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MECHANIZATION AND CROP PRODUCTIVITY, PROFITABILITY AND LABOR USE IN MYANMAR'S DRY ZONE

By

David Mather and Ben Belton

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AUTHORS

David Mather and Ben Belton are Assistant Professors, International Development, in the Department of Agricultural, Food, and Resource Economics (AFRE) at Michigan State University.

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EXECUTIVE SUMMARY

This paper analyzes differences in productivity, profitability and labor use for four major crops produced in Myanmar's Dry Zone, namely monsoon paddy, dry season paddy, sesame, and groundnut, comparing farmers using mechanized land preparation relative to use of animal draft power alone, and comparing farmers using mechanized harvesting/threshing relative to manual or mixed techniques. Analysis is based on data collected by the Rural Economy and Agriculture in the Dry Zone survey (READZ) from 1,578 rural households in four townships in Myanmar's central Dry Zone in 2017 (see Belton et al., 2017).

MECHANIZATION IN LAND PREPARATION

Extent of adoption: The majority of producers of all four crops have begun to use tractors (power tillers or four wheel tractors) during land preparation. Adoption is more advanced among paddy farmers than oilseed producers (93% and 80% of dry season and monsoon paddy cultivators, versus 65% and 63% of sesame and groundnut growers). However, for all these crops, a large majority of households using tractors do so mainly for initial plowing, and continue to use animal draft power for subsequent harrowing.

Cost structure: Most tractors are rented in, whereas most draft animals are owned by the household using them. For example, among the 80% of households that used a tractor for monsoon paddy cultivation, 81% rented them in. Conversely, among the 20% of monsoon paddy growers who used only draft animals for land preparation, 78% used their own. Use of draft animals usually entails opportunity costs (opportunity cost of capital tied up in purchase of cattle, own-produced feed, and the family labor needed for husbandry), but requires no cash outlay at the time of land preparation. In contrast, renting-in tractors requires cash outlay around the time of use, but entails few fixed or opportunity costs.

Yields: Farms using a tractor during land preparation report average yields of dry season paddy and groundnut that are 19% and 18% higher, respectively, than those obtained by households using only animal draft power. There is little difference in monsoon paddy and sesame yields between these two groups. The yield gap between users and non-users of tractors in dry season paddy cultivation is 214 kg/acre (equivalent to $49/acre). For groundnut farmers, the gap is 118 kg/acre ($30/acre). However, these differences are not statistically significant, and are not attributable to differences between tractor and draft animal tillage.

Adoption of complementary inputs: Dry season paddy and groundnut cultivators appear to adopt tractors as part of a portfolio of improved inputs. This is not the case for monsoon paddy and sesame farmers. Dry season paddy and groundnut farmers who use tractors report higher fertilizer application rates than non-tractor users. Tractor users are more likely to apply inorganic fertilizer during dry season paddy cultivation, than non-users (92% vs 69%), and use more on average (119 kg/acre vs 75 kg/acre). In groundnut production, 87% of tractor users apply inorganic fertilizer (vs 75% of those using draft animals only), applying 50 kg/acre (vs 40 kg/acre).

Interestingly, groundnut farmers who use tractors are also significantly more likely to use an improved variety than those using only draft animals (24% as compared to 7%). For all other crops,

tractor users are marginally more likely to use improved varieties, but these differences are not significant.

Crop losses: Growers of dry season paddy and groundnut who used a tractor were less likely to report any pre- or post-harvest crop losses (most of which result from heavy rainfall, flooding or drought) than those using only draft animals. Twenty-nine percent of dry season paddy farmers using a tractor reported crop losses, as compared to 40% of those who did not use tractors. Among groundnut growers the numbers are 16% and 33%, respectively. Tractor users are presumably able to plant earlier on average than households reliant entirely on draft animals, enabling them to harvest in time to avoid events such as heavy rains at the end of the dry season cropping period.

Labor savings: Labor savings obtained from the use of tractors are quite small, ranging from 1 person-day per acre for groundnut, to 3.5 person-days per acre for sesame. Most of the labor saved is family labor, so direct cash savings are limited. This finding may imply that one of the major advantages of tractors, as perceived by farmers, is to reduce the drudgery associated with plowing with draft animals. Plowing requires much greater physical effort than harrowing.

Production costs: Using only a tractor for land preparation is cheaper than using only draft animal power (by between $3.00 and $11.50/acre, depending on the crop), but using both a tractor and draft animal costs approximately $7.50/acre more than using draft animals alone. This difference is minor, being worth less than 5% of the average total cash costs of production of these crops

Profitability: Net margins are similar among growers of monsoon paddy, groundnut and sesame on farms using tractors and those using only draft animals. Tractor users producing dry season paddy earn higher net margins than non-tractor users, but this difference is not statistically significant.

