-farm employment opportunities, along with higher wage rates, have siphoned surplus labor from the agricultural sector to the industrial and service sectors. This has resulted in labor shortages within farm households, especially during the summer months which coincide with peak demands for agricultural labor. Based upon the results of the household survey, 82% of households had at least one member earning an additional source of income through off-farm employment. Whether the off-farm work involves temporary migration to other areas or is based within the local area, such pursuits draw labor away, limiting agricultural production. Survey respondents were asked to rate their agreement for the statement 'Labor shortages within the household has been a significant factor limiting my farm productivity' on a five-point Likert scale (where 1 indicates 'strongly disagree', 2 'disagree', 3 'neither agree nor disagree', 4 'agree', and 5 'strongly agree'). According to the results, the average Likert score was 3.78, with almost 70% of respondents either agreeing or strongly agreeing with the statement, indicating that agricultural production is being negatively affected by household labor shortages. The within household labor shortages have also contributed to general labor shortages for agricultural production in the villages, as farmers claim difficulty in finding workers even if they need to employ them to overcome labor shortages. Limited availability of hired labor is due to the higher demand for farm labor in the summer months which coincides with peak demand for off-farm labor, especially in the construction sector. The statement 'It is difficult to find laborers to work on my farm when I need them' had an average Likert score of 3.5. In addition to the unavailability of farm workers, the increasing daily wage rate is also a significant factor contributing to the problem. Off-farm labor opportunities have driven up daily wages from about CNY60 per day, even as recently as 2012 [9], to an average of CNY160 (the median daily wage rate ranging between CNY100 and CNY300), which may not be affordable for many smallholders—or at least dramatically reduce the returns from potentially lucrative but labor intensive farm activities. Consequently, the appeal of

buoyant dairy and meat prices since 2010 have been offset somewhat by the high opportunity costs of labor.

While much of the investments made through the government's development initiatives have been in the non-agricultural sector, the government has redirected some of its focus under the 'people first' initiative to increase agricultural production, with the goal of improving the livelihood of farm households [12]. For example, various agricultural programs and agricultural subsidies have been initiated to encourage farmers to increase livestock production for the growing demands of urban markets. According to Childs [13], there are entrepreneurial Tibetan farmers that have taken advantage of such initiatives, which have translated into higher incomes. However, while such programs are generally focused on increasing productivity, to date, less emphasis has been placed on value chains and marketing systems [8]. As a result, farmers that have managed to specialize and increase their productivity are still faced with challenges for accessing markets.

The increasing opportunities off the farm, along with the subsequent constraints on the farm, have provided incentives for pursuing livelihood strategies which are having a profound effect on farming communities. The future of traditional small-scale agriculture in particular is at stake, given the diminishing rate of uptake of farming by the younger generation in favor of pursuits off the farm. This is represented by a reduction in the number of households that are able to identify a nominated heir and, to some extent, a reduction in the level of farm involvement by a nominated heir. Overall a fifth of surveyed farmers indicated not having a designated heir to their farm. According to White [14], finding successors for traditional small-scale farm households has become increasingly challenging as a result of a lack of interest from young people in being farmers.

In the Tibetan context, the younger generation are more educated and more likely to be involved in off-farm work, whether at the local level or via migration to other rural or urban areas. Despite their involvement in other income-generating activities or pursuit of an education in urban locations, many Tibetans tend to retain a base in semi-subsistence agriculture by coming back during summer holidays or periods of unemployment to help out on the farm [15]. However, after pursuing alternative livelihoods and building stronger ties away from rural agriculture, many may prefer this lifestyle and decide to move permanently. This is particularly the case for Tibetans who have left the farm household at a younger age, and as a result, the families of such households are aware that they may not return to the parental household [15]. An average Likert score of 3.7 for the statement "Farming in my area is in trouble because the younger generation is not interested in farming" reaffirms the general awareness and concern from the existing generation regarding the gradual erosion of the farming communities. It is evident that, after having spent a lifetime farming the land, the majority of farmers who belong to an aging generation are deeply attached to their farms and would like to see their successors take charge and manage them. However, farmers are also aware of the hardships involved with a farmer's life and so wish their children to settle elsewhere in the city and live a more comfortable life.

For farmers actively managing their farm, the increasing uncertainty related to the future of the farm is a significant factor contributing to farm investment uncertainty. Moreover, with an average Likert score of 3.53 for the statement "In my farm, reducing the amount of labor is more important than increasing production" it appears that increasing agricultural production has become a lower priority for some households.

4.3. Environmental Sustainability

A major constraint to Tibetan farm households expanding farm production is limited agricultural land areas. Despite increasing rural urban migration in Tibet, rural population continues to grow by 11.5%, from 2.09 million in 2000 to 2.33 million in 2017 [1]. Limited farm land areas have been exacerbated by resettlement of herders from pastoral areas to agricultural areas, as discussed above. However, significant land reclamation has also occurred, both for the new settlements as well as marginal land in existing villages, and is often designed for growing new forage crops. Much of the

resettled and reclaimed land is of poor quality, given the shortage of farm land in Tibet often with high soil PH levels and requiring irrigation to make it productive.

