UDP Technology and Rice Yields Among Farmer Beneficiaries of Rainfed Lowland Project Areas in Myanmar

D. Kyaw[1] and G. Hunter[2]

[1] Monitoring and Evaluation Specialist, Fertilizer Sector Improvement Project, IFDC, Myanmar

[2] Chief of Party, Fertilizer Sector Improvement Project, IFDC, Myanmar

Abstract

Since its inception in 2014, the Fertilizer Sector Improvement (FSI) project in Myanmar has introduced urea deep placement (UDP) fertilizer technology, aimed at improving yields and fertilizer use efficiency among rice farmers in its project intervention areas. For this purpose, selected farmers from three major rice-growing regions of Myanmar, located in Yangon, Bago, and Ayeyarwady were given training through effective farm demonstrations and other extension services to promote the use of technology along with other improved inputs. Extensive data were collected among project beneficiaries to determine the effect of UDP technology on yields in comparison to the traditional use of fertilization methods. In this paper, we have made an attempt to use part of the data documented to estimate the factors responsible for variability in productivity levels of rice with the adoption of UDP technology under rainfed conditions during the 2016 wet season. A log linear regression model was employed for empirical estimation to determine the effect of UDP along with other external factors that jointly influence the rice yields in the intervention areas. Our analytical results indicate a significant and positive impact of UDP technology use on rice yields; improved crop intensification practices adopted by farmers also played a crucial role in improving the rice yields. In addition to these factors, male farmers were very successful in adopting the technology and in realizing higher yields in their plots compared to their female counterparts. Other variables, such as area allocated for rice, resulted in yield reduction, implying lack of purchasing power among farmers for additional input use. Along with low credit access, this results in underuse of external inputs. From a policy perspective, these results have wider implications. For instance, limited opportunities exist for crop land expansion in the intervention areas; thus, any increase in yields should come from the effective and efficient use of agro-input technologies, such as high-yielding varieties (HYVs), UDP, and other crop management techniques. The evidence from our empirical analysis further suggests increased and focused government efforts are needed toward promoting the use of efficient soil and fertilizer management technologies, such as UDP, and promoting crop intensification practices among farmers in the lowland rainfed rice cropping system in Myanmar to achieve higher yields and profits from limited expansion of cropping land. The gross margin results also indicate the likely and positive effect of increased access to technologies and participation by women farmers in extension programs for greater benefits to society as a whole.

Introduction

The Myanmar economy is largely dependent on the agriculture sector, which contributes 29% of national gross domestic product (GDP) and 23% of total export earnings in 2014/2015 and in which 65% of the labor force is engaged (CSO, 2015/2016). Growth in the agriculture sector has played a crucial role in the development of Myanmar. Production of the staple food – rice – is central to the country's agriculture sector as it is the main livelihood activity of farmers and a major export item of the country. It occupies more than half of total cultivated land and is a key economic crop that dominates most agricultural economies in developing countries like Myanmar.

Due to limitations of planting area and imported material inputs, raising productivity of paddy should be given a higher priority to meet the objective of national food security and export earnings of the country.

Between 1995 and 2010, paddy yield has increased by 1 t/ha (from 3.08 t/ha to 4.07 t/ha) (Department of Planning, 2015). However, productivity of paddy (2.84 t/ha in 2015) still has been relatively low compared to other Southeast Asian countries, such as Indonesia, Vietnam, Philippines, and Malaysia (USDA, 2016). According to the Department of Planning (2015), paddy yield was stagnant at 3.8 t/ha during 2011 and 2014. Raitzer et al. (2015) pointed out that most farms – with low-input, low productivity, low-quality output, and low returns – are caught in a low equilibrium trap in Myanmar. In order to raise the productivity of paddy production in Myanmar, it is important to identify the core factors influencing it. The FSI project, implemented by the International Fertilizer Development Center (IFDC), began on April 1, 2014, as a three-year project funded by the United States Agency for International Development (USAID), and it was expanded and extended in May 2015 to a five-year project. The goal of the project is to improve food security and increase profitability for smallholder farmers by sustainably increasing agricultural productivity. IFDC is implementing the project with collaborating partners in geographic focal areas covering Yangon, Bago, and Ayeyarwady regions.