MECHANIZATION IN HARVESTING & THRESHING

Two simultaneous transitions are taking place in the mechanization of harvesting and threshing of paddy in the Dry Zone. First, there is a shift from manual harvesting and manual threshing of paddy to manual harvesting and mechanized threshing. Second, there is a shift from manual harvesting plus (manual or mechanized) threshing to combine harvesting. Neither sesame nor groundnut are mechanically harvested at present, and only 1-2% is threshed mechanically by farm households.

Extent of adoption: In the four townships surveyed, in both paddy growing seasons, more than two thirds of paddy farming households used either a thresher or combine (71% in monsoon and 67% in dry season). Use of threshers predominates during monsoon (the main growing season), when 58% of farms used a thresher and 13% used a combine. This pattern is reversed in the dry season, when 41% of paddy cultivators used a combine and 26% used a mechanized thresher.

Seasonal differences: High rates of combine harvester use during the dry season growing period (which precedes the monsoon season) appear to be linked to the ability to harvest and thresh paddy quickly, allowing the following monsoon paddy crop to be planted in time.

An additional reason why combine harvesting is more common in the dry season is that it can reduce the yield and palatability of rice straw that farmers use as fodder for their draft animals. The

monsoon paddy crop provides the bulk of paddy straw for the year, making some farmers unwilling to use combines on this crop.

Higher levels of combine use during the dry season than in the monsoon may also occur because large contiguous expanses of paddy are usually found in areas with access to dry season irrigation. In locations where only monsoon paddy is grown, land use patterns are more fragmented. Areas with dry season irrigation are most attractive to rental service providers, as they can achieve economies of scale by serving many customers at a single location.

Yields: In both seasons, farmers using combine harvesters enjoyed higher yields than those using mechanized threshers. Users of mechanized threshers also achieved higher yields than households who threshed their crops manually. Based on interviews with combine users, the yield gains from combine use appear to be achieved mainly as a result of reduced losses of grain during harvesting and threshing.

During the dry season, combine users obtained 259 kg more paddy per acre than households practicing manual harvesting/threshing (a 19.5% higher yield, worth $60/acre). The yield gap between households using combines and those using mechanized threshers stood at 162 kg/acre (11%, or $37/acre). Differences in yields are of similar magnitude during the monsoon season (202 kg/acre and 141 kg/acre for the same groups of households). However, none of these differences was found to be statistically significant.

Adoption of complementary inputs: During the monsoon season, combine harvester use appears correlated with the adoption of other modern inputs. Use of improved varieties among combine users is greater than among users of mechanized threshers or households who thresh paddy manually (63% vs 45%, vs 40%, respectively). This difference is statistically significant. Use and applications rates for inorganic fertilizer are also higher among combine users relative to those using only manual harvesting/threshing.

A different pattern is evident during the dry season, when use of improved varieties is highest among users of mechanized threshers (56%), followed by users of combines (39%), and households who harvest and thresh manually (30%). Use and application rates for inorganic fertilizer and irrigation are similar across these three sub-groups.

Labor savings: As expected, use of a combine saves a significant amount of labor in harvesting/threshing. In the monsoon season, this is equivalent to 7.3 labor days/acre relative to manual harvesting and mechanized threshing, and 11.2 labor days/acre relative to manual harvesting and threshing. Levels of labor savings during the dry season are very similar to those in the monsoon.

Production costs: Contrary to expectations, the average cost of harvesting/threshing dry season paddy by combine was found to be higher than either manual harvesting and mechanized threshing (by $12/acre) or manual harvesting/threshing (by $19/acre). A rather similar pattern is found in the monsoon season, when the average cost of harvesting/threshing by combine is approximately $13/acre higher than manual harvesting and mechanized threshing, and $10/acre higher than manual harvesting and threshing. However, the additional cost of combine use is considerably less than the value of the difference in yields, whether the yield gains are due to combine use, higher rates of improved input use, or both.

Profitability: For dry season paddy cultivation, the gross and net margins earned by combine users are similar to those obtained by households using mechanical threshers, and those harvesting/threshing manually. Net margins range from an average of $211/acre for combine users to $161 for users of mechanical threshers to $220 for users of labor power alone, but these differences are not statistically significant. During the monsoon season, net margins earned by combine users (mean $142/acre) are higher than those of households using mechanized threshers ($92/acre) or manual labor alone ($116/acre) for harvesting/threshing paddy.

CONCLUSIONS

We draw the following conclusions:

1) Mechanization of land preparation is associated with higher yields in dry season paddy cultivation and groundnut farming, but not in sesame or monsoon paddy cultivation.

2) Productivity increases associated with mechanized land preparation appear to result from: 1) Adoption of complementary inputs (inorganic fertilizer and improved varieties); and 2) Increased timeliness of planting that enables farmers to avoid events such as heavy rains late in the cropping period, which may cause yield loss.

3) There are no observed differences in crop profitability for tractor or draft animal land preparation.

4) Mechanization of paddy harvesting and threshing is associated with higher realized yields as a result of reduced losses of grain during harvesting/threshing and (during the monsoon season) greater propensity to use improved varieties and inorganic fertilizers.

