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CROP PRODUCTION AND PROFITABILITY IN MYANMAR'S DRY ZONE

By

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Food Security Policy *Research Papers*

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EXECUTIVE SUMMARY

This report is one of a series of studies funded by USAID Burma and the Livelihoods and Food Security Fund (LIFT) to understand the current situation and identify potential ways to improve agriculture and the rural economy in different agro-ecological zones of Myanmar. It focuses on Myanmar's Central Dry Zone, home to approximately 10 million people.

The results are based on information from almost 950 crop-producing households on area planted, quantities harvested and sold, and total crop production costs for the 13 predominant crops in the Dry Zone, based on a reference period of the past 12 months prior to the survey interview. The survey also collected parcel-level data on the household's main parcel that was planted to at least one of four main crops of interest, namely paddy, groundnut, sesame and green gram. The parcel-level data includes information by season on seeds and other inputs applied to each crop, use of family and hired labor, use of mechanization and/or draft animal power, irrigation costs, and harvested quantities. Key findings are summarized below.

Land Access and Use

Levels of landlessness are high, most farms are small, and land is unequally distributed. Forty percent of households do not own or operate agricultural land. Almost half of crop farming households (48%) cultivated less than 5 acres. The third of households with the smallest landholdings own just 4% of all crop land.

Lowland area is used primarily for paddy cultivation while upland area is dominated by sesame, along with groundnut, pigeon pea and green gram. Fifty-nine percent of owned and operated agricultural land is upland, and 36% is lowland.

Access to Irrigation

Seventy-five percent of lowland areas have access to irrigation, primarily by dam, while only 6% of upland area is irrigated. Dam irrigation plays a major role in the cultivation of paddy in each of the three seasons, even in the monsoon where 64% of paddy area is irrigated.

Input Use

Use of improved varieties remains low for green gram (8%), groundnut (12%) and sesame (23%). While 42% of paddy seed is improved, this percentage is quite low as compared with other Southeast Asian countries. Efforts to promote improved paddy varieties need to consider the recent and increasing demand for short-duration (90-day) paddy varieties in some communities.

Average monsoon and dry season paddy yields, 2.8 and 3.2 tons/ha in 2016/17, are low relative to many other Asian countries. Rates of application of nitrogen fertilizer appear adequate, indicating that other factors are constraining Dry Zone paddy yields, such as relatively low use of improved varieties and perhaps a higher frequency of adverse weather events, especially flooding.

Crop Yields

Crops in the Dry Zone are subject to a significant amount of yield variation depending on weather condition during a given season. For example, the yield of sesame in a good climatic year is expected to be 55% higher than that of an average year, while yield in an average year is 107% higher than that in a bad year.

Over the past 60 years, climate change has had a dramatic effect on the distribution of rainfall during the monsoon season in the Dry Zone. The number of rainy days during the monsoon has fallen by more than 50%, resulting in a higher frequency of days with excessive rainfall as well as more days of drought stress. Given limited capacity for rainwater infiltration in the uplands, and insufficient drainage in the lowlands, intense rains run off the uplands and flood the lowlands.

With the exception of monsoon paddy, yields for the four main crops were below those expected in the surveyed areas in an average climatic year. Low yields were primarily due to a high frequency of pre- and/or post-harvest yield loss. These losses were primarily related to erratic rainfall (drought, excessive rainfall), poor water control (flooding), and pests. Median yields for growers not reporting yield loss were one to five times higher than those reporting losses, depending on the crop.

There has been an increase over the past 10 years in access to irrigation, use of improved varieties, pesticides, and fertilizer application rates for paddy, sesame, groundnut and green gram. However, only yields of paddy have increased over time (by 12%) while those of sesame, groundnut and green gram have remained stagnant.

Crop Profitability

Low yields resulted in low average profits for the four main crops. The highest profits came from dry season and monsoon paddy, with gross margins of $148/acre and $125/acre, respectively. The gross margins for groundnut ($86/acre), sesame ($82/acre) and irrigated and rainfed green gram ($90/acre and $23/acre, respectively) were very low.

The yield and gross margin results provide strong evidence of the productivity and profitability gains made possible by irrigation. Dry season paddy cannot be grown without irrigation, and it provided the highest average gross margin per acre. Most monsoon paddy is irrigated, and the average and mean yields of irrigated monsoon paddy are 20% higher than those that are rainfed. Lowland farmers with access to dependable irrigation are able to grow paddy in both the dry season and monsoon, which produces double the median annual gross margin relative to households that only grow paddy in the monsoon season. Irrigated green gram has an average gross margin four times larger than that of rainfed green gram.

Reduction in the extensive losses due to flooding on both upland and lowland areas would improve the profitability and resilience of Dry Zone agriculture. In lowland areas this can be achieved by upgrading existing irrigation systems to provide drainage for excess water. In upland areas, tillage systems that improve water infiltration and reduce runoff (e.g., contour ploughing, or planting on ridges) should be tested.

Efforts are needed to diversify Myanmar's pigeon pea exports and increase domestic consumption of pigeon pea. While pigeon pea has historically been an important crop for upland Dry Zone farmers due to its drought tolerance, it is grown almost exclusively for export. Since India imposed an import quota on pigeon pea from Myanmar in 2017, the domestic market price of pigeon pea has fallen dramatically. Developing new sources of both export and domestic demand can help alleviate Myanmar's dependence on India as a market for pigeon pea.

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ACRONYMS

FSP	Food Security Policy
FSPP	Food Security Policy Project
IFPRI	International Food Policy Research Institute
IWMI	International Water Management Institute
JICA	Japan International Cooperation Agency
LIFT	Livelihoods and Food Security Trust Fund
MMK	Myanmar currency (kyat)
READZ	Rural Economy and Agriculture in the Dry Zone
TLU	Tropical Livestock Units
USAID	United States Agency for International Development

1. INTRODUCTION

Agriculture is the main livelihood and source of income for the majority of the rural population (70%) in Myanmar. Although agriculture is the backbone of the rural economy, the technical and economic characteristics of agriculture are understudied and poorly understood. To address this gap, the Rural Economy and Agriculture in the Dry Zone (READZ) survey was conducted in 2017 in four townships, namely Butalin Township in Sagaing region, Magway and Pwint Phyu townships in Magway region and Myittha Township in Mandalay region. The READZ survey is a statistically representative survey of 1,578 rural households in 100 village tracts. These regions are located in the Central Dry Zone of Myanmar, which receives an average of 700 to 1,000 mm of rainfall (JICA 2013) and produces most of the country's sesame, groundnuts and pulses (traditionally a major export earner), and 22% of its rice (IWMI 2015). These four townships were selected because they represent the main Dry Zone cropping systems and forms of irrigation access. The survey was carried out to identify the current status of agricultural production and rural livelihoods in the study areas. This report presents data from the survey regarding agricultural land use, access to irrigation, crop production, productivity, marketing and profitability.

1.1. Overview of Sample Households

The results presented in this paper pertain exclusively to crop farming households. Sixty percent of households in the townships surveyed own or operate agricultural land (Hein et al. 2017). Most of these are small farmers: almost one-half of crop farming households (48%) cultivated less than 5 acres, 27% cultivated between 5 and 10 acres, and 24% cultivated more than 10 acres. The area cultivated per household ranged from 0.25 acres up to 53.5 acres with a median value of 5 acres.

Among landholding terciles, the average area of land cultivated by households in tercile 3 (the third of farms with the largest landholdings) was 14.3 acres, followed by 5.0 acres for tercile 2, and 1.7 acres for tercile 1 (the smallest third of farms).[1] There is a high level of inequality in the distribution of cultivated land. The operated land in tercile 3 accounted for 81% of total cropped land area, while that for tercile 2 accounted for 15% and tercile 1 accounted for only 4% (ibid 2017).

Upland (*ya*) and lowland (*le*) are the dominant categories of agricultural land, accounting for 59% and 36% of operated agricultural land, respectively (ibid 2017). Lowland is used primarily for paddy cultivation, and 76% of lowland areas have access to irrigation by dam, river/stream, or groundwater/well. By contrast, upland is almost entirely rainfed (only 6% is irrigated) and is used primarily for cultivation of sesame, groundnut, and green gram. Nearly half of farms (45%) cultivate only upland parcels, and these average 8.3 acres in size (ibid 2017). Just over one quarter of farms (27%) cultivate only lowland parcels, operating an average of 4.2 acres, while 21% of farms operate both upland and lowland parcels, averaging 8.6 acres in size (ibid 2017).

The READZ survey collected information on area planted, quantity harvested, quantity sold, and total crop production costs for the 13 predominant crops in the Dry Zone, based on a reference period of the past 12 months prior to the survey interview. The survey also collected parcel-level

[1] In order to derive terciles, farms were ranked from smallest to largest, based on the area of agricultural land owned, and divided into three equal groups (landholding terciles). Landholding tercile 1 is comprised of the third of farms operating the smallest landholdings. Landholding tercile 3 is the third of farms with the largest landholdings. Landholding tercile 2 is intermediate.

data on the household's main parcel that was planted to at least one of four main crops of interest, namely paddy, groundnut, sesame and green gram. The parcel-level data includes information on seeds and other inputs applied to each crop, use of family and hired labor, use of mechanization and/or draft animal power, irrigation costs, and harvested quantities.

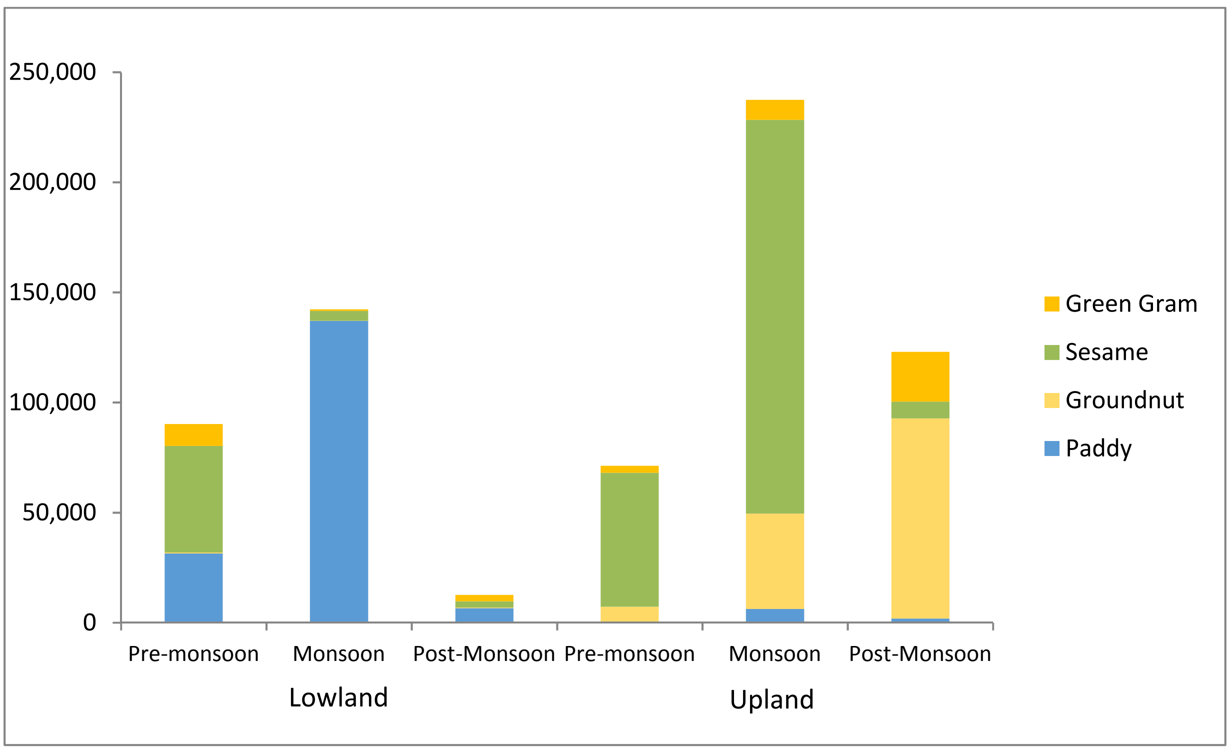
2. LAND USE AND ACCESS TO IRRIGATION

2.1. Area Planted to Target Crops

For the READZ survey, four crops were designated *target crops* (crops of particular interest): paddy, groundnut, sesame and green gram. Among these, the area planted to sesame is the largest, followed by paddy, groundnut and green gram (Figure 1). On both lowland and upland, crops can be classified according to whether they are planted in the pre-monsoon, monsoon, or post-monsoon seasons. In the lowland, for example, the main crop in terms of total area planted is monsoon paddy, with sesame grown during the pre-monsoon season occupying the second largest share (Figure 1). Lowland area planted to paddy accounted for 96% of total area planted in the monsoon, while sesame accounted for 54% of planted area in the pre-monsoon (Appendix Figure 1).

In the uplands, the main crops are sesame, grown during the pre-monsoon and monsoon seasons, and groundnut grown in the post-monsoon (Figure 1). Upland area planted to sesame accounted for 85% of planted area in the pre-monsoon and 75% of planted area in the monsoon, while groundnut accounted for 74% of planted area in the post-monsoon (Appendix Table 1). Green gram is primarily grown in the post-monsoon season, where it accounted for 23% of planted area in lowlands and 18% of planted area in uplands.

Figure 1. Total Area Planted to Target Crops by Lowland/Upland (Acres)



Source: Authors calculations based on READZ household survey data unless otherwise noted.

2.2. Area Planted to All Crops

In both the lowlands and uplands, farmers typically use most of their land for cropping in the monsoon season. Only 11% and 18% of agricultural land area in the lowlands and uplands respectively is fallowed during the monsoon (Appendix Figure 2). By contrast, 71% of lowland area is fallowed in the post-monsoon season, while 76% of upland area is fallowed during the pre-monsoon.

Non-target other crops are primarily planted in the post-monsoon season, when they account for 22% of total area (cultivated and fallow) in both lowlands and uplands (Appendix Figure 2). A question for further research is why only 29% of lowland area is cultivated in the post-monsoon season given that 76% of the lowland area is irrigated. One potential explanation is a lack of water supply during the post-monsoon. This explanation is supported by a recent study of water management and use that indicates that most irrigation in the Dry Zone is currently being used to extend the monsoon season growing period or to safeguard wet-season crops, rather than for full irrigation of dry-season crops (IWMI 2015). In addition, scoping field work in preparation for the READZ survey indicated that in some locations, access to water from dam irrigation schemes has deteriorated over time to the point that paddy cultivation outside of the monsoon season was no longer feasible (Belton et al 2017).