The productivity constraints for paddy stem largely from an insufficient supply of good seeds, fertilizer prices rising more quickly than paddy prices coupled with a lack of farmer knowledge on soil nutrient management, and the slow pace of mechanization outside of several commercial rice-producing areas (World Bank, 2016). Therefore, the FSI project seeks to improve paddy yield and farm income by promoting the application of balanced fertilizer with UDP as well as use of good seed, in addition to strengthening the capacity of input retailers to improve their business management and provide an advisory service to farmers. The FSI project targets farmers in the rainfed lowland rice production areas of Yangon, Bago, and Ayeyarwady regions.

The FSI project methodology involves a series of capacity-building activities that include farmer-level and agro-input dealers' training combined with field demonstrations on the use of improved technologies (seeds, fertilizers, agri-implements) and technology transfer through on-farm as well as organized field days and motivational field trips. The agro-input dealer trainings are designed to enhance agricultural advisory services, which play a crucial role in promoting rice-based cropping system productivity and farm income. Most of the progressive farmers in the project intervention areas participate in farmer training and apply UDP technology. As a part of the FSI project, a crop cut survey is conducted seasonally to determine the yield improvement with UDP technology over the farmers' conventional practice on fertilizer application and to calculate the yield differences between them.

In this paper, we have made an attempt to assess the influencing factors on rice productivity levels in the project intervention areas, namely among farmers who adopted UDP fertilizer technology practices in the rainfed lowland areas in Myanmar. This would further allow us to derive suitable policy implications along with recommendations necessary to promote efficient soil and fertilizer management practices and necessary actions and support required to achieve higher rice productivity levels especially under lowland rainfed environments in Myanmar.

Methodology

Sample of Direct Beneficiary Farmers for Rainfed Paddy Season in 2016

During the 2016 wet season, farmer training on UDP was provided to 1,933 farmers: 1,386 male and 547 female farmers (Table 1) selected from nine townships in Yangon, seven townships in Bago, and 11 townships in Ayeyarwady. A list of direct beneficiary farmers who attended the farmers' training and applied UDP was received following field monitoring by subgrant partners and the project extension team and through key farmer informants (Table 1). The total number of beneficiary farmers (at the end of September 2016) who applied UDP in the wet season of 2016 was 1,617 (1,164 male and 453 female farmers). Table 1 shows that, among the direct beneficiaries, the percentages of UDP users across all regions were 82.8% and 83.9% of female and male farmers, respectively. The lowest percentage of UDP technology beneficiaries were found in Ayeyarwady Region, regardless of gender (Table 1).

The farmer list was sorted first by gender, and from the list, a random sample of farmers was selected for each township. Based on resource availability, crop cuts were conducted across 7% of the total sample (34 female and 83 male farmers).

For the current analysis, we have used data and information collected through crop cuts from 115 farmers (34 female and 81 male farmers).

Table 1. Percentage of direct beneficiary male and female farmers who used UDP during wet season paddy in the FSI project regions.

Region	No. of Direct Beneficiary Farmers in Wet Season 2016			No. of Beneficiary Farmers Using UDP in Wet Paddy 2016			% of Total Beneficiary Farmers Using UDP in Wet Paddy 2016		
	Female	**Male**	**Total**	**Female**	**Male**	**Total**	**Female**	**Male**	**Total**
Yangon	211	459	670	176	392	568	83.41	85.40	84.78
Bago	169	371	540	160	352	512	94.67	94.88	94.81
Ayeyarwady	167	556	723	117	420	537	70.06	75.54	74.27
Total	**547**	**1,386**	**1,933**	**453**	**1,164**	**1,617**	**82.82**	**83.98**	**83.65**

Source: FSI extension team, subgrant partners and key farmers.
A direct beneficiary farmer is any farmer who attended a project training event at any time over the term of the project.

Implementation of Crop Cut Survey

The extension team of the FSI project is well-experienced in conducting crop cut surveys. Six enumerators (who are working as FSI Field Officers and Training

Officers) and a supervisor (FSI Extension Specialist) were involved in conducting the crop cuts and survey during the rainfed paddy season in 2016. They were provided with instructions for crop cuts from the Chief of Party (CoP) and the list of random sample farmers and a questionnaire from the Monitoring and Evaluation Specialist to be used to collect data for gross margin calculations.

