Feed the Future Innovation Lab for Food Security Policy

Research Paper 173 June 2020

Food Security Policy Project (FSPP)

MAIZE AND PIGEON PEA PRODUCTION, PROFITABILITY, AND TIED CREDIT IN SOUTHERN SHAN STATE

By

Peixun Fang and Ben Belton

Food Security Policy *Research Papers*

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Authors' Acknowledgment:

This research is made possible by the generous support of the American people through the United States Agency for International Development (USAID) under the Feed the Future initiative. FSP grant number AID-482-LA-14-0003. The contents are the responsibility of study authors and do not necessarily reflect the views of USAID or the United States Government. This study is also supported with financial assistance from the Livelihoods and Food Security Trust Fund (LIFT). LIFT has received funding from 15 international donors since it was established. The current donors are the UK, the EU, Australia, Switzerland, the USA, Canada and Ireland. We thank these donors for their kind contributions to improving the livelihoods and food security of rural people in Myanmar. The views expressed herein should in no way be taken to reflect the official opinion of any of the LIFT donors. We also thank Mekamu Kedir Jemal (IFPRI) for preparing the maps, and Joey Goeb (MSU) for his suggestions on the regressions.

This study is made possible by the generous support of the American people through the United States Agency for International Development (USAID) under the Feed the Future initiative. The contents are the responsibility of the study authors and do not necessarily reflect the views of USAID or the United States Government

Published by the Department of Agricultural, Food, and Resource Economics, Michigan State University, Justin S. Morrill Hall of Agriculture, 446 West Circle Dr., Room 202, East Lansing, Michigan 48824, USA

Executive summary

This report presents results from by far the most comprehensive survey of maize cultivators ever conducted in Myanmar. This research was designed to test characterizations of hybrid maize farming in the literature on Myanmar empirically, and identify implications for development policy and programming. A study by the World Bank (2016) suggests that returns from maize farming are very high in comparison to other major crops grown in Myanmar, whereas two studies by Woods (2015a; 2015b) list a host of negative impacts associated with hybrid maize cultivation, including reduced food security, widespread and severe indebtedness among the smallest farmers, and deepening inequality.

Our survey represented the population of all maize growing village tracts in the nine major maize growing townships of southern Shan where the security situation at the time of the survey permitted access. A total 884 maize growing and 678 non-maize growing rural households were interviewed. We summarize key survey results and their implications below.

Key findings

- ***Sectoral structure***

Numbers of maize growers in southern Shan more than tripled between 2007 and 2017. About half of all households in surveyed locations now farm maize.

Households with larger landholdings are more likely to farm maize. Seventy nine percent of farms in landholding tercile 3 (the largest third of farms, averaging 10 acres in size) grow maize, compared to 28% in landholding tercile 1 (the smallest third of farms, averaging 2.5 acres).

Many farmers grew local maize varieties before growing hybrids. Nearly two-thirds of farmers who planted maize in 2007 grew local varieties of maize at that time, indicating that maize was already an important commercial crop prior to the widespread uptake of hybrid seed.

- ***Food security***

Farming maize does not reduce crop diversity. Farms in South Shan have much higher crop diversity than other areas of the country. Most of these crops are grown in very small quantities in homegardens for subsistence consumption. Maize farming households grow two more crops on average than non-maize farming households (eleven crops vs nine).

Most food eaten by rural households in southern Shan is purchased. Most households produce a mix of crops for own consumption and sale. Only 12% of farm households produce crops exclusively for subsistence, rising to 25% among non-maize farming households. However, despite high levels of subsistence production 73% of food, by value, is purchased.

There is little difference in the value or composition of foods eaten by maize and non-maize farming households, but maize growers obtain a larger share of their food from own production than non-maize growing farm households (26% vs 19%).

Maize is by far the most important crop grown in terms of contribution to cash incomes. Maize accounts for 54% of the value of crops sold by surveyed households.

- ### *Seed and inputs*

Hybrid maize seed has been adopted widely in southern Shan. Eighty-six percent of maize growers planted hybrid maize seed in 2017.

CP's share of the hybrid maize seed market dropped from around 80% in 2012 to below 50% in 2017. This is true in terms of number of farmers planting (43%), and the quantity (46%) and value (47%) of hybrid maize sales. CP's two largest competitors are Golden Tiger (planted by 16% of farmers and accounting for 11% of market share), and Awba (planted by 7% of farmers and accounting for 16% of market share).

Adoption of hybrid maize has been accompanied by big increases in fertilizer use. The share of maize farming households using compound fertilizer doubled from 2007-2017.

Fertilizer application rates have climbed over time. The average quantity of inorganic fertilizer applied per acre increased 42% from 2007-2017, from 1.2 bags/acre (60 kg) to 1.7 bags/acre (85 kg). Increasing fertilizer application rates are linked to the shift from local to hybrid varieties but may also indicate declining soil fertility after years of maize monocropping.

- ### *Maize yields*

Maize yields have risen over the past decade. Yields rose 23% between 2007 and 2017. This is likely attributable to the shift from cultivation of local to hybrid varieties and associated increases in compound fertilizer use.

Maize yields vary little with farm size. We find no evidence that larger farms attain higher yields. The average yield of farms in landholding tercile 1 is marginally higher (1,265 kg/acre) than that of farms in tercile 3 (1,238 kg/acre). Tercile 2 have the highest average yields (1,391 kg/acre)

Average maize yields are lower than in other countries in the region. The average yield of monocropped maize parcels in our sample area is 1,420 kg/acre. This is about 30% lower than Thailand (1,816 kg/acre) or Viet Nam (1,882 kg/acre), indicating potential for productivity gains.

Small farms grow maize more intensively than large farms. The average seed application rate of farms in terciles 1 and 2 (6.2 kg/acre) is 11% higher than that of farms in landholding tercile 3 (5.5 kg/acre). The average rate of inorganic fertilizer application is 107 kg, 85 kg, and 76 kg per acre, respectively, for farms in terciles 1, 2 and 3.

- ### *Production costs & profitability*

Women contribute 55% of all labor inputs for maize farming. The gender wage gap is significant, but smaller than in agriculture in other parts of the country. Women casual laborers earn 89% of the average daily wage rate earned by male casual workers.

Chemical inputs make up the largest share of production costs. Fertilizers, pesticides and herbicides combined account for 28% of total costs. Hired labor (24%), agricultural machinery rental and operation (20%), and seed (18%) account for the three next largest cost shares.

Interest on loans amounts to just 4% of total maize production costs for households who avail credit for maize cultivation.

Average gross margins for maize during 2017 were modest. The average gross margin for monocropped maize parcels was MMK 165,344/acre ($303/ha at prevailing exchange rates), similar to gross margins for rice in Shan, as reported by survey respondents. This is 2.8 times lower than the average gross margin of $854/ha reported by the World Bank for maize producers in southern Shan in 2013/14. This drop in profitability is attributable mainly to changes in exchange rates and maize prices between the two surveys. The gross margin per acre of maize-pigeon pea intercrop was not significantly different from that of maize monocrop.

Only 5% of maize growers made losses in 2017. This is much lower than for other rainfed crops commonly grown in Myanmar. For instance, 31% of sesame growers and 26% of groundnut farmers in the Dry Zone earned negative gross margins in 2016.

Farms made a profit or broke even on >80% of maize harvests within the past 10 years. Farmers reported making a profit on 55% of past crops and breaking even on 27%, with losses reported on 17% of crops. Small (tercile 1) farms are slightly more likely to report losses than large (tercile 3) farms (21% vs 15%).

Returns to family labor exceed the average agricultural wage. This holds for farms of all sizes. Maize farming incomes thus exceed the opportunity cost farmers' time, even on farms with low family labor productivity. Moreover, maize farms of all sizes are profitable on average, even after accounting for the imputed cost of family labor.

- *Maize prices*

The maize price received by farmers corresponds closely to timing of sale. Sales made later in the year tend to earn higher prices. Farms in tercile 3 make their first sale of maize 17 days later than for those in tercile 1 on average. Moreover, large farms are more likely to hold back part of their crop for sale after 'peak' harvest season. Larger farms tend to earn higher prices as a result.

Larger farms earn higher gross margins per acre on average. Average gross margins increase in step with landholding size, from MMK 140,183/acre for tercile 1 farms to MMK 171,721/acre for those in tercile 3 (a difference of 22%).

- *Credit*

Most farms do not use credit to obtain maize seed and fertilizer. Only 29% of maize farms obtained maize seed as in-kind credit, with 24% obtaining fertilizer in this way. Most maize seed and fertilizer is purchased using agricultural earnings.

Most trader credit is advanced to large farms. Nineteen percent of maize farming households in landholding tercile 1 obtained maize seed in the form of in-kind credit, as compared to 30% of maize farms in tercile 3. In value terms, tercile 3 farms access 67% of in-kind credit advanced for maize seed and fertilizer. Tercile 1 farms utilize 8%.

Output-tied loans are less common than believed and taken mainly by larger farms. One-third of the maize growers who took credit for maize cultivation reported that it was output-tied (i.e. committed them to sell harvested maize to the loan provider). The share of maize growers taking output-tied loans ranges from 4% in landholding tercile 1 to 14% in landholding tercile 3

Taking credit does not affect the sales price obtained by maize growers. The average maize sales price received by farms that borrowed to fund maize cultivation was the same as the price received by farms that did not take credit. Contrary to expectations, maize growers who availed output-tied credit received higher prices for their maize than those who did not.

- *Contract farming*

There is no maize contract farming in any of the townships surveyed. 99.5% of households interviewed reported they had never had a contract with CP company to grow maize. Households who responded "yes" had previously produced hybrid maize seed (not maize grain) for CP under contract. None of these contracts are still in force.

Implications for policy and programming

Input supply and credit markets in southern Shan are highly competitive. There is no evidence to support the claim that large numbers of small maize farmers are heavily encumbered with debt to traders or are coerced into selling harvested maize to traders at below prevailing market prices. As such, policy makers should avoid the temptation to intervene in these markets.

The role of traders in supplying informal agricultural credit for maize farming has been exaggerated. Trader credit is mainly utilized by larger farmers. The supply of formal agricultural credit for maize farming by Myanmar Agricultural Development Bank (MADB) is almost non-existent. There is a need for MADB to ascribe higher institutional priority to maize cultivators, and to identify models for disbursing formal credit to smallholders without formal land use rights.

Farming maize does not erode household food security. There is very little difference in the food consumption patterns of maize and non-maize cultivating farm households. Most households procure most of their food with income earned by working off-farm or selling cash crops. Policies that aim to promote food and nutrition security should therefore pay close attention to ensuring availability and accessibility of food through markets.

Contract farming is not a panacea, because: (1) it will only work in very specific cases, where buyers are unable to secure products of a specific quality or volume through spot markets or direct vertical integration; (2) contracts may be easily broken, by either side, when more attractive alternatives present themselves.

Interventions that allow farmers to delay crop sales may increase returns. Larger farmers obtain higher average prices for their maize, in part by delaying sales. Providing short-term low interest loans to farmers ahead of harvest time could provide a timely cash infusion that would permit them to defer sales until prices rise. On the demand side, expanding commercial banking services to traders, along the lines of Yoma Bank's LIFT-supported Agricultural Finance Program, could increase effective demand for maize during 'peak' season by enabling traders to buy and hold larger quantities of grain than is possible when having to constantly cycle working capital.

Appropriate small-scale mechanization could reduce production costs. Weeding and harvesting maize together account almost 70% of labor costs in maize production. Small low-cost handheld mini-tillers used for weeding and small combine harvesters are in use elsewhere in the region. The suitability of these machines in the Myanmar context should be evaluated.

Maize yields lag behind other countries in the region. The ongoing shift from local maize varieties to hybrids will raise Myanmar's maize productivity. However, growers who use cheaper hybrid seeds do not obtain significantly higher gross margins than those who plant local varieties. To raise both maize productivity and farmer incomes, better extension messaging and credit access will be needed to encourage farmers to buy better quality (but more expensive) seed varieties.

Maize prices are volatile. This is apparent in the large gap between gross margins reported in the World Bank's 2013/14 survey and our own. Government and the private sector should work together proactively to establish additional export markets within the region, whilst continuing to negotiate for larger import quotas with China to reduce volatility in the medium to long term.

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1 Introduction

Hybrid maize was introduced to Myanmar in the mid-1990s by Thai agro-industrial conglomerate Charoen Pokphand (CP). Maize production has boomed since this time, increasing by 540%, from 298,000 t to 1.91 million t (FAO, 2019), to supply a burgeoning export market to China and a rapidly growing domestic animal feed industry in Myanmar. This growth has made maize Myanmar's second most important cereal crop after rice. Most maize production is concentrated in upland areas of Myanmar. Shan State is the most important of these, accounting for approximately half of the country's total planted area of maize (USDA, 2019).

Despite its evident importance in the agriculture of Shan and other upland states, there has been little research on the characteristics of Myanmar's maize boom in terms of farming practices, and livelihood outcomes associated with the crop's introduction into upland farming systems. A previous study of farm production economics (World Bank, 2016) devoted one short chapter to maize production and profitability in Shan, and found the profitability of maize production to be the highest among all the grain crops surveyed in Myanmar, at more than $800 per hectare. A pair of studies based on qualitative interviews in eight villages in North and South Shan by Woods (2015a; 2015b) paints a more detailed, but much more negative, picture. Woods characterizes hybrid maize production in Shan State as a form of contract farming organized by CP, and makes a series of claims about its impacts of maize on farming systems and smallholder livelihoods. The most salient of these are as follows:

1) CP maize production in Shan State has brought about a major transformation in farming systems, from low-input subsistence farming to high-input "cash cropping".

2) The shift from subsistence food cultivation to dependence on maize cultivation for sale has increased food insecurity for smaller farm households.

3) High-input agriculture has created a growing need for capital among farm households. Small farm households have become highly dependent on traders for access to maize cultivation loans, whereas wealthier households generally do not need loans to purchase the inputs.

4) Farmers taking loans from traders 'lose' several times over from: (1) interest paid on loans; (2) purchasing inputs at above market price from traders; (3) selling harvested maize to traders at below-market price.

5) Smaller farm households are unable to afford optimum levels of inputs and hired labor, even with trader loans, and obtain much lower yields and lower incomes per acre than wealthier farmers. Better-off households maximize profits by avoiding debt, applying inputs of optimal quality and quantity, and delaying the sale of maize harvest until market prices increase.

6) Wealth has rapidly been redistributed away from lower income maize farming households to wealthier households and moneylenders. As a result, lower-income households growing CP maize "disproportionately suffer from debt and dispossession" (Woods 2015a, p18)

The apparent disconnect between findings reported by the World Bank and Woods prompted us to seek to treat them as hypotheses to be tested empirically using a representative sample survey of rural households in maize growing areas of southern Shan State.

The survey was designed elicit information on household demographics, livelihood activities, landholdings, productive assets, the composition of farming systems, and detailed plot-level information on maize and pigeon pea cultivation, including input use, labor, mechanization, marketing, and credit utilization. Pigeon pea was selected as a focal crop for the survey along with maize because of its importance as a commercial crop grown for export (mainly to India), that is commonly grown in the same farming systems as maize in Shan. A total of 1562 rural households were interviewed in nine of the major maize growing townships of southern Shan State. These included both maize growers (884) and non-maize growers (678) to permit comparison between of the two types of household.

Details of the survey methodology are reported in the following section. Subsequent sections present results on the role of maize and pigeon pea in farming systems in South Shan, maize and pigeon pea production practices, productivity and profitability, credit access and utilization, and marketing. The final section concludes and presents implications for policy and programming.

2 Survey methodology

2.1 Sample design and approach

The Shan Agriculture and Rural Economy Survey (SHARES) was implemented with 1562 households in nine townships in southern Shan State in May-September 2018. Prior to the design and implementation of SHARES, we conducted fifty-five in-depth scoping interviews with farmers, maize traders, agricultural input providers, government officers, and other actors in 21 townships throughout southern and northern Shan. Scoping interviews were designed to: (1) Identify areas with high concentrations of farms producing maize and pigeon pea. (2) Gain a qualitative understanding of livelihoods and farming systems in these areas. (3) Facilitate design of effective survey instruments. (4) Evaluate the security situation. Information was also collected to support the design and implementation of a complementary survey of maize traders and agricultural input suppliers (see Cho and Belton, 2019).

The household survey was implemented in South Shan only due to the poor security situation in North Shan at the time of scoping. We collected village tract[1] level data on the planted area of all crops from offices of the Department of Agricultural Land Management and Statistics (DALMS) in each township visited. Ten townships in South Shan were selected purposively for inclusion in the survey, based on the density of maize and pigeon pea in each, as determined using DALMS data.

Village tracts accounting for at least 80% of the total area planted to maize and pigeon pea in each of the ten townships were defined as "high maize and pigeon pea strata". Remaining village tracts with any maize or pigeon pea planted were included in sample as "low maize & pigeon pea strata". "Low" strata village tracts were sampled at lower rate the "high" strata, corrected during analysis using survey weights. Village tracts where no maize or pigeon pea were cultivated, or where data was deficient for security reasons, or where security issues were identified during scoping, were excluded from the sample frame (Figure 1 and 2). Following sample frame development, staff of the Department of Population drew a systematic random sample of Enumeration Areas (EA) by probability proportional to size, using the sample frame of the 2014 national census.

During survey rollout, township offices of the General Administrative Department (GAD) refused permission to implement the survey in two village tracts in Langkho, and all but two villages in Namsang township due to security concerns. Namsang township was dropped from the sample frame as a result, and the sample for the two other eastern townships (Langkho, Mongnai) was redrawn. The survey team was later denied access to one further selected village tract in Langkho due to security concerns. This adjustment left a final sample of 99 EAs in nine townships (Taunggyi, Hopong, Lawksawk, Pindaya, Mongnai, Langkho, Hsihseng, Pinlaung and Pekon). A total of 1562 respondent households were interviewed during survey rollout (Figure 3). This sample represented the entire population of these village tracts, totaling 201,285 households, of which households growing maize and/or pigeon pea accounted for 52% of the total.

[1] A village tract is a fourth level rural administrative sub-division, typically comprised of approximately 5 to 10 villages