The shortage of good quality farm land, both in aggregate and on a per household basis, means that expanding agricultural production will be at the intensive rather than extensive margin. That is, more inputs will be applied to existing farm land to increase production. The primary inputs with potential environmental concerns for the environment are fertilizer and water. Tibetan farmers use both organic fertilizers (manure) and inorganic fertilizers (mainly DAP and urea). Manure has been used by farm households for generations, not only as a source of fertilizer, but also for heating by mixing with straw. Manure continues to be an important fertilizer for farm households, but labor constraints are driving a shift to more inorganic fertilizers. Furthermore, inorganic fertilizers such as DAP and urea are heavily subsidized in Tibet (by around 50%), while the heavily subsidized nature means they are sold through regulated channels. The level of subsidization and lack of independent extension advice means some farmers use fertilizer levels in excess of what is required to maximize profits. The desire to intensify production is also likely to increase inorganic fertilizer usage. There is limited research or evidence evaluating water quality in agricultural villages, but the rapid expansion of livestock numbers in these enclosed valleys is likely to impact water quality, while increased fertilizer rates and reduced riparian zones under increasing land pressure will exacerbate the problem.

Although fertilizer is a critical input to crop production in Tibet, water is essential. There is limited dryland cereal production in agricultural areas, and years of low water availability and limited irrigation result in extremely low crop yields. While much forage production has been pushed to marginal lands rather than displacing cereals on the irrigated good quality land, yields of dryland vetch, lucerne, and oats are low and most fodder developments in villages are based around the construction of dams to irrigate reclaimed marginal lands. The extent to which new irrigated areas or maintenance of existing irrigation areas are sustainable is a moot point, as it involves issues beyond local farm irrigation use. Climate change and melting of glaciers will impact water availability in the medium- to long-term, while the Tibetan plateau is seen as a source of irrigation and drinking water for communities elsewhere in China, as well as India and Bangladesh, as the Yarlung Tsangpo forms part of the overall Brahmaputran catchment [16].

Concern over more intensive agricultural land use in Tibet and the broader Qinghai–Tibetan plateau also extends to water quality in terms of sediment load. The Qinghai–Tibet plateau is the source of many of China's major river systems and some of the world's largest agri-environmental stewardship programs, such as the Grain for Green program, which have targeted these issues [17–19]. Converting crop land to perennial and deep-rooting fodder crops like lucerne has been part of the Grain for Green program, but there is also concern about spreading crops (including fodder crops) onto marginal lands.

Concerns over the quality of the catchment systems of the major rivers, as well as the serious degradation evident in pastoral areas, were also behind measures to reduce stocking rates on overgrazed grasslands. Indeed, the Grassland Ecosystem Subsidy and Award Scheme (GESAS) program, which provides eco-compensation payments to herders or farmers in compensation for grazing restrictions or incentive payments to herders and farmers to stock at GESAS-specified sustainable stocking rates, was first trialed in Tibet before being rolled out to the rest of the country in the 12th Five-Year-Plan [20]. The concern over grassland degradation was also partly behind the resettlement of herders to agricultural and semi-agricultural areas.

However, issues related to grassland degradation extend to agricultural areas with the expanding numbers of ruminant livestock in these regions. Before 2000, agricultural households in the southern valleys of Tibet had relatively few ruminant livestock. Small ruminants (sheep and goats) were largely grazed in common in and around villages, and the relatively low numbers were within the feed capacity of the surrounding grasslands on the hill slopes. However, expansion of ruminant livestock in these areas, even with the expansion in fodder crop areas, has placed increasing pressure on the hill grasslands surrounding the agricultural villages. The GESAS programs mentioned above are designed

to limit the grazing pressure, but enforcement of GESAS stocking rates, especially in these poor areas of China and given the lack of administrative resources, is limited, while many of the livestock are still grazed in common.

5. Concluding Remarks

As part of agrarian transition, traditional subsistence-oriented households in Tibet are responding to strong incentives to pursue diverse livelihood strategies. The general direction for many farm households has been a reallocation of household labor away from farming activities and to off-farm employment sectors. Government subsidized development programs which have continued to support employment opportunities off the farm have not only resulted in greater scarcity of farm labor, limiting potential agricultural production, but have also created uncertainties related to the future of farm households and the broader farming communities.

Despite these forces rapidly changing the rural farming landscape, farming still remains a predominant activity for many, and there is much interest and intent for increasing agricultural production and diversifying into integrated crop livestock systems, with an emphasis on dairy. Hence, the question is not related to whether or not farmers are interested in increasing agricultural production, but rather the extent to which they are willing to intensify and scale up production given household circumstances. The significance of butter to Tibetan diets, coupled with the general deficits related to dairy products [9], provides the necessary incentive for investing in dairy production and changing the farming systems to incorporate more forage crops. Increased dairy production has been achieved from an increase in the uptake of improved breeds, along with increased fodder production. However, further specialization and scaling up production for producing a marketable surplus may not be as attractive or feasible for the majority of households, despite the potential for high returns. Labor scarcity and the associated high opportunity costs of farm labor are already impacting current agricultural practices, while increasing uncertainty related to the future of the farm is compelling the aging farming population to trade off higher production for lower labor requirements on farm.

Apart from the labor constraints, a scale up and intensification of farming and livestock systems faces environmental challenges arising from the increased demand for fertilizer and water usage. Thus, not only will the modernization and intensification of these integrated crop livestock systems need to mitigate increasingly tight household labor constraints, be more attuned to household livelihood goals, and be more engaged with external markets, the systems will also need to be environmentally sound. This poses a major research, development, and extension challenge in identifying and facilitating sustainable farming systems in Tibet.

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