The main objective of the crop cut survey is to measure the impact of the UDP technology on rice yield. At the end of each season, the project takes crop cuts in a random sample of beneficiary farmers who used UDP in that season to compare with their fields without UDP. Two 5 meter x 2 meter plots are cut in each farmer's field with and without UDP. The plots are threshed, weighed, and moisture measured to calculate yield per hectare at 14% moisture. In addition, information on the inputs used and their cost, area of wet paddy cultivated and harvested, percentage of the total production sold, and farm-gate paddy price received were collected to estimate the gross margin of wet season paddy in 2016.

Data Analysis

Descriptive statistics: Measures such as percentages, frequencies, means, and standard deviations were used in characterizing rice farmers based on farm size groups (small, medium, and large landholding groups), area harvested under wet land, cultivated rice varieties, cultural practices (broadcasting seeds and transplant paddy), mechanization, agro-inputs used, etc., during the production of wet season paddy in 2016.

Tests of significance: The Chi-square test and analysis of variance were used to find the differences in wet paddy yield with UDP and without UDP, harvested wet paddy land, cultural practice(s), paddy variety, farm size group, sources of seeds, total production cost of wet paddy, and quantity of sales between male and female beneficiary farmers.

Gross margin analysis: The gross margin (GM) by gender, by variety, by cultural practice, and by cropping pattern was calculated to estimate the returns of wet season paddy production in 2016.

The GM is calculated from five data points (USAID, 2013):

1. Total production (TP).
2. Total value of sales (VS).
3. Total quantity of sales (QS).
4. Total recurrent cash input costs (IC).
5. Total units of production (UP), i.e., area in hectares.

$$GM = \frac{(TP \times VS/QS) - IC}{UP}$$

Empirical model:

Productivity is a basic and intuitive measure of crop or varietal performance in the use or adoption of improved technology. Coelli et al. (2005) argued that productivity is the ratio of the output(s) that it produces to the input(s) that it uses (Productivity = Outputs/Inputs). Productivity is raised when growth in output(s) outpaces growth of input(s). Productivity growth without an increase in input(s) is the best kind of growth to aim for rather than attaining a certain level of output (Nin-Pratt et al., 2008).

The rice production decisions by farmers are affected by pricing factors, such as farm-gate price of rice, farm-gate price of substitute food crops like maize, world price of rice and maize, and prices of fertilizer, influencing yields indirectly. Also, non-price factors, such as irrigation, investment in research and development, extension services, capital and credit access, and biotic factors, such as favorable agro-climatic conditions, and development of rural infrastructure, affect farmers' production (Yu and Fan, 2009).

Glenn et al. (2013) suggests that improvement in soil fertility management is one of the nine areas of intervention for increasing productivity at the farm level in Myanmar. Very few studies have estimated the influence of fertilizer on rice productivity levels and increased efficiency in Myanmar. This paper seeks to further address the gap in the existing literature on the specific subject matter, namely in estimating the determinants of improved paddy yield with UDP technology use among the farmers in the lowland rainfed region during the wet paddy season of 2016.

Based on the household-level crop cut survey data collected in wet paddy season 2016, we herein derive the output-response relationships from estimated production function, assuming profit maximization objective by farmers. The log linear regression model (using natural logs for variables on both sides of the model) was estimated to generate the desired linearity in parameters. By this, the coefficient of such log-log model estimated can be interpreted as *percent change* in the dependent variable for a *percent change* in the independent/explanatory variables.

$$In\ (Y) = \beta_0 + \beta_1\ In(x_1) + \beta_2\ In(x_2) + \beta_3\ In\ (x_3) + \beta_4\ In(x_4) + \beta_5\ In(x_5) + \beta_6\ In(x_6) + \beta_7 x_7 + \beta_8 x_8 + \beta_9 x_9 + \mathcal{E}_i$$

where Y = Average wet season yield of paddy with UDP (kg/ha)

X_1 = Log lagged average price of paddy (MMK/kg)

X_2 = Log average price of prilled urea (MMK/kg)

X_3 = Yield difference between yield with UDP and without UDP technology (t/ha)

X_4 = Harvested land of wet season paddy (ha)

X_5 = Number of crops grown in a year

X_6 = Cost of harvesting machine (MMK/ha)

X_7 = Number of labor use in paddy production (number of labor/ha)

X_8 = Dummy variable for gender of sample farmer (male=1, female=0)

X_9 = Dummy variable for paddy variety (HYV=1, local=0)

The above model was employed due to the simplicity in the interpretation of the parameters and the data meeting the Ordinary Least Square criteria. The model was subjected to a diagnostic test. The double logarithmic model was tested for normality to ascertain the nature of the distribution of the residuals. The presence or absence of multicollinearity was verified with the help of the Variance Inflation Factor. Lastly, the value of R^2 adjusted was used to determine the goodness of fit of the model.