Figure 1. Final sample frame and sampled village tracts

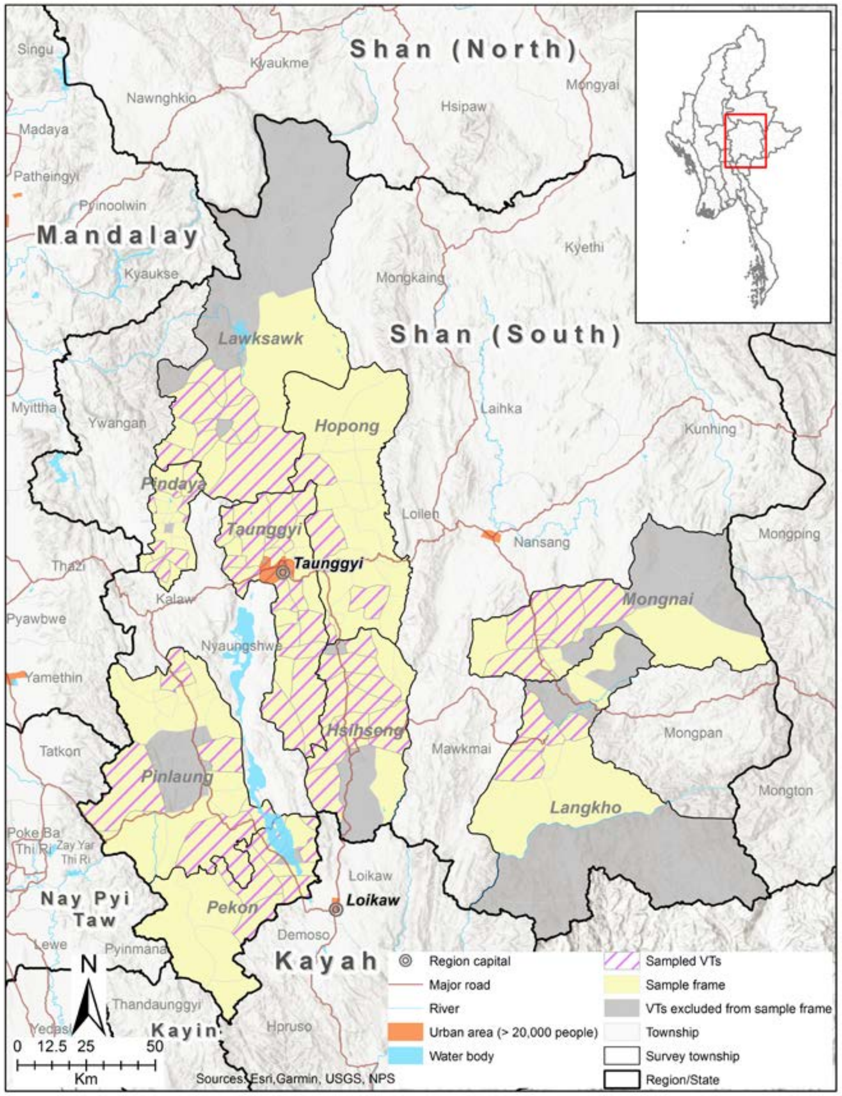


Figure 2 Sample strata

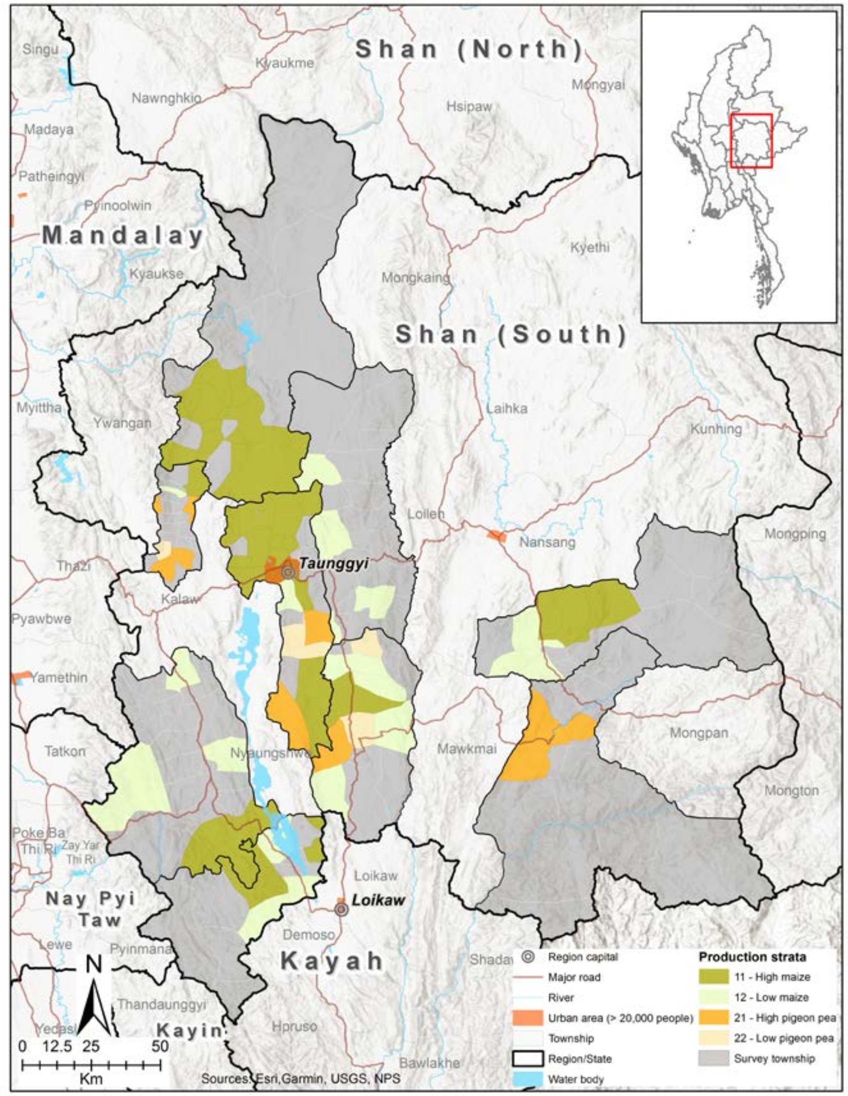
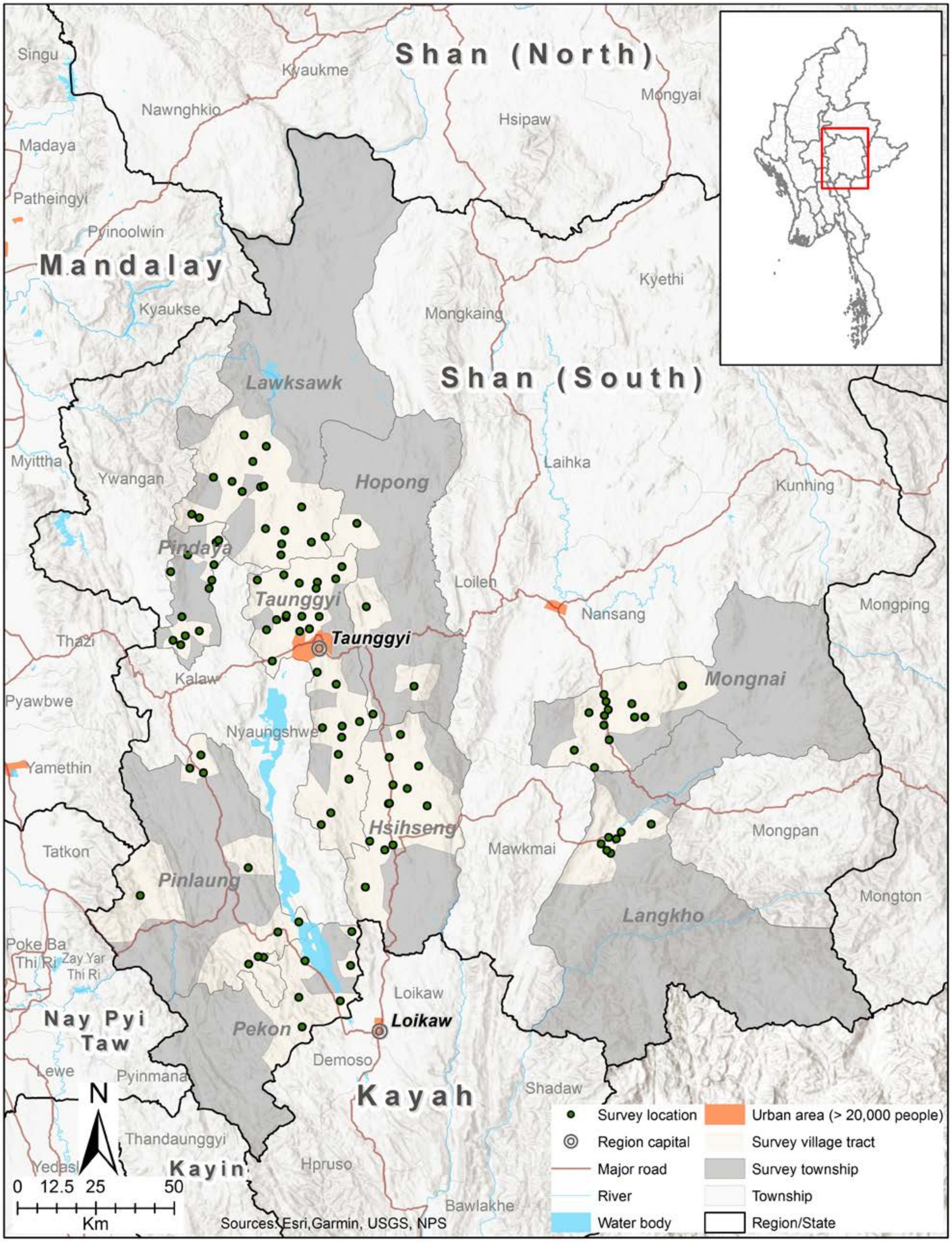


Figure 3 Surveyed village tracts and enumeration areas



Following preliminary analysis of survey results, 13 qualitative in-depth follow up interviews were conducted with rural households in four townships in southern Shan in April 2019 to obtain additional insights on farming systems and livelihoods.

2.2 Survey questionnaire and data analysis

The survey instrument was designed to collect information on agricultural practices in two different ways. First, at the farm level, by recording the area, quantity and value of crops produced and consumed during the 12 months preceding the survey, along with aggregate costs of production. Second, at the level of an individual 'sample plot'.

Fifty-three percent and 35% of households with cultivated land planted maize and pigeon pea, respectively. From these households we randomly selected[2] a single sample parcel of agricultural land utilized in the cultivation of maize monocrop, pigeon pea monocrop, or maize-pigeon pea intercrop. Almost all maize and pigeon pea cultivated in the area surveyed is planted during the monsoon season. We therefore restricted data collection from the sample parcel to the most recently completed monsoon season maize and/or pigeon pea crop (i.e. planted in the 2017 monsoon season).

Information collected on the sample parcel included detailed information on the following: type, quantity, and value and source of seed and other inputs applied; terms and utilization of credit used for input acquisition; use of family, hired, and exchange labor; use of agricultural machinery and draft animals; the history of land utilization and farming practices. Information on maize and pigeon pea marketing was collected at the farm level because where more than one parcel of land is dedicated to a single crop, crops from these plots are usually pooled prior to sale.

In the following analysis we categorize households into terciles based on area of agricultural land operated, to parse out differences in the household behavior related to landholding size. Landholding terciles are obtained by ranking all households in the sample in ascending order of area of land cultivated and dividing into three groups of equal size. Tercile 1 consists of the third of households with the smallest area of cultivated land, and tercile 3 consists of the third of households with the largest area of cultivated land.

We use area of land cultivated, rather than area of land owned, to determine household landholding terciles. Seventy-seven percent of households in locations surveyed report owning land, while 85% have access to cultivated land. Among the 8% of households who have access to land but do not own it, more than half (53%) of parcels of land utilized for agriculture are borrowed. Borrowed land is usually obtained from parents and will eventually be inherited. This means that around half of households who are formally landless (i.e. do not own the land they farm) but have access agricultural land are *de facto* landed. Therefore, in the analysis that follows we do not distinguish a separate class of landless farm households.

[2] In order secure a sufficiently large sample of households with each type of cropping pattern, the sequence of priority for random selection of the sample parcel was: 1) parcel with both maize and pigeon pea intercropped, 2) parcel with pigeon pea monocrop, 3) parcel with maize monocrop.

3 The role of maize & pigeon pea in farming systems in South Shan

3.1 Land and farming systems

This subsection presents results on the characteristics of landholdings, sample parcels used to cultivate maize and pigeon pea, and farming systems in the locations surveyed.

Rates of landlessness are low. As noted above, 85% of households own or can access agricultural land. This relatively high level of access to land likely reflects the recent closure of the land frontier in surveyed areas of southern Shan. Until quite recently, households that needed agricultural land were able to obtain it by clearing forest, but most accessible forestlands with cultivable soils have now been cleared and brought under permanent cultivation. Just 2% of surveyed household reported practicing shifting cultivation at present. Seven percent reported having done so in the past, and one quarter of households reported that either or both parents' households had done so (Win and Zu, 2019).

Table 1 Sample parcel characteristics

Item	Tercile 1	Tercile 2	Tercile 3	All
Parcel size (acres)	1.1	1.9	4.1	2.8
Ownership status (%)				
Owner operated	69	92	94	82
Borrowed-in	19	5	2	10
Rented-in	10	3	4	6
Other	0	0	0	0
Documentation (%)				
Form 7	6	12	15	12
Form 105	4	8	7	7
Contract	4	6	3	4
Tax Receipt	2	1	1	1
Other document	0	0	0	0
No document	83	73	73	75
Plot slope (%)				
Flat	40	35	49	42
Slight slope	49	49	41	45
Moderate slope	9	12	9	10
Steep slope	2	4	1	2
Soil quality (%)				
Good	23	12	27	21
Fair	51	66	58	60
Poor	26	22	14	19
Cropping practice (%)				
Maize monocrop	52	51	52	52
Maize-pigeon pea intercrop	34	29	39	35
Pigeon pea monocrop	15	20	9	13

Landholdings are moderately sized. The average area of land cultivated is 5.2 acres (median 3.5 acres). The average area of land owned by households in landholding terciles 1, 2 and 3 is 1.5, 4.3, and 10 acres, respectively, and the smallest third of farms cultivate less than 2.5 acres of land each (Win and Zu. 2019). The average maize/pigeon pea plot is sized 2.8 acres. The average size of maize/pigeon pea plots farmed by tercile 3 households (4.1 acres) is more than twice the size of plots farmed by households in tercile 2 (1.9 acres), and nearly four times the average size of plots farmed by households in tercile 1 (1.1 acres) (Table 1).

Land tenure security is weak, and land rental is limited. Seventy-five percent of all agricultural parcels do not have any documentation related to land ownership or tenure. Among the 25% of parcels with some form of documentation, just under half have Form 7 (the most secure form of land title, introduced in 2012). Eight percent of all agricultural parcels are borrowed, and 5% are leased-in (Win and Zu, 2019). Similar patterns are observed for parcels used to grow maize/pigeon pea. Of these, 82% are owner-operated, 10% are borrowed-in, and 6% are leased-in from private owners. The tenure status of maize/pigeon pea parcels is similar to the tenure status of land overall. Three quarters of maize/pigeon pea parcels have no ownership or tenure documentation, 12% of have Form 7, and 7% have Form 105 (the land use certificate that pre-dated Form 7) (Table 1). Rates of land rental are surprisingly low in a context where commercially oriented agriculture is developing quickly. It is not clear whether this is a function of weak tenure security, land scarcity, or insufficient returns from farming.

Households with larger landholdings have slightly stronger tenure security status than those with less land. For instance, 83% maize/pigeon pea parcels farmed by households in landholding tercile 1 have no formal use rights documentation, as opposed to 73% of those farmed by tercile 3 households, and 15% of parcels farmed by households in tercile 3 have Form 7, compared to 6% of parcels farmed by households in tercile 1 (Table 1)

About half of sample parcels are mono-cropped to maize. Fifty-two percent of sample parcels are used for maize mono-cropping. Around one-third of sample parcels (35%) are devoted to maize/pigeon pea intercrop, and 13% are utilized for pigeon pea monocropping. There is no clear association between farm size and propensity to intercrop or monocrop maize and pigeon pea (Table 1).

Maize and pigeon pea are overwhelmingly grown on rainfed land. Unirrigated upland (*ya*) is the main type of agricultural land in the area surveyed, accounting for three-quarters (77%) of all farmland. Irrigated lowland (*le*) accounts for 13% of land (Win and Zu, 2019). Ninety-seven percent of land used to grow maize is categorized as ya land. Virtually all maize and pigeon pea (>99%) is grown during the monsoon season without irrigation.

Most maize and pigeon pea is grown on flat or slightly sloping land with fair quality soil. Flat and slightly sloping land accounts for 43% and 46% of maize/pigeon pea parcels, respectively. Moderate and steeply sloping lands account for only 10% and 1% of parcels under maize or pigeon pea cultivation. The soil quality of most parcels used for maize/pigeon pea cultivation is 'fair' (60%), with around 20% of parcels each considered to be of 'good' or of 'poor' quality. The largest third of farms occupy marginally more flat parcels and marginally fewer slightly sloping parcels than farms in terciles 1 and 2, and a similar share of steep or very steep parcels. Tercile 3 farms also occupy slightly more parcels with good soil quality and slightly fewer with poor soil quality, relative to farms in tercile 1 or 2 (Table 1). Together, these results show that maize and pigeon pea are not usually grown on very marginal lands, and that plot quality is only weakly linked to landholding size.

However, the large average size of parcels owned by tercile 3 households, compared to those in terciles 1 and 2, means that these relatively small advantages are compounded.

Most households cultivate homegardens. Most households (83%) have a small garden (i.e. they cultivate crops in their home compound). Most crops grown in homegardens in Shan are for primarily own consumption

A wide variety of crops are grown. Surveyed households reported growing a total 57 crops. Nearly all farm households grow some vegetables (88%). More than 60% grow at least one root crop (most importantly garlic, turmeric, ginger and potato), fruit (especially mango, banana, and avocado), or legumes other than pigeon pea (most commonly soy and lab-lab bean). Maize and paddy are each grown by just of over half of households. Non-food crops are also grown by nearly half of households, of which ornamental flowers and cheroot leaf (cured and used for manufacturing traditional cigars) are the most common (grown by 37% and 11% of households, respectively). Pigeon pea and oilseeds (most importantly groundnut) are both grown by around one third of households (Table 2). Maize and pigeon pea are grown in monoculture or intercropped together.

Households with more land grow a greater diversity of crops. Households in landholding tercile 3 (the largest third of farms) are more likely than households in landholding tercile 1 or 2 to grow most types of crop. There are relatively few, mostly minor, crops for which this pattern does not hold (Table 2).

Table 2 Share of farm households growing major crops/crop groups, by landholding tercile

	Share of farm households producing (%)				
Crop/crop type[3]	**Tercile 1**	**Tercile 2**	**Tercile 3**	**All**	**T3-T1 (%)**
Vegetables	85	88	93	88	8
Root crops	55	72	67	64	12
Fruits	58	63	69	63	12
Legumes	58	61	63	61	5
Maize	28	55	79	53	51
Paddy	35	54	66	51	31
Non-food crops	48	48	45	47	-4
Pigeon Pea	16	39	53	35	37
Oilseeds	18	32	41	30	23
Coffee and tea	18	17	15	17	-2
Tree crops	9	5	8	8	-1
Other cereal	8	5	6	6	-2

[3] **Vegetables** include Chilies, Cabbage/Cauliflower, Mustard/Kailan, Okra, Tomato, Eggplant, Cucumber, Gourd/Chayote, Pumpkin, Sweetcorn, Roselle, Coriander, Chinese chives, Morning glory, Other vegetables; **Root crops** include Ginger, Tumeric, Garlic, Shallot/Onion, Potato; **Fruits** include Watermelon, Musk melon, Other melon, Pineapple, Strawberry, Banana, Mango, Papaya, Citrus fruits, Avocado, Apple/Pear, Jackfruit, Dragon fruit; **Legumes** include Soy Bean, Green Gram, Black Gram, Chick Pea, Lab-lab bean, Long bean, Rice bean, Butterfly bean, Chinese bean, Garden pea, Kidney bean, Lentil, Lima bean, Other beans; **Non-food crops** include Sugarcane, Gamone, Betel leaf, Tobacco, Cheroot leaf, Ornamental flowers; **Oilseed crops** include Groundnut, Sesame, Sunflower, Niger; **Tree crops** include Bamboo and other trees; **Other cereal** includes Wheat, Sorghum, Millet.

Larger landholdings are associated with maize, pigeon pea, and paddy cultivation. Tercile 3 farmers are, respectively, 51 percentage points, 37 percentage points and 30 percentage points more likely to grow these crops than farmers in tercile 1 (Table 2). Although all three are rightly considered 'smallholder crops', it is the upper strata of smallholders than specialize most strongly in their production.

The average number of crops grown per household is high. Farm households grow an average of 10.2 different crops. Households with more land grow to more crops on average (11.8 crops for households in tercile 3, vs 8.5 crops for households in tercile 1) (Table 3).

Most crops are grown for home consumption. Among the average 10.2 crops grown per household, 8.1 are produced mainly for home consumption, and 0.7 are grown for both home consumption and sale. An average of 1.3 crops per household are reported to be grown mainly for sale (Table 3).

Table 3 Number of crops grown for home consumption and sale by maize farming and non-maize farming households, by landholding tercile

Household and crop types	Tercile 1	Tercile 2	Tercile 3	All
All farming households				
All crops	8.5	10.4	11.8	10.2
Crops mainly for home consumption	7.2	8.2	9.2	8.1
Crops for home consumption & sale	0.6	0.8	0.8	0.7
Crops mainly for sale	0.8	1.4	1.8	1.3
Maize farming households				
All crops	9.3	11	11.9	11.1
Crops mainly for home consumption	7.2	8.4	9.2	8.6
Crops for home consumption & sale	0.5	0.6	0.8	0.7
Crops mainly for sale	1.6	1.9	1.9	1.9
Non-maize farming households				
All crops	8.2	9.5	11.2	9.1
Crops mainly for home consumption	7.2	7.8	9.0	7.6
Crops for home consumption & sale	0.6	0.9	0.9	0.7
Crops mainly for sale	0.5	0.8	1.2	0.7
Difference (maize HH – non-maize HH)				
All crops	1.0	1.5	0.8	2.1
Crops mainly for home consumption	0.0	0.6	0.2	1.0
Crops for home consumption & sale	-0.1	-0.3	-0.2	-0.1
Crops mainly for sale	1.1	1.1	0.7	1.2

Farming maize is not associated with low crop diversity. Maize farmers grow 2.1 more crops on average than non-maize farming households (11.1 vs 9.1). This includes one additional crop produced mainly for home consumption, and 1.2 additional crops grown mainly for sale (Table 3). This pattern is likely linked to the higher average landholdings of maize farmers compared to non-maize farmers, and the positive association between landholding size and number of crops planted.

Few farm households produce food exclusively for subsistence, or exclusively for sale. By far the most common strategy is production of crops for both sale and subsistence. Seventy-one percent of non-maize farming households and 96% of maize farming households do so. Only 3% of farm households report producing exclusively for the market, underlining the continuing importance of production for home consumption. This share is similar among both maize and non-maize farming households. Only 12% of farm households produce crops exclusively for home consumption. This figure rises to 25% among non-maize farming households, but even here subsistence production is concentrated among the third of households with the smallest landholdings, for whom the figure is 37% (Table 4).

Table 4 Share of maize farming and non-maize farming households, growing crops for subsistence and sale by landholding tercile

Share of HH growing crops…	Tercile 1	Tercile 2	Tercile 3	All
All farming households (%)				
Exclusively for home consumption	28	7	0	12
Exclusively for sale	5	3	2	3
For home consumption & sale	67	90	98	85
Maize farming households (%)				
Exclusively for home consumption	5	1	0	1
Exclusively for sale	6	2	2	3
For home consumption & sale	89	97	98	96
Non-maize farming households (%)				
Exclusively for home consumption	37	14	2	25
Exclusively for sale	4	3	3	4
For home consumption & sale	59	82	95	71

Maize and pigeon pea are two of the most highly commercial crops produced. Nearly all households growing maize or pigeon pea (95% for both) reported that these crops are produced mainly for sale (Table 5). At the aggregate level, most groups of crops are reported to be produced mainly for home consumption, but this obscures some important intra-group differences. For instance, all producers of cheroot leaf report producing mainly for sale. Seventy-seven percent of tea and 60% of coffee producers, respectively report producing these crops mainly for sale or for sale and home consumption. 60% of chickpea producers, 59% of sesame producers, 48% of niger producers, 40% of garlic producers, 41% of strawberry/pineapple producers, and 32% of potato producers also report producing mainly for sale or sale and consumption.

Maize is by far the most important crop grown in terms of contribution to cash incomes. Maize accounts for 54% of the value of crops sold by households in the survey area. Cheroot leaf is the next most important cash crop, contributing 9% of the value of marketed crops. Potato, garlic, tea, and paddy each contribute 4-5% of marketed crop value. Despite being cultivated almost exclusively for sale by more than one third of surveyed farm households, pigeon pea only contributes 2% of total marketed crop value. This reflects low pigeon pea yields per acre (especially when intercropped), and the very low market value of the crop during the survey year due to an import ban from India – the major market for Myanmar pigeon pea. In the areas surveyed, paddy is grown principally for home consumption (marketed surplus 21%).

Table 5 Share of farm households growing major crops/crop groups, by landholding tercile the purpose of growing, and sales as share of total production

Crops/ Crop groups	Purpose of Growing (% of HH reporting)			Marketed surplus (%)	Share of value of marketed surplus (%)
	Mainly for sale	Home-consumption and sale	Mainly for home-consumption		
Vegetables	1	2	97	1	5
Root crops	7	16	77	34	12
Fruits	5	6	89	18	4
Legumes	4	4	92	16	1
Maize	95	2	3	100	54
Paddy	0	16	84	21	4
Non-food crops	17	2	81	71	10
Pigeon pea	95	4	1	99	2
Oil seed crops	16	14	70	46	2
Coffee and tea	34	39	27	68	5
Tree crops	3	0	97	7	<1
Other cereal	5	3	92	4	<1

Households with limited land are less likely to substitute maize for paddy. Around one third of farm households produce neither maize nor paddy. These are concentrated among the smallest third of farms (63% in tercile 1). Roughly similar shares of households produce paddy but no maize, maize but no paddy, and maize plus paddy (19-25%). Among these, households with smaller landholdings are more likely to produce paddy by no maize (45% in tercile 1, vs 18% in tercile 3). Households are equally likely to produce maize but no paddy, irrespective of landholding size (31% in tercile 1, vs 35% in tercile 3). Households with relatively large landholdings are much more likely to grow both crops than those with less land (9% in tercile 15, vs 9% in tercile 3) (Table 6). These figures underline that many households with very small landholdings lack land suitable for either paddy or maize cultivation, and that land-limited households are more likely to devote land to paddy than to maize. This finding suggests that land-poor households prioritize subsistence paddy production, while those with larger asset endowments are more willing and/or able to allocate part of their holdings to maize, with cultivation of both crops the preferred strategy for most households with sufficient land.

Table 6 Share of farm households growing maize and paddy, by landholding tercile and area of land area operated

Crop combination	Tercile 1	Tercile 2	Tercile 3	All	Operated land (acres)
No maize, no paddy	63	27	10	35	2.7
Paddy, no maize	45	37	18	19	3.7
Maize, no paddy	31	34	35	21	5.7
Maize & paddy	9	32	59	25	8.9

3.2 Food security

In this subsection we evaluate links between crop production decisions and household food security, using data from the SHARES consumption expenditure module. The module recorded the quantity and value (imputed, in the case of own-production) of food consumed by surveyed households within the past 7 days, and the source of that food (market, own-production, or gift). This allows us to compare food consumption among maize growing and non-maize growing farm households. We exclude non-farm households to allow for comparability among agricultural producers

Most food is purchased. The shares (by value) of total food consumption obtained from purchase, own production, and gifts are 73%, 23%, and 4%, respectively (Figure 4). Although, as the previous section shows, most crops produced by the household are retained for home consumption, the quantities produced are often very small, and are not adequate ensure self-provisioning for most farm households. Thus, fruits were the only type of food where more than half of consumption (56%), by value, originated from own production. More than one third of cereals, vegetables, and spices consumed are from subsistence production.