5) Surprisingly, despite substantially reducing labor requirements, mechanized harvesting and/or threshing does not appear to lower average production costs or result in significantly higher average gross or net margins.

6) Together, these findings suggest that some of the main advantages that mechanization provides to farm households result from: 1) Improved reliability and timeliness of planting and harvesting in a context where farm labor is increasingly difficult to obtain; 2) Reduction of risk associated with weather-induced crop losses; 3) Reduced grain loss during harvesting/threshing by combine, and; 4) Minimization of the physical drudgery associated with farming.

CONTENTS

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ACRONYMS

FSP	Food Security Policy
FSPP	Food Security Policy Project
IFPRI	International Food Policy Research Institute
LIFT	Livelihoods and Food Security Trust Fund
MMK	Myanmar currency (kyat)
READZ	Rural Economy and Agriculture in the Dry Zone
USAID	United States Agency for International Development

INTRODUCTION

This paper analyzes differences in productivity, profitability and labor use for four major crops produced in Myanmar's Central Dry Zone, namely monsoon paddy, dry season paddy, sesame, and groundnut, comparing farmers using mechanized land preparation relative to use of animal draft power alone, and comparing farmers using mechanized harvesting/threshing relative to manual or mixed techniques. Whether and how crop yields and net crop income differs by use or not of mechanization in land preparation or harvesting/threshing is an important question, given the generally low levels of yields and net crop income experienced by farm households in the Dry Zone (Mather et al., 2018). The question of how mechanization affects demand for labor is also prescient given the need for farmers to find cost savings in the face of rising rural wages, and the concerns that rapid mechanization may reduce the availability of agricultural work for households depending on wage labor for their livelihoods.

Findings are derived from analysis of the Rural Economy and Agriculture in the Dry Zone survey (READZ) of 2017 (see Belton et al., 2017). READZ surveyed 1,578 rural households and is representative of rural areas in four townships in Myanmar's Central Dry Zone: Budalin Township (Sagaing Region), Magway and Pwintbyu Townships (Magway Region), and Myittha Township (Mandalay Region). The results presented are derived from an analysis of detailed plot- and crop-level data on use of machinery, animal draft power and other inputs in crop production collected under READZ.

Recent evidence from the READZ survey shows that rapid agricultural mechanization is underway in the Dry Zone (Filipski et al, 2018). On the supply side, this is being driven by thriving rental markets, falling machine prices, and increased financing options. On the demand side, mechanization is also driven by increases in the cost of labor, as real farm wages increased by more than a third from 2012 to 2016 (*ibid*).

The majority of producers of the four main crops have begun to use tractors (power tillers or four wheel tractors) during land preparation. Adoption is more advanced among paddy farmers than oilseed producers (93% and 80% of dry season and monsoon paddy cultivators, versus 65% and 63% of sesame and groundnut growers). However, for all these crops, a large majority of households using tractors do so mainly for initial plowing, and continue to use animal draft power for subsequent harrowing. For example, 63% of monsoon paddy growers (and 72% of dry season paddy growers) use a combination of tractor and animal draft power in land preparation. By contrast, mechanization of harvesting and threshing is almost exclusively confined to paddy.

LAND PREPARATION

Introduction

When we compare crop yields of Dry Zone farmers who used a tractor for land preparation relative to those that did not, the 'no' group is composed of households that used animal draft power exclusively in land preparation. When moving from animal-drawn plows to tractors, yield increases are possible only when mechanization improves tilling quality (Pingali, 2007) or enables timelier planting. However, the available evidence indicates that generally no significant yield difference exists between animal draft and tractor tillage. For example, Herdt (1983) and Binswanger (1978) found that yield differences between animal draft and tractor farms were negligible after accounting for differences in fertilizer use.

Mechanized land preparation for monsoon paddy

Table 1 compares yields, gross and net margins and labor use per acre between monsoon paddy growers that used (a) either a tractor alone or a tractor along with animal draft power in land preparation (Tractor & Draft) relative to (b) growers that used animal draft power alone (Draft only). Although the mean yield of monsoon paddy growers that used a tractor for land preparation (1,136 kg/acre) is slightly higher than that of farmers using only animal draft power (1,092 kg/acre), this difference is not statistically significant (Table 1).

Table 1. Mechanization in land preparation for monsoon paddy

	Yield (kg/acre)		Gross margin ('000 MMK/ac)		Net margin ('000 MMK/ac)	
Land preparation	Tractor & Draft	Draft only	Tractor & Draft	Draft only	Tractor & Draft	Draft only
mean	1,136	1,092	141	203[c]	100	113
median	1,216	1,045	143	200	109	112
count	303	73	303	73	303	73
	Family labor days/acre		Hired labor days/acre		Total labor days/acre	
Land preparation	Tractor & Draft	Draft only	Tractor & Draft	Draft only	Tractor & Draft	Draft only
mean	1.2	4.0[c]	1.4	1.7	2.7	5.7[c]
median	0.0	2.5	0.7	0.0	2.0	4.4
count	304	73	304	73	304	73

Notes: a, b, c indicate that the corresponding means are significantly different at the 10%, 5%, and 1% levels, respectively. Source: All tables are authors' calculations based on READZ household survey data.