Results and Discussion

Family Size, Rainfed Paddy Land With and Without UDP, and Farm Size Group

The average family size of sampled male farmers was 4.86, which is higher than the average family size of sampled female farmers (4.54). The mean wet paddy land with UDP was nearly the same for both sampled male and female farmers (male 0.099 ha and female 0.094 ha). The wet paddy land without UDP of sampled female and male farmers was 4.0 and 3.56 ha, respectively.

According to the Settlement and Land Record Department (2010), different farm size groups are classified into five categories: landless, marginal (less than 2 acres), small (less than 5 acres), medium (less than 10 acres) and large (more than 10 acres). Following that criteria, the majority of sampled female farmers (40%) owned/worked with small paddy land, while the majority of sampled male farmers (40%) owned/worked with medium paddy land (Figure 1). Nearly the same percentage of both sampled male and female farmers were classified in the other two farm size groups of marginal and large landholders.

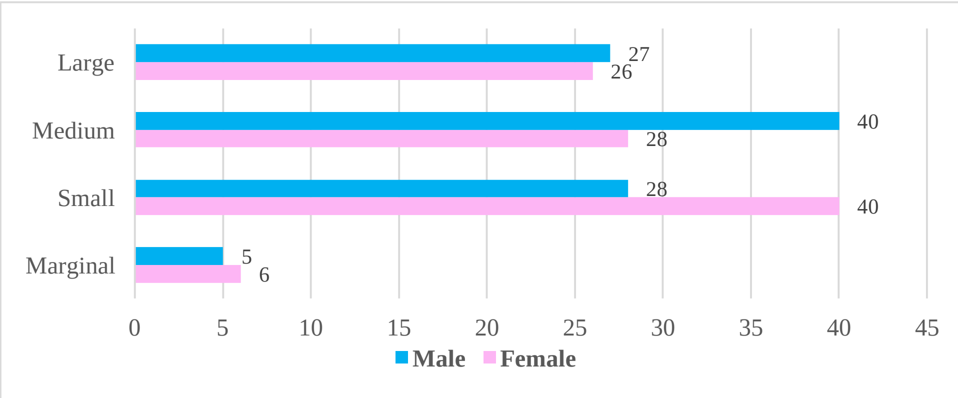


Figure 1. Different farm size groups of sample beneficiary farmers by gender.

Cropping Pattern, Cultural Practice, Paddy Variety Used, and Effect of UDP on Yield

The majority of both female and male sampled farmers grew gram crops after rainfed paddy (Figure 2). Summer paddy production was determined by the availability of water. Thirty-one percent of female and 16% of male farmers planted summer paddy (or dry paddy) after wet paddy. Furthermore, 11% of female and 8% of male farmers grew three crops per year (wet paddy, gram crops, and dry paddy). The rest of the farmers (23% of female and 15% of male farmers) grew only one crop – rainfed paddy only. Therefore, the mean number of crop grown per year for the sampled farmers was about two.