Figure 4 Share of food consumption (value) in past 7 days, by food group and source

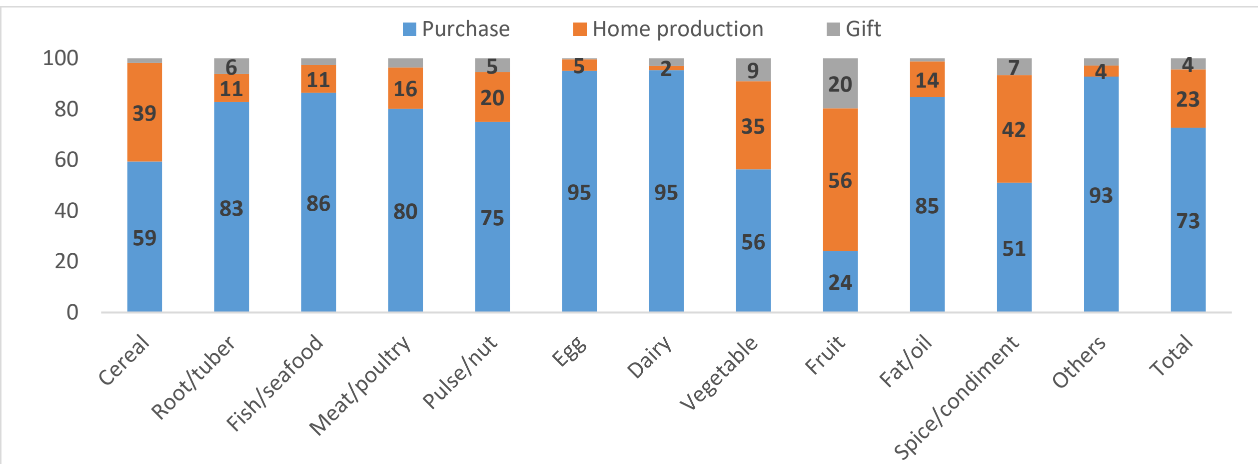
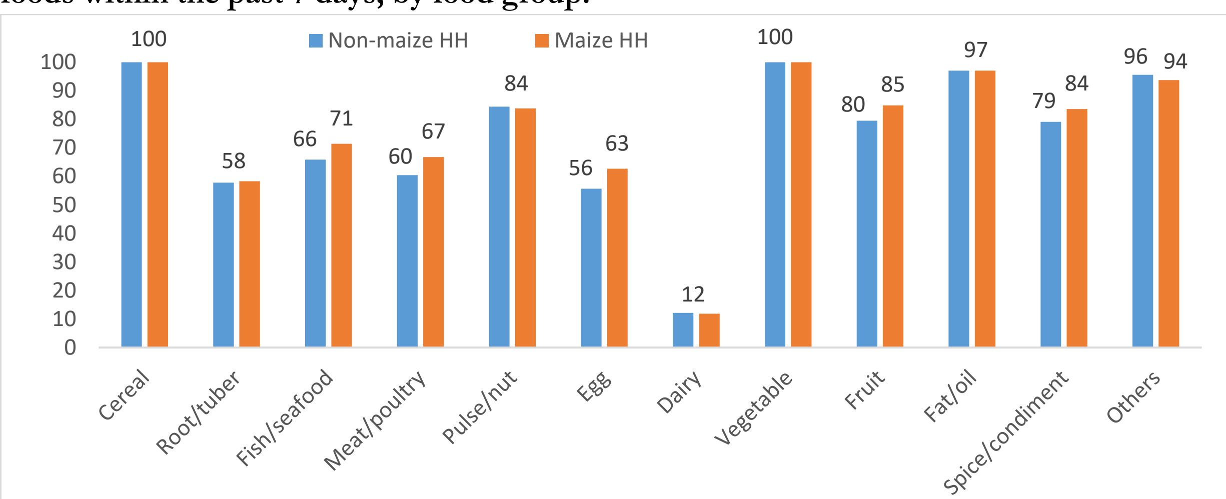


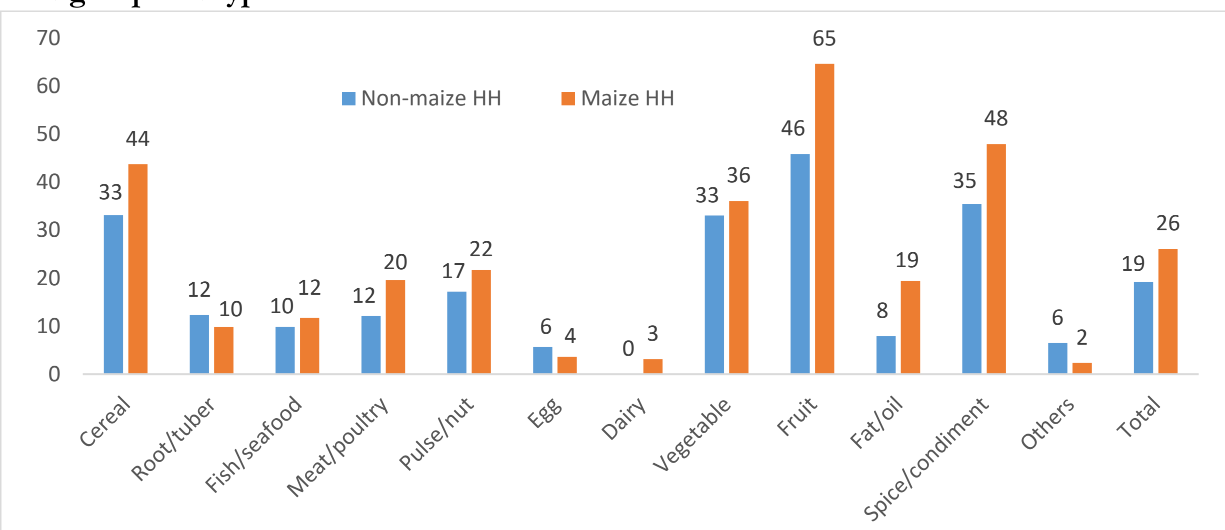
Figure 5 Shares of maize growing and non-maize growing farm households consuming foods within the past 7 days, by food group.



Households that farm maize have similar food consumption patterns to households that do not farm maize. There is little difference in the shares of maize growing and non-maize growing households consuming each food group within the past seven days (Figure 5).

Maize growing households obtain more of their food from own production (26%) than non-maize growing farm households (19%). This pattern holds across most food groups, both in terms of share of households consuming (Figure 6), and value of food consumed. Among 60 items of food listed in the SHARES questionnaire, there were 31 items for which there was no difference in likelihood of consumption from own production among maize and non-maize growing households, 22 items where maize growers were more likely than non-maize growers to consume from their own production, and only 7 foods for which non-maize growers were more likely than maize growers to have consumed self-produced crops. Maize farming households are much more likely to obtain the most important subsistence crop - rice - from own production than non-maize farming households (44% of rice consumed by maize farming households was obtained from own consumption, as compared to 33% of that consumed by non-maize farmers). These results suggest that the decision to cultivate maize does not lead farm households to abandon subsistence food production, at least in aggregate.

Figure 6 Share of HH consuming foods sourced from own production within past 7 days, by food group and type of farm



There is no difference in the value of foods consumed by maize and non-maize farming households. The mean value of consumption per capita per day for non-maize growing farm households (MMK 1,792) is almost the same as that of consumption by maize growing households (MMK 1,772), but the median value of daily consumption per capita is 6% lower for non-maize growing farm households than for maize growers (MMK 512 vs MMK 546). There is no significant difference in the value of food consumed at home by maize and non-maize growers.

The patterns described above are largely independent of landholding size. Maize farmers obtain a higher share of consumption from own production than non-maize farming households across almost all food groups and landholding terciles, with partial exception of tercile 1, in which maize growing households obtain slightly less cereals, roots/tubers, eggs, and vegetables from own production than non-maize growing households (Table 7). This suggests that there may be some trade-offs between production of some food and non-food crops for the smallest third of farmers, but not for others. The total value of food consumed at home does not differ significantly among maize and non-maize growers in each landholding tercile. At the food group level, the only significant difference is that maize growers consume more cereal from their own production than non-maize growers.

Table 7 Share of food consumption (by value) obtained from own production by maize and non-maize farming households, by food group and landholding tercile

	Tercile 1		**Tercile 2**		**Tercile 3**		**All**	
	Non-maize	**Maize**	**Non-maize**	**Maize**	**Non-maize**	**Maize**	**Non-maize**	**Maize**
Cereal	27	21	42	43	37	53	33	44
Root/tuber	11	6	11	16	21	8	12	10
Fish/seafood	8	12	13	14	7	11	10	12
Meat/poultry	17	18	6	17	9	21	12	20
Pulse/nut	16	25	20	22	15	21	17	22
Egg	6	4	6	4	4	3	6	4
Dairy	0	6	0	5	0	2	0	3
Vegetable	34	31	33	40	28	36	33	36
Fruit	39	58	53	61	56	69	46	65
Fat/oil	5	9	9	17	18	26	8	19
Spice/condiment	33	37	36	55	45	47	35	48
Others	5	1	6	4	14	1	6	2

4 Production technology, productivity and profitability

4.1 Cropped area and yields

Larger farms are more likely to plant maize and pigeon pea. Farmers in landholding tercile 3 are nearly three times more likely to plant maize than those in tercile 1 (79% vs 28%). Tercile 3 farms are also three times more likely than tercile 1 farms to plant pigeon pea (53% vs 16%).

Larger farms devote more land to maize and pigeon pea. The average area per household planted to maize and pigeon pea is 4.6 acres and 3.8 acres, respectively. Households in tercile 3 devote six times more land on average to maize than households in tercile 1 (7.3 acres vs 1.2 acres). As a result, larger farms harvest larger quantities of both crops on average. For instance, tercile 3 maize growers harvest more than six times as much on average as those in tercile 1 (9.34 t vs 1.45 t) (Table 8).

Table 8 Maize and pigeon pea production characteristics, by landholding tercile

Item	Tercile 1	Tercile 2	Tercile 3	All
Farm households growing maize (%)	28	55	79	53
Farm households growing PP* (%)	16	39	53	35
Mean area planted to maize (acres)	1.2	2.4	7.3	4.6
Mean area planted to PP (acres)	1.2	2.1	5.9	3.8
Maize as % cropped area (maize growers only)	74	59	60	62
PP as % cropped area (PP growers only)	74	53	52	56
Quantity of maize harvested (kg/household)	1,449	3,302	9,341	5,911
Quantity of PP harvested (kg/household)	185	270	591	413
Maize yield (kg/acre)	1,265	1,391	1,238	1,293
PP yield (kg/acre)	187	166	139	157

*PP = pigeon pea

Maize yields vary little with farm size. We find no evidence that larger farms attain higher yields. The average yield for farms in landholding tercile 1 is marginally higher (1,265 kg/acre) than that attained by farms in tercile 3 (1,238 kg/acre). Farms in the middle of the size distribution have the highest average yields (1,391 kg/acre) (Table 8). Yields obtained by farms in landholding tercile 2 are significantly different (p=>0.1) to yields obtained by farms in tercile 1 and 3.

Average maize yields are lower than other countries in the region. The average maize yield from mono-cropped maize parcels in our sample area is 1,420 kg per acre (Table 8). This is approximately one quarter to one third lower than reported in some other southeast Asian countries (e.g. Thailand 1,816 kg/acre, Viet Nam 1,882 kg/acre), indicating potential for further intensification (FAO, 2019).

There is considerable variation in average maize yields between townships. The yield ranges from 1,642 kg/acre in Pinlaung to 713 kg/acre in Pindaya township (average 1,293 kg/acre[4]). Farmers in Pindaya were more likely to plant local varieties and to produce to maize for home

[4] This figure includes yields from parcels intercropped with pigeon pea

consumption (as animal feed) than farmers in other townships, and 30% (Table A1). Yields in all other townships average above 1200 kg/acre. According to World Bank (2016), the yield in Taunggyi and Namsang townships is 1472 kg/acre, which is close to our result for Taunggyi (1446 kg/acre).

Pigeon pea yields are far lower than maize yields. As noted above, the yield of monocropped maize is 1,420 kg per acre. This is 6.7 times higher than the yield of mono-cropped pigeon pea parcels (212 kg/acre). Intercropped maize and pigeon pea have a combined yield of 1310 kg/acre (1,173 of maize and 137 kg of pigeon pea) (Table 9)[5]. Difference in yield between the two crops are reflected in the quantities produced per farm. Maize production averages 5,911 kg per household; pigeon pea just 413 kg (Table 8).

Table 9 Maize and pigeon pea yield of the sample parcels, by cropping pattern

	Maize only	Maize and PP	PP only	All
Mean size of sample parcel	2.9	3.4	2.1	3.0
Mean maize yield (kg/acre)	1,420	1,173	n/a	1,293
Mean PP yield (kg/acre)	n/a	137	212	157

Small farms attain the highest pigeon pea yields. Pigeon growing households in tercile 1 attain yields that are approximately one-third higher than those obtained by pigeon pea growers in tercile 3 (187 kg/acre versus 139 kg/acre).

4.2 Seed

4.2.1. Seed varieties

Hybrid maize has been adopted widely in southern Shan. A large majority (86%) of maize growers planted hybrid maize seed in 2017. This figure is very close to the 85% reported by USDA (2018) and 81% reported by World Bank (2016). Use of hybrid seed is nearly as common among farms with small landholdings (tercile 1) as those in tercile 3 (83% and 88%, respectively). Farmers with less land are slightly more likely to plant local seed varieties (used by 17% of farms in landholding tercile 1 and 12% in tercile 3). 'Local varieties' are comprised of traditional open pollinated varieties (OPVs), used by 9% of farmers, and 'Than Te' variety (used by 5% of maize growers). Our interviews with traders indicate that Than Te seed originates from a village in Taungyi of the same name, where CP formerly contracted farmers to multiply CP888 variety maize seed. Some farmers were said to have retained seed and multiplied it for sale informally, selling it with the name Than Te. (Table 10).

CP's share of the hybrid maize seed market is less than 50%. This is true in terms of number of farmers planting (43%), and the quantity (46%) and value (47%) of hybrid maize sales. CP's two largest competitors are Golden Tiger (planted by 16% of farmers and accounting for 11% of the hybrid maize seed market by value), Awba (planted by 7% of farmers and accounting for 16% of

[5] Yield of intercropped maize and pigeon pea was calculated by dividing the production of each crop by the area of the parcel. This is because pigeon pea is harvested several months after maize, during which time, pigeon pea plants usually grow to take up the entire area of the parcel, making it difficult to estimate the area devoted to each crop separately.

market share by value). Numerous 'other hybrids', are planted by 22% of farmers, and account for the same share of value. Farmers in our sample reported planting at least 24 varieties of maize in 2017. This shows that the hybrid maize market has diversified rapidly as it has developed (Table 10).

Table 10 Share of maize farming households using seed by variety, and quantity and value of varieties used (market share), by landholding tercile

	Tercile 1	Tercile 2	Tercile 3	All
Farm households using (%)				
Local varieties	17	14	12	14
CP 808	13	18	26	21
CP 888	30	17	16	18
Other CP	3	4	4	4
Golden Tiger 029	20	13	16	16
Awba 621	4	9	6	7
Other hybrids	13	24	21	21
Any hybrid	83	86	88	86
CP hybrid/all hybrid	46	39	46	43
Non-CP hybrid/all hybrid	54	61	54	57
Quantity (%)				
Local variety	14	14	7	9
CP 808	15	22	26	24
CP 888	31	19	16	18
Other CP	3	4	4	4
Golden Tiger 029	19	9	11	12
Awba 621	5	8	13	11
Other hybrids	12	24	22	22
CP hybrid/all hybrid	49	45	46	46
Non-CP hybrid/all hybrid	51	55	54	54
All varieties	7	24	69	100
Value (%)				
Local variety	6	6	3	4
CP 808	19	27	26	26
CP 888	30	18	15	17
Other CP	4	4	4	4
Golden Tiger 029	20	10	10	11
Awba 621	8	11	18	16
Other hybrids	13	24	22	22
CP hybrid/all hybrid	53	49	46	47
Non-CP hybrid/all hybrid	47	51	54	53
All varieties	7	23	70	100

Maize seed purchases are concentrated among households with larger landholdings. Maize farming households in landholding tercile 3 account for 69% of maize seed purchases by quantity and 70% by value. Households in landholding tercile 1 account for just 7% of maize seed purchases by volume and value (Table 10). These figures reflect the unequal distribution of land among farm households (farming households in tercile 3 own 67% of land, while those in tercile 1 own 9%).

Farmers with larger landholdings are more likely to use more expensive seed varieties. For instance, maize farming households in landholding tercile 3 were twice as likely to plant CP 808 as those in tercile 1 (used by 26% and 13% of farms tercile 3 and tercile 1 respectively), but half as likely to plant CP 888 (used by 16% of farms tercile 3 and 30% of farms in tercile 1). Similarly, Golden Tiger 029 – a relatively cheap Thai maize seed variety marketed by a Myanmar company – accounts for 20% of the value of seed purchased by farmers in tercile 1, but 10% of purchases among farmers in tercile 3, whereas Awba 612 - a more expensive variety licensed by a Myanmar company from the multi-national Syngenta – accounts for 8% of the value of purchases among farmers in tercile 1, but 18% for farmers in tercile 3 (Table 10).

Farmers with medium and small landholdings plant maize more intensively than those with large landholdings. The average seed application rate of farmers in landholding tercile 3 (5.5 kg/acre) is 11% lower than that for farms in terciles 2 and 1 (6.2 kg/acre). Farms in tercile 3 use less maize seed per acre than those terciles 2 and 1, irrespective of the type of seed (local variety, cheap hybrid, or expensive hybrid). Farms in tercile 2 apply larger quantities of expensive hybrid maize varieties than those in tercile 1 (6.2 kg/acre, versus 5.6 kg/acre). Conversely, farms in tercile 1 apply larger quantities of local varieties and cheap hybrids than those in tercile 2. These results are consistent with the finding that farms in tercile 2 are more productive than those in terciles 1 or 3, and are indicative of capital constraints that limit the ability of smaller farms to plant more expensive (presumably a proxy for better quality) seed varieties, and limit the ability of larger farms to apply optimal quantities of inputs (Table 11).

Table 11 Maize seed application rates, by type of seed and landholding tercile

Quantity of…	Tercile 1	Tercile 2	Tercile 3	All
All maize seed applied (kg/acre)	6.2	6.2	5.5[a]	5.9
Local variety maize seed applied (kg/acre)	7.9	6.8	6.5	6.9
Hybrid maize seed applied (kg/acre)	5.9	6.1	5.4[b]	5.7
Expensive hybrid maize seed applied (kg/acre)	5.6	6.2	5.4[c]	5.7
Cheap hybrid maize seed applied (kg/acre)	6.3	5.9	5.4	5.8

Note: Expensive hybrid seed varieties are defined as those with price higher than the mean price of all the seed varieties. [a] Significantly less maize seed per acre than farmers in tercile 1 ($p<0.1$) and 2 ($p<0.01$). [b] Significantly ($p<0.01$) less hybrid maize seed per acre than farmers in tercile 2. [c] Significantly less expensive hybrid maize seed per acre than farmers in tercile 2 ($p<0.01$).

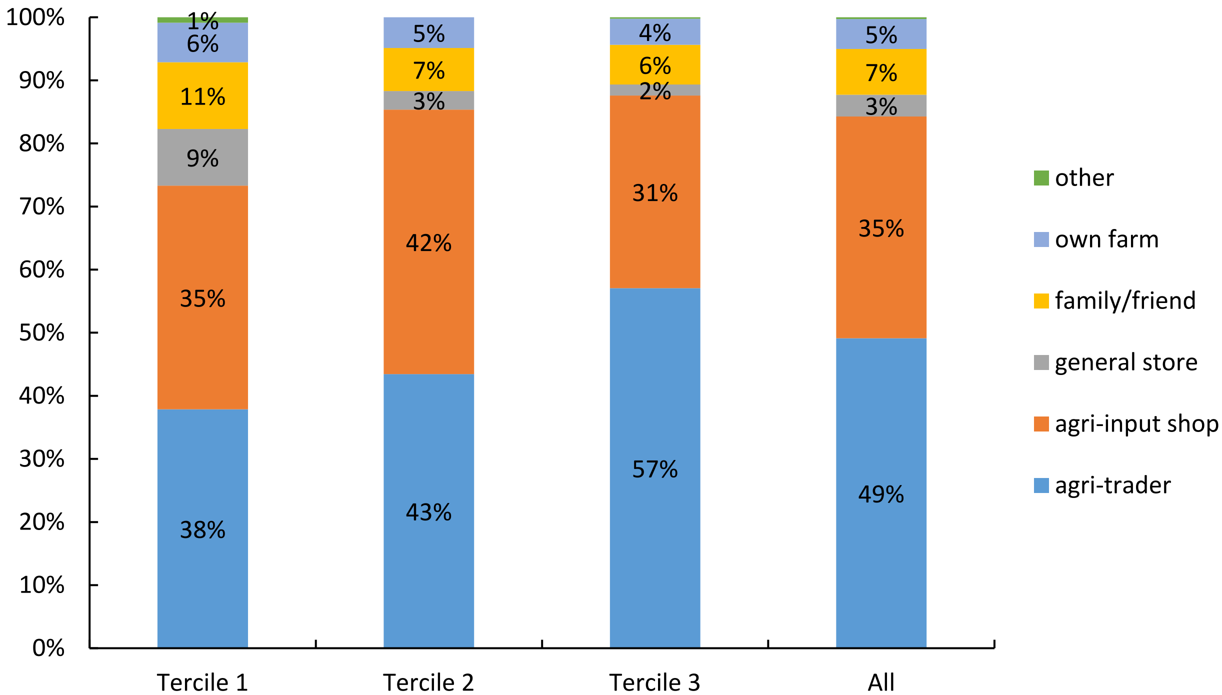
Use of improved pigeon pea varieties is extremely limited. Farmers reported using a total of five pigeon pea seed varieties. These included, yellow, red and white cultivars, and two named varieties - Yezin 1, and Kywe Shan Shwe Dingar. Farmers with less cultivated land planted pigeon pea more intensively. Farmers in landholding tercile 1 planted 3.4 kg of pigeon pea seed per acre, while those in tercile 3 planted 2.3 kg per acre.

4.2.2. Sources of seed

Traders and agricultural input shops are the two main sources of maize seed. In terms of numbers of customers, traders accounted for around half of maize seed sales (49%), and agricultural input shops account for 35%, for a total of 84% of sales. Other sources of seed include family and friends, own farm, and general stores. These acted together as a source of maize seed for around 15% of households. The distribution of seed sales follows a similar pattern in terms of quantity. Traders account for 53% of total seed sales by quantity, agricultural input shops provide 37%, and other sources 9%.

Large farms are more likely to obtain maize seed from traders than small farms. Fifty-seven percent of farmers in landholding tercile 3 obtained maize seed from traders, as compared to 38% of farmers in tercile 1. Farmers in landholding tercile 1 and 2 are somewhat more likely to source maize from agricultural input shops than farms in landholding tercile 3. The tendency for farmers with larger landholdings to source seed from traders has implications farmer access to credit, as it is more common for traders to supply maize seed as in-kind credit than agricultural input supply shops (Cho and Belton, 2019). The smallest third of farms (tercile 1) are most likely to receive seed from family or friends, or to source from their own farms, likely reflecting a higher propensity to use local varieties of maize seed as compared to farmers with more land (Figure 7).

Figure 7 Sources of maize seed by cultivated landholding tercile



The amount of maize seed sourced from businesses as acting as representatives for CP is modest. Seventeen percent of farmers reported purchasing maize seed from traders or input supply businesses acting as CP representatives. Moreover, forty-two percent for farmers who purchased seed from CP representatives reported buying non-CP seed from them.

There is little difference in the price paid for maize seed by farmers, irrespective of farm size. There is no significant difference in prices paid for maize seed by farmers in all three landholding terciles, irrespective of source. CP808, an expensive maize seed variety, is the only variety for which prices paid by farmers differ significantly by landholding tercile. Tercile 3 farmers paid significantly less than farmers in tercile 1 ($p<0.1$) and tercile 2 ($p<0.01$), perhaps because farms purchasing large quantities of seed were able to avail discounts (Table 12).

Table 12 Mean price of maize seed by source and landholding tercile (MMK/kg)

	Tercile 1	Tercile 2	Tercile 3	All
Source				
Maize trader	5,454	5,434	5,239	5,320
Agri-input shop	5,145	5,497	5,365	5,377
General store	4,563	4,258	3,836	4,298
Family/friend	2,753	3,108	3,252	3,075
All sources	4,942	5,258	5,123	5,132
Variety				
CP 808	6,287	6,335	5,587[a]	5,881
CP 888	4,978	4,900	4,977	4,955
Golden Tiger 029	5,453	5,511	5,317	5,401
Local variety	2,323	2,185	2,479	2,339
Thai 333	4,968	5,259	5,297	5,237

Note: All prices exclude cost of any interest on loans. Maize seed provided for free by family & friends is excluded from cost calculations. [a] Significantly lower maize seed price than farmers in tercile 1 ($p<0.1$) and 2 ($p<0.01$).