Monsoon paddy growers who used a tractor for land preparation have a lower mean and median gross margin per acre[1] relative to those who did not (Table 1). This is perhaps not surprising given

[1] A farmer's gross margin for a specific crop is based on plot-level data on productivity and costs, and is defined as gross revenue (yield multiplied by the farmer's sale price of the crop, or the township median for non-sellers) less variable (cash) costs of purchased seeds, other purchased inputs such as fertilizer, hired labor, machine and animal draft

that the gross margin only includes cash costs paid by the farmer, and thus does not include the fixed and variable costs of draft animal ownership, nor the opportunity cost of family labor spent in land preparation (i.e. driving a pair of oxen with a plow) and other activities. We thus also compute a net margin,[2] which is defined as gross revenue less the cash variable costs listed in footnote #1, less estimates of the fixed and variable costs of ownership of draft animals and implements (and tractors), and imputed values of own seed, own manure, and the opportunity cost of family labor spent on land preparation and other activities. Accounting for the fixed and variable costs of animal draft ownership is particularly important given that among the 20% of monsoon paddy growers that use only animal draft power for land preparation, 78% use their own draft animals. By contrast, 81% of tractor use for monsoon paddy is rented and thus involves cash costs.

While the average net margin of those using tractors in land preparation is still lower than those using only draft animals, the difference is not significant, and the median net margin is virtually the same (Table 1). We also find that households using a tractor save an average of three person-days per acre of labor, most of which is family labor (Table 1). As expected, use of a tractor also offers an advantage in terms of the time required for land preparation, as those using a tractor only in monsoon paddy land preparation complete this preparation in an average of 0.5 days/acre, as compared with an average of 2.1 days/acre for those using tractor and animal draft, and 3.3 days/acre for those using draft animals alone.

Given our approach to valuing the fixed costs of animal draft ownership, our estimated cost of draft animal ownership should be considered a lower-bound, conservative estimate. To investigate this further, we compute the average and median total costs[3] per acre of land preparation for households using (a) a tractor only, (b) tractor and animal draft power, and (c) animal draft power only. We find that use of a tractor only in land preparation costs between 4,000 to 15,000 MMK/acre ($3.00 to $11.50/acre) less than using draft animal power only, depending on the crop (Table 2). Using both a tractor and animal draft costs approximately 10,000 MMK/acre ($7.50/acre) more than using draft animals only. It is not clear why combining tractor and animal draft use in land preparation would cost more than using animal draft power alone, though this difference represents less than 5% of the average total (cash) cost of production for these four crops (Mather et al, 2018).

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rental, variable costs of tractor/machine use for owners (such as fuel costs), and irrigation costs (fuel and rental fees for pumps or irrigation fees from dam schemes) where applicable.

[2] There are two main ways to generate an estimate of the fixed cost of operating capital for animal draft and implement ownership (or tractor ownership). The first is to compute the annual cost of depreciation of the animals and implements. The second is to simply use the average rental rate for animal draft power to value the opportunity cost of the farmer's capital invested in oxen and plows or other implements in land preparation and other related activities (LIFT, 2016). Given data limitations, we opt for the second approach, applying the median rental rate by type of animal draft activity multiplied by the draft animal owner's actual usage amount of his/her draft animals in land preparation and other activities. We also include variable costs of draft animal maintenance reported by the household (labor, feed, veterinary services, etc), net of the value of any draft animals sold, and multiplied by the parcel crop area (used to compute the yields, margins and labor use in this report) divided by the household's total area cultivated that year. For the few farmers who own their own tractors, we use the same approach to value the fixed costs of tractor ownership.

[3] By total costs, we mean both cash costs and fixed and variable costs of tractor or draft animal ownership, as used in the computation of net margins described in footnote 2.

Mechanized land preparation for dry season paddy

Among the ninety-three percent of dry season paddy farmers who used a tractor for land preparation, 72% used both a tractor and animal draft power in land preparation. Farmers using a tractor for land preparation had higher mean and median yields relative to those that did not, though the difference is not statistically significant (Table 3). This yield difference of 214 kg/acre is equivalent to 63,000 MMK/acre ($49/acre) and represents a 19% yield increase.