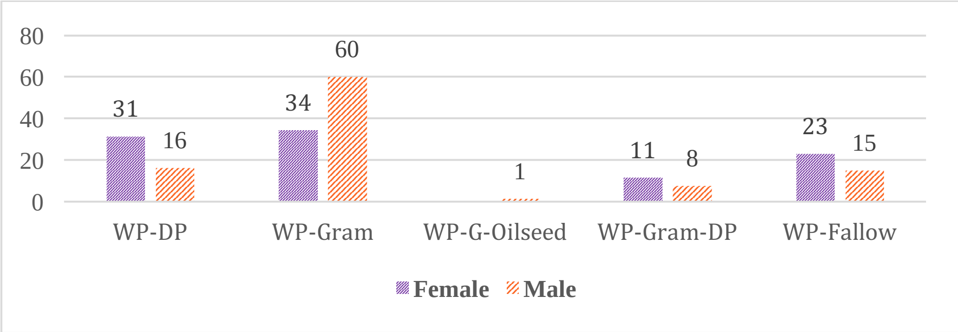
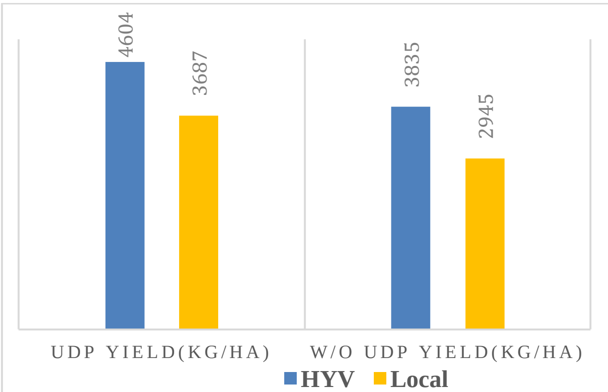


Figure 2. Cropping pattern of sample beneficiary farmers by gender.

The majority of both sampled male and female farmers used HYVs in wet paddy season production (Table 2). A quarter of sampled female farmers and 14% of sampled male farmers used local varieties because of the higher sale price received for the local rice variety, such as Paw San Yin. More than half of the sampled female farmers and nearly half of sampled male farmers practiced transplanting for wet paddy production.

The analysis of variance indicated a significant increase in yield with UDP at a 1% significance level regardless of variety (Figure 3A). The same amount of briquette urea (BU) (108 kg/ha) was applied in wet season paddy regardless of variety. The quantity of broadcast prilled urea used varied between the two types of paddy variety (Figure 3B).



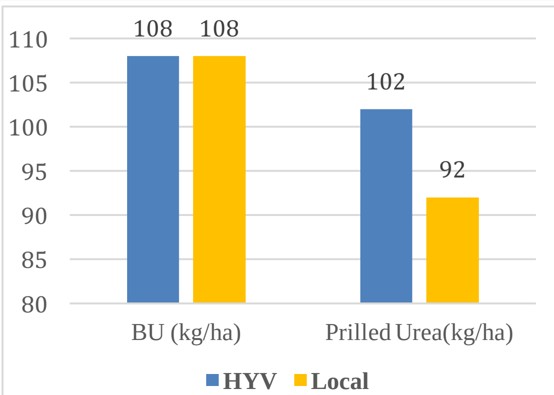


Figure 3. (A) Rainfed paddy yield with and without UDP by variety and (B) different types of urea used by variety.

More than half of the sampled female farmers and 48% of the sampled male farmers transplanted paddy (Table 2). The sampled farmers applied nearly the same amount of prilled urea regardless of the cultural practices. The sampled farmers who broadcast seeds received a little higher yield, with or without UDP, than sampled farmers who transplanted.

Regarding sources of seeds, the majority of sampled male and female farmers used their own seeds for wet season paddy production. A quarter of both male and female farmers bought seeds from other farmers, and 16% of total sampled farmers bought seeds from the Department of Agriculture (Table 2). Farmers usually keep grain as seeds for planting in the next season. The sampled farmers, through project training activities, became aware of the value of using good seeds, which can be bought from both public (Department of Agriculture) and private (seed growers and seed dealer/company) sectors.

Table 2. Paddy variety, cultural practice, and sources of seeds by gender (%).

Gender	Paddy Variety		Cultural Practice		Sources of Seeds			
	Local	HYV	Broadcast Seeds	Trans-planting	Own Seeds	Buy from Seed Growers	Buy from DOA	Buy from Dealer/ Company
Female	25.7	74.3	45.7	54.3	62.9	25.7	11.4	0
Male	13.8	86.2	51.2	48.8	53.8	26.2	18.8	1.2
Total	17.4	82.6	49.6	50.4	56.5	26.1	16.5	0.9

Source: Authors' computations.

Used of Fertilizers, Cost of Fertilizer, and Yield of Wet Season Paddy by Gender

Depending on the soil fertility and pH level, 36% of both female and male sample farmers applied a basal fertilizer such as triple superphosphate (TSP), muriate of potash (MOP) and compound fertilizers in wet season paddy. The majority of sample farmers (86% of total sample) used TSP as a basal fertilizer.