Most pigeon pea seed is sourced from farmers' own farms. Sixty percent of pigeon pea growers used seed saved from the previous cycle on the own farms. A further 28% of pigeon pea farmers received the seed from family or friends (Table A2). The average price of pigeon pea seed is MMK 731 per kg (Table A3). Farmers pay similar prices for pigeon pea seed, irrespective of landholding size or variety.

4.3 Fertilizer and other chemical inputs

Most maize and pigeon pea growers use inorganic fertilizers. 87% of maize/pigeon pea growers used an inorganic fertilizer on the sample parcel during the past growing season. Compound fertilizer (NPK) was the most popular inorganic fertilizer, used by 79% of maize/pigeon pea growers, followed by urea, used by 43%. Use of manure is quite limited (used by 19% of households), reflecting low levels of draft animal ownership in southern Shan (Soe & Kyaw, 2019). Use of pesticides and herbicides is also low, applied by around one quarter of maize/pigeon pea growers (Table 13).

Small farms have lower rates of input adoption. For example, 90% of maize/pigeon pea growers in landholding tercile 3 used inorganic fertilizer, as compared to 77% of farms in tercile 1. These percentages are very close to the shares of households in these landholding terciles using hybrid maize seed, suggesting that adoption of inorganic fertilizer is closely associated with adoption of hybrid seed. Pesticide and herbicide use is slightly less common among the smallest third of farms than on larger farms, possibly suggesting a tendency to substitute pesticides and herbicides for labor.

Table 13 Share of maize and pigeon pea growers using inputs, by landholding tercile

Input	Tercile 1	Tercile 2	Tercile 3	All
Compound	72	75	84	79
Urea	40	36	50	43
T-super	4	16	11	12
Potash	3	0	2	2
Any inorganic fertilizer	77	87	90	87
Manure	14	22	19	19
Pesticide	20	28	26	26
Herbicide	21	25	26	25

Small farms apply all types of fertilizer more intensively than large farms. The average rate of total inorganic fertilizer application is 107 kg, 85 kg, and 76 kg per acre, respectively, for maize/pigeon pea growers in landholding terciles 1, 2 and 3. The average quantity of fertilizer applied per acre by the smallest third of farms is 29% greater than that applied by the largest third of farms. The combined rate of application of inorganic fertilizers by households in landholding tercile 1 is significantly higher than that of households in landholding terciles 2 ($p<0.05$) and tercile 3 ($p<0.01$). Households in landholding tercile 3 apply compound fertilizer, urea, and other inorganic fertilizers at significantly lower rates than households in tercile 1 ($p<0.01$; $p<0.05$; $p<0.1$, respectively) (Table 14).

Table 14 Fertilizer application rate by landholding tercile (kg/acre)

		By landholding tercile			By type of seed	
Fertilizer	**All**	**T 1**	**T2**	**T 3**	**Local**	**Hybrid**
Compound (kg/acre)	63	81	63**	55***	66	65
Urea (kg/acre)	41	52	45	35**	27	43**
Other inorganic fertilizer (kg/acre)	43	57	48	36*	31	49*
All inorganic fertilizer(kg/acre)	84	107	85**	76***	75	90*

Note: 1) *p<0.1; **p<0.05; ***p<0.01, as compared to landholding tercile 1 while comparing between different landholding terciles; 2) Farmers not using any inorganic fertilizer are excluded in this table. About 13% of maize/pp growers did not use any inorganic fertilizer

Rates of fertilizer application are higher on hybrid maize seed varieties than local. Total inorganic fertilizer application is significantly higher on hybrid maize ($p<0.1$) than local variety maize. Interestingly, there is no difference in rates of compound fertilizer applied to the two types of seed, but urea and other organic fertilizers are applied to hybrid maize seed at a significantly higher rates than to seed of local origin. This may indicate that locally produced maize varieties are less responsive to fertilizer inputs than hybrids, but could also reflect farmers using local seeds having less access to capital than those using hybrids.

Fertilizer application rates are highest on mono-cropped maize parcels. The average rate of fertilizer application on mono-cropped maize parcels is 97 kg/acre. This falls to 80 kg/acre on intercropped maize/pigeon pea parcels and 56 kg on pigeon pea parcels, perhaps reflecting the nitrogen fixing properties of pigeon pea, as well as the more limited response of pigeon pea to fertilizers as compared to hybrid maize (Table 15).

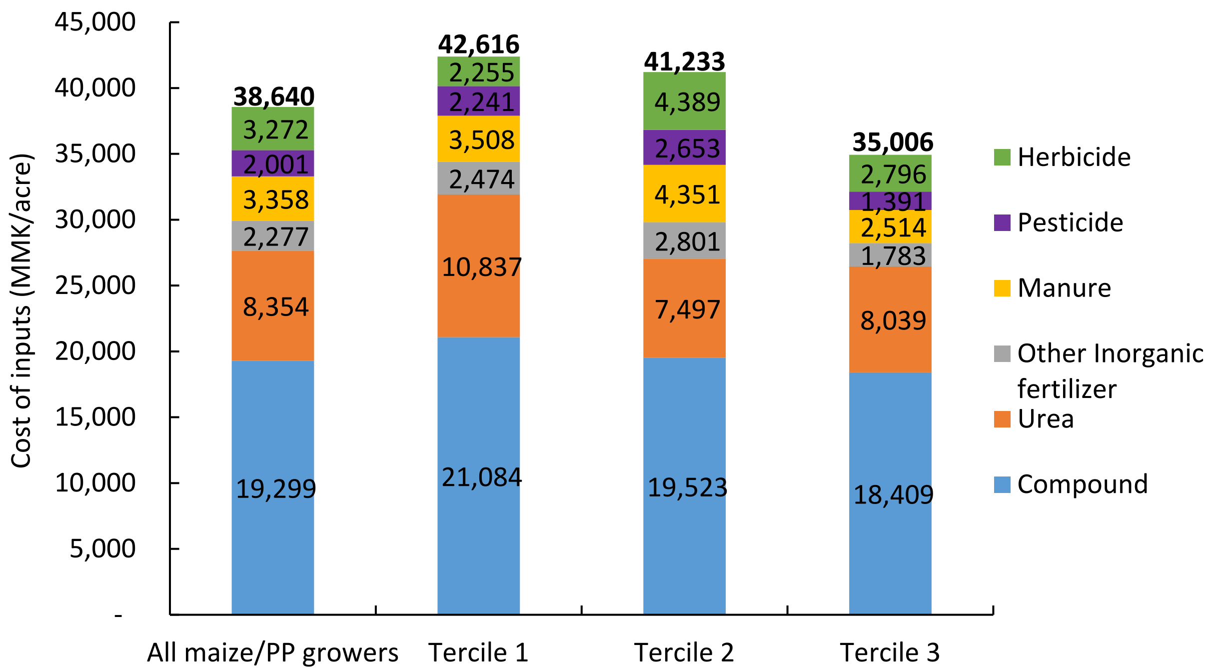
Table 15 Share of maize and pigeon pea growers using inorganic fertilizer (%) and application rate (kg/acre), by landholding tercile and cropping pattern

Crop	Tercile 1	Tercile 2	Tercile 3	All
Share of households using (%)				
Maize only	78	94	92	90
Both maize & PP	89	91	95	93
PP only	49	69	58	62
Quantity used (kg/acre)				
Maize only	107	97	90	97
Both maize & PP	121	81	69	80
PP only	57	64	39	56

Note: Farmers who did not use inorganic fertilizer were excluded from calculation of the average application rate.

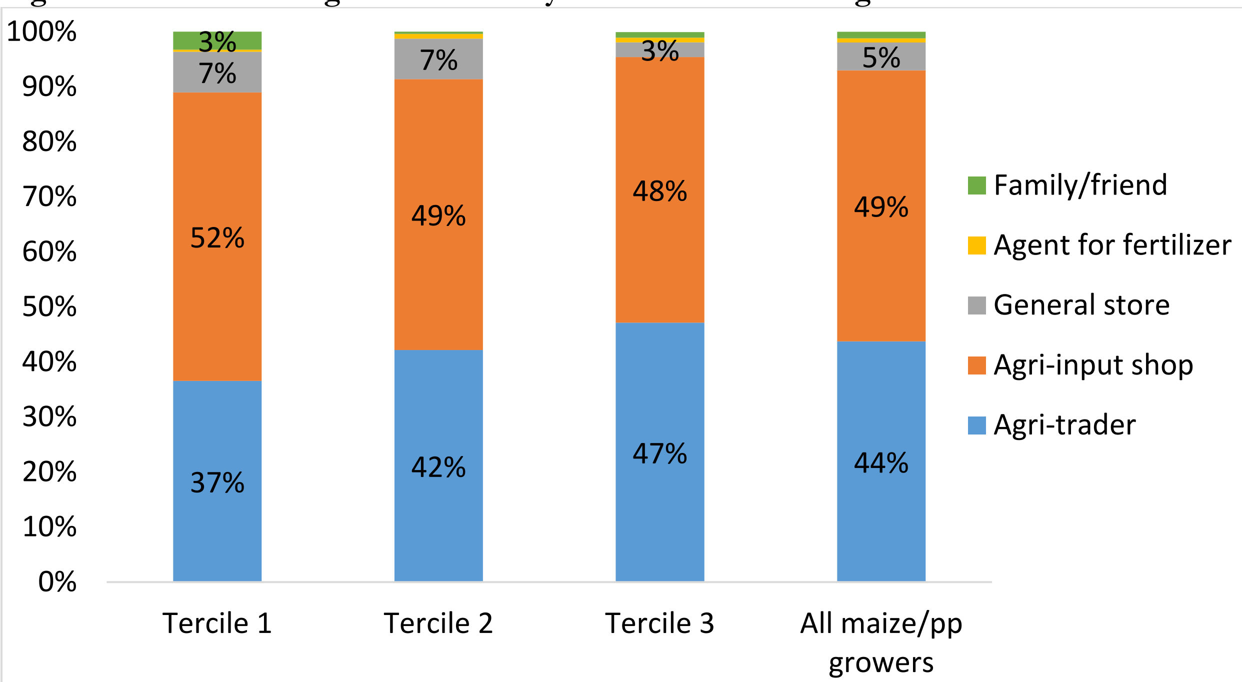
Small farms spend more per acre than large farms on all chemical inputs other than herbicide. Farmers in tercile 1 spend 26% per acre more on chemical inputs than those in tercile 3 (MMK 42,616/acre vs. MMK 35,006/acre) (Figure 8). As the unit price paid for these inputs varies little with landholding size, this supports the observation that small farms cultivate maize and pigeon pea more intensively than larger farms. Compound fertilizer accounts for around half of the cost of chemical inputs (Table A4).

Figure 8 Composition of the various inputs cost per acre on the sample parcel by cultivated landholding tercile



Input shops and traders are the main sources of inorganic fertilizer for maize/pigeon pea growers. Farmers obtain inorganic fertilizer from these sources in roughly equal numbers; 49% from input shops, 44% from traders. Smaller farms (landholding tercile 1) were slightly less likely than farms in tercile 3 to purchase fertilizer from traders (37% and 47%, respectively) (Figure 9).

Figure 9 Sources of inorganic fertilizer by cultivated landholding tercile



Use of pesticides on maize is limited. Only 7% of households growing monocropped maize used pesticides, indicative of the relatively low vulnerability of maize to most insect pests. Rates of pesticide use are relatively high on monocropped pigeon pea, as the crop is prone to high levels of pest infestation, and are higher in larger farms (rising from 45% in tercile 1 to 60% in tercile 3). Around one quarter of households used herbicides in maize cultivation (Table 16).

Table 16 Share of maize and pigeon pea growers using pesticide and herbicide, by landholding tercile and cropping pattern

Crop	Tercile 1	Tercile 2	Tercile 3	All
Households using pesticide (%)				
Maize only	7	8	6	7
Both maize & PP	28	35	35	34
PP only	45	53	60	54
Households using herbicide (%)				
Maize only	20	36	22	26
Both maize & PP	24	24	27	26
PP only	17	9	31	17

4.4 Labor

Maize and pigeon pea cultivation utilizes a mix of family, hired, and exchange labor. As expected, virtually all (98%) of households growing these crops employ family labor. Family labor accounts for 56% of all labor days utilized in cultivation the two crops. Two-thirds (66%) of maize farming households employ hired casual labor, accounting for around one third of total labor days worked. Very few households (<1%) employ permanent agricultural labor. Exchange labor (in which individuals work for others without pay, in the expectation that an equivalent amount of labor will be returned to them when needed) is a common practice, used by one third of maize farming households, and contributing 18% of labor days used in maize monocropping (Table 17 & Table 18).

Table 17 Share of maize growers using labor on maize only sample parcel by activity

% of households using…	Hired labor			Family labor			Exchange labor	All labor
	♀	♂	♀+♂	♀	♂	♀+♂		♀+♂
Land Preparation	2	10	11	18	48	53	6	59
Planting	33	26	41	79	81	95	14	100
Fertilizer/pesticide/herbicide application	11	15	24	48	74	91	2	96
Weeding	32	18	39	79	70	91	16	99
Harvesting & drying Maize	37	34	46	83	81	95	21	100
Shelling Maize	15	30	33	54	70	80	21	84
Any Activity	54	59	66	90	90	98	34	100

Note: The results of maize and pigeon pea intercropping parcels are very similar to the maize only parcels, so only maize only parcels and pigeon pea only parcels are provided here.

Table 18 Person days of labor per acre, by type, landholding tercile, & cropping pattern

Type of labor	T 1	T 2	T 3	Maize only	Maize & PP	PP only	All
All labor (days/acre)	37.9	28.7	23.4	27.0	31.1	22.6	28.1
Hired labor (days/acre)	5.6	8.7	9.7	8.9	10.1	3.5	8.6
Hired female labor	3.2	5.6	5.6	5.3	5.9	2.3	5.1
Hired male labor	2.1	2.8	3.6	3.1	3.7	0.9	3.1
Family labor (days/acre)	26.6	16.1	10.4	13.3	17.1	17.9	15.6
Family female labor	14.6	8.1	5.0	6.8	8.7	9.2	8.0
Family male labor	12.0	8.0	5.4	6.4	8.4	8.8	7.6
Exchange labor (days/acre)	5.7	3.8	3.2	4.8	3.9	1.2	3.9
Hired labor (%)	15	30	42	33	33	15	31
Family labor (%)	70	56	45	49	55	79	56
Exchange labor (%)	15	13	14	18	13	5	14

Small farms are more labor intensive than large farms. The total reported labor use for maize production is 27 days per acre, which is very close to the result (25 days/acre) reported by World Bank (2016). The smallest third of farms utilize 38% more labor days per acre than the largest third of farms (37.9 days/acre vs 23.4 days/acre). Family labor accounts for 56% overall of labor inputs, which is very similar to the figure reported by World Bank (2016) for South Shan (55%). As expected, small farms are more reliant on family labor than large farms. Family labor contributes

70% of the total labor days utilized by farms in tercile 1, as compared to 45% of labor days utilized by farms in tercile 3. Conversely, large farms are more dependent on hired casual labor, which supplies 42% of their labor requirements, compared to 15% for small farms. Interestingly, exchange labor accounts for a similar share of labor inputs (around 14%), irrespective of farm size (Table 18).

Weeding and harvesting are the two most labor intensive activities. For maize parcels, these two activities demanded almost 70% of total labor use. Weeding and harvesting also accounted for about 53% of the total labor use on pigeon pea parcels (see Table A6). In contrast, land preparation and shelling maize, which are already highly mechanized each account for only 7% of total labor days each (Table 18). This indicates scope to reduce labor demand further through judicious use of herbicides, mechanization of weeding (e.g. small-scale rotary tillers, perhaps in association with use of seed drills to ensure even spacing between rows), and mechanization of harvesting (combine harvesters).

Women contribute slightly more than half the labor utilized in maize and pigeon pea cultivation. Women contribute 55% of total labor days[6]. This figure varies vary little, irrespective of farm size or cropping system (maize/pigeon pea, monocrop/intercrop). Men and women generally contribute a similar amount of family labor, whereas women contribute slightly more hired labor than men (Table 19).

Table 19 Number of person days labor per acre, by activity, for mono-cropped maize

	Hired labor			Family labor			Exchange labor	All labor	
Activity	♀	♂	♀+♂	♀	♂	♀+♂	♀+♂	Days	%
Land Preparation	0.1	0.1	0.2	0.4	0.7	1.1	0.7	1.9	7
Planting	0.7	0.4	1.2	1.1	1.0	2.0	0.4	3.6	13
Fertilizer/pesticide/herbicide application	0.1	0.1	0.2	0.2	0.5	0.7	0.0	1.0	4
Weeding	2.2	0.9	3.3	2.6	1.9	4.5	1.7	9.5	35
Harvesting & drying Maize	2.0	1.3	3.5	2.0	1.9	3.9	1.7	9.2	34
Shelling maize	0.2	0.3	0.5	0.5	0.4	1.0	0.3	1.8	7
Any Activity	5.3	3.1	8.9	6.8	6.4	13.3	4.8	27.0	100

Note: 1) Total of hired female and male labor is slightly smaller than the total hired labor because some respondents did not remember the gender of the hired labor. 2) Number of labor person days for each activity does not include the households that did not perform the activity.

There is no strict gender division of labor. Men devote more labor days to land preparation and fertilizer and pesticide application than women, and women spend more time weeding and harvesting than men, but men and women participate in all stages of maize and pigeon pea cultivation.

There is a significant gender wage gap in agriculture, but it is smaller than in other parts of the country. Women employed as casual laborers in maize/pigeon pea cultivation earned 89% of the average daily wage earned by male workers (Table 20). The gap was largest for activities typically

[6] This calculation is based on total hired labor and family labor. We were unable to collect information on the gender of exchange labor.

viewed as "men's work" (land preparation and fertilizer and chemical application), and smaller for activities in which women account for a larger share of the workforce. Previous studies show that there is a significant gender wage gap in agriculture in other area in Myanmar. In the Delta, women's average agricultural wages are about two thirds of men's (Cho et al. 2017), and in the Dry Zone, women agricultural laborers earn about 80% of the daily wage earned by men (Belton & Filipski, 2019). We surmise that the smaller gap in maize/pigeon pea farming in Shan, relative to other parts of the country where different crops predominate, may be linked the relatively weak gender division of labor in the former, as noted above.

Table 20 Average daily wages for casual hired labor, by activity, cropping pattern and gender (MMK/day)

Activity	Maize only parcels		PP only parcels		All parcels		Gender wage gap (%)
	♀	♂	♀	♂	♀	♂	
Land preparation	3,562	4,696	4,000	5,981	3,557	4,675	24
Planting	3,814	4,319	3,183	3,408	3,646	4,172	13
Fertilizer/chemical application	3,599	4,701	2,500	4,046	3,651	4,704	22
Weeding	3,718	3,878	3,447	3,341	3,569	3,830	7
Harvesting & drying maize	3,656	3,931	n/a	n/a	3,542	3,838	8
Shelling maize	3,649	3,912	n/a	n/a	3,683	3,954	7
Harvesting PP	n/a	n/a	3,371	3,751	3,488	3,669	5
Drying/husking/winnowing PP	n/a	n/a	3,045	4,042	3,345	3,753	11
Any activity	3,708	4,126	3,330	3,877	3,585	4,027	11

4.5 Cost structure

The subsection draws together data from previous subsections to present crop enterprise budgets for maize and pigeon pea monocropping and intercropping.

Chemical inputs make up the largest share of production costs in maize and pigeon pea farming. Fertilizers, pesticides and herbicides combined account for 28% of total costs. Hired labor (24%), agricultural machinery rental and operation (20%), and seed (18%) account for the three next largest cost shares. This pattern is similar across both maize monocrop and maize-pigeon pea intercropped parcels. Draft animal rental costs account for just 1% of total production costs, underlining the high level of mechanization in land preparation for these crops. Costs associated with transporting maize or pigeon pea to the point of sale account for 7% of total production costs.

Interest on loans amounts to just 2% of production costs. Even among households who avail credit for maize cultivation, interest accounts for only 4% of production costs[7](Table 21). This finding suggests that obtaining maize farming inputs on credit is unlikely, in itself, to result in unmanageable levels of indebtedness. Farmers availing credit would be only marginally more impacted by low yields or low farmgate prices than those purchasing inputs outright.

[7] This includes the amounts paid by farmers availing interest free credit. Excluding these cases, interest accounts for 5% of total costs incurred by farmers borrowing to fund maize cultivation

Table 21 Average value and share of the maize and pigeon pea production costs per acre on the sample parcel

	Maize tercile 1	Maize tercile 2	Maize tercile 3	All Maize	Maize only	Maize & PP	PP only
Cost (MMK/acre)							
Chemical inputs	40,705	42,035	30,351	36,096	39,836	32,505	13,627
Hired labor	23,191	32,299	34,207	31,572	29,225	33,827	5,245
Machinery	26,314	30,117	26,141	27,487	27,330	27,637	4,167
Seed	24,210	28,083	22,965	24,883	26,827	23,016	681
Transportation	8,890	11,658	7,284	9,021	10,289	7,804	1,787
Interest	2,516	3,487	2,439	2,800	2,701	2,894	1,121
Draft animal	1,373	1,488	611	1,039	813	1,257	854
Total	127,198	149,166	123,998	132,898	137,019	128,940	27,482
Cost share (%)							
Chemical inputs	32	28	24	27	28	26	48
Hired labor	18	22	28	24	18	20	14
Machinery	21	20	21	21	20	21	15
Seed	19	19	19	19	25	21	7
Transportation	7	8	6	7	8	8	9
Interest	2	2	2	2	2	2	3
Draft animals	1	1	0	1	1	1	4

Note: Table only includes parcels on which maize is grown (i.e. monocropped pigeon pea parcels excluded).

Smaller farms spend more on chemical inputs, larger farms spend more on hired labor. Maize farms in landholding tercile 1 spent an average of 34% more per acre on chemical inputs, as compared to farms in landholding tercile 3 (MMK 40,705/acre vs MMK 30,351/acre). Conversely, farms in landholding tercile 3 spent an average of 48% more on hired labor than farms in tercile 1 (MMK 34,207 vs MMK 23,191). This finding is consistent with farms with small landholdings cultivating them intensively and suggests that smaller farmers are not heavily constrained in their ability to purchase inputs. Large farms have insufficient family labor to meet their needs and are consequently more dependent on hired labor than small farms. Except for chemical inputs and hired labor, maize/pigeon pea growers allocate similar shares of their farm budgets to all other inputs, irrespective of farm size, indicating agricultural machinery use and adoption of hybrid maize seed are scale neutral.

Farmers in landholding tercile 2 have the highest production costs per acre. Tercile 2 farms spent 17% more on production per acre than those in tercile 1 (significant, $p<0.1$), and 20% more than those in tercile 3 (significant, $p<0.01$). Production costs appear correlated to farm productivity, as maize yields are also highest on tercile 2 farms.