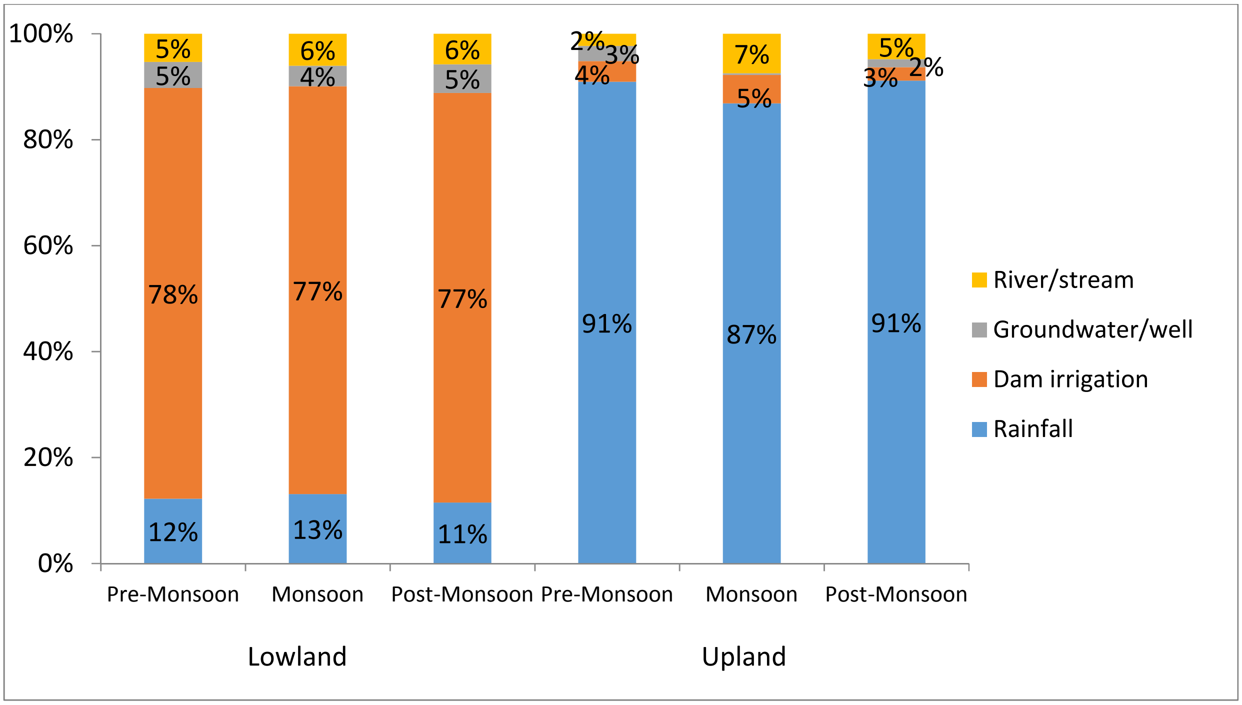
2.3. Area Planted by Type of Water Source

For many years, one of the Ministry of Agriculture's strategies to increase rice production has been the construction of dams and expansion of irrigation canals. From 1988 to 2014, 240 dams were completed across the country, and 327 river pumping stations were completed between 1995 and 2014, with much of this investment being made in the Dry Zone (Department of Agricultural Planning 2014).

In all seasons, most of the cropped upland area is rainfed while most of the lowlands cropped area is irrigated. For example, in the monsoon, 87% of upland area planted is rainfed, while only 13% of lowland area is rainfed (Figure 2). Lowland irrigated area is predominantly supplied from dams, which account for 78% of planted lowland area in the monsoon, followed by 6% from rivers/streams and 4% from groundwater/wells. By contrast, dam irrigation in the uplands accounts for only 5%, approximately the same amount of irrigated upland area in the monsoon supplied by rivers/streams (7%).

Dam irrigation plays a major role in the cultivation of paddy in each of the three seasons, as 83% of paddy area is irrigated by a dam in the pre-monsoon, 64% in the monsoon, and 84% in the post-monsoon (Appendix Table 3). It is important to note that only 29% of paddy area in the monsoon is rainfed, thus most monsoon paddy is irrigated. The second most important lowland crop by area is sesame, of which 84% is irrigated. By contrast, 99% of upland monsoon sesame, groundnut and green gram area is rainfed, and only 8 and 12% of upland dry season sesame and green gram area is irrigated.

Figure 2. Share of Total Area by Water Source for Target Crops by Season and Lowland/Upland



2.4. Area Planted by Cropping Pattern

In this section, we investigate the prevalence of three kinds of cropping patterns: monocropping, intercropping and mixed cropping. Monocropping refers to growing only one crop on a parcel. Intercropping is when two or more crops are grown on a parcel and when different crops are planted either within the same row or in adjacent rows. Mixed cropping is when two or more crops are grown on a parcel, but they are not intercropped.

The vast majority of cultivated lowland and upland parcels are monocropped, regardless of season, ranging from a low of 74% of planted area in rainfed uplands during the monsoon to 100% of planted area in rainfed lowlands in the pre-monsoon (Tables 1 and 2). Intercropping is almost exclusively practiced on rainfed parcels, as the highest rate of intercropping in irrigated lowlands is 2% of planted area (in the pre-monsoon) and 7% of planted area in irrigated uplands (also in the pre-monsoon). Intercropping is most prevalent in the rainfed uplands, accounting for 10% of planted area in the pre-monsoon, 26% in the monsoon and 15% in the post-monsoon. While there is intercropping of rainfed lowlands, the amount of area covered is low compared with the uplands, given that 94% of uplands area is rainfed as compared with only 24% of lowlands area.

The most common intercrop in the rainfed uplands was sesame-pigeon pea, which accounted for 61% of intercropped area in the monsoon, followed by groundnut-pigeon pea (27%) and groundnut-sesame (7%). Likewise, in rainfed lowlands, sesame-pigeon pea accounted for 32% of intercropped area in the monsoon followed by groundnut-pigeon pea (11%).

Table 1. Percentage of Area Planted by Cropping Pattern and Season, Lowlands

Cropping pattern	Rainfed			Irrigated		
	Pre-monsoon	Monsoon	Post-monsoon	Pre-monsoon	Monsoon	Post-monsoon
Monocropping	100.0%	80.2%	78.4%	98.4%	99.4%	98.8%
Intercropping	0%	19.7%	21.6%	1.6%	0.6%	0.9%
Mixed cropping	0%	0.1%	0.0%	0.0%	0.0%	0.3%

Source: Authors calculations based on READZ household survey data unless otherwise noted.

Table 2. Percentage of Area Planted by Cropping Pattern and Season, Uplands

Cropping pattern	Rainfed			Irrigated		
	Pre-monsoon	Monsoon	Post-monsoon	Pre-monsoon	Monsoon	Post-monsoon
Monocropping	90.3%	73.7%	81.2%	92.7%	91.3%	99.1%
Intercropping	9.7%	25.8%	14.5%	7.3%	5.9%	0.9%
Mixed cropping	0.0%	0.5%	4.3%	0.0%	2.8%	0.0%

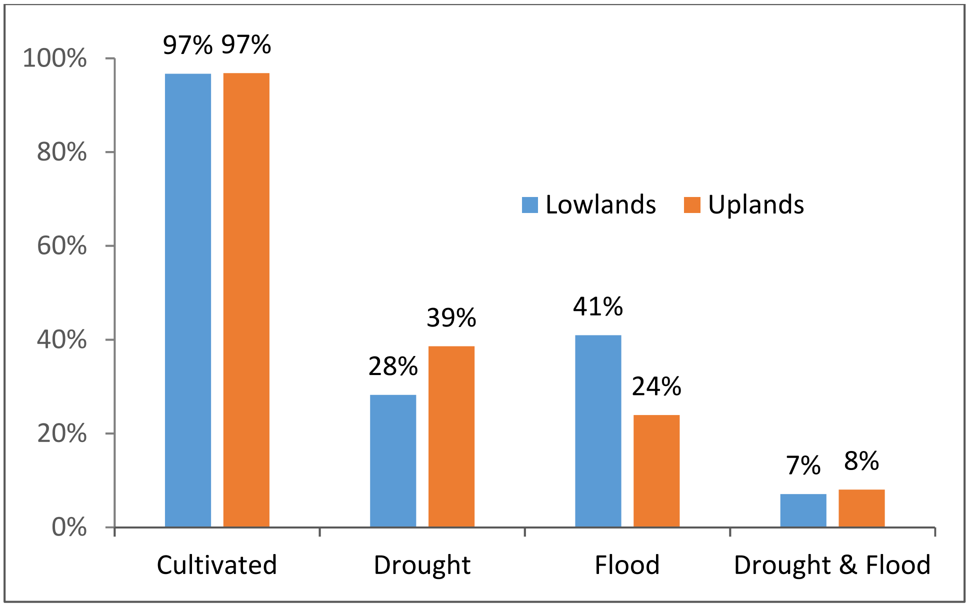
2.5. Parcels Cultivated or Affected by Drought/flood

Almost all (97%) of upland and lowland parcels were cultivated in at least one season during the previous year, leaving only 3% of upland and lowland parcels under fallow for the entire year (Figure 3). Drought and flooding were common on both types of land, though drought was more prevalent on uplands (39% of parcels) relative to lowlands (28%), while flooding was more prevalent in the lowlands (41% of parcels) relative to the uplands (24%). In addition, 7% and 8% of lowland and upland parcels respectively were adversely affected by both drought and flooding in the previous 12 months.

2.6. Cropping Intensity

Cropping intensity is a measure of the extent of land cultivation of a specific parcel throughout an entire year. It is computed as the total area cultivated across the three seasons on a given parcel divided by the area of the parcel, expressed as a percentage. For example, a household that cultivates no area during the year would have a cropping intensity of 0, while one that cultivates all of one parcel for one season only, and leaves the parcel fallow in the other two seasons would have a cropping intensity of 100. A parcel that is fully planted for each of the three seasons would attain the maximum cropping intensity of 300.

Figure 3. Share of Agricultural Parcels Cultivated/Drought/Flood Affected in Last 12 Months



In the lowlands, we find that parcels that are irrigated have a higher cropping intensity (191) than those without irrigation (122). This demonstrates a large benefit in the lowlands from access to irrigation, which enables farmers to attain a higher amount of area planted during the year. This finding is consistent with research from Soe (2011) which also found that access to irrigation in the Dry Zone results in higher cropping intensity. The cropping intensity in the uplands does not differ between parcels with (162) or without (164) access to irrigation. This may suggest that the higher cost of irrigation water in the uplands leads to it being used for intensification/yield stability rather than expansion of the cropped area.[2]

While one of the advantages of widespread access to irrigation on lowland parcels is higher cropping intensity, there is not much difference in the average cropping intensity of lowland parcels (174) relative to upland parcels (164). The reason for this is because while dam irrigation enables lowland paddy, sesame and green gram to be grown in the pre-monsoon, and enables the majority of paddy area to be irrigated during the monsoon, it apparently does not provide sufficient water for the post-monsoon, as 71% of lowland area remains in fallow that season. Likewise, farmers with upland parcels appear to have a similar lack of water (rainfall) in the pre-monsoon, as 76% of upland area is fallowed in that season.

[2] Section 4.4 explains why dam irrigation (very prevalent in lowlands) costs less than irrigation via pumping water from rivers/streams or groundwater/wells, which together account for more than half of upland irrigation.

3. CROP PRODUCTION AND MARKETING

3.1. Percentage of Farm Households Growing Major Crops

In this section, we present analysis of crop production and marketing for the thirteen predominant ('major') annual crops grown in the Dry Zone. We also present analysis of input use for the four main crops of interest, paddy, groundnut, sesame and green gram.

Nearly all sampled households (96%) owning or operating agricultural land engaged in production of one or more of the 13 crops predominantly grown in the Dry Zone. The number of annual crops grown ranged from 1 to 8, with an average of 3 crops per household. The most widely planted crops are sesame, paddy, groundnut, pigeon pea, chickpea, green gram and sorghum (each grown by more than 20% of households). Sixty-eight percent of households reported producing sesame and 48% cultivated paddy, while 33% grew groundnut or pigeon pea (Table 3).

3.2. Average Area Planted to Major Annual Crops over Previous 12 Months

Among the 13 major annual crops planted over the previous 12 months, the average acreage planted per household was highest for sesame (5.1 acres), followed by groundnut (4.7 acres), paddy (4.1 acres) and pigeon pea (3.7 acres) (Table 3).

Table 3. Percentage of Households Growing Major Crops and Household Average/Median Area Planted

Crop	% of farm households growing crop	Household area planted by crop (acres)	
		mean	median
Paddy	48	4.1	2.5
Groundnut	33	4.7	2.9
Sesame	68	5.1	3.0
Sunflower	5	2.5	1.8
Pigeon pea	33	3.7	1.7
Green gram	21	2.7	2.0
Black gram	3	2.1	1.3
Chickpea	22	3.3	2.0
Other beans	9	2.2	1.4
Maize	1	1.6	1.0
Sorghum	21	2.4	2.0
Cotton	3	2.7	3.0
Chilli	8	1.3	1.0

3.3. Crop Management Practices

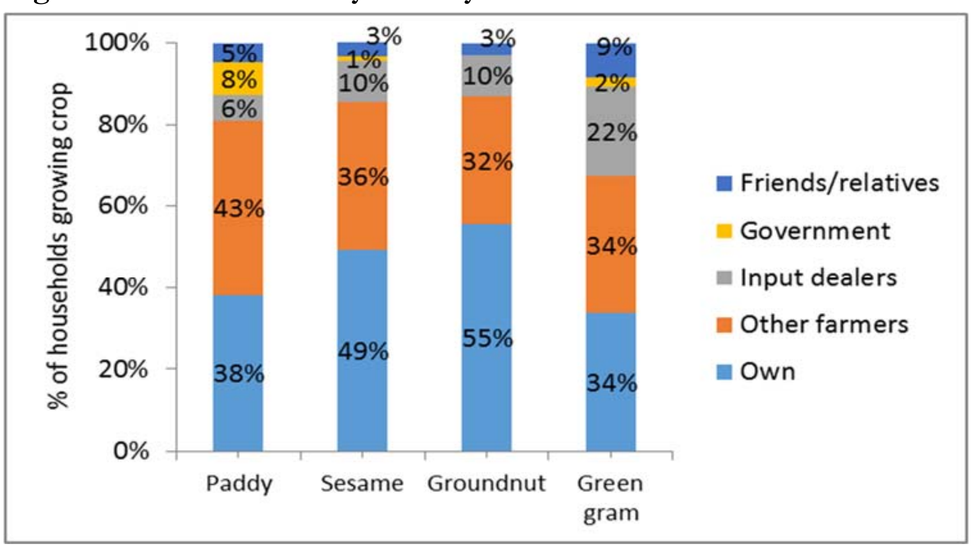
The following sub-sections outline input use for the four main crops of interest: paddy, sesame, groundnut, and green gram.

3.3.1. Seeds

For each of these four crops, the main sources of seed are own production and other farmers. The share of these two sources combined ranged from 68% for green gram (34% own seed, 34% from other farmers) to 87% for groundnut (Figure 4). In regard to other potential sources of seed, only six to ten percent of growers of paddy, sesame and groundnut obtained their seed from input dealers, compared to 22% of green gram growers. While 8% of paddy seed was sourced from the government, this source accounted for less than 2% of seed for the other crops. Irrespective of season, use of improved varieties is low for green gram (8%), groundnut (12%) and sesame (23%).

While 42% of paddy seed was an improved variety, this percentage is quite low as compared with other Southeast Asian countries such as Cambodia (where 59% of paddy is an improved variety), Laos (71%), Vietnam (96%) and Thailand (100%) (Maredia and Reyes 2016). However, 27% of communities in the four townships covered by READZ noted that farmers in their village had shifted to shorter-duration varieties in response to climate change.[3]

Figure 4. Sources of Paddy Seed by Season



[3] The community-level statistics cited in this paper come from the READZ Dry Zone community survey. A description of the community survey and its methodology is provided by Belton et al. (2017). This survey covered 300 villages across 14 townships within the three main regions of the Dry Zone, Magway, Sagaing and Mandalay. Results presented in this paper only include responses from the 99 villages interviewed in the four townships that were covered by both the community and household surveys (Butalin, Magway, Pwint Phyu and Myittha).

For example, in scoping research prior to the community survey, key informants frequently reported that farmers had begun using a 90-day duration rice variety to minimize the risk of crop losses due to water shortages late in the production cycle or heavy rainfall during flowering (Oo 2018). Thus, efforts to promote improved paddy varieties need to consider the increasing demand for short-duration paddy varieties in some communities, which may not have been tested and adapted yet to local conditions.

3.3.2. Inputs

Fertilizer is the most commonly used input for all four target crops, ranging from 75% for green gram to 96% for paddy (Table 4). The percentages of sesame, groundnut and green gram growers using inorganic fertilizer were also high, ranging from 72% for green gram to 86% for post-monsoon groundnuts. Pesticide is the second most widely used input for all crop types. About half the growers of these crops used pesticides, with the highest rate for post-monsoon groundnuts at 63% (Table 4). The frequency of herbicide and fungicide use was relatively low, ranging between 6 to 30% for the former and between 9 to 31% for the latter.