BU was applied once, 25-35 days after sowing time at the rate of 108.68 kg/ha. On the other hand, various fertilizers such as prilled urea, compound fertilizer, TSP, MOP, compound fertilizer with herbicide (most popular), Comet brand fertilizer with S, special fertilizer to get a maximum tiller number, and special fertilizer to get good panicles, etc., were applied in the paddy field without BU (or UDP). In Ayeyarwady Region, three males and one female farmer did not use fertilizer in their paddy field.

The majority of sampled male and female farmers used prilled urea (at an average rate of 114 kg/ha). Only 28% of sampled female and 39% of sampled male farmers applied compound fertilizer at an average rate of 82 kg/ha for female and 99 kg/ha for male farmers (Table 3). The total fertilizer cost for the sampled female farmers was not much different with or without UDP, but the cost of fertilizer in wet paddy fields without UDP was significantly higher than the fertilizer cost with UDP in sampled male farmers (Table 3).

The average rainfed paddy yield with UDP was significantly higher than the average yield without UDP in both male and female sampled farmers at the 1% level of significance (Table 3). Both paddy fields with and without UDP were under the farmer's management and they used the same variety of paddy. It is concluded that the yield response is due to deep placement of the urea.

Table 3. Average fertilizer used, cost of fertilizer, and yield of wet season paddy in 2016.

		Use Prilled Urea without UDP (kg/ha)	Use Compound Ferterilizer without UDP (kg/ha)	Total Fertilizer Cost with UDP (MMK/ha)	Total Fertilizer Cost without UDP (MMK/ha)	Average Paddy Yield with UDP (kg/ha)	Average Paddy Yield without UDP (kg/ha)
Female	Mean	98.66	81.75	66,449.63	68,847.26	4,070.28	3,303.32
	N	30	10	35	35	35	35
	Std. Dev	55.71	40.85	15,994.02	38,170.54150	1,018.75	1,025.39
Male	Mean	120.87	98.76	67,039.01	83,334.92	4,607.70	3,845.95
	N	71	31	80	80	80	80
	Std. Dev	63.55	36.10	15,882.85	43,520.31	1,021.29	927.78
Total	Mean	114.27	94.61	66,859.63	78,925.64	4,444.13	3,680.80
	N	101	41	115	115	115	115
	Std. Dev	61.89	37.52	15,848.76	42,330.72	1,045.96	986.39

Source: Authors' computations.

Gross Margin of Rainfed Paddy Production of the Sample Male and Female Farmers

With UDP, the average net returns over cash costs of the sampled beneficiary male and female farmers was U.S. $278 and U.S. $228/ha, respectively (Figure 4A). Without UDP, the sampled male and female farmers received $177 and $109/ha, respectively. By means of technology, GM increased by 109% in female and 57% in male farmers.

A higher gross margin was received with an HYV of paddy both with and without UDP (Figure 4B). By applying UDP, the sample farmers received $280/ha for the HYV of paddy, while a lower GM, $173/ha, was received in an HYV without UDP. Without UDP, GM of the local variety was $76/ha, and it was $173/ha with UDP. Due to UDP technology, GM increased by 126% in local variety and 62% in HYV of paddy.

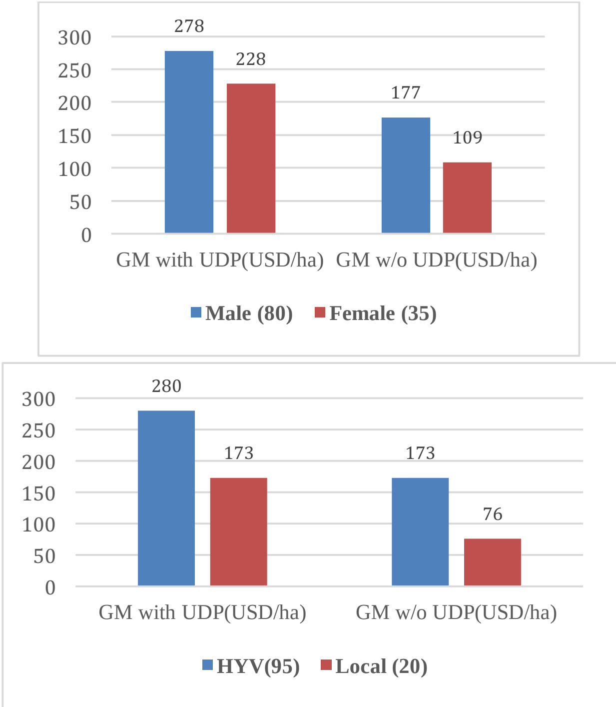


Figure 4. ***(A) Gross margin of wet season paddy with UDP and without UDP by gender and (B) by paddy variety.***