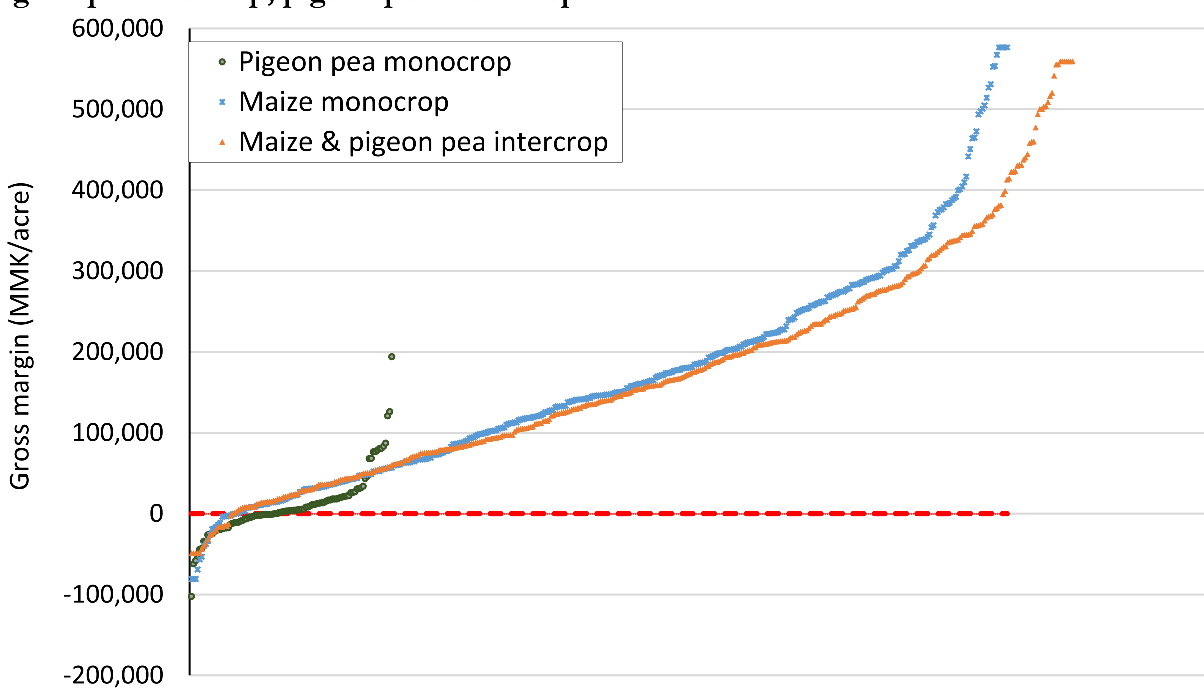
Pigeon pea production costs are only on fifth of maize of maize cultivation costs. The production costs for pigeon pea monocropping are only MMK 27,482/acre, as compared to MMK 137,019 for monocropped maize, and MMK 128,940 for intercropped maize/pigeon pea. Chemical inputs account for about half of pigeon pea production costs. Production costs for monocropped maize are similar to those reported by World Bank for South Shan (equivalent to around MMK 160,000/acre at 2014 exchange rates) (World Bank, 2016)

4.6 Profitability

In this subsection we analyze the profitability of maize and pigeon pea cultivation by landholding tercile and cropping pattern.

Average gross margins for maize during 2017 were modest. The average gross margin for monocropped maize parcels in the present study (MMK 165,344/acre, or $303/ha at prevailing exchange rates at the time of the survey) (Table 22). This figure is 2.8 times lower than the average gross margin of $854/ha reported by the World Bank for maize producers in southern Shan in 2013/14 (World Bank, 2016). The gap between these two figures is attributable in part to differences in the exchange rate at the time of the two surveys. The kyat weakened from approximately MMK1000 = $1 in 2014 to MMK 1350 = $1 in 2018. However, even after adjusting to 2014 exchange rates, the gross margin obtained by the present study is approximately half ($408/ha) that reported by World Bank. The gross revenue figures reported by World Bank are higher than those in the present survey (MMK 451,359/ acre vs MMK 302,364/acre). This appears to be the result of a higher average farmgate price (MMK 299/kg vs MMK236/kg), combined with higher average maize yields (1507 kg/acre vs 1420 kg/acre) reported in the World Bank survey, relative to the present survey. The price differential between the two surveys reflects the tendency of maize prices to fluctuate considerably from year to year, particularly as a result of periodic disruptions in access to the main export market in China.

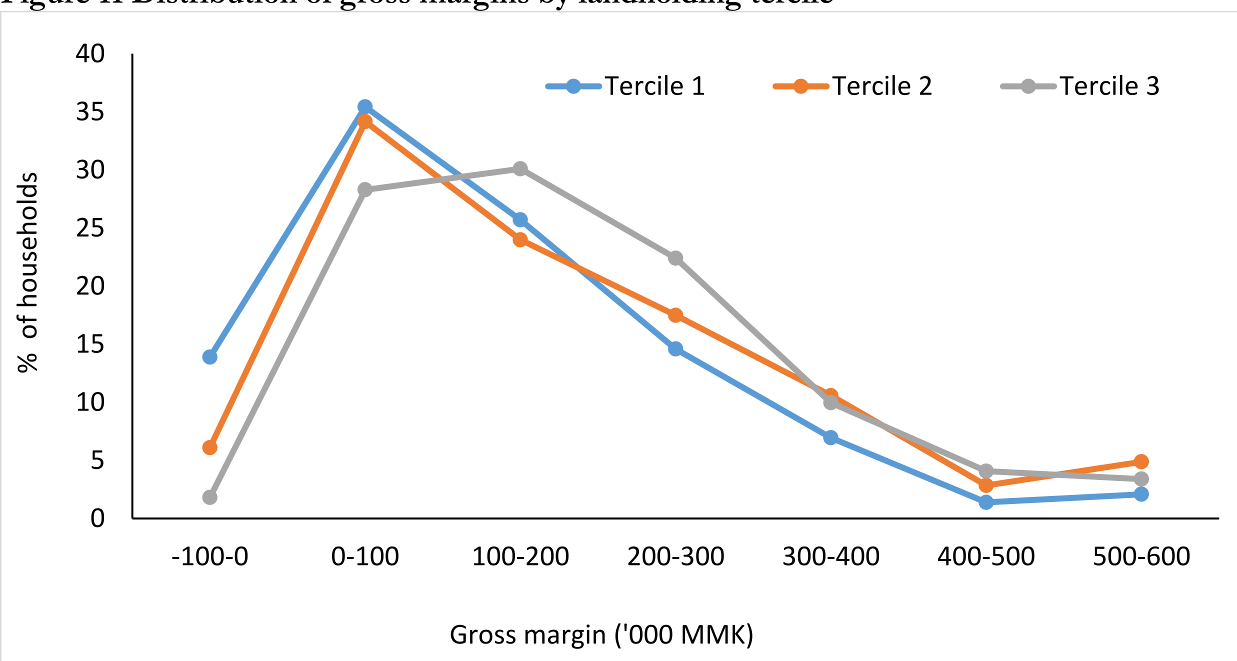
Figure 10 Distribution of gross margins/acre for farms producing maize monocrop, maize-pigeon pea intercrop, pigeon pea monocrop



Variability in maize gross margins is low relative to other rainfed crops. Only 5% of maize growers received negative gross margins for maize harvested in 2017 (Figure 10), and the spread of gross margins is quite small compared to some other rainfed crops grown in Myanmar. For example, 31% of sesame growers and 26% of groundnut farmers in the Dry Zone obtained negative gross margins in 2016[8]. Pigeon pea performed very poorly in the survey year due to the collapsing prices following a ban on imports to India. Forty-two percent of farmers who monocropped pigeon pea returned negative gross margins.

Larger farms have higher average gross margins per acre. Average gross margins increase in step with landholding size, from MMK 140,183/acre for tercile 1 farms to MMK 171,721/acre for those in tercile 3 (a difference of 22%) (Table 22). Smaller farms are more likely to obtain negative gross margins: 14% of tercile 1 farms failed to break even, as compared to 6% of tercile 2 farms, and 2% of tercile 3 farms (Figure 11). Although farms in tercile 2 have the highest gross revenues, reflecting high levels of expenditure on seed and chemical inputs, their returns to cash capital (gross revenue / total cost of cash inputs) are the same as those of farms in tercile 1, at 2.1. Tercile 3 farms have returns to cash capital of 2.4, meaning that farmers in landholding tercile 3 earn MMK 300 more than those in tercile 1 for every MMK 1,000 spent on production. We hypothesize that farmers in tercile 3 obtain higher prices for their maize than those in tercile 1 and 2, because they are able to reserve more maize grain for sale after peak season when maize prices are higher (see section 5.1).

Figure 11 Distribution of gross margins by landholding tercile



[8] Calculated using unpublished data from the Rural Economy and Agriculture in the Dry Zone survey.

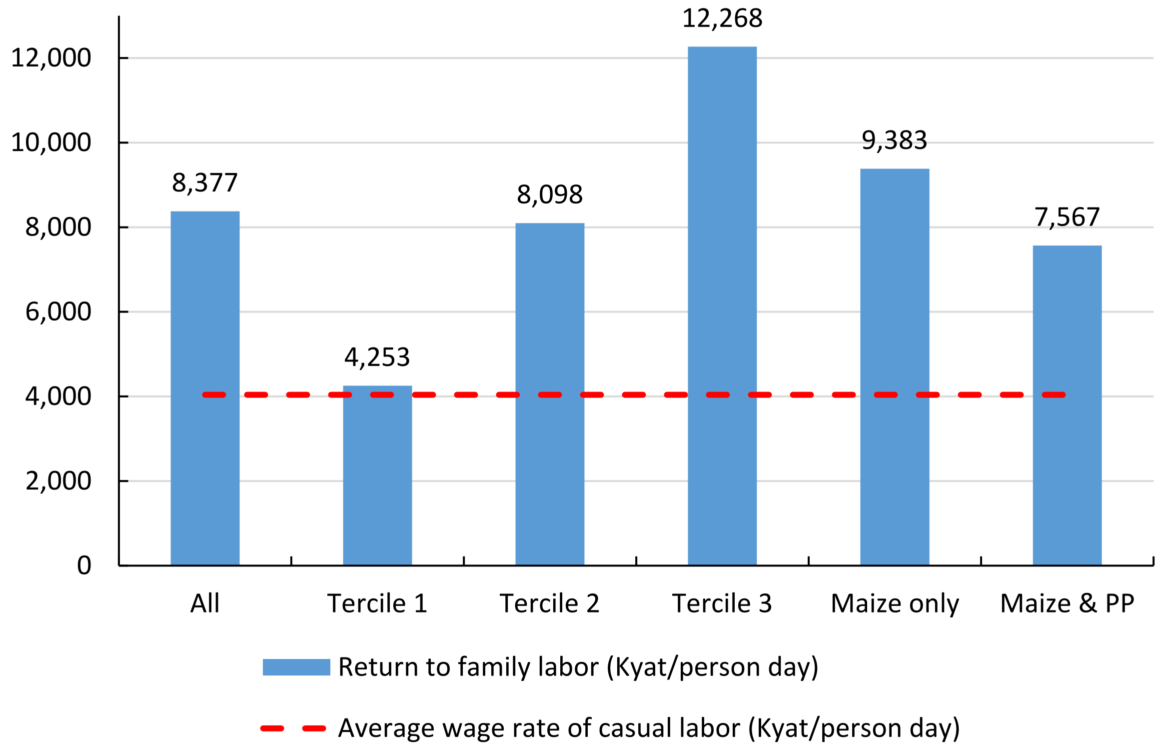
Table 22 Gross margin and profitability indicators for maize cultivation on the sample parcel

	Maize tercile 1	Maize tercile 2	Maize tercile 3	All maize	Maize only	Maize & PP	PP only	Paddy
Maize yield (kg/acre)	1,265	1,391	1,236	1,287	1,420	1,171		
Gross revenue (MMK/acre)	267,381	309,060	295,719	294,972	302,364	287,874	41,105	287,366
Total costs of cash inputs (MMK/acre)	127,198	149,166	123,998	132,898	137,019	128,940	27,482	144,052
Gross margin (MMK/acre)	140,183	159,894	171,721	162,074	165,344	158,934	13,623	143,314
Return to cash capital (MMK/MMK)	2.1	2.1	2.4	2.2	2.2	2.2	1.5	2.0
Imputed cost of family & exchange labor (MMK/acre)	133,934	79,638	56,322	78,148	73,070	83,025	77,393	
Total costs including imputed cost of family labor (MMK/acre)	261,132	228,805	180,321	211,046	210,090	211,965	104,875	
Margin including imputed cost of family labor (MMK/acre)	6,249	80,255	115,398	83,926	92,274	75,909	-63,769	
Total family labor and exchange labor (days/acre)	33	20	14	19	18	21	19	
Return to family labor (MMK/person day)	4,253	8,098	12,268	8,377	9,383	7,567	711	
Average cost of hiring casual labor (MMK/day)	4,063	4,033	4,024	4,039	4,147	3,953	4,042	
Family labor maize productivity (kg/person day)	38	70	88	67	81	56		
Benefit-cost ratio	1.02	1.35	1.64	1.40	1.44	1.36	0.4	

Note: 1) Table only includes parcels on which maize is grown (i.e. monocropped pigeon pea parcels excluded). 2) Gross margin of paddy in Shan State is based on SHARES data. 3) The calculation of return to family labor considers exchange labor as family labor. Return to family labor = Gross margin / Imputed cost of family & exchange labor. 4) Return to cash capital = Gross revenue / Total cost of cash inputs. 5) Benefit-cost ratio = Gross revenue / Total costs including imputed cost of family labor and exchange labor.

Larger farms obtain higher returns to family labor. Tercile 3 farms used less than half the family labor inputs of farms in tercile 1 (14 days, vs 33 person days/acre) and obtained returns to family 2.9 times higher than farmers in tercile 3 (MMK 4,253 and MMK 12,268 per day, respectively). This means that members of tercile 3 households earn almost three times more income per capita from their labor inputs into maize cultivation than members of households in tercile 1 (Figure 12).

Figure 12 Returns to family labor, by landholding and cropping pattern



Returns to family labor exceed the average agricultural wage, for farms of all sizes. Even among farms in tercile 1, the average daily return from maize cultivation is greater than the average daily wage (MMK 4,253, vs MMK 4,039). Maize farming incomes thus exceed the opportunity cost farmers' time, even for the third farms with the lowest family labor productivity.

Maize farms of all sizes are profitable on average, even after accounting for the cost of family labor. Smallholder agriculture is often unprofitable after accounting for the cost of family labor. This is not the case for the maize farms surveyed, as farms in all terciles earned positive gross margins, even after factoring in the imputed cost of family labor. Never-the-less, the gross margin earned by farmers in tercile 1 after accounting for family labor is extremely low (MMK 6249/acre); 18 times less than that earned by farms in tercile 3 (MMK 115,398/acre). Expressed in different terms, maize farms in tercile 1 had an average benefit-cost ratio of 1.02, indicating that they broke even after accounting for the cost of family labor. The average benefit-cost ratios of farms in tercile 2 and 3 were 1.35 and 1.64, respectively, meaning that they earned profits of MMK 350 and MMK 640 for every MMK 1000 invested. This suggests that larger farms allocate labor more efficiently on average than small and medium farms. Considering cropping patterns, the average benefit-cost ratio of monocropped maize parcels (1.44) was slightly higher than that of intercropped maize-pigeon pea parcels (1.36), indicating that monocropping is more profitable when the cost of family labor is take into consideration.

Farms report making a profit or breaking even on more than 80% of maize harvests. Respondents were asked to report the number of times that they had grown maize within the past 10 years, and the number of occasions during those years on which they had made a profit, broken even, or made a loss. Farmers reported making a profit in more than half (55%) of their crops, and breaking even on around one-quarter (27%), with losses reported on just 17% of crops (Table 23).

Table 23 Share maize growers making profit, breaking even, and losing money during the past 10 years (%).

	Profit	Break even	Loss
Tercile 1	48	28	21
Tercile 2	57**	25	18
Tercile 3	56**	28	15**
Total	55	27	17

Note: *p<0.1; **p<0.05; ***p<0.01, as compared to landholding tercile 1.

Large farms are more likely to make a profit and less like to lose money than small farms. Although the incidence of profit, break even, and loss is quite similar among farms in all landholding terciles, small farms reported a significantly lower frequency of profitable crops than medium and large farms ($p<0.05$), and tercile 3 farms reported a significantly lower frequency of losses than tercile 1 or tercile 2 farms ($p<0.05$) (Table 23). These results are consistent with findings on variation in profitability by farm size.

5 Crop marketing and credit

5.1 Crop Marketing

Almost all maize and pigeon pea is produced for sale. Smaller maize growers are slightly more likely to than those in other terciles to retain some maize for home use. Eighty-eight percent of maize producers in tercile 1 sold maize, as compared to 98% in of those in tercile 3. Ninety-one percent of pigeon pea growers who harvested pigeon pea sold their crop. Seventeen percent of pigeon pea growers did not harvest their monsoon 2017 crop because it was not profitable to do so following the collapse of pigeon pea prices due to restrictions placed by India on pulse imports from Myanmar. All most all the harvested maize (99%) and pigeon pea (95%) was sold (Table 24). Very little maize or pigeon pea was retained for own consumption, gifted or used as in-kind payment for hired labor.

Table 24 Share of maize/pigeon pea growers selling crop and the share of quantity sold

	Tercile 1	Tercile 2	Tercile 3	All
Share of maize growers selling maize (%)	88	95	98	95
Share of PP growers selling harvested PP	86	95	91	91
Marketed surplus of maize (in quantity) (%)	97	99	100	99
Marketed surplus of PP (in quantity) sold	92	98	95	95

Farms with larger landholdings earn slightly higher prices for their maize, irrespective of timing of sale. During October-March (the months when large numbers of farms of all sizes sold maize), the average maize price received by farms in landholding tercile 1 (MMK 219/kg) was 4.4% lower than the average price earned by farms in tercile 2 (MMK 229/kg), and 10.6% than lower ($p<0.01$) than the average earned by farms in tercile 3 (MMK 245/kg). The average price earned by farms in tercile 2 was 6.5% lower ($p<0.01$) than the average price obtained by farms in tercile 3 (Figure 13). One possible explanation for this price differential would be that there are differences in grain quality associated with seed choices made by farmers, with wealthier farmers more likely to plant more expensive seeds that produce large, uniformly sized grains, although regression results in Table 35 in Section 6 do not support this inference.

The maize price received by farmers corresponds closely to timing of sale. The main period for maize sales runs from October to March. Sales begin in earnest in October, pick up further in November, reach their peak in December and January, and begin to slow down February and March. Maize prices were at their lowest at the beginning of the 2017 harvesting season, and climbed steadily thereafter, particularly from January onward (Figure 14). This price progression may reflect both grain supply (which begins to diminish after January), and grain moisture content (before the end of the monsoon season farmers sometimes have difficultly drying harvested maize, resulting in grain with a moisture content over the preferred 14-15%, which is purchased at discounted prices).

Figure 13 Average maize prices received by landholding tercile

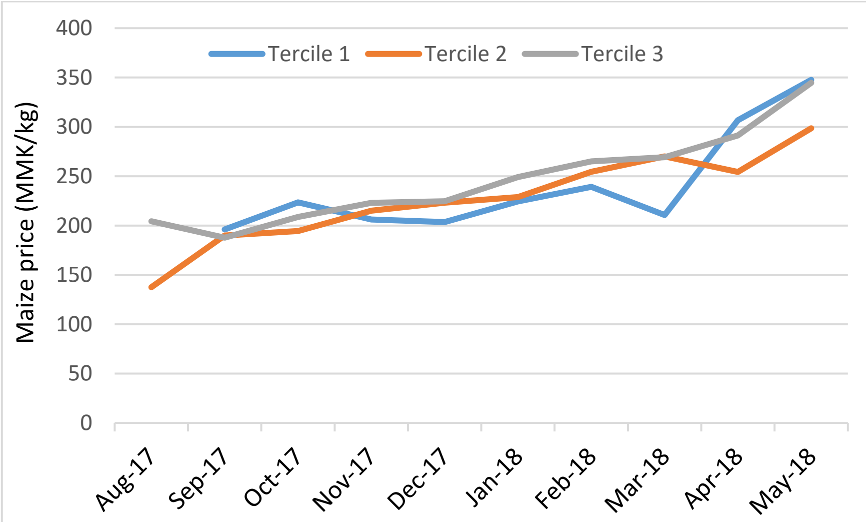


Figure 14 Distribution of maize sales by date and landholding tercile

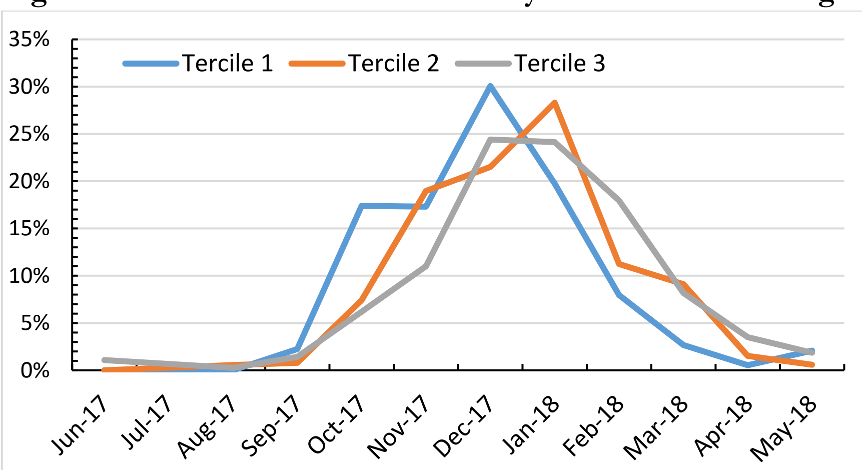
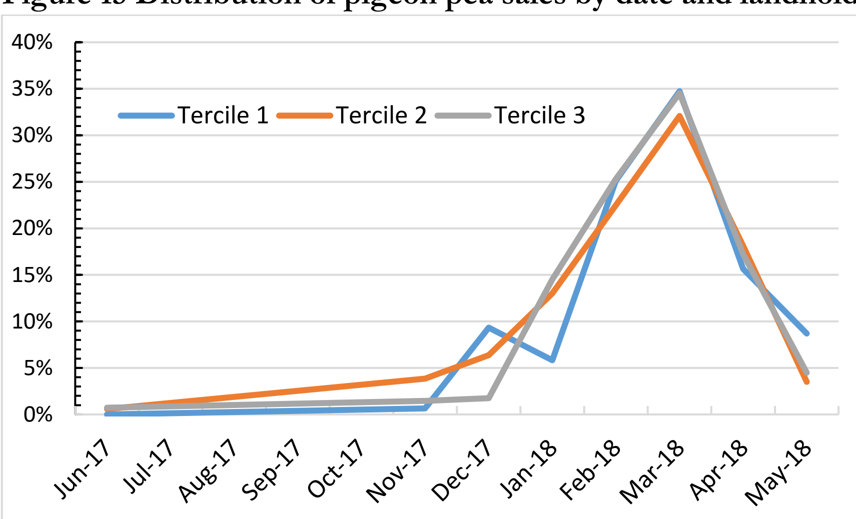


Figure 15 Distribution of pigeon pea sales by date and landholding tercile



Smaller farms harvest and sell maize earlier than large farms. The average date of maize harvest by farms in tercile 1 is 16 days earlier than for those in tercile 3, and the date of first sale is 17 days earlier (Both the harvest date and sales date of the farms in tercile 2 and 3 are significantly later than those in tercile 1). The number of days between harvest and first sale averages 19 days, and varies little with landholding, suggesting that most farms make their first sale as soon as the crop is processed and dried (Figure 14, Table 25).

Timing of pigeon pea harvest and sales is unrelated to landholding size. Pigeon pea sales are concentrated in a shorter period than maize sales. Peak months are February and March. Timing of pigeon pea sales is unrelated to landholding size. Most farmers (91%) sold pigeon pea on a single occasion, likely because the quantity produced was small (Figure 15, Table 25).

Table 25 Average date of maize and pigeon pea harvest and first sale, by landholding tercile

	Maize			Pigeon pea		
	Harvest date	Sales date	Days between harvest & first sale	Harvest date	Sales date	Days between harvest & first sale
Tercile 1	Nov. 7	Nov. 28	18	Jan. 24	Feb. 20	26
Tercile 2	Nov. 18**	Dec. 11**	18	Jan. 20	Feb. 10	20
Tercile 3	Nov. 23***	Dec. 14***	20	Jan. 24	Feb. 16	22
All	Nov. 18	Dec. 10	19	Jan. 22	Feb. 15	23

Note: Average date of harvesting/selling maize/PP is estimated based on reported month of harvesting/selling maize. *p<0.1; **p<0.05; ***p<0.01

Farms with larger landholdings are more likely to make multiple maize sales. Eighteen percent of maize growers sold maize on two occasions, and 4% sold maize on three occasions. One quarter (27%) of maize growing households in landholding tercile 3 sold maize on two occasions, as compared to 7% of those in tercile 1. This pattern likely reflects the small quantities of maize produced by households with limited land, and the inability of relatively poorly resourced households to delay sales (Table 26).