Table 2. Total costs per acre of land preparation by type and by crop

	Total costs per acre of land preparation by type (MMK/acre)					
	Monsoon paddy			Dry season paddy		
Land preparation	Tractor only	Tractor & Draft	Draft only	Tractor only	Tractor & Draft	Draft only
mean	24,499	44,595	35,010	27,111	40,305	31,079
median	23,938	40,000	30,000	23,000	36,000	32,000
count	70	217	73	21	65	8
	Sesame			Groundnut		
Land preparation	Tractor only	Tractor & Draft	Draft only	Tractor only	Tractor & Draft	Draft only
mean	15,991	33,401	30,299	16,827	33,220	23,206
median	12,000	30,000	26,400	13,750	26,667	18,750
count	61	148	112	17	59	57

Table 3. Mechanization in land preparation for dry season paddy

	Yield (kg/acre)		Gross margin ('000 MMK/ac)		Net margin ('000 MMK/ac)	
Land preparation	Tractor & Draft	Draft only	Tractor & Draft	Draft only	Tractor & Draft	Draft only
mean	1,333	1,119	188	164	156	90
median	1,393	1,115	204	112	178	60
count	91	7	91	7	91	7
	Family labor days/acre		Hired labor days/acre		Total labor days/acre	
Land preparation	Tractor & Draft	Draft only	Tractor & Draft	Draft only	Tractor & Draft	Draft only
mean	0.9	2.6[c]	1.2	1.0	2.2	3.5[a]
median	0.3	2.0	0.6	0.0	2.0	2.5
count	92	8	92	8	92	8

Notes: a, b, c indicate that the corresponding means are significantly different at the 10%, 5%, and 1% levels, respectively.

There are several reasons that may explain this yield difference, apart from the type of land preparation. First, farmers using tractors are less likely to report pre- or post-harvest yield loss relative to users of animal draft only (29 to 40%, respectively). Tractor users are thus presumably able to plant earlier on average than households reliant entirely on draft animals, enabling them to harvest in time to avoid events such as heavy rains at the end of the dry season cropping period. Second, while use of an improved variety is similar among those using tractors relative to those that do not (42 and 36%, respectively) (Table 4), tractor users are more likely to use inorganic fertilizer (92 and 69%) and to use more of it on average (119 kg/acre relative to 75 kg/acre). The only input whose application rate is higher among draft power only farmers is manure, for which they average 2.9 carts applied as compared with 2 carts for tractor users. This suggests that higher dry season paddy yields among those using tractors in land preparation are largely due to higher fertilizer use, though may also be due in part to a lower probability of yield loss attributable to timelier planting.

Table 4. Mechanization in land preparation and use of improved varieties

	% of households using improved variety	
Crop	Tractor & Draft	Draft Only
Monsoon paddy	53	47
Dry season paddy	42	36
Groundnut	24[c]	7
Sesame	28	26

Notes: a, b, c indicate that the corresponding percentages are significantly different at the 10%, 5%, and 1% levels, respectively.

Mean and median gross and net margins are higher for farmers using a tractor in land preparation relative to those that do not, though the mean differences are not statistically significant (Table 3). Labor saved by tractor use is only 1.3 person-days/acre.

Mechanized land preparation for groundnut

Sixty-three percent of groundnut farmers used a tractor for land preparation. Farmers using a tractor for land preparation had higher mean and median yields relative to those that did not, though the difference is not statistically significant (Table 5). This yield difference of 118 kg/acre is equivalent to 38,900 MMK/acre ($30/acre) and an 18% increase in yield.

As with dry season paddy, there are several reasons that may explain this yield difference, apart from the type of land preparation. First, farmers using tractors are less likely to report pre- or post-harvest yield loss relative to users of animal draft only (16 to 33%, respectively). Second, those using tractors are more likely to use an improved variety (24 to 7%, respectively), to use inorganic fertilizer (87 to 75%, respectively) and to use more of it on average (50 to 40 kg/acre, respectively), while using the same average amount of manure. This suggests that higher input use among tractor users largely explains their higher groundnut yields, though may also be due in part to a lower probability of yield loss attributable to timelier planting.

While the mean gross margin for draft power only users is slightly higher than that of tractor users, this difference is not significant (Table 5). By contrast, the mean and median net margins of tractor users are slightly higher than those using only draft power. Use of a tractor results in a relatively small saving of one person-day of labor per acre in land preparation.

Table 5. Mechanization in land preparation for groundnut

	Yield (kg/acre)		Gross margin ('000 MMK/ac)		Net margin ('000 MMK/ac)	
Land preparation	Tractor & Draft	Draft only	Tractor & Draft	Draft only	Tractor & Draft	Draft only
mean	796	678	96	106	50	41
median	653	613	66	111	38	26
count	78	61	78	61	78	61
	Family labor days/acre		Hired labor days/acre		Total labor days/acre	
Land preparation	Tractor & Draft	Draft only	Tractor & Draft	Draft only	Tractor & Draft	Draft only
mean	1.3	2.5[b]	0.9	0.7	2.3	3.3[a]
median	0.3	1.4	0.3	0.0	1.1	2.0
count	78	59	78	59	78	59

Notes: a, b, c indicate that the corresponding means are significantly different at the 10%, 5%, and 1% levels, respectively.