As expected, organic fertilizer (manure) was mainly applied during the monsoon when it can decompose. Herbicide was also applied more frequently in the monsoon, when weed competition is higher, relative to the post-monsoon (Table 4).

Application rates of total inorganic fertilizer for each crop did not differ much by season, nor did average application rates of different types of fertilizers (Table 5). An exception to this is green gram, where the total inorganic fertilizer application rate in the lowlands was close to twice that of the uplands (74 to 40 kg/acre), a result likely due to the fact that most lowland green gram is irrigated while most upland green gram is rainfed. Paddy growers had a much higher average total inorganic fertilizer rate (120 kg/acre) relative to growers of the other main crops, such as the average of 55 kg/acre for sesame and 51 kg/acre for groundnut (Table 5).

Table 4. Percentage of Paddy, Sesame, Groundnut, and Green Gram Growers Using Inputs by Type

			Upland Groundnut		
Input	Lowland Paddy	Upland Sesame	Monsoon	Post-Monsoon	Green gram
	----------- % of crop growers using inputs by type --------				
Any fertilizer	96	87	90	87	75
Inorganic fertilizer	96	82	79	86	72
Organic fertilizer	50	75	59	22	26
Pesticide	47	51	48	63	58
Herbicide	30	6	19	7	8
Fungicide	9	15	17	31	15

Table 5. Average Quantity of Inorganic Fertilizers Applied by Type and by Crop (Kg/Acre), among Those Applying Each Type of Fertilizer

Crop	Urea	T-super	Potash	NPK	All Inorganic Fertilizer
	--------- kilogram/acre of fertilizer applied --------				
Lowland Paddy	74	72	55	64	120
Upland Sesame	30	42	30	38	55
Upland Groundnut	29	47	34	42	51
Lowland green gram	43	44		45	74
Upland green gram	21	20	20	33	40

For organic fertilizer, sesame growers applied the average highest rate of manure (3.4 carts/acre), followed by paddy and monsoon groundnut (2.4 and 2.3 carts/acre), and by post-monsoon groundnut and green gram (1 and 0.8 carts/acre). Not surprisingly, average manure application rates are related to livestock ownership measured by Tropical Livestock Units per acre (TLU[4]). Households in the highest TLU tercile applied approximately 2 to 3 times as many carts/acre of manure as households in TLU tercile 1.

The frequency of input usage and average application rates of inorganic fertilizer by land-holding tercile show some evidence that farmers with less landholding (those in land tercile 1 or 2) are cultivating their parcels more intensively than those with more landholding. For example, the average inorganic fertilizer application rate for paddy is 126 kg/acre in land tercile 1, 131 kg/acre for tercile 2 and 96 kg/acre in tercile 3. For sesame, the average fertilizer rate for land tercile 1 is 65 kg/acre, 52 kg/acre for tercile 2 and 51 kg/acre for tercile 3. Likewise, the percentage of paddy growers using pesticides falls from 56% for the lowest land tercile (tercile 1) to 50% for land tercile 2 and to 36% for the highest land tercile (tercile 3). We also see this pattern with pesticides and fungicides used on green gram: for pesticides, 61% for tercile 1, 67% for tercile 2, and 47% for tercile 3; for fungicides 16% for tercile 1, 25% for tercile 2 and 4% for tercile 3.

3.4. Weather Conditions and Expected and Observed Crop Yields

Before presenting observed yields from the household survey data, we first provide some context by presenting expected yields under different growing conditions from the community survey. In order to assess the impact of climate change and variability on crop productivity, the community survey asked local leaders about typical yields of seven major crops in years when climatic conditions were *good, average, or bad*.[5]

[4] TLU = number of cows/oxen/draft animals + (0.4*number of pigs) + 0.2*(number of goats) + 0.02*(number of chickens) + 0.06*(number of ducks) (FAO 2007).

[5] Non-climatic factors like fertilizer use and irrigation access that influence crop productivity at the level of individual farms were assumed to be constant across the three different categories of annual climate conditions.

Table 6. Average Expected Crop Yields by Type of Climatic Year in Butalin, Magway, Pwint Phyu and Myittha Townships

	Average yield by type of climatic year					
	Baskets/acre			Kilograms/hectare		
Crop	Good	Average	Bad	Good	Average	Bad
Monsoon paddy	70.1	52.7	33.5	3,622	2,722	1,731
Dry season paddy	91.8	71.0	49.8	4,740	3,664	2,571
Groundnut[1]	52.2	36.7	16.2	1,474	1,036	458
Sesame	11.2	7.2	2.9	686	444	181
Pigeon pea	10.6	6.9	3.3	855	554	268
Green gram	12.7	8.0	3.9	993	620	301

Source: READZ Community Survey. Notes: 1) with shell.

The results indicate that the major crops of the Dry Zone are subject to a high level of yield variation depending on weather conditions during a given year. Monsoon and dry season paddy have the least amount of expected yield variation between good, average and bad climatic years, which is not surprising given that paddy in the Dry Zone is predominantly irrigated, even in the monsoon. For example, the yield from a good climatic year for monsoon paddy is expected to be 33% higher than that of an average year, while an average year's yield is 57% higher than that of a bad year (Table 6). By contrast, crops that are predominantly rainfed in the Dry Zone have considerably more yield variation across climatic conditions, especially when comparing the difference between an average and a bad climatic year. For example, the sesame yield from a good climatic year is expected to be 55% higher than that of an average year, while yield in an average year is 107% higher than that in a bad year.

Given this context, the observed yield of paddy from the household survey (55 baskets/acre, or 2,851 kg/ha) was close to the expectation for an average climatic year, while the annual yield of groundnut (28 baskets/acre or 1,745 kg/ha) and sesame (4.6 baskets/acre, 285 kg/ha) fell between the expected yields for an average and a bad climatic year (Tables 6 & 7). Pigeon pea was the only rainfed crop that met its yield expectation for an average year, with a yield of 7.5 baskets/acre (606 kg/ha). Green gram performed the worst, with an average yield of 4.4 baskets/acre (339 kg/ha), which is just above the yield expectation for a bad year.

However, it should be noted that the paddy yield expectations for a good year are well below average paddy yields of neighboring countries. For example, paddy yield in a good monsoon (dry season) of 3,568 kg/ha (4,672 kg/ha) is comparable with that from Cambodia (3,200 kg/ha), but well below that of Thailand (6,090 kg/ha) and Vietnam (6,120 kg/ha) (LIFT 2016). Given that the average application rates of Nitrogen to monsoon paddy (95 kg/ha) met a general blanket recommendation level (ibid 2016)—and that for dry season paddy (97 kg/ha) was slightly lower than the recommendation of 110 kg/ha—this suggests that other factors may be constraining paddy yields in the Dry Zone, such as relatively low improved varietal use, unreliable irrigation water control, insufficient drainage, and perhaps more frequent adverse weather conditions.

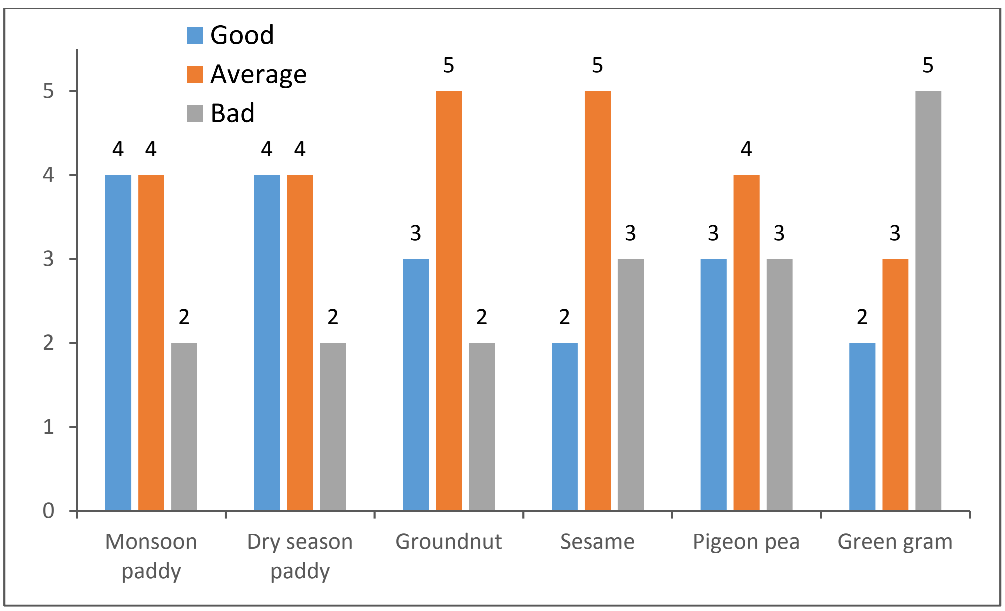
Table 7. Mean and Median Annual Yield by Crop

	Average annual yield			
	Baskets/acre		Kilograms/hectare	
Crop	mean	median	mean	median
Paddy	55.2	55.6	2,851	2,869
Groundnut[1]	27.9	26.7	788	753
Sesame	4.6	4.0	285	246
Sunflower	6.3	5.0	227	179
Pigeon pea	7.5	4.9	606	394
Green gram	4.4	3.0	339	234
Chickpea	8.3	7.5	642	580

Source: READZ Household Survey. Notes: 1) with shell.

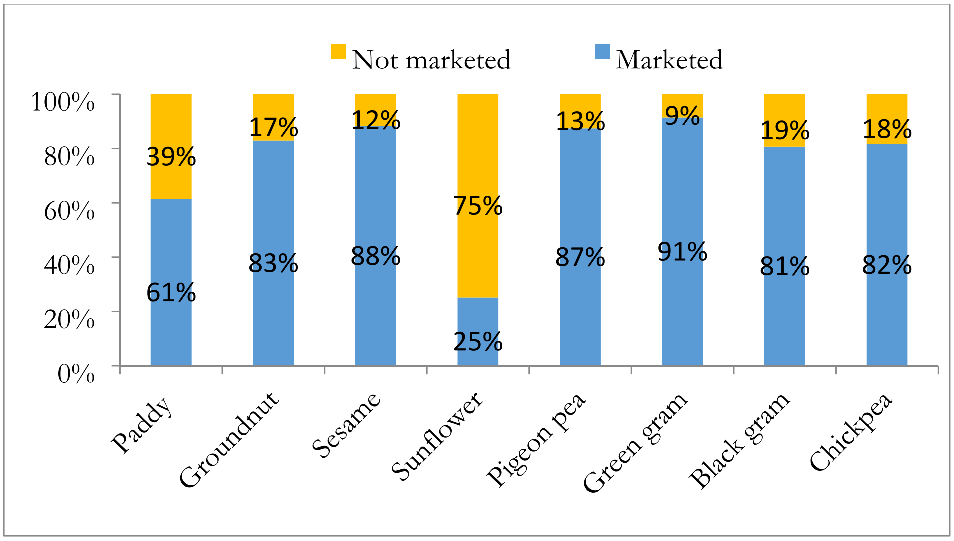
The community survey also elicited information on the frequency of good, average, and bad climate conditions for each crop over the past 10 years. Monsoon and dry season paddy experienced good climate conditions during four of the past ten years, while growers of groundnut and pigeon pea experienced these conditions in three of the last ten years, and growers of sesame and green gram in only two of the last ten years (Figure 5). Conditions were bad for five out of the last ten years for green gram, three years for sesame and pigeon pea, and only two years for monsoon and dry paddy and groundnut. These results suggest that green gram has been most adversely affected by climatic conditions over the past ten years, along with sesame and pigeon pea to a lesser degree.

Figure 5. Frequency of Good, Average, and Bad Climate Conditions in the Last 10 Years, by Crop, in Butalin, Magway, Pwint Phyu, and Myittha Townships



Source: READZ Community Survey.

Figure 6. Percentage of Households That Marketed Major Crops, by Crop



3.5. Crop Marketing

The majority of households marketed most of their production of major crops, with the exception of sunflower, for which only 25% of growers sold the crop (Figure 6). Sixty-one percent of paddy growers sold at least some paddy, and more than 80% of growers of groundnut, sesame, pigeon pea and green and black gram sold at least some of their production (Figure 6).

The percentage of paddy growers who sell paddy in the Dry Zone (61%) is lower relative to the Delta, where 75% of paddy growers sold in the monsoon and 79% in the dry season (Cho, Belton, and Boughton 2017). Paddy sellers have double the median paddy area planted per capita (0.8 acres/capita) relative to non-sellers of paddy (0.4 acres/capita).

The shares of marketed production of paddy, groundnut, sesame and sunflower were similar with the percentage of households who sold those crops (Figure 7). The share of marketed production of pigeon pea (67%) and black gram (58%) is lower than expected (Figure 7), as conventional wisdom holds that Myanmar households don't consume many pulses (with the exception of chickpea). However, because the household survey did not collect information on expected future sales, quantity reserved for seed or paid out to hired laborers, it is not possible to estimate the precise shares of total production that were sold as well as quantities reserved for own consumption.

Nearly all paddy producers (97%) sold their harvested production unmilled, while nearly all groundnut producers (93%) sold it unshelled (Figure 8). All growers of sesame, pigeon pea, green gram, black gram and chickpea growers sold their crop threshed, while 62% of sesame growers sold it threshed and 38% sold it as oil.

Figure 7. Share of Total Production Sold by Crop

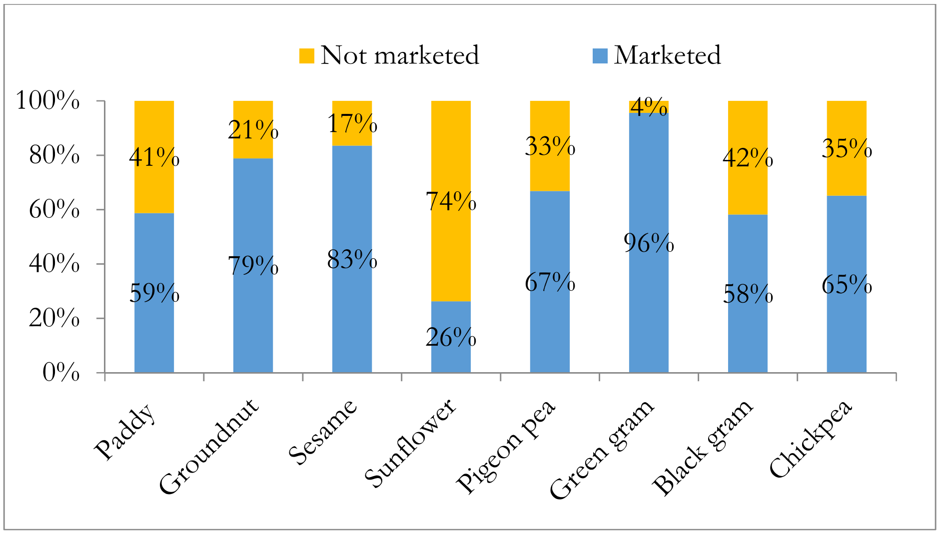
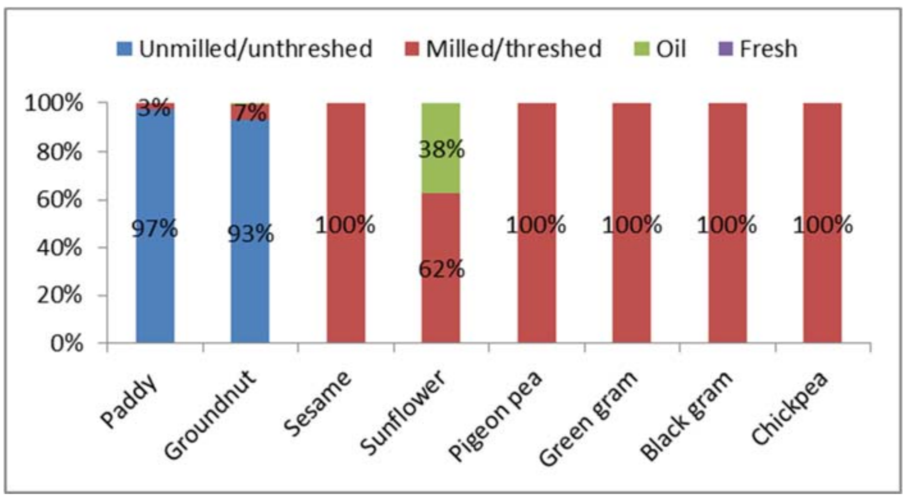


Figure 8. Share of Total Amount Sold in Different Crop States



3.6. Sale Prices of Major Crops

The sale prices of different crops differ depending on the form and time of sale (though the household survey does not provide information on when crop sales were made). The average sale price of paddy was 6,457 MMK[6]/basket (309 MMK/kg) while the sale price of milled rice was 18,696 MMK/basket (550 MMK/kg) (Table 8). Among the oilseed crops, the average sale price of sunflower oil was the highest (3,633 MMK/viss) followed by threshed sesame (37,456 MMK/basket).