Table 26 Number of crop sales by maize and pigeon pea farmers, by landholding tercile

Number of crop sales	Tercile 1	Tercile 2	Tercile 3	All
Maize growers (%)				
No sale	9	4	3	5
Single sale	91	96	97	95
Two sales	7	15	27	18
Three sales	1	2	6	4
Pigeon pea growers (%)				
No sale	7	7	10	9
Single sale	93	93	90	91
Two sales	3	4	2	3
Three sales	0	0	<1	<1

Farmers with maize cultivation loans sell their maize later than those without. Receiving credit enabled households to sell maize approximately one to two weeks later than they would have done without a loan. Differences in the timing of sales between the two groups are significant for all maize growers ($p<0.01$), and those in landholding tercile 1 ($p<0.05$) and tercile 3 ($p<0.1$) (Table 27). Thus, rather than forcing indebted farmers to sell maize earlier than they would have preferred, it appears that, particularly for the smallest farmers, access to trader credit relieved pressure to sell quickly. This suggests that the price advantages of delaying payment can offset the costs of interest payments on in-kind loans.

Table 27 Average date of first sale of maize, by cultivated landholding tercile and by whether the maize growers took credit for maize farming

	Harvest date			Sales date		
	Not taking maize credit	**Taking maize credit**	**Diff. (days)**	**Not taking maize credit**	**Taking maize credit**	**Diff. (days)**
Tercile 1	November 2	November 19	17***	November 23	December 11	18**
Tercile 2	November 17	November 19	2	December 7	December 14	7
Tercile 3	November 20	November 28	8**	December 11	December 19	8*
All	November 15	November 23	9***	December 6	December 16	10***

Note: Average date of harvesting/selling maize is estimated based on reported month of harvesting/selling maize. *$p<0.1$; **$p<0.05$; ***$p<0.01$

5.2 Credit

Most farms obtain maize seed and fertilizer without using in-kind credit. Most maize growers used cash to purchase maize seed fertilizer. Only 29% of maize farms obtained maize seed as in-kind credit, with 24% obtaining fertilizer in this way (Table 28). There were no maize growers who received only fertilizer as in-kind credit (i.e. all growers received only maize seed, or both maize seed and fertilizer as in-kind credit). Almost all purchased pigeon pea seed (97%) was obtained without credit.

Most cash used to pay for maize seed and fertilizer originates from agricultural earnings. Sixty-three percent of maize farming household utilized savings to fund purchases of maize seed and fertilizer. Eighty-four percent of households who used savings to purchase maize seed accumulated them from agriculture. Farmers with limited land were more likely to use savings from non-agricultural activities to fund maize seed purchases. For example, 28% of the tercile 1 farmers used savings from non-agricultural activities, compared to only 14% of farmers in tercile 3. Only 9% of farmers used cash that had been borrowed (fully or partially) to purchase maize seed and fertilizer (Table 28).

Small farms have less access in-kind credit than large farms. Only 19% of maize farming households in tercile 1 obtained maize seed as in-kind credit, compared to 30% of maize farms belonging to landholding tercile 3 (Table 28). We hypothesize that this reflects a preference among providers of in-kind credit to lend to farmers with large landholdings because they buy large quantities of inputs, represent relatively low credit risks, and – if the credit is tied – supply large volumes of harvested maize. The shares of households that obtained fertilizer as in-kind credit are slightly lower than those who purchased maize seed in this way.

Table 28 Share of maize growers obtaining maize seed and fertilizer for cash payment or as in-kind credit, by landholding tercile

Source of funds for maize seed & fertilize	Tercile 1	Tercile 2	Tercile 3	All
Maize seed				
Received as in-kind credit (%)	19	35	30	29
Paid in cash (%)	77	69	73	73
Cash all borrowed (%)	5	5	8	6
Cash partly borrowed (%)	4	5	1	3
Cash all saved (%)	68	60	63	63
Savings from agriculture (%)	77	81	89	84
Saving from non-farm sources (%)	28	19	14	18
Inorganic fertilizer				
Received as in-kind credit (%)	15	30	24	24
Paid in cash (%)	66	64	72	68
Cash all borrowed (%)	4	2	3	3
Cash partly borrowed (%)	2	1	2	2
Cash all saved (%)	60	61	66	63
Did not purchase fertilizer	19	6	5	8
Maize seed and inorganic fertilizer				
Received in-kind credit for:				
Both maize seed and fertilizer	15	30	24	24
Only maize seed	3	5	6	5
Only fertilizer	0	0	0	0
Neither maize seed nor fertilizer	81	65	70	71

Note: (1) Pigeon pea growers who did not grow maize are not included in this table. (2) Some maize growers paid seed in both cash and in-kind credit, so total share can be larger than 100%.

Maize growers with larger landholdings are most likely to take output-tied loans. One-third (27%) of maize growers in landholding tercile 1 took credit for maize farming (including all cash and kind loans for maize seed, fertilizer, other inputs, and labor), as compared to 47% and 40% of tercile 2 and 3 growers did, respectively. Approximately one-third of the maize growers who took credit for maize cultivation reported that it was output-tied (i.e. committed them to sell harvested maize to the loan provider). Interestingly, maize growers with more land are more likely to take output-tied loans than those with little land. The share of maize growers taking output-tied loans rises from just 4% in landholding tercile 1 to 14% in landholding tercile 3 (Table 29).

Few recipients of output-tied credit reported sell maize sooner than they would have preferred in order to repay the loans. Only 8% of maize farmers who availed credit did so. Larger famers were more like to report having sold more quickly than they preferred than small farms (as reported by 12% of tercile 3 farms that availed credit, versus 1% of tercile 1 farms).

Table 29 Share of maize growers taking credit for maize farming and tied credit, by cultivated landholding tercile

% of maize growers…	T1	T2	T3	All
Taking credit for maize farming	27	47	40	40
Committed to sell to credit provider (among all maize growers)	4	10	14	11
Committed to sell to credit provider (among maize growers taking credit)	15	21	34	27
Selling sooner than preferred to repay loan (among all maize growers)	0	3	5	3
Selling sooner than preferred to repay loan (among maize growers taking credit)	1	6	12	8

Note: These figures are based on loans for maize seed, fertilizer, other inputs, and labor for maize farming

Larger farms avail the majority of in-kind credit in terms of value. The largest third of farms (tercile 3) avail two thirds (65%) of the total value of in-kind credit availed for purchases of seed and fertilizer for maize cultivation, whereas the smallest third of farms avails only 8% of the total value of in-kind maize farming credit. This spread corresponds closely with the distribution of land among farmers in the three terciles. As reported by Win and Zu (2019), in South Shan, farm households in landholding tercile 1 (including both maize and non-maize growers) own 9% of agricultural land, while those in tercile 3 own 67%.

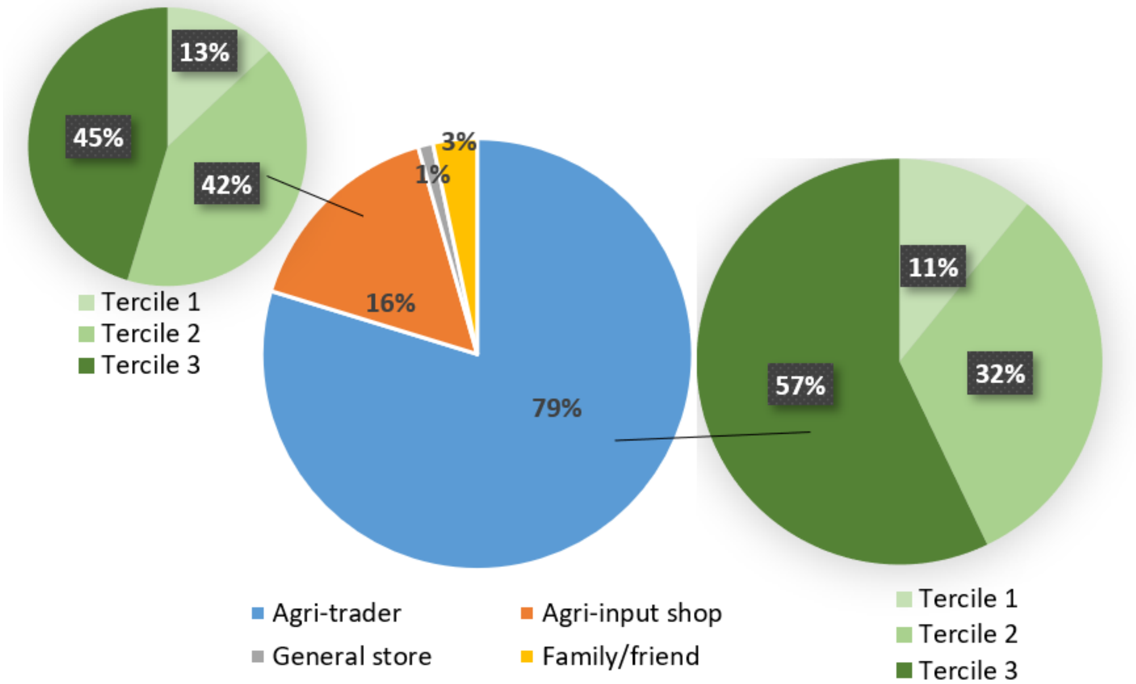
Table 30 Share of value of maize seed and fertilizer purchased as in-kind credit and cash down among maize growers by landholding tercile

Source of funds for maize seed & fertilizer	Tercile 1	Tercile 2	Tercile 3
Maize seed			
Received as in-kind credit (%)	6	22	72
Paid in cash (%)	7	22	71
Both	7	22	71
Inorganic fertilizer			
Received as in-kind credit (%)	10	31	59
Paid in cash (%)	10	25	66
Both	10	27	64
Maize seed and inorganic fertilizer			
Received as in-kind credit (%)	8	27	65
Paid in cash (%)	8	23	68
Both	8	24	67

Note: 1) Pigeon pea growers who did not grow maize are excluded from this table.

Traders are the main providers of in-kind credit to maize farmers. Seventy-nine percent of households who received in-kind credit obtained it from traders, whereas 16% obtained it from input supply shops (Figure 16). This is consistent with findings from Cho and Belton (2019), who report that traders provide in-kind credit to maize farmers more frequently than input suppliers. Farms in landholding tercile 1 account for 11% of recipients of in-kind credit provided by traders and input suppliers, while farms in tercile 3 make up 57% of in-kind credit recipients.

Figure 16 Share of farmers accessing in-kind credit by type of lender, and share of borrowers by landholding tercile



Most loans are taken during planting season and repaid after harvest. Close to 90% of borrowing to fund maize cultivation took place in the months of May to July, peaking in June, when more than three quarters of all loans were taken. Most in-kind loans (79%) were repaid around harvest time (October-February) (Table 31).

Table 31 Share of maize growers taking and repaying cash and in-kind loans for maize seed, by month and landholding tercile

	Cash					In-kind				
	HH taking loans (%)	Households repaying loans (%)				HH taking loans (%)	Households repaying loans (%)			
Month	All	All	T1	T2	T3	All	All	T1	T2	T3
May	7	12	0	30	4	10	8	1	11	7
Jun	75	9	67	0	0	78	1	4	0	1
Jul	5	0	0	0	0	2	1	0	0	1
Aug	0	8	0	26	0	0	0	0	0	0
Sep	0	0	0	0	0	0	1	5	0	1
Oct	0	0	0	0	0	0	4	15	6	1
Nov	0	3	17	0	2	0	12	16	13	11
Dec	0	19	0	14	27	3	18	28	19	16
Jan	12	28	16	15	38	4	26	23	23	29
Feb	0	5	0	0	8	1	19	0	18	23
Mar	1	10	0	8	14	1	6	6	9	5
Apr	0	4	0	0	7	1	3	1	2	5

Small farms tend to repay in-kind loans earlier than large farms. For instance, 15% of farmers in tercile 1 repaid in-kind loans in October, and none repaid in February, whereas only 1% of those tercile 3 repaid in October and 23% repaid in February. The difference in the timing of sales is not necessarily a function of having availed credit, as it is consistent with the tendency documented above for smaller farmers to sell maize quickly after the harvest due to the need to generate cash incomes, whether or not they had outstanding loans. The pattern of repayment of cash loans is somewhat less clear cut, with around half repaid in December and January and the remainder of repayments distributed across other months (Table 31).

Small farmers do not pay higher rates of interest for in-kind credit. The average rate of interest paid for maize seed received as in-kind credit was a flat rate of 3.9% per month, with an average loan duration of 7.9 months. Monthly interest rates for in-kind borrowing of compound fertilizer and urea are both slightly lower than for maize seed, at about 3.3%, with average loan durations are also slightly shorter at 7.3 months. The rates of interest paid do not vary significantly by landholding tercile. Maize growers availing in-kind credit pay approximately 30% more for inputs than those buying inputs outright in cash (Table 32).

Table 32 Terms of interest on in-kind purchases of maize seed and fertilizer, by landholding tercile

	Tercile 1	Tercile 2	Tercile 3	All
Maize seed				
Average loan duration (months)	7.6	8.0	7.9	7.9
Interest rate (%/month)	2.9	3.9	4.0	3.9
Price of seed (MMK/kg)	5723	5988	5354	5611
Total interest paid (MMK/kg)	1257	1894	1703	1715
Total interest paid (%)	22	32	32	31
Compound & Urea fertilizer (combined)				
Average loan duration (months)	7.3	7.4	7.3	7.3
Interest rate (%/month)	3.1	2.8	3.8	3.3
Price of compound/urea (MMK/kg)	514	463	459	469
Total interest paid (MMK/kg)	114	95	128	115
Total interest paid (%)	22	21	28	24

Note: Interest on in-kind loans usually takes one of two forms: (1) a fixed markup on each unit of product purchased (e.g. an additional MMK 1000 per bag of seed); (2) a flat monthly interest rate paid on the value of goods procured on credit. The interest rates reported in this table are an amalgam of both forms of interest. Cash borrowed is excluded because of the small number of observations.

Some farms report paying no interest on in-kind loans. Seventeen percent of farmers reported paying no interest on in-kind loans of maize seed, as compared to 5% of farmers borrowing cash to pay for maize seed. This share varies little by landholding tercile and is similar for both maize seed and fertilizer

Taking credit did not significantly affect the sales price obtained by maize growers. The average maize sales price received by farms that borrowed to fund maize cultivation was the same as the price received by farms that did not take credit (both MMK 236/kg). Maize growers in landholding tercile 2 who took credit received significantly lower ($p<0.01$) price than those who did not (MMK 218/kg and MMK 238/kg, respectively), but farms in tercile 3 that had availed credit received significantly higher price (p<0.05) than those that did not (MMK 251/kg vs. MMK 241/kg). There was no significant difference in the price received for maize by farms in tercile 1, irrespective of whether they had taken credit (Table 33).

Table 33 Mean maize sales price (MMK/kg), by credit utilization and landholding tercile

		Took credit for maize farming			Committed to sell maize to the credit provider		
	All	**No**	**Yes**	**(Y-N)**	**No**	**Yes**	**Y-N**
Tercile 1	219	216	224	7	219	207	-12
Tercile 2	229	238	218	-20***	229	222	-8
Tercile 3	245	241	251	11**	243	258	15**
All	236	236	236	0	235	245	10*

Note: *** p<0.01, ** p<0.05, * p<0.1

Maize growers who received output-tied credit received higher prices for their maize than those who did not. This result was found to be significant (p<0.1) for all farms, and those in tercile 3 (p<0.05), but not for farms in terciles 1 or 2. The results demonstrate conclusively that farmers are not coerced into selling harvested maize at below prevailing market rates by credit providers. Rather, it speaks to the existence of a highly competitive market for crop sales, in which farmers can easily find alternative buyers if prices offered are perceived to be inadequate.

6 Regression results

Section 5 presents descriptive results suggesting that maize sale prices, yields, and gross margins may be affected by wide range of factors including credit utilization, farm size, input use, and labor use decisions. However, in each case, only univariate relationships are analyzed, and possible mechanisms for action are inferred inductively. In reality, these outcomes are the result of multiple factors working simultaneously. In this section we present three ordinary least squares (OLS) regressions to control for the simultaneous relationships between multiple variables hypothesized to affect: (1) maize prices received by farmers; (2) maize yields; (3) gross margins of maize per acre. We test the strength of these relationships and their significance. The definitions and means of the variables used in the regressions are presented in the Appendix (Tables A7, A8, and A9).

6.1 Maize sales prices

Table 34 presents results controlling for a range of potential factors using OLS regressions. The dependent variable is the unit maize price (i.e. MMK/kg). Transportation cost has been subtracted from the maize price, so the maize price here is the farmgate price. We first test the hypothesis that maize farmers who took credit received lower maize sale prices, accounting for availing cash loan or in-kind credit for inputs and labor, and commitment to sell harvested maize to the credit provider. In subsequent regressions, we control for other factors considered likely to affect maize price. These include: (a) timing of sale; (b) factors that might affect maize quality (e.g., varieties planted, input use, soil quality); (c) farmer characteristics (e.g. landholding size, years of experience, ethnicity).

The first regression starts with the most parsimonious specification, with only the variables related to taking credit for maize farming. The results show there is no significant difference in the maize sales price received by farmers who took credit for maize seed and fertilizer, and those who did not. Furthermore, there was no difference in the price received by farmers who were committed to sell maize to a credit provider, and farmers who were not. Taking credit to pay for the labor for weeding helped farmers receive a significantly higher maize price. These results support the conclusion from Section 5 that farmers are not coerced into selling harvested maize at below prevailing market prices by credit providers.

The next three regressions control for other factors that could affect the maize sales price, by gradually adding variables related to the timing of sale, factors that might affect maize quality, and maize farmer characteristics. The variable of taking credit for labor for weeding turns insignificant after controlling these other factors. Therefore, our above conclusions regarding the associations with taking credit for maize cultivation stand after adding these control variables. The results of the full model also verify our conclusion in Section 5 that maize farmers who sold their maize later in the year received higher prices than those who did not, with farmers making sales outside of 'high' season receiving MMK 32/kg more for their crops. Similarly, farmers who sold maize on two or three occasions received significantly higher prices for these sales than for their first sales.

Table 34 Regressions on the relationship between maize price and credit taking, timing of sale, factors related to maize quality, and farmer characteristics

	(1) Taking credit for maize farming	(2) With timing of sale	(3) With factors related to maize quality	(4) With seller characteristics
Took cash loan for maize seed, fertilizer	-7.445	-5.088	-6.948	-6.463
	(11.750)	(10.761)	(10.586)	(9.252)
Took in-kind credit for maize seed, fertilizer	4.163	5.401	2.987	2.340
	(8.607)	(8.905)	(8.153)	(6.483)
Took credit for labor for planting maize	6.347	1.896	2.226	3.976
	(6.079)	(9.880)	(8.838)	(7.987)
Took credit for labor for weeding	12.926**	11.848**	5.861	4.166
	(5.749)	(4.526)	(10.807)	(6.525)
Committed to sell maize to the credit provider	7.308	7.978	6.707	3.975
	(4.834)	(5.324)	(4.157)	(3.189)
2nd maize sale of the year (based = 1st sale)		18.529***	16.186***	12.607***
		(2.552)	(1.743)	(2.477)
3rd maize sale of the year (based = 1st sale)		27.140***	22.209***	16.527**
		(5.808)	(6.662)	(5.898)
Sold maize in high season		-34.685***	-32.986***	-31.839***
		(2.150)	(1.422)	(2.241)
Seed variety: CP 808 (base = local)			12.047	5.688
			(7.026)	(6.793)
Seed variety: CP 888 (base = local)			-19.462	-22.035
			(11.663)	(13.777)
Seed variety: Other CP (base = local)			-2.258	-4.299
			(12.335)	(13.051)
Seed variety: Other cheap hybrid (base = local)			6.499	1.058
			(7.861)	(8.909)
Seed variety: Other expensive hybrid (base = local)			3.808	0.413
			(10.790)	(10.795)
Inorganic fertilizer application rate (100 kg/acre)			-0.338	-0.138
			(2.001)	(2.080)
Whether used pesticide			0.359	-1.282
			(7.739)	(7.423)
Whether used herbicide			-6.576	-5.951
			(8.523)	(5.677)
Soil quality: Fair (base = good)			-3.534	-1.183
			(2.008)	(2.771)
Soil quality: Poor (base = good)			-16.850***	-11.133***
			(3.279)	(2.211)
Buyer from local village tract				4.355
				(6.625)
Buyer's ethnicity same as the HH head				-0.807
				(1.489)
Landholding Tercile 2 (base = Tercile 1)				1.713
				(5.591)
Landholding Tercile 3 (base = Tercile 1)				16.514***
				(1.550)
No. of years growing maize in past 10 years				1.416**
				(0.458)
Whether control HH head characteristics (age, gender, education)	No	No	No	Yes
Whether control location (township)	Yes	Yes	Yes	Yes
Observations	1,003	1,003	1,003	998
R-squared	0.053	0.192	0.246	0.294
AIC	10666	10507	10437	10316

Note: Authors' compilation based on SHARES. Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

We expected maize farmers who planted higher quality seeds (e.g. CP 808) to receive higher prices for their harvested maize than those who did not. Farmers with larger landholdings were more likely to adopt high-quality, expensive seed varieties. However, our results show that buyers were indifferent to seed variety when purchasing maize. With various variables controlled in the full model (regression 4), farmers in landholding tercile 3 still earn MMK 17/kg more for their maize than those in landholding tercile 1. A possible explanation could be that large farmers have better relationships with buyers, enabling them to receive higher prices. Maize planted on good-quality soil sold at MMK 11/kg more than the maize planted on poor-quality soil. It is possible that the quality of the maize grown on higher quality soil was better. More experienced maize farmers received a marginally higher maize price, perhaps because they were better at negotiation or buyer identification.

6.2 Maize yields

Table 35 presents the relationship between the maize yield of sample parcels and variables related to taking credit for maize farming, as well as other factors believed to affect maize yield, including seed variety, soil quality, seed and fertilizer application rate, technology use, and labor use. We use the maize yield of sample parcels because most of the detailed explanatory variables we collected were at the sample parcel level. Because those data are not at household level, we did not use sample weights in the regressions here. We also follow this method while running regressions on gross margins.

Credit for maize cultivation is generally used for purchasing seed and fertilizer or hiring labor. As input use can affect maize yield, taking loans can affect maize yields indirectly. Maize yield is sensitive to the timing of activities including planting and first weed control. To capture this, in addition to the variable of taking credit for maize seed and fertilizer, we added two variables; taking credit for labor for planting maize, and taking credit for weeding. These variables are included in regression 1. More and higher-quality input use is expected to increase maize yield. These variables are included in regression 2. Regression 3 adds maize growers' characteristics (e.g. number of years growing maize in the past 10 years, landholding size). The dependent variable is simply the maize yield (kg/acre).

Taking cash loans or in-kind credit can increase farmers' access to inputs, but the cost of interest could also reduce input application rates, which would decrease maize yield. Our results show that maize yields do not differ significantly between growers who obtain seed and fertilizer on credit and those who do not, regardless the source being cash loan or in-kind credit. Interestingly, growers who used credit to hire labor for weeding obtained 154 kg/acre higher maize yields than those did not. This striking result suggests that some maize growers may not know the effect of weed control on yields, or that they lack financial resources to hire labor after paying for seed and fertilizer. Increasing inputs of family labor and hired labor both increase maize yields. An additional one person-day per acre of hired labor or family labor increases maize yield results by 7.6 kg/acre and 1.8 kg/acre, respectively.