Mechanized land preparation for sesame

Sixty-five percent of sesame farmers used a tractor for land preparation. Approximately half of all sesame growers reported pre- or post-harvest yield loss, and 14 percent of those using draft power (and 20 percent of those using tractors) reported zero yield. We drop the cases of zero sesame yield from the following analysis given that the goal is to estimate the potential productivity, financial and labor-saving gains from tractor use, and cases with zero yield subsequently report zero harvest and threshing costs and labor, which are a significant portion of total costs of production for sesame.

The average yield of those using only draft animals is slightly higher than that of tractor users, though this difference is not significant, and the median yields are similar (Table 6). Although the average and median gross margins for sesame are higher for those using only draft animals, the average and median net margins are nearly the same as those of tractor users. Tractor users also saved an average of 3.5 person-days of labor in land preparation, about half of which is family labor.

Table 6. Mechanization in land preparation for sesame

	Yield (kg/acre)		Gross margin ('000 MMK/ac)		Net margin ('000 MMK/ac)	
Land preparation	Tractor & Draft	Draft only	Tractor & Draft	Draft only	Tractor & Draft	Draft only
mean	159	170	116	149	75	75
median	135	130	73	106	37	38
count	215	124	215	124	215	124
	Family labor days/acre		Hired labor days/acre		Total labor days/acre	
Land preparation	Tractor & Draft	Draft only	Tractor & Draft	Draft only	Tractor & Draft	Draft only
mean	1.0	3.5[c]	1.1	2.1[a]	2.2	5.7[c]
median	0.3	2.0	0.3	0.0	1.4	3.5
count	215	123	215	123	215	123

Notes: a, b, c indicate that the corresponding means are significantly different at the 10%, 5%, and 1% levels, respectively.

In summary, we find that use of a tractor in land preparation is associated with higher yields for dry season paddy and groundnut, but not for sesame or monsoon paddy cultivation. Productivity increases associated with mechanized land preparation appear to result from: 1) adoption of complementary inputs (inorganic fertilizer and improved varieties); and 2) increased timeliness of planting that enables farmers to avoid events such as heavy rains late in the cropping period, which may cause yield loss. Labor savings from use of a tractor in land preparation are relatively small, and there are no observed differences in crop profitability for tractor or draft animal land preparation. This suggests that the widespread use of tractors in land preparation is due to 1) improved reliability and timeliness of planting in a context where farm labor is increasingly difficult to obtain; 2) reduction of risk associated with weather-induced crop losses; and 3) minimization of the physical drudgery associated with farming.

HARVESTING AND THRESHING

Introduction

There are two transitions currently occurring in harvesting and threshing of paddy in the Dry Zone. First, the shift from manual harvesting and manual threshing of paddy to manual harvesting and mechanized threshing. Second, the shift from manual harvesting plus (manual or mechanized) threshing to combine harvesting. Neither sesame nor groundnut are mechanically harvested at present, and only 1-2% is threshed mechanically by farm households.

In contrast to the case of mechanized land preparation, there is evidence that use of a combine harvester or a mechanized thresher can result in significant quantitative and qualitative yield gains relative to manual reaping, threshing and winnowing of paddy. For example, manual cutting, harvesting and handling can result in yield losses of one to three percent, while manual threshing can result in yield losses of two to six percent (FAO, 1999; Alavi et al, 2012). By contrast, a combine harvester performs each of these functions yet results in a post-harvest yield loss of only one to two percent (Gummert, 2017). Another advantage of combine harvesting or mechanized threshing is timelier completion of harvesting and threshing, which can have a positive effect on cropping intensity and yields of crops planted immediately after the current crop (Pingali, 2007). In addition, timelier harvesting and threshing can avoid potential grain damage that can lower paddy sale prices (IRRI, 2013). That said, combine harvesters are not as effective as manual reaping if the crop has become lodged due to inclement weather, and can leave more straw in the field, which could be a concern for households relying upon straw for livestock feed (ibid, 2013).

In the four townships surveyed, in both paddy growing seasons, more than two thirds of paddy farming households used either a thresher or combine (71% in monsoon and 67% in dry season). Use of threshers predominates during monsoon (the main growing season), when 58% of farms used a thresher and 13% used a combine. This pattern is reversed in the dry season, when 41% of paddy cultivators used a combine and 26% used a mechanized thresher.

There are three likely reasons why combine harvester use is much more frequent for dry season relative to monsoon paddy. First, 75% of dry season paddy growers plant monsoon paddy on the same parcel, thus combine harvester use allows these farmers to harvest and thresh paddy quickly, allowing the following monsoon paddy crop to be planted in time. Second, combine harvesting leaves more straw in the field, and the monsoon paddy crop provides the bulk of paddy straw for the year for livestock, making some farmers unwilling to use combines on this crop. Third, higher levels of combine use during the dry season than in the monsoon may also occur because large contiguous expanses of paddy are usually found in areas with access to dry season irrigation. In locations where only monsoon paddy is grown, land use patterns are more fragmented. Areas with dry season irrigation are thus more attractive to rental service providers, as they can achieve economies of scale by serving many customers at a single location.