[6] MMK is Myanmar kyat (local currency)

Table 8. Average Sale Price per Unit of Different Crops in MMK

	Unthreshed/Unmilled		Threshed/Milled		Oil
Crop	per basket	per kg	per basket	per kg	per viss
Paddy	6,457	309	18,696	550	
Groundnut	7,944	697	27,654	1,093	
Sesame			37,456	1,506	
Sunflower			13,788	951	3,633
Pigeon pea			23,942	736	
Green gram			25,463	808	
Black gram			30,344	951	
Chickpea			34,453	1,101	
Other beans			21,545	680	

4. CROP PRODUCTION COSTS AND PROFITABILITY

4.1. Long-term Labor

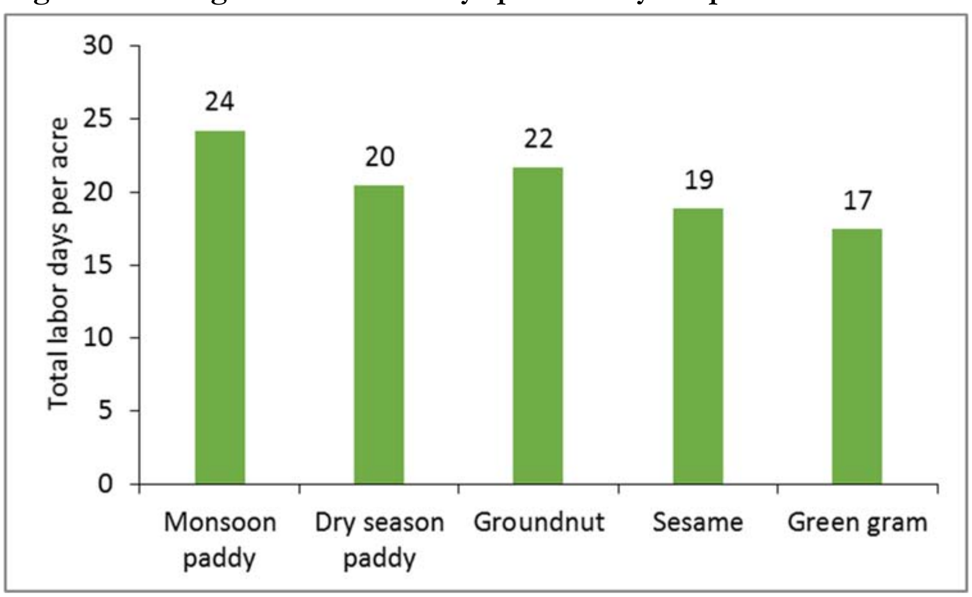
Only 2.4% of households that owned or operated land hired long-term labor for their farms. Households with the largest landholdings (tercile 3) hired the majority of long term labor (81%), while those in tercile 2 accounted for 16% and those from land tercile 1 only 3%. Most long-term laborers were men (84%). On average, households hired permanent labor for 214 days, at an average wage of MMK 5,685 per day.

4.2. Casual Labor

Among households that owned or operated land, 93% hired casual labor for use in crop production. The average demand for labor per acre (family and hired labor) for monsoon and dry season paddy was 24 and 20 labor days/acre, respectively (Figure 9). The difference in labor demand between monsoon and dry season paddy is largely due to the fact that 41% of dry season paddy is harvested via combine as compared with 13% of monsoon paddy. Combine use in the dry season saves an average of 6.4 labor days/acre relative to households that used manual harvesting and mechanized threshing, and 11.3 labor days/acre relative to those using both manual harvesting and threshing (Mather 2018). Groundnut used an average of 22 labor days/acre, sesame 19 days/acre and green gram 17 days/acre.

As we found with other types of inputs, farmers in the lowest land tercile (those with the lowest landholdings) tend to cultivate their parcels more intensively than those in the middle and highest land tercile. For example, monsoon paddy growers in land tercile 1 use 12% more labor per acre (family and hired) relative to paddy growers in the middle (2) and highest (3) terciles.

Figure 9. Average Total Labor Days per Acre by Crop



The difference is even greater for groundnut and sesame growers, as those in land tercile 1 use 49% and 29% (respectively) more labor per acre than those in the middle land tercile, and 28% and 43% (respectively) more than in the highest land tercile.

The share of labor days used in specific farming activities varies considerably between different crops, due in part to the nature of the crop and in part to differing rates of mechanization by crop. For example, in monsoon and dry season paddy production, 30 and 39% of labor (respectively) is spent on seeding preparation, transplanting and sowing seed (Table 9).[7] By contrast, sowing for groundnut, sesame and green gram only requires six to seven percent of total labor used. The labor used for weeding ranges from 19% of labor demand for monsoon paddy to 34% for sesame and green gram. Given the heavy labor requirements for weeding of groundnut, sesame and green gram, it is surprising that there are not higher levels of herbicide use on those crops (Table 4).

Twenty-seven percent of labor for monsoon paddy is spent on harvesting, compared with less than half that amount (12%) for dry season paddy (Table 9), which is due to the more frequent use of combine harvesting in the dry season, as noted above. Harvest labor for sesame, groundnut and green gram accounts for 26% to 33% of total labor, as these crops are harvested manually.

Threshing/drying only requires 4% of total labor for monsoon paddy (Table 9), because 13% of monsoon paddy is harvested/threshed by a combine harvester and 58% is threshed mechanically. Dry season paddy requires only 1% of total labor for threshing given that 41% of dry season paddy is harvested/threshed by a combine harvester and 26% is threshed mechanically. Likewise, only 6% of labor spent on green gram is for threshing, as 40% of green gram is threshed mechanically.

Table 9. Share of Labor Days per Acre, by Crop and Farming Activity (%)

Activity	Monsoon paddy	Dry season paddy	Groundnut	Sesame	Green gram
Seedling preparation	5	7	0	0	0
Land preparation	13	12	12	17	13
Transplanting	18	24	0	0	0
Sowing seed	7	8	6	6	5
Weeding	19	27	28	34	34
Fertilizer application	4	4	3	3	3
Pesticide application	2	4	2	3	5
Field monitoring	0	0	0	0	0
Harvesting	27	12	26	25	33
Threshing / drying	4	1	22	12	6
Hauling / Transporting	1	1	1	0	1

[7] Both monsoon and dry season paddy were predominantly established by direct seeding (a labor saving approach): 75% of monsoon paddy growers and 80% of dry season paddy growers used this method.

By contrast, less than 2% of groundnut or sesame is mechanically threshed, thus manual threshing and drying requires 22 and 12% of total labor demand for those two crops, respectively. This suggests that mechanized threshing of these crops could significantly reduce labor costs for growers of those crops.

In the Dry Zone, there is a significant gender gap for wages in agricultural labor across four of the five crops listed. Female laborers' wages for monsoon and dry season paddy, groundnut and sesame production range between 80 to 86% of the wage rate for males (Figure 10). For example, female laborers hired in monsoon paddy production earn MMK 4,090 per day as compared with MMK 4,639 for male laborers on the same crop (i.e., 80% of male wages) (Figure 10). By contrast, the wage gap in the Delta is considerably larger as female farm laborers there earn only about two thirds of the daily wage earned by male laborers (Cho, Belton, and Boughton 2017). It is not known why both male and female wages for green gram are considerably lower than those for other crops (Figure 10). One explanation could be that labor employed for green gram harvesting may be younger persons as the work is not as energy-intensive compared with that for other crops. For example, the average harvest daily wage for monsoon sesame and monsoon groundnut is double that of monsoon green gram.

4.3. Production Costs and Profitability: Annual Data

Among the eight of the main crops in the Dry Zone, the average production cost per acre of paddy (monsoon and dry season combined was highest at 169,092 MMK/acre, followed by groundnut (131,683 MMK/acre) and black gram (121,528 MMK/acre) (Table 10). The average cost of production for monsoon and dry season paddy reflects primarily the monsoon crop which accounts for almost 80% of annual paddy production. Although average paddy production costs are the

Figure 10. Average Men's and Women's Daily Wage Rates by Crop (MMK/Day)

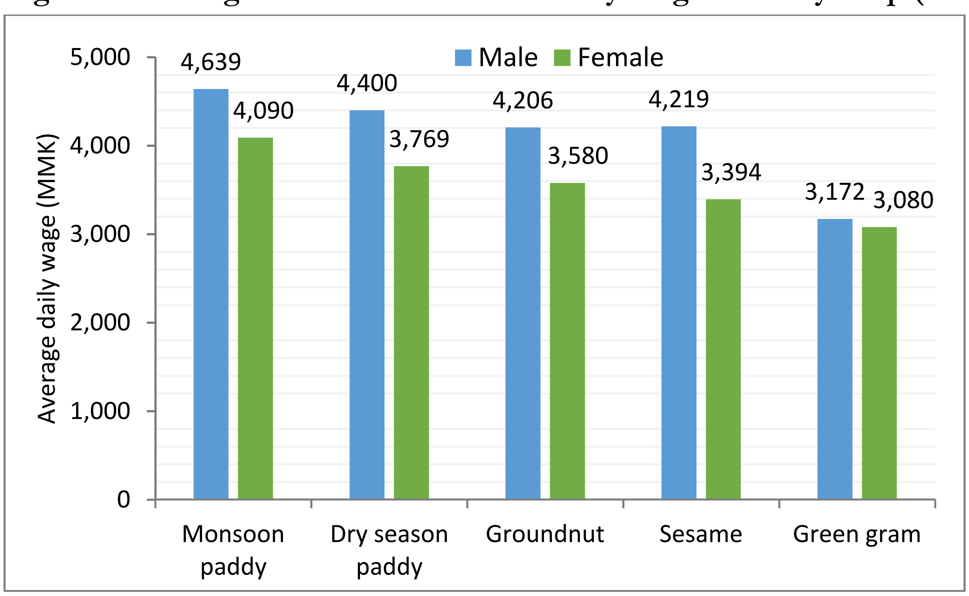


Table 10. Production Cost and Gross Margins from Annual Data (MMK per Acre)

	Production cost		Gross margin	
Crop	Average	Median	Average	Median
Paddy	169,092	166,667	181,614	174,012
Groundnut	131,638	111,111	85,466	70,330
Sesame	95,761	86,779	71,638	55,249
Sunflower	54,805	38,750	50,811	39,000
Pigeon pea	64,287	44,118	149,733	71,765
Green gram	77,887	55,333	33,881	12,397
Black gram	121,528	114,286	96,990	86,667
Chickpea	109,972	100,000	175,765	138,000

highest among the major crops listed, paddy also returns the highest average gross margin (value of output minus variable costs) of 181,614 MMK/acre (Table 10). The average gross margins of green gram, groundnut, sesame and sunflower were quite low, driven in large part due to low yields, as discussed further below.

4.4. Production Costs: Parcel-level Data

As noted above, the household survey asked respondents for detailed information on the harvested quantity and costs of production with respect to the 'main' parcel on which they grew one of the four target crops of interest (paddy, groundnut, sesame or green gram). This parcel-specific information is helpful for two reasons. First, it provides estimates of gross margins that are likely to be more accurate than those based on annual harvested quantities and total production cost by crop (as shown in Table 10). Information on parcel-level crop production costs are elicited separately by season, for only one parcel, and itemize the different cost items (i.e., seeds, other inputs, hired labor, hired mechanized and/or animal draft power, and irrigation costs). With the exception of groundnut, average total production costs/acre based on parcel-level data for these four crops are approximately 10 to 15% higher than those generated by annual recall data on total farm production by crop in Table 10. Second, it enables us to compute the structure of the cost of production for different crops.

With the exception of groundnut, the costs of hired labor, inputs and machinery are the three largest production cost categories and together account for between 79% and 88% of production costs for the four target crops (Figure 11). Tables 11 and 12 present the average value and share of production costs allocated to different types of inputs by households growing monsoon and dry season paddy, groundnut, sesame and green gram. Among these four crops, monsoon and dry season paddy have the highest costs of production per acre (180,333 and 188,920 MMK/acre, respectively) (Table 11), followed by groundnut (132,093 MMK/acre), sesame (100,955 MMK/acre) and green gram (85,134 MMK/acre) (Table 12).

Figure 11. Composition of Parcel-Level Total Costs of Production by Crop

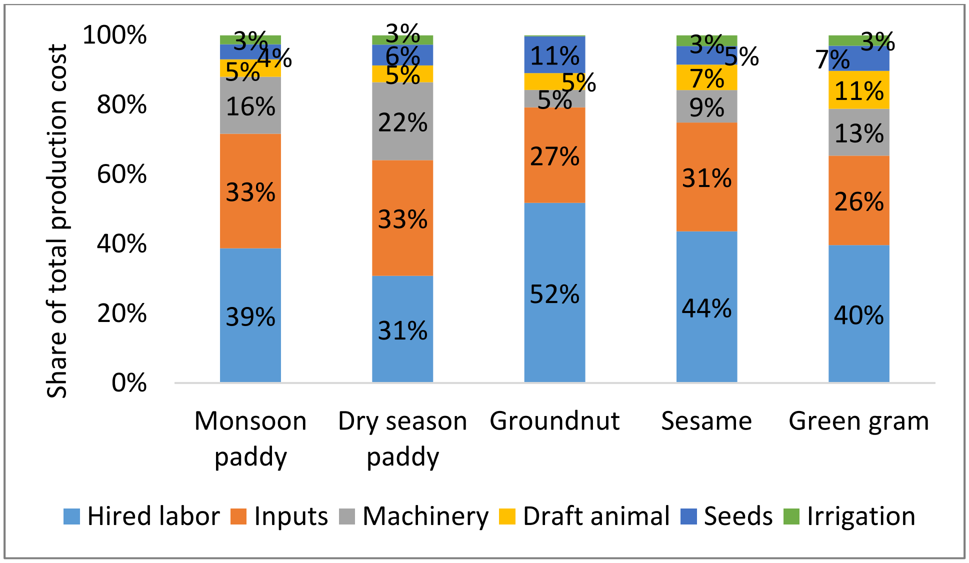


Table 11. Average Value and Share of Monsoon and Dry Season Paddy Production Costs per Acre

	Monsoon paddy		Dry season paddy	
Type of input	Cost per acre (MMK)	Share (%)	Cost per acre (MMK)	Share (%)
Hired labor	71,377	39%	60,666	31%
Inputs	60,618	33%	65,330	33%
Machinery	29,715	16%	43,450	22%
Draft animal	9,490	5%	9,641	5%
Seeds	4,565	4%	5,508	6%
Irrigation	4,567	3%	4,324	3%
All	180,333	100%	188,920	100%

Note: Shares of each type of input are computed as the average share across households.