Table 35 Regressions on the relationship between maize yield and credit taking, timing of sale, factors related to maize quality, and farmers characteristics

	(1)	(2)	(3)
	Taking credit for maize farming	With farming practice	With farmer characteristics
Took cash loan for maize seed, fertilizer	35.928	72.369	70.588
	(66.888)	(66.568)	(70.420)
Took in-kind credit for maize seed, fertilizer	14.164	-16.921	-17.563
	(35.792)	(42.617)	(40.581)
Took credit for labor for planting maize	43.480	-67.206	-49.803
	(118.720)	(110.939)	(113.048)
Took credit for labor for weeding	238.507***	187.133***	154.033**
	(60.066)	(51.917)	(61.113)
Soil quality: Fair (base = good)		-74.236**	-75.661**
		(29.688)	(33.618)
Soil quality: Poor (base = good)		-330.116***	-316.467***
		(40.552)	(42.490)
Seed variety: CP 808 (base = local)		387.595***	402.870***
		(51.079)	(48.255)
Seed variety: CP 888 (base = local)		253.031**	270.910***
		(83.857)	(77.382)
Seed variety: Other CP (base = local)		337.240***	345.554***
		(85.398)	(79.843)
Seed variety: Other cheap hybrid (base = local)		287.142***	294.771***
		(48.313)	(41.470)
Seed variety: Other expensive hybrid (base = local)		307.256***	319.250***
		(44.036)	(38.543)
Maize seed application rate (kg/acre)		65.566***	61.837***
		(11.301)	(10.692)
Inorganic fertilizer application rate (100 kg/acre)		47.326***	51.237***
		(9.910)	(9.849)
Whether used manure		116.009*	92.123
		(57.710)	(57.714)
Whether used pesticide		-115.908***	-106.420***
		(28.986)	(26.754)
Whether used herbicide		96.323	94.082
		(54.928)	(63.679)
No. of hired labor days per acre		7.847***	7.599***
		(0.765)	(0.808)
No. of family labor and exchange labor person days per acre		1.722*	1.835**
		(0.799)	(0.802)
Pigeon pea intercropped w/ maize		-17.478	-24.038
		(25.918)	(28.708)
Landholding Tercile 2 (base = Tercile 1)			125.408**
			(51.910)
Landholding Tercile 3 (base = Tercile 1)			76.579
			(51.263)
Formal land tenure			59.873
			(40.824)
No. of years growing maize in past 10 years			5.227*
			(2.612)
Whether control HH head characteristics (age, gender, education)	No	No	Yes
Whether control location (township)	Yes	Yes	Yes
Observations	800	800	798
R-squared	800	800	798
AIC	12333	12118	12067

Note: Authors' compilation based on SHARES. Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Rural-urban migration is accelerating rapidly in southern Shan (Thu et al, 2019), and is likely to make agricultural labor increasingly scarce in coming years. This suggests that further small-scale mechanization will become necessary, particularly for weeding (land preparation and maize shelling are already heavily mechanized). In the absence of mechanized weeding, use of herbicides is likely to increase as an alternate means of labor saving, with significant environmental and health risks. In the meantime, increasing the availability of loans to cover the cost of hiring labor could contribute to increases in maize productivity.

As expected, higher maize seed and fertilizer application rates bring higher yields. Applying an additional 1 kg of maize seed per acre increases yields by 62 kg/acre, while applying an additional 100 kg of inorganic fertilizer per acre increases yields by 51 kg/acre. Also in line with expectations, hybrid seed varieties generate much higher yields than local maize varieties. The most expensive seed, CP 808, produces the highest yields; 403 kg/acre higher than local varieties. Other cheaper hybrids generate yields that are higher than local seed varieties, but slightly lower than expensive hybrid varieties (e.g. the yield of CP 888 is 271 kg/acre higher than that of local varieties). Regarding soil quality, the yield from plots with soil quality subjectively assessed as 'good' is 316 kg/acre higher than from plots with 'poor' soil quality. Plots with fair quality soil also generate slightly higher (76 kg/acre) yields than those with poor soil. Growers who used pesticide obtained maize yields 106 kg/acre lower those who did not. This indicates that pesticides were used primarily in the event of pest attacks that lower yields.

We also controlled for maize farmers' characteristics. Our result shows that each additional year of experience of growing maize during the past 10 years earns farmers 5 kg/acre higher yields. With respect to cultivated landholding size, only the yield for farms in landholding tercile 2 is significantly higher than tercile 1, which is consistent with results presented in Section 4.

6.3 Maize gross margins

Table 36 presents regression results on how maize gross margins are affected by factors including credit, farming practices, and farmer characteristics. As credit for maize cultivation can facilitate access to production inputs and labor but also represents an additional cost to farmers, it has the potential to influence farm profitability.

The dependent variable is the gross margin per acre of monocropped maize and intercropped maize-pigeon pea sample parcels (revenues from intercropped pigeon pea are included in the gross margin calculation). Variables related to taking credit for maize farming are all insignificant. This implies that gross margins are not significantly affected by whether farmers take credit for maize farming, regardless of the source being cash loan or in-kind credit, and regardless of whether the credit is output-tied (i.e. commits to recipients to sell harvested maize to the credit provider). This demonstrates again that maize growers are not disadvantaged by availing credit through traders or input suppliers, regardless of landholding size. Farmers planting maize on parcels with soil quality rated 'good' received significantly higher gross margin per acre than those planting on 'fair' or 'poor' quality plots, suggesting that advice on soil conservation measures has potential to benefit the maize growers.

Table 36 Regressions on the relationship between maize gross margin per acre and credit taking, farming practices, and farmers characteristics

	(1)	(2)	(3)
	Only vars related to credit taking	With farming practice	With farmer characteristics
Took cash loan for maize seed, fertilizer	13,046	14,542	13,049
	(23,665)	(24,910)	(26,170)
Took in-kind credit for maize seed, fertilizer	-3,047	-13,921	-14,412
	(15,061)	(16,799)	(16,817)
Took credit for labor for planting maize	-7,145	-20,052	-17,658
	(17,721)	(13,313)	(15,742)
Took credit for labor for weeding	22,923	25,702	20,481
	(26,888)	(25,510)	(25,857)
Committed to sell maize to the credit provider	3,280	9,699	6,817
	(7,541)	(9,673)	(9,833)
Soil quality: Fair (base = good)		-21,716**	-19,412**
		(7,525)	(7,452)
Soil quality: Poor (base = good)		-89,679***	-81,694***
		(12,287)	(11,170)
Seed variety: CP 808 (base = local)		66,425***	62,518***
		(15,077)	(14,741)
Seed variety: CP 888 (base = local)		21,081	22,089
		(19,845)	(20,674)
Seed variety: Other CP (base = local)		43,184*	41,843*
		(20,165)	(22,067)
Seed variety: Other cheap hybrid (base = local)		44,841**	40,882**
		(14,536)	(15,076)
Seed variety: Other expensive hybrid (base = local)		54,900***	55,056***
		(14,695)	(15,348)
Maize seed application rate (kg/acre)		6,313***	6,624***
		(1,631)	(1,863)
Inorganic fertilizer application rate (100 kg/acre)		8,045**	9,097**
		(2,911)	(3,248)
Whether used manure		-6,145	-9,627
		(7,363)	(8,910)
Whether used pesticide		-37,050**	-35,033**
		(12,621)	(11,618)
Whether used herbicide		15,902	13,255
		(9,132)	(12,539)
No. of hired labor days per acre		-494	-609
		(563)	(545)
No. of family labor and exchange labor person days per acre		535	772
		(435)	(491)
Pigeon pea intercropped w/ maize		30,946***	24,067**
		(7,618)	(9,209)
Landholding Tercile 2 (base = Tercile 1)			42,819**
			(15,485)
Landholding Tercile 3 (base = Tercile 1)			50,579**
			(16,142)
Formal land tenure≠			5,173
			(7,986)
No. of years growing maize in past 10 years			911*
			(413)
Whether control HH head characteristics (age, gender, education)	No	No	Yes
Whether control location (township)	Yes	Yes	Yes
Observations	814	814	812
R-squared	0.056	0.163	0.184
AIC	21545	21447	21372

Note: Authors' compilation based on SHARES. Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1;
≠ Formal land tenure = in possession of Form 7 or Form 105 for sample parcel.

Although high-quality maize varieties such as CP 808 are expensive, they are a worthwhile investment: CP 808 adopters obtained gross margins MMK 62,518/acre higher than adopters of local varieties. Importantly however, growers who used cheaper hybrid seeds such as CP 888 did not obtain significantly higher gross margins than those who planted local varieties. This result helps to explain the persistence of farming local maize varieties despite very high levels of access to hybrid seed. Use of expensive higher-quality seed varieties is most common among larger farmers. This result suggests that smaller farmers are unwilling, or unable due to lack of access to credit, or risk aversion, to utilize expensive varieties. This finding could also point to supply side limitations, with traders and input suppliers preferring to sell limited stocks of the best quality seeds to favored customers.

As expected, gross margins are positively correlated with seed and fertilizer application rates, but these relationships are quite weak. Farmers using pesticides gained significantly lower gross margin per acre, suggesting pesticides are used primarily in the event of pest attacks that lower yields. Interestingly, although pigeon pea generates low revenues, intercropping maize with pigeon pea produces gross margins that are MMK 30,946 per acre higher than from maize monocropping. This may be linked to the nitrifying properties of leguminous pigeon pea, which might allow farmers to substitute the crop for inorganic fertilizer.

We also controlled for the characteristics of maize farmers. Maize growers in landholding tercile 2 and 3 received MMK 42,819 and MMK 50,579 more per acre respectively than those in tercile 1. As discussed in the maize price regression, wealthier farmers received higher sales prices. On the other hand, they may also benefit to some extent from cost savings due to economies of scale. This is shown in the profitability analysis in Section 4.6, where the wealthier maize growers receive higher revenues per acre while paying a similar amount for operating costs per acre. Maize growers also gain higher gross margins per acre with increasing years of maize cultivation experience, but the differences are small. There is no association between gross margins and the possession of formal use rights (Form 7 or Form 105) to the parcel used to cultivate maize, suggesting that formalizing land tenure will not raise farm profitability.

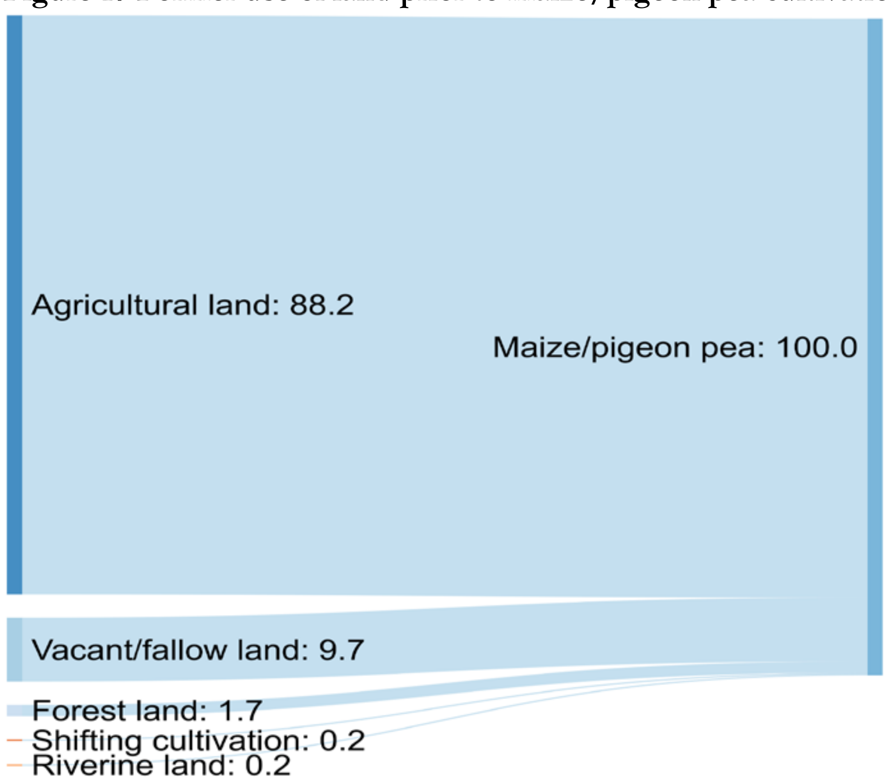
7 The evolution of maize farming

7.1 Land use change

The number of maize growers in our sample more than tripled from 224 to 817 between 2007 and 2017. These figures underline the extremely rapid rate at which maize cultivation in southern Shan has expanded over this period.

Farms with large landholdings started to grow maize earlier on average. On average, farms in landholding tercile 3 grew maize for the first time on the sample parcel four years earlier those in tercile 1 (2007 and 2011, respectively). There are two possible interpretations of this finding. First, households with larger landholdings have more financial resources and are more willing to risk devoting part of their land to new crop than households with less land and capital. Over time, smaller farmers with less land become familiar with maize cultivation and the costs and risks of cultivation fall due to clustering effects, as numbers of input suppliers and traders grow, making farmers more willing to allocate part of their land to maize. Second, landholding sizes are related to the lifecycle of the household. Recently formed households tend to have less land than those that are well established and have had time to accumulate and/or inherit land, so households in landholding tercile 1 have farmed for fewer years, and adopted maize more recently on average, than those tercile 3. Households on landholding tercile 1 acquired their sample parcels five years more recently than those in tercile 3 on average (2008 and 2003, respectively), lending some weight to the latter interpretation.

Figure 17 Former use of land prior to maize/pigeon pea cultivation



Most land currently used for maize/pigeon pea cultivation was under agricultural use prior to being put into production of these crops. Just over 10% of parcels of land currently used to grow maize/pigeon pea was 'vacant/fallow' or forest land at the time is was put into maize/pigeon pea cultivation, indicating that some expansion of these crops is occurring at the extensive margin. Interestingly only 0.2% of land was reported to have been used for shifting cultivation immediately before being used for permanent cultivation of maize/pigeon pea, suggesting that their cultivation has not been a major driver of agricultural sedentarization. Most land used to grow maize/pigeon pea (88%) was already under permanent crop cultivation at the time it was first planted to these crops by survey respondents (Figure 17).

The rate at which households have started to plant maize has outstripped the rate at which they acquire new land. Households were asked about the history of their 'sample parcel' (a randomly selected parcel of land, used at the time of the survey to cultivate maize/pigeon pea). Until 2012, households acquired new 'sample parcels' at a faster rate than they began to plant maize, though there was a strong relationship between year of land acquisition and year of first planting maize. From 2012 onward, the rate at which households began to plant land to maize outstripped the rate at which they acquired new sample parcels, suggesting that maize was increasingly substituted for part of the other crops grown by the household, rather than added as a new crop when additional land was acquired (Figure 17)

Most farmers have never planted a crop other than maize on their sample parcel since acquiring it. Just under one-quarter (23%) had done so, consistent with the finding that most households began planting maize when they acquired new land. The share of farmers having previously grown a crop other than maize varied little by landholding tercile (ranging from 20% in tercile 1 to 24% in tercile 2). Among households who had previously planted another crop, rice was by far the most common of these (58% of parcels), followed by groundnut and sesame (28%). Most rice replaced by maize was rainfed upland (*ya*) dry rice (grown on 46% of maize parcels formerly utilized for cultivation of other crops). Hill (*taungya*) rice was grown on 10% of previously utilized parcels. Interestingly, households with more land were more likely to have grown hill rice (reported on 14% of parcels for households in landholding tercile 3, as opposed to 1% of parcels for tercile 1). Rice previously grown on parcels later utilized for maize cultivation was used almost entirely for subsistence consumption, whereas oilseeds were grown for subsistence and sale in roughly equal portions.

Very few farm households have abandoned maize cultivation. Among all surveyed households (including both maize and non-maize growers), 224 reported having cultivated maize in 2007. Of these 224 households, 222 continued to do so in 2017.

7.2 Technological change

Many maize farmers grew local varieties of maize before growing hybrids. Nearly two-thirds (62%) of farmers who planted maize in 2007 grew local varieties of maize. The share of farmers planting local maize varieties declined to 39% in 2012, and 14% in 2017 (Table 37). This result indicates that maize was already an important commercial crop prior to the widespread uptake of hybrid seed.

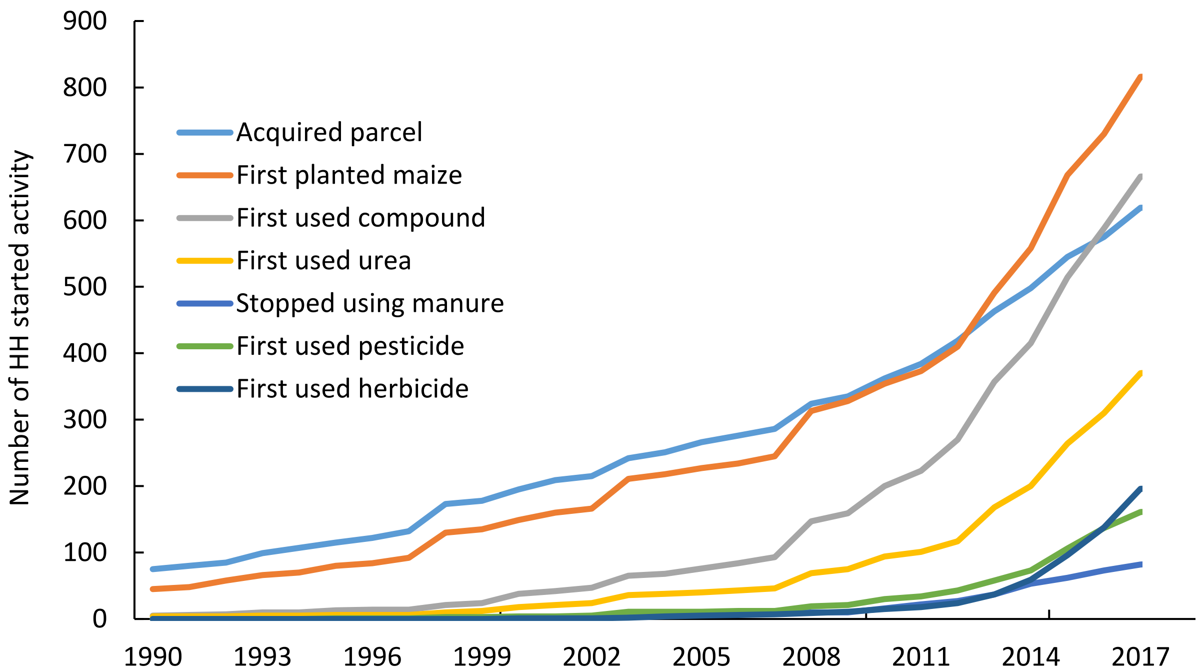
Table 37 Share of maize growers using different varieties of maize seed in 2007, 2012, and 2017

Item	2007	2012	2017
Number of HH growing	24,884	41,932	85,741
Share of HH growing variety (%)			
Local variety*	62	39	14
Hybrid	38	61	86
Among hybrid seed:			
Total CP hybrid	81	81	50
Total non-CP hybrid	19	19	50

NOTE: *Including Than Te variety

Hybrid maize cultivation has been accompanied by big increases in fertilizer use. Year of first use of compound fertilizer on the sample parcel closely tracks year of first planting maize (though not all household planting maize use compound fertilizer) and increased particularly rapidly after 2012. Use of urea on the sample parcel also grew quickly after 2012, though at a lower rate than compound, reflecting the greater importance of the latter in maize cultivation. Most recently, since 2014 there has been an uptick in pesticide and herbicide use, perhaps – especially in the case of herbicide - in response to a tightening labor market that has made labor for weeding more scarce, but their use in maize cultivation remains quite limited (Figure 18). Forty one percent of households that had ever used manure on the sample have stopped doing so (Table A5), mainly within the past five years, likely reflecting diminishing availability as agricultural machinery has been substituted for draft animals (see Soe and Kyaw, 2018).

Figure 18 Cumulative number of households started the below activities by year



The share of maize farming households using compound fertilizer and hybrid seed doubled from 2007 to 2017. Forty-two percent of households growing maize on the sample parcel used compound fertilizer in 2007, doubling to 84% in 2017. This shift corresponds closely to the use of hybrid seed, used by 38% of households in 2007 and 86% in 2017. The share of households using urea increased by 10 percentage points over the decade but declined slightly from 2012 to 2017. More than 20% of maize/pigeon pea growers used pesticide and herbicide in 2017, up from less than 5% in 2007. Herbicide use jumped particularly quickly from 2012, when it was used by only 4% of households, up to 26% in 2017, likely due to reasons of increasing labor scarcity, as noted above, and possibly also due to increases in supply (Table 38).

Table 38 Share of maize growers using inputs on the sample parcel, by year

Input	2007	2012	2017
Compound	42	65	84
Urea	38	55	48
Pesticide	4	10	21
Herbicide	2	4	26

Note: The inputs use history questions were only asked to maize growers

Fertilizer application rates have climbed over time. The average quantity of fertilizer (compound + urea) applied per acre increased by 42% from 2007-2017, from 1.2 bags/acre (60 kg) to 1.7 bags/acre (85 kg). Interestingly, increasing rates of compound fertilizer application accounted for the entire increase, with average application rates of urea by falling by 20% per acre (Table 39). Increasing rates of compound fertilizer application are likely linked to the shift from local to hybrid varieties of maize, but may also be indicative of declining soil fertility in fields that have undergone multiple years of maize monocropping.

Table 39 Number of bags of compound and urea applied per acre by maize growers

Application rate (bags/acre)	2007	2012	2017	% change '07-'12	% change '12-'17	% change '07-'17
Compound	0.9	1.1	1.3	22	18	44
Urea	1.0	0.9	0.8	-10	-11	-20
Compound + urea	1.2	1.4	1.7	17	21	42

Note: 1 bag of fertilizer = 50kg

Average maize yields have increased over the past decade. Average yields rose 23% between 2007 and 2017, from 1054 kg/acre to 1293 kg/acre[9]. The yield increase reported by farmers who cultivated in all three years was 36% (up from 1059 kg/acre to 1436 kg/acre) (Table 40). This is increase is likely attributable to the shift from cultivation of local to hybrid varieties over this period and associated increase in compound fertilizer use, with households that began farming maize earlier less likely to use hybrid seed and compound fertilizer from the outset of production. The results also show that reduced soil fertility associated with cropping maize on a parcel for multiple years may be offset by input use.

[9] These figures includes average yields across both monocropped maize and intercropped maize/pigeon pea parcels.

Table 40 Maize yields by, years of experience growing maize

Households that grew in…	2007	2012	2017
Any year	1,054	1,159	1,293
Local maize seed	951	986	845
Hybrid maize seed	1,230	1,278	1,364
Both 2012 and 2017	n/a	1,159	1,369
Local maize seed	-	986	992
Hybrid maize seed	-	1,278	1,429
All 2007, 2012, and 2017	1,059	1,259	1,436
Local maize seed	955	1,061	913
Hybrid maize seed	1,239	1,410	1,514

Table 41 Weighted number of households in surveyed townships planting maize varieties, by year.

Variety	2007	2012	2017
CP 808	304	2293	17917
CP 888	7012	17453	15860
Golden Tiger 029	251	1102	13442
Local maize variety	10783	9145	7932
Thai 333	488	886	5969
Awba (Syngenta) 621	0	417	5632
Than Te	4618	7333	3922
TF 222	327	1104	2614
CP 201	280	427	1884
Armo 288	0	63	1603
Super 981	78	164	1224
TP1	302	102	1048
Tha Ra Phu	0	0	982
CP 111	0	0	575
CP 301	80	279	555
CP M100	0	0	420
Premier 515	0	0	326
GT 722	0	0	295
KS 959	0	0	283
Armo 339	0	0	180
Thai Gold	0	86	87
Yezin 10	89	0	70
Yezin 11	0	79	0
'Don't know'	0	0	1273
'Others'	271	1000	1646
Total	24884	41932	85741

The market for hybrid maize seed has diversified rapidly since 2012. When asked about varietal history, 81% of farms that used hybrid maize seed in 2007 and 2012 reported using a variety produced by CP in those years. This share declined to 50% in 2017 as numerous companies began to promote alternative varieties of hybrid seed. However, the total population of maize farmers more than doubled over this period, so CP's total maize seed sales would have increased, despite declining market share. The composition of CP seed also changed, CP 888 (the original variety introduced to Myanmar by CP) gradually lost market share to CP808 (a newer, more expensive, variety). The number of maize seed varieties in used increased from 13 in 2007 to 23 in 2017 (Table 41).