Mechanization of harvesting and threshing of dry season paddy

Farmers who use a combine harvester for dry season paddy enjoy higher mean and median yields relative to those using manual harvesting and a mechanized thresher (Manual / Thresher) or those using manual harvesting and threshing (Manual Only) (Table 7), though the differences are not

statistically significant.[4] The yield difference of 162 kg/acre between those using a combine with those using a mechanized thresher is equivalent to 47,900 MMK/acre ($37/acre) and an 11% yield difference. Likewise, the yield difference of 259 kg/acre between those using a combine relative to manual harvesting/threshing is equivalent to 76,600 MMK/acre ($60/acre) and a 19.5% yield difference.

Table 7. Mechanization in harvesting and threshing of dry season paddy

	Yield (kg/acre)			Gross margin ('000 MMK/ac)			Net margin ('000 MMK/ac)		
Harvest / Threshing	Combine	Manual / Thresher	Manual Only	Combine	Manual / Thresher	Manual Only	Combine	Manual / Thresher	Manual Only
mean	1,585	1,423	1,326	253	185	245	211	161	220
median	1,672	1,393	1,254	260	201	237	212	178	205
count	48	25	12	48	25	12	48	25	19
	Family labor days/acre			Hired labor days/acre			Total labor days/acre		
Harvest / Threshing	Combine	Manual / Thresher	Manual Only	Combine	Manual / Thresher	Manual Only	Combine	Manual / Thresher	Manual Only
mean	0.0	0.7[c]	0.6[d]	0.1	7.7[c]	11.0[f]	0.1	7.4[c]	11.3[f]
median	0.0	0.5	0.0	0.0	6.0	14.0	0.0	7.0	16.8
count	48	25	12	48	25	12	48	25	12

Notes: a, b, c (d, e, f) indicates that the corresponding means are significantly different at the 10%, 5%, and 1% levels, respectively, comparing Combine households with Manual/Thresher households (with Manual only).

While our data do not enable us to attribute yield differences between mechanized harvesting or threshing relative to other crop management decisions, the yield advantage of combine users appears to be due to combine use for several reasons. First, combine users interviewed by READZ noted that they achieved higher yields due to reduced losses of grain during harvesting and threshing. Second, rates of inorganic fertilizer use are similar across the three groups. That said, use of improved varieties is higher among those using combines (39%) and mechanized threshers (56%) relative to those using only manual harvesting/threshing (30%) (Table 8).

The gross and net margins for combine users relative to those using manual harvesting/threshing of dry season paddy are similar (Table 7). However, gross and net margins for those using a mechanized thresher are considerably lower than those of combine users or those using manual harvesting/threshing, though the differences are not statistically significant. Not surprisingly, use of a combine saves a significant amount of labor in harvesting/threshing, equivalent to 7.3 labor days/acre relative to those doing manual harvesting and mechanized threshing, and 11.2 labor days/acre relative to those using manual harvesting/threshing.

[4] In evaluating the yield, financial and labor use implications of mechanization in dry season (pre-monsoon) paddy, we drop n=13 cases of zero yield for farmers using only manual harvesting and threshing. These cases represent 41% of all cases of manual harvesting and threshing. Such cases would have zero expenditure on harvesting/threshing, and some of them might have chosen mechanized harvesting and/or threshing in the absence of achieving zero yields.

Table 8. Mechanization in harvesting and threshing and use of improved paddy varieties

	% of households using improved variety		
Crop	Combine	Manual / Thresher	Manual only
Dry season paddy	39	56	30
Monsoon paddy	63[c,f]	45	40

Notes: a, b, c (d, e, f) indicates that the corresponding percentages are significantly different at the 10%, 5%, and 1% levels, respectively, comparing Combine households with Manual/Thresher households (with Manual Only).

The average cost per acre of harvesting/threshing by combine in the dry season is approximately 14,800 MMK/acre ($12/acre) higher than use of manual harvesting and mechanized threshing, and 24,000 MMK/acre ($19/acre) higher than manual harvesting/threshing (Table 9). That said, the additional cost of combine use is considerably less than the value of the difference in yields, whether the yield gains are due to combine use, higher rates of improved input use, or both. In addition, as noted above, it is likely that many dry season combine users have chosen to harvest by combine so as to ensure timely preparation of monsoon paddy on the same parcel.

Table 9. Costs per acre of mechanization in harvesting and threshing of paddy

	Costs per acre of harvesting & threshing by type (MMK/acre)					
	Dry season paddy			Monsoon paddy		
Harvest / Threshing	Combine	Manual / Thresher	Manual Only	Combine	Manual / Thresher	Manual Only
mean	49,215[c,f]	34,447	25,226	49,655[c,f]	32,568	36,923
median	49,242	33,000	25,000	52,402	24,250	30,000
count	48	25	12	59	230	92

Notes: a, b, c (d, e, f) indicates that the corresponding means are significantly different at the 10%, 5%, and 1% levels, respectively, comparing Combine households with Manual/Thresher households (with Manual Only).