Although total production costs per acre for monsoon and dry season paddy are similar, hired labor for monsoon paddy is approximately 11,000 MMK/acre higher than that for the dry season, reflecting the lower use of combine harvesters for monsoon paddy (Table 11). The cost of mechanization services are about 13,000 MMK/acre higher for dry season as compared with monsoon paddy, reflecting higher combine rental costs.

While most monsoon and dry season paddy is irrigated, paddy growers in the Dry Zone only pay an average of 4 to 5,000 MMK/acre for irrigation, which is considerably less than the average 29,248 MMK/acre paid by Delta dry season paddy producers (Cho, Belton, and Boughton 2017). The reason for this large difference in the cost of irrigation for dry season paddy has to do with the predominant irrigation source in each zone and its ownership (public vs. private).

Table 12. Average Value and Share of Groundnut, Sesame, and Green Gram Production Costs per Acre

	Groundnut		Sesame		Green gram	
Type of input	Cost per acre (MMK)	Share (%)	Cost per acre (MMK)	Share (%)	Cost per acre (MMK)	Share (%)
Hired labor	72,261	52%	47,842	44%	38,795	40%
Inputs	33,759	27%	33,221	31%	24,562	26%
Machinery	8,134	5%	8,452	9%	10,872	13%
Draft animal	7,258	5%	7,943	7%	7,491	11%
Seeds	9,871	11%	1,024	5%	1,224	7%
Irrigation	809	0%	2,473	3%	2,190	3%
All	132,093	100%	100,955	100%	85,134	100%

Note: Shares of each type of input are computed as the average share across households.

Nearly all dry season paddy in the Dry Zone receives dam irrigation (Appendix Table 3), while almost all dry season paddy in the Delta is irrigated by pumping from rivers/streams. In the Dry Zone, irrigation fees are quite low (2,000 MMK/acre for both seasons) as the dams are publically owned,[8] and only about 25% of dry season paddy parcels report having paid an irrigation fee.[9] By contrast, most dry season paddy production in the Delta is irrigated by privately controlled pumping from rivers/streams, and pump rental and fuel costs per acre are considerably higher than irrigation fees.

Average hired machinery cost/acres for groundnut and sesame are only about one-fourth to one-third those for paddy as the only machinery used for groundnut and sesame production is for land preparation (Table 12). Average hired labor costs/acre are relatively lower for green gram relative to groundnut and sesame in part because 40% of green gram is mechanically threshed while the other crops are manually threshed.

4.5. Gross Margins, Crop Losses, and Yields: Parcel-Level Data

We next present parcel-level gross margins for the four target crops, which are calculated as the gross revenue from a given parcel in a given season less the production costs associated with that parcel from that season.[10] As expected, gross margins for dry season paddy are higher than those of monsoon paddy (Table 13), given that there is considerably more sunlight during the dry season,

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[8] Farmers pay MMK 9,000 per acre per season for full irrigation of paddy in the dry season; MMK 6,000 per acre per season for irrigation of non-paddy crops in the dry season; and MMK 3,000 per acre per season for irrigation during the wet season, regardless of the type of crop (IWMI 2015).

[9] According to an irrigation official, no action has been taken against farmers failing to pay irrigation fees owed in recent years, and irrigation continues to be provided to farmers' fields whether they paid the irrigation fee or not.

[10] Crop-specific production costs include the costs of seeds (if purchased), other inputs such as fertilizer, manure (if purchased) and pesticides, rental costs of machinery (tractors, combines, threshers) and animal draft power, fuel and other variable costs for tractor owners, hired farm labor, and rental fees and fuel for irrigation pumps and irrigation fees paid for access to dam irrigation.

Table 13. Parcel Gross Margins by Crop

	Gross margin (MMK/acre)			Gross margin ($US/acre)	
Crop	mean	median	# of cases	mean	median
Dry season Paddy	189,892	203,438	106	148	158
Monsoon Paddy	160,604	152,536	397	125	119
Rainfed	164,996	143,184	105	128	111
Irrigated	159,087	154,536	292	124	120
Groundnut	111,060	81,417	176	86	63
Sesame	105,115	70,167	489	82	55
Green gram	52,210	8,292	115	41	6
Rainfed	29,108	(5,552)	80	23	(4)
Irrigated	115,986	93,506	35	90	73

leading to higher average yields. However, gross margins for groundnut, sesame and rainfed green gram are very low. One reason for this is that a large percentage of households report pre- and/or post-harvest crop losses for these crops. For example, 57% (43%) of sesame producers in the lowlands (uplands) reported having either pre- and/or post-harvest crop losses (Table 14).

Table 14. Percentage of Households with Pre- and/or Post-Harvest Crop Losses

Lowland Crop	% HHs with pre-harvest losses	% HHs with post-harvest losses	% HHs with pre- or post-harvest losses
Dry season Paddy	37	9	39
Monsoon Paddy	23	4	24
Rainfed	22	3	23
Irrigated	24	4	24
Sesame	57	3	57
Green gram	30	0	30
Chickpea	25	0	25
Upland Crop			
Groundnut	16	2	16
Sesame	43	3	44
Green gram	34	1	34
Chickpea	33	0	33
Pigeon pea	10	1	10

Likewise, one-third of growers of dry season paddy, green gram, and upland chick pea report either pre-or post-harvest crop losses, along with one-quarter of monsoon paddy and lowland chickpea growers. The two crops with the lowest percentages of households reporting pre-harvest yield loss—10% for pigeon pea and 16% for groundnut—are the two upland crops most resistant to drought.

The effect of crop loss on gross margins is seen more clearly when we separate gross margins of households that do not report crop loss from those that do. For example, median gross margins for dry and monsoon paddy and groundnut are four to five times higher among households that did not report crop loss (Table 15). For sesame and irrigated green gram, those without yield loss achieve median gross margins of 157,964 and 169,940 MMK/acre, respectively, while those with yield loss had median gross margins of only 19,529 MMK/acre and a loss of (21,042) MMK/acre, respectively. The most frequently reported reasons for pre-harvest yield loss for paddy include flooding and excessive rain, while those for groundnut, sesame and green gram include excessive rain and lack of rain (Table 16). Flooding and excessive rain are the most frequently reported reasons for post-harvest yield loss (Table 17).

Table 15. Parcel Gross Margins by Crop with and Without Crop Losses

	Gross margin (MMK/acre) **Without** crop losses reported			Gross margin (MMK/acre) **With** crop losses reported		
Crop	mean	median	# of cases	mean	median	# of cases
Dry season Paddy	272,079	269,846	65	67,240	66,024	41
Monsoon Paddy	201,216	198,072	294	39,599	61,250	103
Rainfed	193,668	183,667	79	71,561	63,000	26
Irrigated	203,900	210,014	215	29,513	42,600	77
Groundnut	123,379	110,777	144	44,548	45,436	32
Sesame	186,248	157,964	237	19,529	7,800	252
Green gram	85,023	45,267	76	(14,234)	(21,042)	39
Rainfed	49,841	(2,385)	52	(10,320)	(23,571)	28
Irrigated	174,899	169,940	24	(26,997)	(2,156)	11

Table 16. Reported Reasons for Pre-Harvest Crop Losses by Crop (%)

	Paddy	Groundnuts	Sesame	Green gram
Flooding	38.8	6.7	13.6	13.2
Excessive rain	24.2	31.7	38.9	39.2
Lack of rain	12.4	24.1	22.3	17.8
Pests	16.0	18.2	13.4	17.8
Diseases	1.1		2.9	
Wild Animals	0.5		0.3	3.2
Extreme temperatures	1.9	11.6	3.4	1.4
Spoilage			1.0	1.7
Does not know	0.9		0.4	
Others	4.3	7.8	3.8	5.7
Total	100.0	100.0	100.0	100.0

Table 17. Reported Reasons for Post-Harvest Crop Losses by Crop (%)

	Paddy	Groundnuts	Sesame	Green gram
Flooding	41.8		23.1	
Excessive rains	25.8	17.6	45.2	100.0
Lack of rains	4.1	32.2	6.1	
Pests	12.4	8.8	2.2	
Diseases	5.0			
Extreme temperatures	2.4	26.8	2.2	
Spoilage	4.1	14.6	8.6	
Others	4.5		12.7	
Total	100.0	100.0	100.0	100.0

Crop loss has a large negative effect on crop yields, which is particularly noticeable when we compare yields with and without reported yield loss (Table 18). For example, the median yield of the main lowland crops among households without yield loss was between one to three times higher than the median yield of those without yield loss. Similar results are seen with the main upland crops, with the exception of groundnut, for which households experiencing yield loss have 75% lower yields.

Monsoon paddy and irrigated green gram are the only crops for which average observed yields from the sample parcels met their expected level in an average climatic year (Table 18). Among the uplands crops, pigeon pea performed the best, with an average observed yield that met its expected level in a good year. Among farmers that did not report yield loss, average yields of each of the other crops (except for rainfed green gram) met or exceeded the expected yield in an average climatic year. However, even among rainfed green gram growers that did not report yield loss, observed yields were still considerably lower than those from an average climatic year. Further research is needed to better understand the very low observed yields of rainfed green gram.

Table 18. Parcel Sample Yields of Lowland and Upland Crops, With and Without Crop Losses

	Parcel Sample Yield (baskets/acre)					Parcel sample yield (baskets/acres)			Parcel sample yield (baskets/acres)		
	Potential yield[1]		--- Parcel sample ---			yield	Median	# cases	yield	Median	# cases
Lowland Crop	Good	Average	Mean	Median	# cases	**Without** crop losses			**With** crop losses		
Dry season Paddy	92	71	62.2	66.7	101	78.2	80.0	63	37.3	40.0	38
Monsoon Paddy	70	53	54.6	57.1	381	61.8	62.2	287	31.7	30.1	94
Rainfed			47.5	50.0	97	53.6	53.3	74	27.7	24.0	23
Irrigated			56.9	60.0	284	64.6	66.7	213	33.0	40.0	71
Sesame	11	7	4.8	3.5	163	8.4	8.0	64	2.1	0.0	99
Green gram	13	8	8.0	6.7	41	10.3	8.0	28	2.8	0.7	13
Chickpea	12	7	6.5	6.4	79	8.0	7.5	59	1.7	0.0	20
Upland Crop											
Groundnut	52	37	30.5	26.7	170	32.7	27.8	138	18.6	15.0	32
Sesame	11	7	5.9	5.0	314	7.9	6.7	170	3.3	3.3	144
Green gram	13	8	3.7	2.5	73	4.5	3.3	48	2.2	1.0	25
Chickpea	12	7	6.5	4.0	27	8.9	6.7	21	1.7	1.3	6
Pigeon pea	11	7	10.1	8.5	81	11.1	11.8	65	4.5	4.7	16

Notes: 1) Potential yield based on 2017 Dry Zone Community survey for a good relative to an average climatic year, and/or expert opinion.

4.6. Climate Change and Yield Loss

When we multiply the percentage of growers by crop type reporting pre- and post-harvest yield loss (Table 14) by the reasons for yield loss (by crop) (Tables 16 and 17), it is clear that the main source of yield loss for sample farmers is not lack of water, but rather the lack of control over water (Table 19). For example, flooding adversely affected yields of 18% of paddy growers in the dry season and 11% in the monsoon (Table 19). Excessive rainfall was the second most frequent reason for paddy yield loss, adversely affecting yields of 11% of growers in the dry season and 7% in the monsoon. Excessive rainfall was the most frequent reason for yield loss for upland sesame and green gram, as 18% of upland sesame growers and 14% of green gram growers cited this cause for yield loss). However, lack of rain is the second most frequent cause of yield loss for upland sesame and green gram, resulting in yield loss for 10% and 6% of growers of these crops, respectively.

Myanmar is ranked second in the list of countries most affected by climate change (Kerft et al. 2014), and the underlying cause of these pre- and post-harvest yield losses is how climate change has affected the distribution of rainfall in the Dry Zone over the past 60 years. A recent study that used rainfall data from Magway township demonstrates these changes. Although this data is from the central-southern Dry Zone, the general findings should apply across the Dry Zone where similar upland cropping systems are practiced and rainfall is similarly variable (Cornish et al. 2018). The study found that while the average amount of rainfall during the monsoon season has not changed between 1951 and 2016, the number of rainy days during the monsoon fell from 156 to 69 days during that period—a decline of 56% in rainy days (ibid 2018). Consequently, the average amount of rainfall per rainy day increased dramatically, which increases the probability of yield loss due to either excessive rainfall or flooding. In addition, the number of days with dry surface soil more than doubled from around 20% of the monsoon to greater than 50% (i.e., more days of drought stress) (ibid 2018). Increased frequency of flooding and drought is also reflected in the Dry Zone community survey, in which 28% of the communities reported that flooding has become "much more frequent" in the last 30 years, while 38% said that droughts had become "much more frequent."

Table 19. Percentage of Households with Pre- and/or Post-Harvest Crop Losses Due to Flooding, Excessive Rain, Lack of Rain, and Pests, by Crop

Lowland crop	Flooding	Excessive rain	Lack of rain[1]	Pests
Dry season Paddy	18	11	5	7
Monsoon Paddy	11	7	3	4
Sesame	8	24	13	5
Green gram	4	12	5	5
Upland crop				
Groundnut	1	5	4	3
Sesame	7	18	10	6
Green gram	4	14	6	6

Notes: 1) only includes households reporting pre-harvest loss.

To further illustrate the changing characteristics of rainfall in the Dry Zone, Cornish et al. (2018) compared years with similar average cumulative monsoon rainfall from early (1959) and late (2000) in their study period. In 1959, 78% of the monsoon rain fell in daily totals of less than 10 mm, and 100% of the rain fell in amounts of less than 30mm per day. By contrast, in 2000, only 34% of monsoon rain fell in daily totals of less than 10 mm, and 30% of rain was in days greater than 30mm, including one day with 112 mm (ibid 2018). With limited capacity for rainwater infiltration in the uplands, and insufficient drainage in the lowlands, intense rains run off the uplands and flood the lowlands. This has a very important policy implication in that, for the monsoon season, without improved rainwater management through improved infiltration in the uplands and drainage in lowlands, expansion of irrigation area and/or improvement in irrigation reliability will have only limited benefits due to the risk of crop loss from flooding.

As noted above, the second most frequently reason cited for pre-harvest yield loss for upland sesame and green gram is lack of rain. Beginning approximately 10 years ago, the month of July shifted from being a month of reliable rainfall to a month of drought in the Dry Zone. This by itself can significantly reduce yields of crops like rainfed sesame or green gram. However, in recent years, this drought period has increased from four to six weeks in some years. This significant reduction in rainfall early in the monsoon was also found by Cornish et al. (2018), who report that average June-July rainfall for 2011–2016 (80 mm) in Magway township was less than half the 1998–2002 average (188 mm).

The parcel-level gross margin and yield results provide evidence of the productivity and profitability gains made possible by irrigation. For example, dry season paddy would not be grown without irrigation, and it provides the highest gross margin per acre. Second, mean and median yields of irrigated monsoon paddy are 20% higher than those of rainfed paddy. Third, green gram grown in the lowlands is predominantly irrigated, and produces a gross margin four times larger than that from rainfed (upland) green gram. These findings are consistent with research from Soe (2011) which found that access to irrigation in the Dry Zone results in higher farm income per acre. That said, until sufficient drainage capacity is developed for irrigation schemes, expansion of irrigation area and/or improvement in irrigation reliability will have only limited benefits due to the frequency of flooding in the lowlands.