Use of local maize seed varieties persists. Local varieties (excluding Than Te) remain the fourth most common variety, used by 9% of farmers in 2017, but this share has declined sharply from 2007, when 43% of famers reported planting local varieties, making them the most widely used maize seed at that time. Two government produced hybrids (Yezin 10 and Yezin 11), are the least commonly used varieties, highlighting the comparative disadvantage that Myanmar's public sector faces in producing and distributing hybrid seed in a highly competitive market.

There is no maize contract farming in any of the townships surveyed. All households interviewed were asked, "Have you ever had a contract with CP company to grow maize?": 99.5% responded "no". Seven of the eight households who responded "yes" were from Than Te village in Taungyi township, where CP once operated a contract farming scheme for seed multiplication farms producing hybrid maize seed (not maize grain). None of these contracts were still in force, and all of them were reported to have ended between 2013 and 2016.

7.3 Farmer perceptions of maize cultivation

In order to test hypotheses about the possible attributes and impacts, positive and negative, of maize cultivation we asked respondents a series of Likert scale style questions about their perceptions. Respondents were asked to respond to 22 statements, beginning with the words "maize farming…". Possible responses were 'agree', 'neither agree nor disagree', 'disagree', or 'not applicable'. 'Not applicable' answers are excluded from the analysis of frequency of responses presented in Figure 19 below.

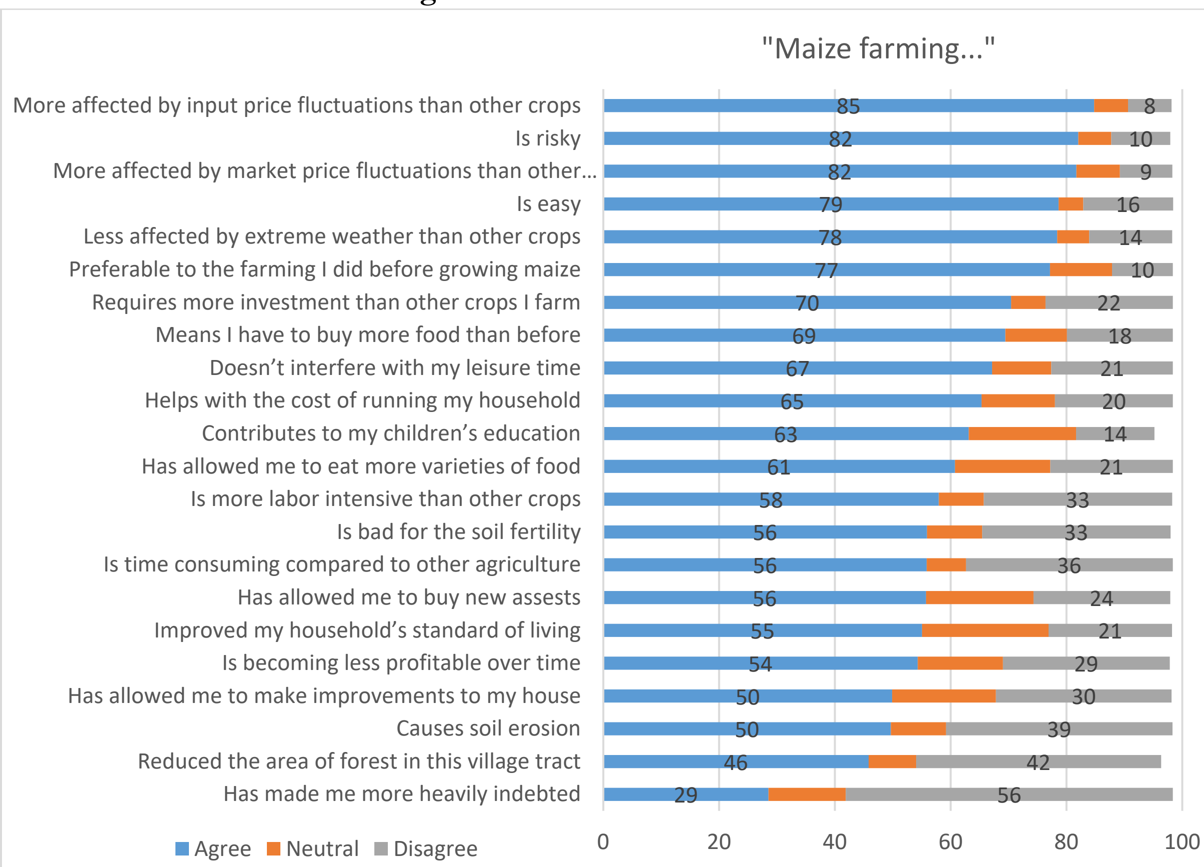
This attempt to elicit information was only partially successful. When reviewing the data generated it became apparent that there is a strong cultural tendency for respondents to express agreement with the interviewer for the sake of maintaining harmony and avoiding conflict. This is evident in the distribution of responses: at least half of respondents agree with all but 2 statements, even where the statements partially contradict one another (e.g. 'Maize farming is less labor intensive than other crops', 58% agree; 'Maize farming is time consuming compared to other agriculture, 56% agree). Nevertheless, there is enough variation in the level of agreement across responses for some general tendencies to be discerned.

First, the three statements eliciting the highest level of agreement (>80%) concern to maize being a risky crop due to higher levels of price fluctuation than other crops, and high levels of input use and investment relative to other crops. Statements with positive attributes also score highly, with close to 80% of respondents in agreement that maize farming is 'easy', preferable to the type of farming practiced previously, and less affected by extreme weather than other crops.

Statements attracting a moderate level of agreement (roughly 55-65%) relate mainly to effects on standard of living (e.g. 'maize farming has allowed me to buy new assets', 56%; 'maize farming helps with the cost of running my household', 65%) or food security ('maize farming means I have to buy more food than before', 69%; 'maize farming has allowed me to eat more varieties of food', 61%). This suggests that maize farming has had relatively neutral impacts on standards of living and food security overall.

Interestingly, two of the statements attracting least agreement relate to two hypothesized environmental impacts of maize cultivation, with 50% and 46% of respondents, respectively, agreeing with the statements 'maize farming causes soil erosion', and 'maize farming has reduced the area of forest in the village tract'. The statement with by far the lowest level of agreement (29%), and the only one for which 'disagree' responses exceed 50%, is 'maize farming has made me more heavily indebted'. This stands in sharp contrast to the picture of widespread indebtedness and dispossession associated with maize cultivation, as painted by Woods (2015).

Figure 19 Share of maize farmers agreeing, responding neutrally to, or disagreeing with, statements about maize farming



8 Conclusions

This report presents results from by far the most comprehensive survey of maize and pigeon pea cultivation ever conducted in Myanmar. The survey represented all maize growing village tracts in the nine major maize growing townships of southern Shan where the security situation at the time of the survey permitted access. A total 884 maize growing and 678 non-maize growing rural households were interviewed. This research was designed to test empirically characterizations of hybrid maize farming present in the literature on Myanmar and identify implications for policy and development programming. We summarize key findings and their discuss implications below.

Input supply and related credit markets in southern Shan are highly competitive. There is no evidence to support the claim that large numbers of farmers are heavily encumbered with debt to traders or are coerced into selling harvested maize to traders at below prevailing market prices. As such, policy makers should avoid the temptation to intervene in these markets.

Traders play a much smaller role in the supply of informal agricultural credit for maize cultivation than commonly believed. Trader credit is mainly utilized by larger farmers, who make up the bulk of maize growers. The supply of formal agricultural credit for maize farming through Myanmar Agricultural Development Bank (MADB) is almost non-existent. This reflects the bank's continuing prioritization of rice cultivation loans, limited institutional penetration in southern Shan, and low levels of formalized land tenure which precludes borrowing from the bank. This indicates the need to ascribe higher institutional priority to maize cultivators, and to identify models for disbursing formal agricultural credit to smallholders without formal land use rights documents.

Farming maize does not erode household food security. There is very little difference in food the consumption patterns of maize and non-maize cultivating farm households. On average, maize farmers own more land, grow more types of crop, and obtain more food from their own production than non-maize growing farm households. Almost all farmers grow maize as part of a mix of commercial and subsistence, and most households procure most of their food with income earned by working off-farm or selling cash crops. crops. The fully self-sufficient subsistence farm household is now largely a romantic mythical figure. Policies that aim to promote food and nutrition security should therefore pay close attention to ensuring availability and accessibility of food through markets.

There is no strong evidence that hybrid maize farming results in widening inequality. Large farms (tercile 3) obtain higher gross margins per acre on average than smaller farms. This appears linked to timing of maize sales, more efficient use of inputs, and use of higher quality seed varieties. The ability of larger farms to delay sales may be linked, in part, to their ability to access credit, with the price gains associated with delaying sales more than offsetting the additional cost of interest. Large farms therefore perform better than small in terms of profitability and returns to family labor. However, there is no evidence that smaller farmers are unable to access adequate inputs, the gap between small and large farm gross margins is not great, and small farms are only marginally more likely than large to lose money on maize crops. Negative gross margins were rare in the year our survey took place, and much less frequent than for other common rainfed crops grown in Myanmar. Interest paid on loans accounts for only

4% of the total production costs of maize farms that avail credit, and virtually all households that reported having planted maize in 2007 continued to do so in 2017. These facts give little reason to believe that southern Shan's hybrid maize boom has resulted in significant economic or social differentiation, and even less that it has been a driver of widespread dispossession through small farmer debt.

Contract farming is only viable under very specific circumstances. Our survey shows definitively that CP never organized contract farming of maize grain in any the nine townships surveyed. Our qualitative interviews suggest that CP did briefly initiate maize grain contract farming in Kalaw township (outside our study area) on a small scale in the late 1990s to promote its products, but quickly abandoned this model. Availing output-tied credit with no specifications or obligations relating to product volume, quality, or price, and no division of management functions between contractor and contractee does not meet the basic definition of contract farming set out by Little and Watts (1994) in their classic volume on the subject. The maize grain used in animal feed manufacturing is a low value commodity, with limited quality differentiation. Vertical coordination of production through contracts therefore offers maize grain buyers no advantage over procurement through spot markets. In contrast, hybrid maize seed, for which CP did previously organize contract farming in the village tract of Than Te, is a high value product that must be produced in compliance with specialized protocols and conform to high quality standards. CP ultimately abandoned hybrid maize seed production in Myanmar however, in part because farmers from Than Te retained and multiplied seed in breach of contract, in order to sell it under their own informal 'brand'. This discussion has important policy implications. Contract farming is not a panacea, because: (1) it will only work in very specific cases, where buyers are unable to secure products of a specific quality or volume through spot markets or direct vertical integration; (2) contracts may be easily broken, by either side, when more attractive alternatives present themselves.

Interventions that allow farmers to delay crop sales may increase returns. Larger farmers obtain higher average prices for their maize, in part by delaying sales. Providing short-term loans to farmers ahead of harvest time could provide much a needed cash infusion that would permit them to defer sales until prices rise. On the demand side, expanding commercial banking services to traders along the lines of Yoma Bank's LIFT-supported Agricultural Finance Program, could increase effective for maize demand during 'peak' season by enabling traders to buy and hold larger quantities of grain than is possible when having to constantly cycle their working capital.

Appropriate small-scale mechanization could reduce production costs. Weeding and harvesting maize together account almost 70% of labor costs in maize production. Using credit to hire labor for weeding maize is positively associated with gross margins, but labor is becoming increasingly scarce. Land preparation and maize shelling are already highly mechanized, showing that farmers value labor saving and drudgery reducing innovations. Small low-cost handheld mini-tillers could minimize labor requirements and have proven effective in Nepal's uplands (Paudel et al. 2019), and could help reduce both labor demand for weeding maize and rising herbicide use, but their use may demand optimized spacing of maize rows. Small combine harvesters capable harvesting maize on rough terrain are available in neighboring Thailand. The suitability of these machines in the Myanmar context should be evaluated.

Maize yields lag behind other countries in the region. The long run trend for farmers to shift from local maize varieties to hybrids will likely see Myanmar's maize productivity increase further in coming years. However, although hybrids are associated with higher yields, our regressions show that growers who use cheaper hybrid seeds such as CP 888 do not obtain significantly higher gross margins than those who plant local varieties. This helps to explain why a significant number of farmers continue to grow local maize varieties. In order to raise both maize productivity and farmer incomes, better extension messaging and credit access will be needed to encourage farmers to buy better quality (but more expensive) seed varieties.

Maize prices are volatile. This is apparent in the large gap between gross margins reported in the World Bank's 2013/14 survey and our own. Price volatility makes it difficult for farm households to accumulate savings over the long run as a good return in one year can easily be wiped out by a poor return the following year. Exports account for about half of Myanmar's maize production (USDA, 2018). Much of the price volatility in Myanmar's maize market is linked to its dependence on China as the major market for exported maize. Myanmar recently diversified its maize markets in response to a long shut down of informal cross-border trade with China in 2018, and now exports considerable quantities to Thailand. Government and the private sector should work together proactively to seek to establish additional export markets within the region, whilst continuing to negotiate for larger import quotas with China could help to further reduce market volatility over the medium to long run.

References

Cho, A. and Belton, B. 2019. *Growth and Transformation in Off-Farm Segments of the Maize Value Chain in Shan State*. Research Paper 156. December 2019. East Lansing: Michigan State University.

FAO. 2019. FAOSTAT database. Food and Agriculture Organization of the United Nations, Rome, Italy. Accessed May 27, 2019.

Little, P.D. and Watts, M.J. 1994. Living Under Contract: Contract Farming and Agrarian Transformation in Sub-Saharan Africa. Madison: University of Wisconsin Press

Mather, D., Aung, N., Cho, A., Naing, Z.M., Boughton, D., Belton, B., Htoo, K., Payongayong, E. 2018. *Crop Production and Profitability in Myanmar's Dry Zone*. Research Paper 102. July 2018. East Lansing: Michigan State University.

Paudel, G.P., KC, D.B., Rahut, D.B., Justice, S.E., McDonald, A.J., 2019. Scale-appropriate mechanization impacts on productivity among smallholders: Evidence from rice systems in the mid-hills of Nepal. *Land Use Policy*. 85: 104–113.

Soe, K.W. and Kyaw, S. 2019. *Agricultural Mechanization Southern Shan State*. Food Security Policy Project Research Highlights, Myanmar *16*, February 2019, East Lansing: Michigan State University.

Thu, E.T.T., Htun, K.M., Belton, B. 2019. *Migration in Southern Shan State: Characteristics and Outcomes*. *Feed the Future Innovation Lab for Food Security Policy Research Paper 136*. East Lansing: Michigan State University.

USDA. 2018. *Burma - Union of Grain and Feed Annual 2018 Annual Report*. Washington, D.C. U.S. Department of Agriculture, Foreign Agriculture Service.

Win, K.Z. and Zu, A.M. 2019. *Agricultural Land in Southern Shan State*. Food Security Policy Project Research Highlights, Myanmar *17*, February 2019, East Lansing: Michigan State University.

Woods, K., 2015a. *CP maize contract farming in Shan State, Myanmar: A regional case of a place-based corporate agro-feed system*. BRICS Initiatives for Critical Agrarian Studies (BICAS).

Woods, K. 2015b. *Opportunities, Risks and Growing Inequality: The Charoen Pokphand Group and Maize Smallholder Production in Shan State, Myanmar*. Myanmar, Yangon: Land Core Group

World Bank. 2016. *Myanmar: Analysis of farm production economics*. Washington, D.C.: World Bank Group.

Appendix

Table A1 Maize cultivation and production by township

Township	% of farmers growing	% of growers selling	Yield (kg/acre)	Mean area planted (acre)	Maize area in total cultivated area (%)
Lawksawk	69	99	1209	6.7	68
Taunggyi	52	98	1446	5.1	71
Hopong	80	98	1327	4.6	59
Mong Nai	74	100	1236	5.6	74
Hsi Hseng	45	96	1229	3.9	61
Langhko	32	98	1484	3.3	57
Pekon	23	84	1201	3.8	68
Pindaya	37	70	713	2.9	47
Pinlaung	22	100	1642	2.1	42

Table A2 Share of households obtaining pigeon pea seed by source (all seed, and 3 most common varieties)

	Agri-trader	Agri-input shop	General store	Family/friend	Farm (saved from previous crop)
All PP seed	6	5	1	28	60
Local variety (Yellow)	7	3	0	24	65
Local variety (Red)	6	5	1	32	56
Local Variety (White)	0	16	0	28	56

Table A3 Unit price of pigeon pea seed used of all seed and 3 most common varieties, by tercile

	Tercile1	Tercile2	Tercile3	All HH
All PP seed	775	761	685	731
Local variety (Yellow)	762	706	726	728
Local variety (Red)	778	673	747	716
Local Variety (White)	778	673	747	716

Table A4 Average value and share of input costs per acre on the sample parcel, by landholding tercile

	Tercile 1		Tercile 2		Tercile 3		All HHs	
Item	Cost per acre (MMK/acre)	Share (%)	Cost per acre (MMK/acre)	Share (%)	Cost per acre (MMK/acre)	Share (%)	Cost per acre (MMK/acre)	Share (%)
Compound	21,084	49	19,523	47	18,409	53	19,299	50
Urea	10,837	25	7,497	18	8,039	23	8,354	22
Other inorganic fertilizer	2,474	6	2,801	7	1,783	5	2,277	6
Manure	3,508	8	4,351	11	2,514	7	3,358	9
Pesticide	2,241	5	2,653	6	1,391	4	2,001	5
Herbicide	2,255	5	4,389	11	2,796	8	3,272	8
All inputs	42,616	99	41,233	100	35,006	100	38,640	100

Table A5 Share of households ever applied manure in the sample parcel growing maize that stopped doing so

Item	Total	Tercile 1	Tercile 2	Tercile 3
weighted N of HH still using	15,132	2,856	5,857	6,418
weighted N of HH stopped	10,710	1,818	2,970	5,923
% of HH that stopped using	41	39	34	48

Table A6 Number of person days labor per acre, by activity, for mono-cropped pigeon pea

	Hired labor			Family labor			Exchange labor	All labor
Item	♀	♂	♀+♂	♀	♂	♀+♂	♀+♂	
Land Preparation	0.1	0.1	0.2	2.0	1.1	3.1	0.1	3.3
Planting	0.3	0.3	0.6	1.2	1.4	2.6	0.4	3.6
Fertilizer pesticide herbicide application	0.0	0.1	0.1	0.7	0.1	0.8	0.0	1.0
Weeding	1.3	0.2	1.6	2.1	3.4	5.4	0.4	7.4
Harvesting Pigeon Pea	0.4	0.2	0.7	1.8	2.0	3.8	0.2	4.6
Drying/Husking/Winnowing Pigeon Pea	0.2	0.1	0.3	1.0	1.2	2.2	0.1	2.6
Any Activity	2.3	0.9	3.5	8.8	9.2	17.9	1.2	22.6

Table A7 Variables Included in the Maize Price Regression

Variable name	Definition	Mean
Maize price	Average unit maize price (Kyat/kg) maize growers received in each sale	221
Took cash loan for maize seed, fertilizer	=1 if grower borrowed cash for maize farming, =0 otherwise	0.07
Took in-kind credit for maize seed, fertilizer	=1 if grower in-kind credit for maize farming, =0 otherwise	0.31
Took credit for labor for planting maize	=1 if grower took credit to hire labor for planting maize, =0 otherwise	0.03
Took credit for labor for weeding	=1 if grower took credit to hire labor for weeding, =0 otherwise	0.03
Committed to sell maize to the credit provider	=1 if grower commits to sell maize to the credit provider, =0 otherwise	0.11
Maize sale occasions	Whether maize was sold in 1st, 2nd, or 3rd occasion	-
Sold maize in high season	=1 if grower sold maize in high seasons (i.e. Oct to Jan), =0 otherwise	0.72
Inorganic fertilizer application rate	How many 100-kg of inorganic fertilizer applied per acre on the sample parcel	1.46
Whether used pesticide	=1 if grower used pesticide on the sample parcel, =0 otherwise	0.20
Whether used herbicide	=1 if grower used herbicide on the sample parcel, =0 otherwise	0.25
Soil quality	Subjectively assessed soil quality as good, fair, or poor	-
Buyer from local village tract	=1 if grower and maize buyer are from the local village tract, =0 otherwise	0.54
Buyer's ethnicity same as the HH head	=1 if the household head of the grower's family and maize buyer are the same ethnicity, =0 otherwise	0.57
No. of years growing maize in past 10 years	Number of the years the grower planted maize in the past 10 years	6.97

Table A8 Variables Included in the Maize Yield Regression

Variable name	Definition	Mean
Maize yield	Maize yield (kg/acre) of the sample parcel	1,259
Took cash loan for maize seed, fertilizer	=1 if grower borrowed cash for maize farming, =0 otherwise	0.17
Took in-kind credit for maize seed, fertilizer	=1 if grower in-kind credit for maize farming, =0 otherwise	0.28
Took credit for labor for planting maize	=1 if grower took credit to hire labor for planting maize, =0 otherwise	0.03
Took credit for labor for weeding	=1 if grower took credit to hire labor for weeding, =0 otherwise	0.03
Soil quality	Subjectively assessed soil quality as good, fair, or poor	-
Maize seed application rate	Amount (kg) of seed applied per acre on the sample parcel	5.55
Inorganic fertilizer application rate	How many 100-kg of inorganic fertilizer applied per acre on the sample parcel	1.20
Whether used manure	=1 if grower used manure on the sample parcel, =0 otherwise	0.08
Whether used pesticide	=1 if grower used pesticide on the sample parcel, =0 otherwise	0.15
Whether used herbicide	=1 if grower used herbicide on the sample parcel, =0 otherwise	0.22
Number of hired labor days	The amount of hired labor days used on the sample parcel	8.97
Number of family labor days	The amount of family labor days used on the sample parcel	17.95
Pigeon pea intercropped w/ maize	=1 if pigeon pea was intercropped with maize on the sample parcel, =0 otherwise	0.53
Formal land tenure	=1 if in possession of Form 7 or Form 105 for sample parcel, =0 otherwise	0.19
No. of years growing maize in past 10 years	Number of the years the grower planted maize in the past 10 years	9.46

Table A9 Variables Included in the Maize Gross Margin Regression

Variable name	Definition	Mean
Gross margin per acre	Gross margin per acre (Kyat/acre) of maize and PP from the sample parcel	173,015
Took cash loan for maize seed, fertilizer	=1 if grower borrowed cash for maize farming, =0 otherwise	0.16
Took in-kind credit for maize seed, fertilizer	=1 if grower in-kind credit for maize farming, =0 otherwise	0.28
Took credit for labor for planting maize	=1 if grower took credit to hire labor for planting maize, =0 otherwise	0.03
Took credit for labor for weeding	=1 if grower took credit to hire labor for weeding, =0 otherwise	0.03
Committed to sell maize to the credit provider	=1 if grower commits to sell maize to the credit provider, =0 otherwise	0.11
Soil quality	Subjectively assessed soil quality as good, fair, or poor	-
Maize seed application rate	Amount (kg) of seed applied per acre on the sample parcel	5.57
Inorganic fertilizer application rate	How many 100-kg of inorganic fertilizer applied per acre on the sample parcel	1.20
Whether used manure	=1 if grower used manure on the sample parcel, =0 otherwise	0.08
Whether used pesticide	=1 if grower used pesticide on the sample parcel, =0 otherwise	0.15
Whether used herbicide	=1 if grower used herbicide on the sample parcel, =0 otherwise	0.21
Number of hired labor days	The amount of hired labor days used on the sample parcel	8.95
Number of family labor days	The amount of family labor days used on the sample parcel	18.09
Pigeon pea intercropped w/ maize	=1 if pigeon pea was intercropped with maize on the sample parcel, =0 otherwise	0.52
Formal land tenure	=1 if in possession of Form 7 or Form 105 for sample parcel, =0 otherwise	0.19
No. of years growing maize in past 10 years	Number of the years the grower planted maize in the past 10 years	9.35