Mechanization of harvesting and threshing of monsoon paddy

Farmers that use a combine harvester for monsoon paddy enjoy significantly higher mean and median yields relative to those using manual harvesting and a mechanized thresher or those using only manual labor for harvesting/threshing (Table 10). The yield difference of 141 kg/acre between those using a combine with those using a mechanized thresher is equivalent to 43,300 MMK/acre ($34/acre) and a 13% yield gain. Likewise, the yield difference of 202 kg/acre between those using a combine and those using only manual harvesting/threshing is equivalent to 62,000 MMK/acre ($48/acre) and a 19% yield gain.

The yield difference between users of combines and mechanical threshers may be partially due to combine use, given that the two groups have a similar probability of using irrigation and inorganic fertilizer and had similar average fertilizer use rates. That said, use of an improved variety is higher among users of combines relative to threshers (63 to 45 percent) (Table 8). The yield difference between combine users and manual harvesters/threshers may be due to not only combine use but

also differences in input use as combine users are more likely to have used an improved variety (63 to 40%) and to have used inorganic fertilizer and applied it at a higher average rate.

Table 10. Mechanization in harvesting and threshing of monsoon paddy

	Yield (kg/acre)			Gross margin ('000 MMK/ac)			Net margin ('000 MMK/ac)		
Harvest / Threshing	Combine	Manual / Thresher	Manual Only	Combine	Manual / Thresher	Manual Only	Combine	Manual / Thresher	Manual Only
mean	1,267[b,e]	1,126	1,065	173	139	187	142[b]	92	116
median	1,317	1,115	1,254	169	134	203	143	105	111
count	59	230	92	59	230	92	59	230	92
	Family labor days/acre			Hired labor days/acre			Total labor days/acre		
Harvest / Threshing	Combine	Manual / Thresher	Manual Only	Combine	Manual / Thresher	Manual Only	Combine	Manual / Thresher	Manual Only
mean	0.1	1.0[c]	3.1[f]	1.0	7.9[c]	9.6[f]	1.0	8.4[c]	12.8[f]
median	0.0	0.0	0.3	0.0	6.6	7.0	0.0	7.2	11.0
count	59	230	92	59	230	92	59	230	92

Notes: a, b, c (d, e, f) indicates that the corresponding means are significantly different at the 10%, 5%, and 1% levels, respectively, comparing Combine households with Manual/Thresher households (with Manual Only).

Average and median gross and net margins of combine users are higher than those using manual harvesting and mechanized threshing (Table 10). Although the average and median gross margins of combine users are lower than those using only manual harvesting/threshing, average and median net margins are higher for combine users. As with dry season paddy, use of a combine for monsoon paddy saves a significant amount of both harvest and threshing labor, equivalent to 7.4 labor days/acre relative to those doing manual harvesting and mechanized threshing, and 11.8 labor days/acre relative to those doing manual harvesting/threshing.

While the monsoon paddy net margins of combine use are higher than those using mechanized threshers or manual labor alone for harvesting/threshing, the average cost per acre of harvesting/threshing by combine is approximately 17,100 MMK/acre ($13/acre) higher than use of manual harvesting and mechanized threshing, and 12,700 MMK/acre ($10/acre) higher than manual harvesting and threshing (Table 9). However, the additional cost of combine use is considerably less than the value of the difference in yield, whether the yield gains are due to combine use, higher rates of improved input use, or both.

CONCLUSIONS

Our analysis reveals the following main conclusions.

1) Mechanization of land preparation is associated with higher yields in dry season paddy cultivation and groundnut farming, but not in sesame or monsoon paddy cultivation.

2) Productivity increases associated with mechanized land preparation appear to result from: 1) Adoption of complementary inputs (inorganic fertilizer and improved varieties); and 2) Increased timeliness of planting that enables farmers to avoid events such as heavy rains late in the cropping period, which may cause yield loss.

3) There are no observed differences in crop profitability for tractor or draft animal land preparation.

4) Mechanization of paddy harvesting and threshing is associated with higher realized yields as a result of reduced losses of grain during harvesting/threshing and (during the monsoon season) greater propensity to use improved varieties and inorganic fertilizers.

5) Surprisingly, despite substantially reducing labor requirements, mechanized harvesting and/or threshing does not appear to lower average production costs or result in significantly higher average gross or net margins.

6) Together, these findings suggest that some of the main advantages that mechanization provides to farm households result from: 1) Improved reliability and timeliness of planting and harvesting in a context where farm labor is increasingly difficult to obtain; 2) Reduction of risk associated with weather-induced crop losses; 3) Reduced grain loss during harvesting/threshing by combine, and; 4) Minimization of the physical drudgery associated with farming.

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