One exception to this pattern is sesame, the results for which are complicated by a high frequency of both yield loss as well as cases of zero yield. For example, the average rainfed (upland) sesame gross margin was 120,460 MMK/acre relative to 70,343 MMK/acre for irrigated (lowland) sesame. However, 56% of irrigated sesame growers reported pre- or post-harvest yield loss and 30% reported zero yield, as compared with 45% and 10% of rainfed sesame growers, respectively. If we drop the cases of zero yield, the gross margins from irrigated and rainfed parcels are approximately the same, at 186,000 MMK/acre and 185,000 MMK/acre, respectively. Given that the irrigated and rainfed sesame growers used similar fertilizer application rates, it is not clear why the irrigated producers had a significantly higher number of cases of zero yield.

While pigeon pea has historically been an important crop for upland Dry Zone farmers due to its drought tolerance, it is grown almost exclusively for export. Historically, India has purchased 90% or more of Myanmar's pigeon pea exports. However, in 2017, India enacted an import quota which has significantly reduced Myanmar's pigeon pea exports to India and, thus, led to a dramatic decline in the local market price for pigeon pea in Myanmar. Given the increased frequency and severity of

Box 1. Interview with Daw Hla San a Female Farmer in the Mandalay Region

Daw Hla San is a female farmer in the Mandalay Region of Myanmar's Dry Zone whose experience during the most recent monsoon season provides an example of just how damaging adverse climatic events can be to farmers trying to subsist on rainfed crop production. Like the majority of farmers in the Dry Zone, she lives in a village that does not have access to irrigation from a dam, river/stream, or tube well. The main crops grown in the village include groundnut, sesame, pigeon pea, and tomato. Because of the low returns from rainfed crop production in this village, households rely heavily on remittances sent by family members living in Yangon, the largest city in Myanmar.

Daw Hla San's most profitable crop in recent years has been groundnut, a crop that (along with pigeon pea) is more tolerant to drought and other climatic shocks relative to sesame and green gram, the other main crops cultivated in the Dry Zone. Although she applied inorganic fertilizers and manure to her groundnut, she only harvested 18 baskets/acre (506 kg/ha). This is less than half the expected groundnut yield in the Dry Zone during an average climatic year. There are two main reasons for her low yield. First, her soil is rocky, which is not ideal for groundnut. Second, during the optimal time for harvesting her groundnuts (November), there was heavy rainfall, which delayed her groundnut harvest. When groundnut harvest is delayed beyond the optimal harvest time, the stalks of the groundnut pods decay. When laborers try to pull the pods up out of the ground the stalks break, and many of the pods remain under the ground. Because of this problem, Daw Hla San had to pay four times the normal amount she spends on hired labor to harvest her groundnut, as laborers had to return after the initial harvest to dig up the groundnuts stuck below ground. Given her low yield and higher than normal production costs, she only earned $11/acre of profit from groundnut, her most profitable crop. When the value of family labor and manure used is also considered, she ended up with a loss of $54/acre.

The other crop she planted at the beginning of the monsoon was sesame, which historically has been one of the most profitable crops in the Dry Zone. However, its production has been adversely affected in recent years by the increased frequency of drought shocks early in the monsoon, the main growing season. In recent years, this drought period has increased from four to six weeks, and a six week drought in the middle of this year's monsoon resulted in her losing her entire sesame crop. This demonstrates that research is needed on cropping systems adapted to the extended early monsoon season drought.

While pigeon pea has historically been an important crop for Daw Hla San due to its drought tolerance, its market price fell dramatically in 2017 when India enacted an import quota on Myanmar's exports of pigeon pea. Given pigeon pea's drought tolerance and the increased frequency and severity of drought in the Dry Zone, an important strategy for the government would be to diversify sources of pigeon pea export demand. In addition, domestic consumption of pigeon pea could be increased if the government purchased it for the military, schools, etc. Both strategies would require investment in processing, and the latter would require promotion of recipes.

drought in the Dry Zone, and pigeon pea's drought tolerance, an important strategy to help the zone's upland farmers would be for the government and private sector to diversify sources of pigeon pea export demand, though this would require investment in processing. A complementary strategy to increase demand for pigeon pea could be to encourage domestic consumption of pigeon peas in Myanmar for the military, schools, hospitals and prisons, though this would also require investment in processing as well as promotion of recipes.

4.7. Parcel-Level Cropping System Gross Margins

The cropping system gross margin is the total gross margin for a specific parcel across the three seasons of a year. The four most common lowland cropping systems are: 1) fallow-paddy-fallow (or single crop paddy); 2) paddy-paddy-fallow (or double crop paddy); 3) sesame-paddy-fallow (or double crop oilseed/paddy); and 4) sesame-paddy-chickpea (or triple crop oilseed/paddy/pulse). Comparing the first two cropping systems, lowland farmers that are able to grow paddy in both the dry season and monsoon (Paddy-Paddy-Fallow) have more than double the mean and median gross margin of households that only grow paddy in the monsoon season (Fallow-Paddy-Fallow) (Table 20).

Most cropping systems with sesame in the lowlands are irrigated. The cropping systems including pre-monsoon sesame, Sesame-Paddy-Fallow and Sesame-Paddy-Chickpea, have considerably higher cropping system gross margins relative to single-season paddy (Fallow-Paddy-Fallow). These results provide more evidence of the value of dependable irrigation in that it enables production of paddy in the pre-monsoon period, as well as improving the yields of pre-monsoon sesame.

Upland cropping systems are primarily oilseed-based, either sesame or groundnut or both. Average cropping system gross margins in the uplands are typically less than half those for the lowlands, for two main reasons (Table 21). First, the crop with the highest gross margins – paddy – is not frequently grown there. Second, a large percentage of upland sesame, green gram and chickpea growers (43%, 34% and 33% respectively) suffered large reductions in yield due to pre- and post-harvest crop loss.

Table 20. Lowland Cropping System Parcel Gross Margins

	Gross margin (MMK/acre)			Gross margin ($US/acre)	
Lowland cropping system	mean	median	# of cases	mean	median
Fallow - Paddy - Fallow	163,757	160,000	143	127	124
Rainfed	127,412	113,188	59	99	88
Irrigated	187,359	221,384	84	146	172
Paddy - Paddy - Fallow	328,661	358,667	57	256	279
Sesame - Paddy - Fallow	259,288	229,111	46	202	178
Sesame - Paddy - Chickpea	283,472	284,250	45	220	221

Table 21. Upland Cropping System Parcel Gross Margins

	Gross margin (MMK/acre)			Gross margin ($US/acre)	
Upland cropping system	mean	median	# of cases	mean	median
Fallow - Sesame - Groundnut	241,545	183,752	43	188	143
Fallow - Sesame - Other crop	171,118	99,219	22	133	77
Fallow - Sesame/Pigeon pea intercrop	137,799	98,038	22	107	76
Fallow - Groundnut/Pigeon pea intercrop	106,769	150,738	13	83	117
Fallow - Sesame - Fallow	74,035	44,906	21	58	35

In conclusion, analysis at the parcel level for both individual crop and cropping system gross margins shows that crop production in the Dry Zone faces a number of serious challenges that together result in low net returns for production of many crops. First, a large number of households report crop losses due to challenges such as erratic rainfall (excessive rainfall, lack of rain), flooding, and pests. Second, the problems of flooding, excessive rainfall and drought in these townships appear to have become worse over time due to climate change.

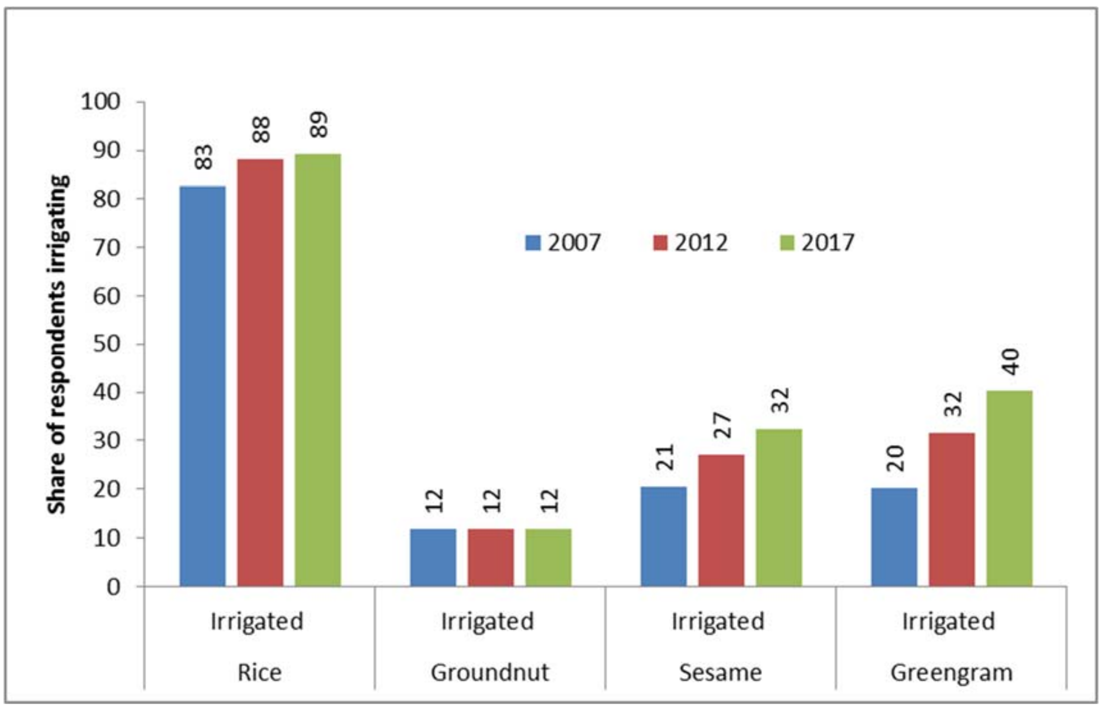
5. TECHNOLOGY USE OVER TIME

This section presents the history of agricultural practices by surveyed households over a 10-year recall period (2007 - 2017) to identify patterns of technological change for the four main target crops.[11] Over the past 10 years, access to irrigation has expanded, particularly for sesame and green gram (Figure 12). For example, the percentage of households using irrigation in the pre-monsoon on paddy increased from 83 to 89% between 2007 and 2017, while it increased more rapidly for sesame (21 to 32%) and green gram (20 to 40%) (Min Naing 2017).

The use of improved varieties remains low in the surveyed areas, with only 24% of farms reporting use of improved varieties. However, since 2007, the use of improved paddy varieties has increased from 25% to 42% of growers, and from 14 to 23% for sesame (ibid 2017). Groundnut improved variety use was still low at 12% in 2017, as is green gram at 8%.

The reported share of household using pesticides doubled for all major crops except green gram. For example, it increased from 25% to 59% for paddy, from 37% to 75% for groundnut, and from 29% to 65% for sesame. It was already high at 94% of households in 2007 for green gram. Use of inorganic fertilizer was already widespread in 2007, with over 95% of farmers reporting applications of either urea or NPK (Nitrogen-Phosphate-Potassium). However, farmers of all crops use higher average quantities per acre now than they did ten years ago.

Figure 12. Share of Households Using Irrigation in Pre-Monsoon Season, by Crop



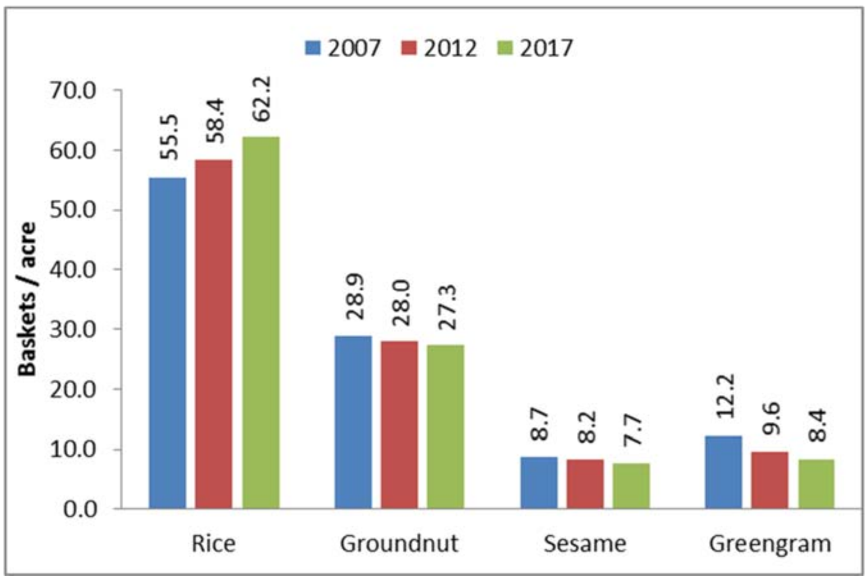
Source: Min Naing 2017.

[11] The statistics and figures in this section are from Min Naing 2017.

Although there has been an increase in the past 10 years in access to irrigation, use of improved varieties, pesticides, and fertilizer application rates across the target crops, only yields of paddy have increased over time. For example, the average yield of paddy in 2017 was 62.2 baskets per acre (1,300 kg/acre), a statistically significant increase of 12% in yield from ten years earlier (55.5 baskets/acre, or 1,160kg/acre) (Figure 13). Groundnut yield remained stagnant over the past ten years, while sesame yields decreased slightly from 8.7 to 7.7 baskets/acre (213 to 189 kg/acre), a significant difference. While average green gram yield fell from 12.2 baskets/acre to 8.4 baskets/acre (399 to 275 kg/acre), this difference was not statistically significant. That said, given the sensitivity of sesame and green gram to adverse weather conditions, more observations would be needed to determine whether or not a declining trend in yield for these crops has occurred.

Since irrigation, improved varieties, and commercial inputs are typically yield-enhancing technologies (or at least yield stabilizing), we would expect that continued increases in the use of these modern inputs will eventually result in higher (and/or more stable) yields for more crops. Nevertheless, yield outcomes reported in the household survey suggest that this is not yet the case.

Figure 13. Change in Average Sample Yield of Major Crops over the Past Decade



Source: Min Naing 2017.

6. LIVESTOCK PRODUCTION

Livestock is an important component of agriculture in Myanmar, as livestock are important assets for rural households. Sixty-four percent of all surveyed households (farm and non-farm) reared animals of some kind (Table 22). Eighty-percent of households that own agricultural land raise livestock of some kind, while 44% of landless households raise livestock. Relative to households that own agricultural land, landless households are much less likely to raise large animals such as cow/oxen, water buffalo, or draft animals (20% for landless and 69% for landed households, respectively). The share of landed and landless households raising medium livestock (pigs, goats) are relatively similar at 9% and 13%, respectively, as is the share of households raising small livestock (chickens, ducks) at 34% and 28%, respectively.

Chickens, cows/oxen and draft animals were the most common animals raised, though only about a third of households raise each of these types of animal (Table 22). Almost all the cows/oxen appear to be raised for live sale, meat and/or milk, and not for use as draft animals.[12] Among livestock owners, 34% sold live animals during the past year, and 7% sold animal products (meat, eggs, milk, etc). Given that only 3% of chicken owners sold chicken byproducts, this suggests that chicken eggs are almost entirely consumed by their owners. Only 17% of cow/oxen owners sold byproducts, suggesting that any milk production is largely consumed by their owners, if at all.

In the past year, households raising chickens sold an average of nine chickens, while those raising pigs and cattle sold an average of only two animals (Table 23). Households received an average price of about MMK 549,000 per draft animal, MMK 360,000 per cow, MMK 212,000 per pig, and MMK 4,600 per chicken sold. Average gross margins were quite low for households raising chickens, reflecting the small scale of production, and indicating that poultry rearing is likely a source of food and supplementary income for most of these households, rather than a primary livelihood strategy.

Table 22. Percentage of Households Rearing and Selling Livestock

		Among households rearing each type of animal			
Animals	% of HHs rearing animals	% HHs selling live animals	% selling animal products	% reporting labor costs	% reporting other costs[1]
Chickens	31	33	3	2	55
Ducks	1	20	0	0	55
Pigs	9	42	2	1	74
Goats	1	57	33	20	74
Cows/Oxen	23	23	17	5	59
Water buffaloes	0.3	64	0	0	50
Draft animals	35	13	7	3	54
Any animal	64	34	7	3	53

[12] The READZ survey includes a module on farm assets owned, and only 2% of households that report ownership of cattle/oxen in the livestock holding module also report ownership of a draft cow/oxen or draft water buffalo as assets in the asset module.

Table 23. Average Number of Animals Sold, Average Price, and Average Gross Margin

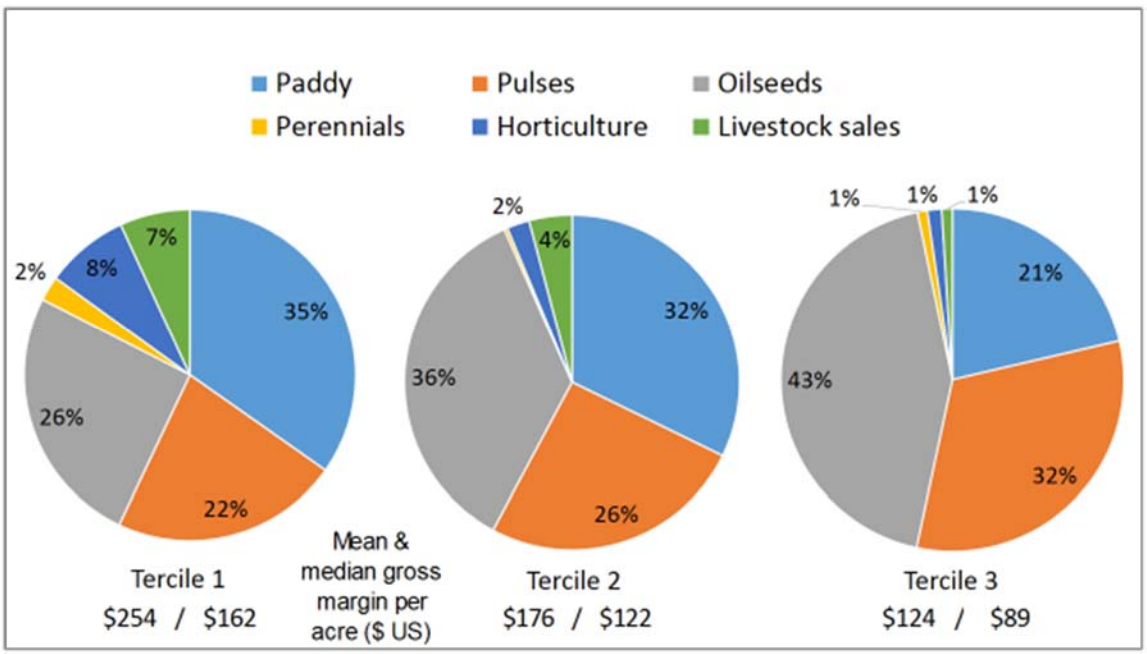
Animals	Average number of animals sold	Average price per animal (MMK)	Average gross margin (MMK)	Number of cases
Chickens	9	4,577	29,850	133
Ducks	8	3,152	19,537	2
Pigs	2	211,678	258,849	53
Goats	23	28,720	333,853	11
Cows/Oxen	2	360,741	456,521	83
Water buffaloes	5	432,382	2,479,106	3
Draft animals	2	548,819	582,283	73

7. WHOLE FARM GROSS MARGINS

For each household that owned or operated agricultural land, whole farm gross margins were estimated by summing the gross margins of the major field crops with gross margins from perennial crops (mainly mango and banana), vegetables (primarily cucumber, shallot and tomato) and livestock sales. The gross margins of paddy, groundnut, sesame, and green gram are derived from a combination of annual crop data on harvested quantities and total costs of each crop and the household's primary agricultural parcel.[13] Gross margins from livestock are only computed for those households that reported sale of live animals or animal products during the last year.

The average whole farm gross margin of households that owned agricultural land was 1,300,660 MMK/year ($1,100/year). Whole farm gross margins vary widely according to land holding size. The average whole farm gross margin for households in the largest landholding tercile ($1,748/year) was 2 times higher than that for households in tercile 2 ($898/year) and 4 times higher than that in tercile 1 ($430/year). The average annual gross margin earned from one acre of land was $187. Households in the lowest landholding tercile 1 ($254/acre) earned higher gross margins per acre than those in tercile 2 ($176/acre) or tercile 3 ($124/acre) (Figure 14).

Figure 14. Share of Whole Farm Gross Margins of Households with Owned or Operated Agricultural Land, by Landholding Tercile



[13] Because of the high frequency of yield losses reported by households in different seasons, the gross margin of the sample parcel for a particular crop may or may not be representative of the household's gross margins of the same crop on other parcels. For this reason, we use a combination of the sample parcel gross margin for the area of the sample parcel, and apply the household level 'gross margin by crop from annual recall data' to the remaining area planted to that crop.

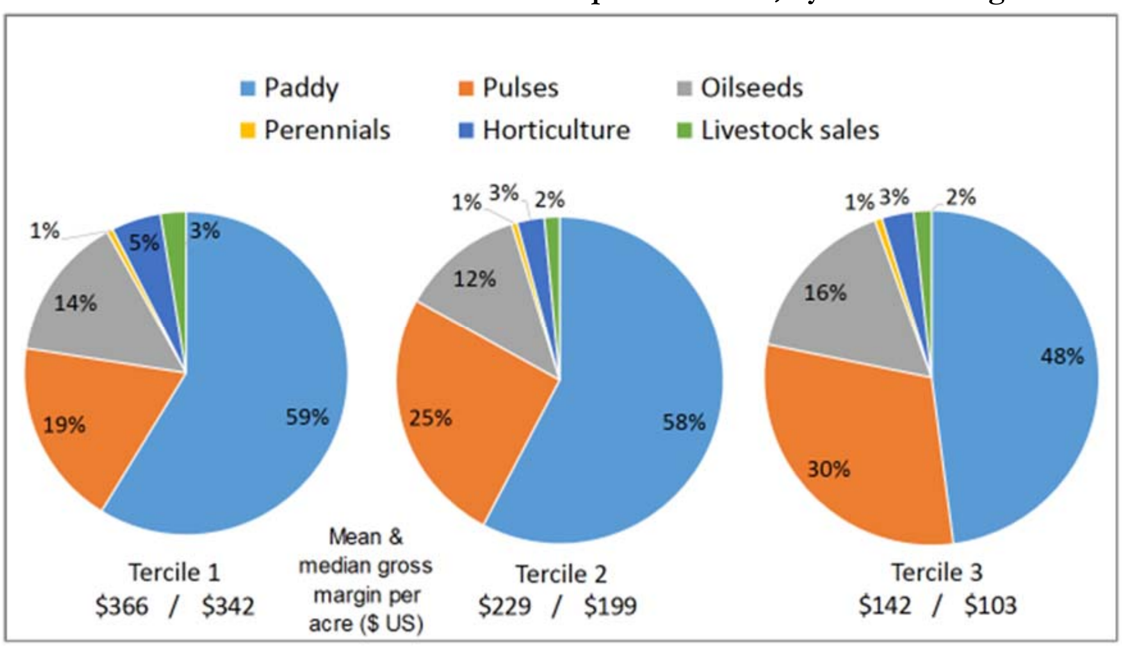
One reason why average gross margins per acre are highest for households in the lowest landholding tercile (tercile 1) is because yields of the dominant crops monsoon paddy, sesame, groundnut and green gram are 8 to 18% higher (depending on the crop) than those of households in tercile 2, and 2 to 31% higher than yields of households in tercile 3. The likely reason to explain the differences in yield by land tercile is that farmers with less landholding cultivate these main crops more intensively than those with more landholding, using on average more inorganic fertilizer per acre and more labor days per acre, as noted in the sections on crop management and casual labor.

Farm diversification is inversely proportional to landholding size, as farmers with the least amount of land (tercile 1) have a greater degree of farm diversification than farmers in tercile 2 or 3 (Figure 14). Paddy accounts for the largest share of total farm income among farmers in the lowest land tercile (35%), while oilseed crops are the largest component in farm income for the middle and upper land terciles (36% and 43% respectively). The increase in the share of oilseeds in farm income by land tercile reflects the fact that households in tercile 3 have a larger proportion of upland relative to lowland in their land holding.

The share of pulses in farm income also increases by landholding from 22% for households in land tercile 1 to 32% for those in land tercile 3, for the same reason as the share of income from oilseeds. Horticultural crops and livestock sales are primarily of importance to those in the lowest land tercile, accounting for 8% and 7% of their farm income, respectively. Perennials account for only 1 to 2% of farm income depending on the land tercile.

Figure 15 presents the share of whole farm gross margins by crop among (a) households with only lowland parcels (27% of farm households) and (b) households with both lowland and upland parcels (21% of farm households).

Figure 15. Share of Whole Farm Gross Margins of Households with Owned or Operated Lowland or Combination of Lowland and Upland Parcels, by Landholding Tercile



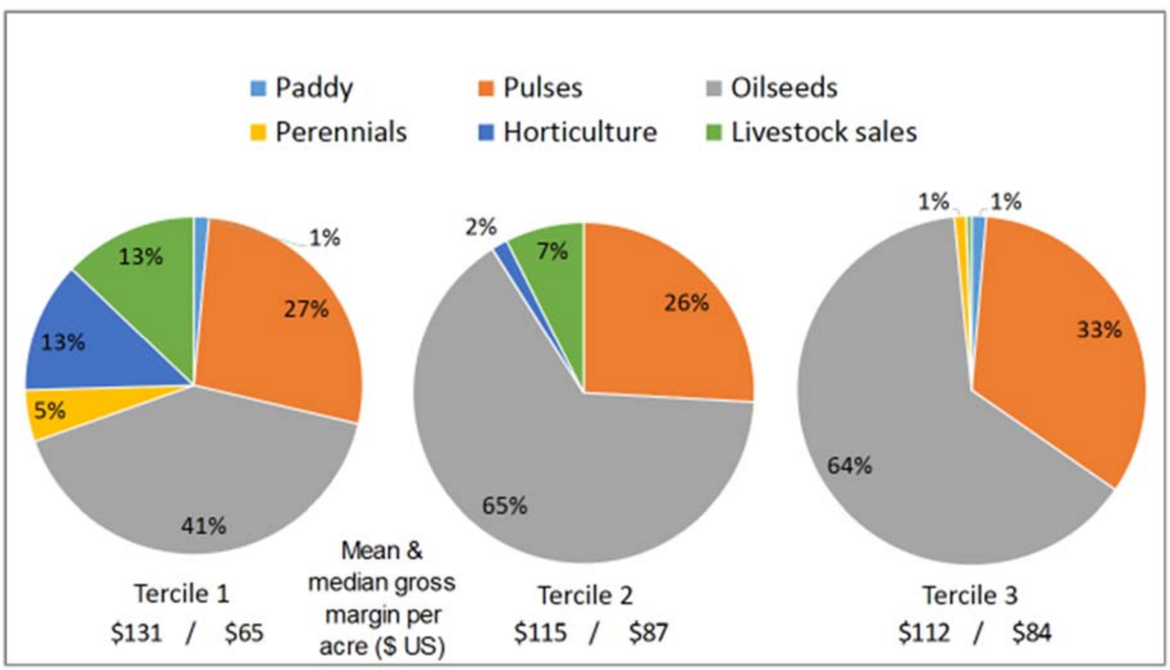
As expected, farm income for these households is dominated by paddy, which accounts for between 48% and 59% of farm income depending on the land tercile (Figure 15). Pulses are the second most important crop for these households, whose share of farm income ranges from 19% in land tercile 1 to 30% for land tercile 3. Oilseeds account for 12 to 16% of farm income, while horticulture accounts for only 3% to 5% and livestock sales for 2 to 3% of farm income.

The average whole farm gross margin of lowland and lowland/upland households was $1,117 per year, while the average for households with only upland parcels was $910 per year. However, the median whole farm gross margin of lowland and lowland/upland households ($766) was nearly double that of households with only upland parcels ($393), likely reflecting the higher average gross margins of lowland paddy relative to upland sesame and groundnut.

Among the lowland only and lowland/upland households, the average whole farm gross margin per acre is considerably higher in land tercile 1 ($366/acre) relative to those in tercile 3 ($142/acre) (Figure 15). This is likely due to the fact that, for households with both lowland and upland parcels, upland area only accounts for an average of 10% of total landholding for those in the lowest land tercile as compared with an average of 41% for those in the highest land tercile. Thus, those in the lowest land tercile are much more concentrated on paddy production relative to those in the higher land terciles.

In Figure 16, we present shares of whole farm gross margins among households that only cultivated upland parcels (45% of farm households). As expected, farm income for these households is dominated by sesame, which accounts for 41% of farm income for those in the lowest land tercile and 64% for those in the highest (Figure 16).

Figure 16. Share of Whole Farm Gross Margins of Households with Owned or Operated Lowland or Upland Parcels Only, by Landholding Tercile



Pulses were the second most important crop, accounting for 27% to 33% of farm income, depending on the land tercile. Households in the lowest land tercile are the most diversified, with horticulture and livestock sales both accounting for 13% of farm income, and perennials with 5%. Livestock sales are clearly more important for upland farmers than lowland, for whom the share of livestock in farm income is only 2 to 3% for each land tercile.

Unlike farmers with lowland parcels, the average whole farm gross margin per acre of upland only farmers in land tercile 1 ($131) is not much larger than those in tercile 2 ($115) and tercile 3 ($112). This is due to the fact that yields of upland sesame, pigeon pea and green gram are similar across land terciles.

8. CONCLUSIONS

Our main findings are summarized as follows:

1) Levels of landlessness are high, as 40% of households do not own or operate agricultural land.

2) Most farms are small, and land is unequally distributed. Almost one-half of crop farming households (48%) cultivated less than 5 acres. The third of households with the smallest landholdings own just 4% of all crop land.

3) Fifty-nine percent of owned and operated agricultural land is categorized as uplands, and 36% lowlands. Lowland area is used primarily for paddy cultivation while upland area is dominated by sesame, along with groundnut, green gram and pigeon pea.

4) Seventy-five percent of lowland areas have access to irrigation, primarily by dam, while only 6% of upland areas are irrigated. Dam irrigation plays a major role in the cultivation of paddy in each of the three seasons, even in the monsoon where 64% of paddy area is irrigated.

5) Use of improved varieties is low for green gram (8%), groundnut (12%) and sesame (23%). While 42% of paddy seed is improved, this percentage is quite low as compared with other Southeast Asian countries. Seeds for these crops are overwhelmingly sourced from farmers' own reserves or from other farmers, with little seed purchased from input traders or the government.

6) Crops in the Dry Zone are subject to a significant amount of yield variation depending on weather conditions during a given season. For example, the yield of sesame in a good climatic year is expected to be 55% higher than that of an average year, while yield in an average year is 107% higher than that in a bad year.

7) Over the past 60 years, climate change has had a dramatic effect on the distribution of rainfall during the monsoon season in the Dry Zone. The number of rainy days during the monsoon has fallen by more than 50%, resulting in a higher frequency of days with excessive rainfall as well as more days of drought stress. Given limited capacity for rainwater infiltration in the uplands, and insufficient drainage in the lowlands, intense rains run off the uplands and flood the lowlands.

8) Observed farmer yields for dry season paddy, sesame, groundnut and green gram were below those expected in an average climatic year. Low yields were primarily due to a high frequency of farmers (between 25% and 57%, depending on the crop) suffering pre- and/or post-harvest yield loss. These losses were primarily related to erratic rainfall (lack of rain, excessive rainfall), poor water control (flooding), and pests. Median yields for growers not reporting yield loss were one to five times higher than those reporting losses, depending on the crop.

9) Average monsoon and dry season paddy yields (2.8 and 3.2 tons/ha) were low relative to many other Asian countries, despite apparently adequate rates of nitrogen fertilizer application. This suggests that other factors are constraining paddy yields, such as lower use of improved varieties and perhaps a higher frequency of adverse climatic shocks.

10) The highest gross margins (profits) came from dry season and monsoon paddy, at $148/acre and $125/acre, respectively. Due to low yields, the gross margins for groundnut ($86/acre), sesame ($82/acre) and irrigated and rainfed green gram ($90/acre and $23/acre, respectively) were very low.

The following recommendations could address constraints to agricultural growth in the Dry Zone. First, the yield and gross margin results provide evidence of the productivity and profitability gains that could be possible through a) improved water control to minimize losses due to flooding and b) improvements in access to and quality of irrigation. The potential of irrigation to improve crop income is illustrated by the following:

a) Dry season paddy, which can only be grown with irrigation, provided the highest average gross margin per acre at $148/acre in 2016/17;

b) Monsoon paddy is also irrigated, and its mean and median yields are 20% higher than those of rainfed monsoon paddy;

c) Lowland farmers with access to dependable irrigation are able to grow paddy in both the dry season and monsoon, and have roughly double the median annual gross margin relative to households that only grow paddy in the monsoon season; and

d) Irrigated green gram has an average gross margin four times larger than that of rainfed green gram. Given their lack of tolerance to drought shocks, yields of upland sesame and green gram production could benefit the most from improved access to irrigation.

Even before expansion of new irrigation investments, existing irrigation systems need to be upgraded with improved drainage to reduce losses due to flooding in the monsoon season. For the uplands, improved tillage methods should be evaluated in order to improve infiltration and reduce runoff during intense rain. FAO has developed a detailed manual of various Soil and Water Conservation (SWC) techniques specifically targeted for the Dry Zone (Kahan 2001). However, although Cools (1995) demonstrated positive economic returns from SWC measures at the farm level in the Dry Zone, he found that farmers were often failing to implement even traditional approaches. In many cases, the benefits may not be apparent for several years and some benefits may accrue downstream, outside the areas where projects are implemented (IWMI 2015). Thus, it is important to recognize the public good nature of SWC initiatives, and that incentives and external financial resources may be needed to encourage farmers to implement SWC projects on any significant scale (ibid 2015).

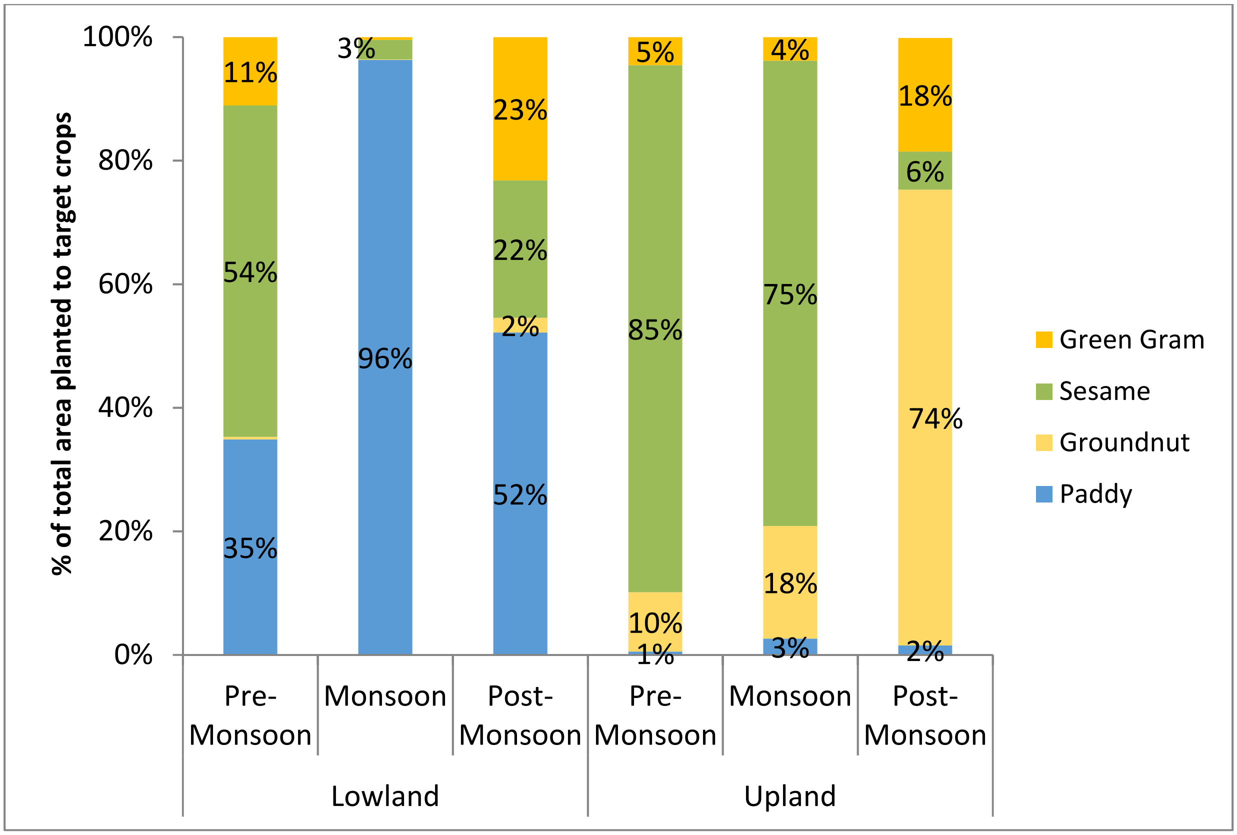
Second, the relatively low use of improved varieties for all the major crops suggest a need to accelerate testing and dissemination of improved varieties of paddy, oilseeds and pulses through farmer participatory on-farm testing, and encourage small-scale seed multiplication enterprises and dissemination of trial packs. Efforts to promote improved paddy varieties need to consider the recent and increasing demand for short-duration (90-day) paddy varieties in some communities.

Third, introduction of mechanized threshing for sesame and groundnut could significantly reduce labor costs for those two predominant crops of rainfed areas, as manual threshing and drying requires 12 and 22% of total labor demand for those two crops, respectively.

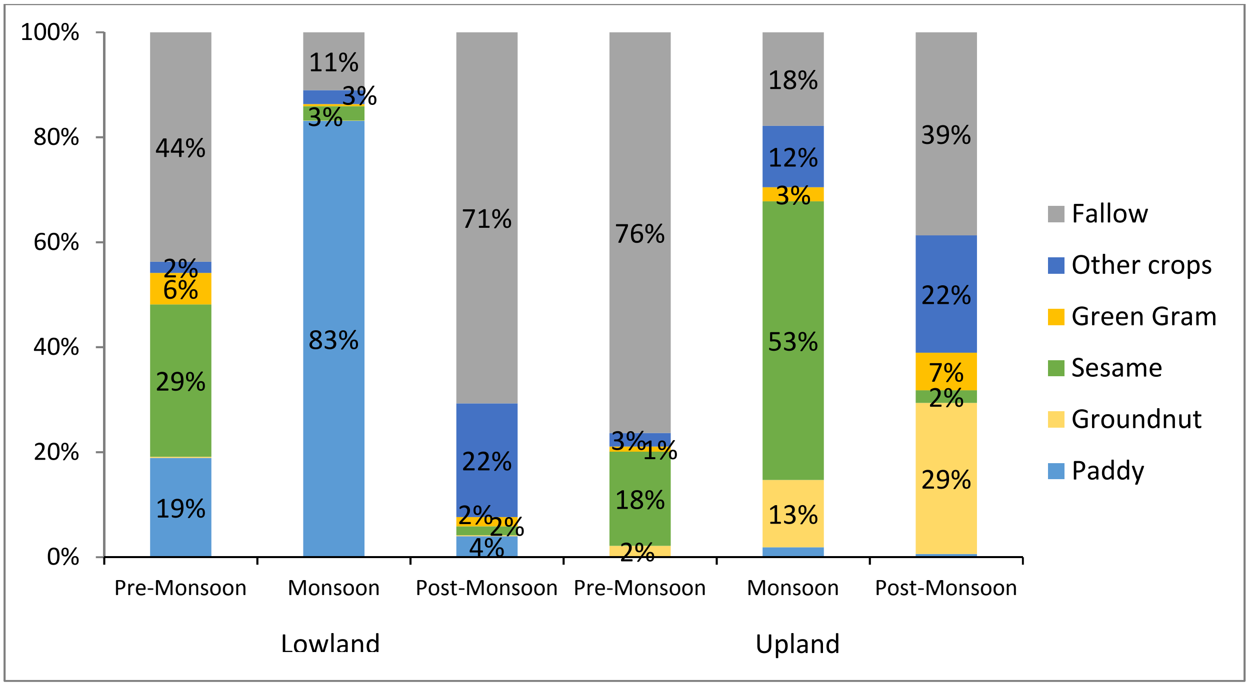
Fourth, while pigeon pea has historically been an important crop for upland Dry Zone farmers due to its drought tolerance, it is grown almost exclusively for export. However, since India imposed an import quota on Myanmar's pigeon pea exports, the domestic market price of pigeon pea has fallen dramatically. Given the increased frequency and severity of drought in the Dry Zone, and pigeon pea's drought tolerance, an important strategy to help the zone's upland farmers would be for the government and private sector to diversify sources of pigeon pea export demand, though this would require investment in processing. Another option could be to encourage domestic consumption of pulses in Myanmar for the military, schools, hospitals and prisons. This would also require investment in processing as well as promotion of recipes.

APPENDIX

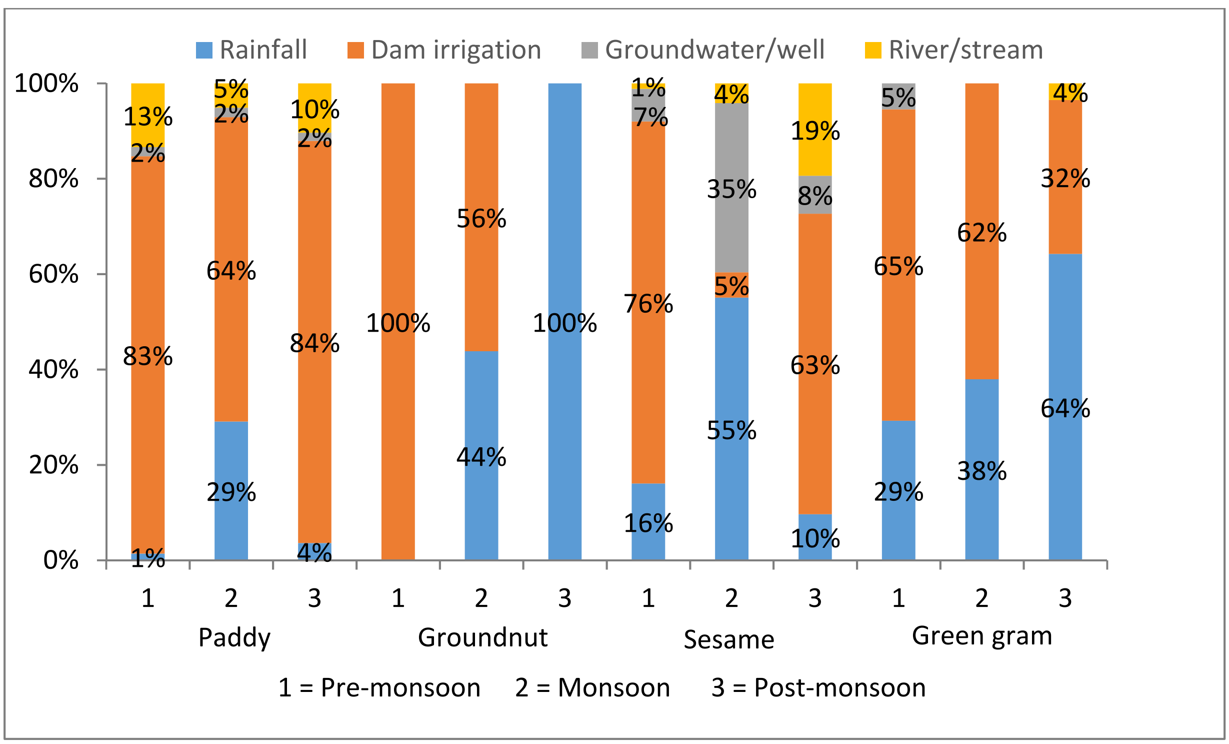
Appendix Figure A 1. Share of Planted Area to Target Crops by Season



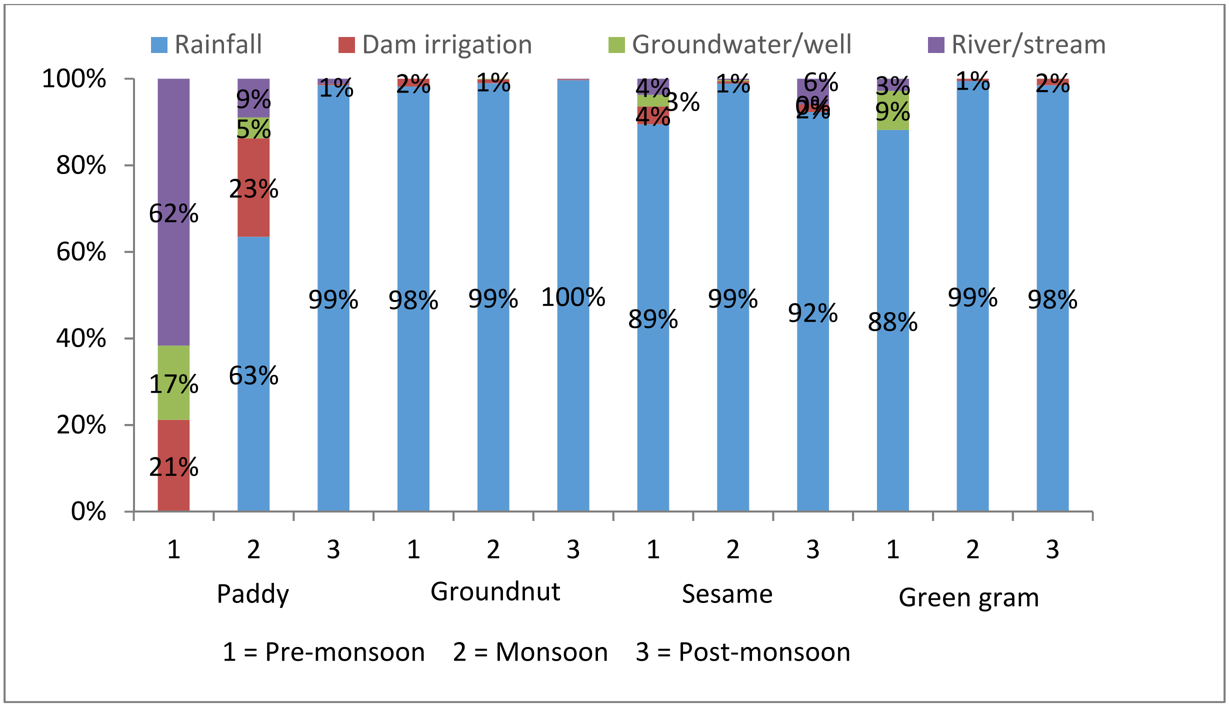
Appendix Figure A 2. Share of Area Planted to All Crops and Fallow Land by Season



Appendix Figure A 3. Share of Lowland Area Planted to Target Crops by Water Source



Appendix Figure A 4. Share of Upland Area Planted to Target Crops by Water Source



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