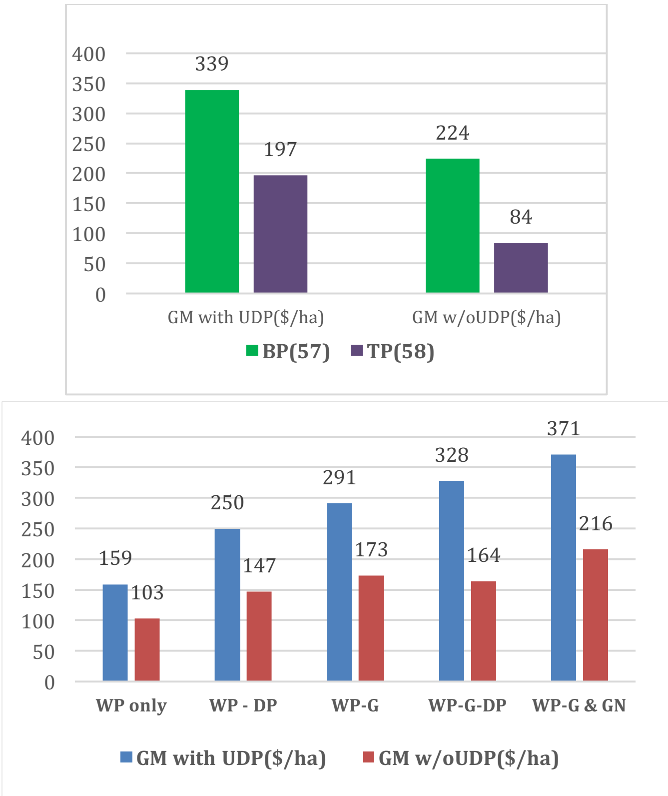


Figure 5. ***(A) Gross margin of wet season paddy with UDP and without UDP by practice and (B) by cropping pattern.***

Due to higher cost of labor for transplanting paddy plants and other extra costs, such as seedbed preparation cost, weeding cost, etc., the total cost of production was much higher. Moreover, the sample farmers who practiced broadcasting seeds received a little higher yield both with and without UDP. Therefore, the GM of paddy with UDP using the broadcast-seed method provided $339/ha, and it was $224 without UDP (Figure 5A). Applying UDP with the transplanting method gave $197/ha, and it was $84/ha without UDP. By means of UDP technology, the GM increased by 134% with transplanting paddy plants and 51% with broadcast paddy seeds.

Figure 5B shows that the sampled farmers who grow three crops (such as wet paddy, then gram and oil seeds, or wet paddy followed by gram and dry paddy) in a year received higher GM than the farmers who grow two crops or only one crop. The GM with UDP was significantly higher than the GM without UDP in all cropping patterns. The GM with UDP was more than $300/ha for the sampled farmers who grew (i) wet paddy followed by gram and oil seeds, and (ii) wet paddy followed by gram and then dry paddy (Figure 5B). Due to technology, the GM increased by 54% in wet paddy (WP) only, 70% in WP followed by dry paddy (DP), 68% in WP followed by gram (G), 113% in WP-G-DP, and 72% in WP-G-Groundnut.

Descriptive Statistics of the Variables in the Model

Table 4 shows the means, minimum, maximum, and the standard deviations values of the continuous variables used in the yield respond model. Two dummy variables were created for gender (male = 1, female = 0) and paddy variety (HYVs of paddy = 1, local paddy variety = 0).

It is shown in the table that the maximum and the minimum average UDP yield of paddy in the project intervention regions are 6.75 t/ha and 1.93 t/ha, respectively. On average, the beneficiary farmers produce 4.44 t/ha, leading to 56% opportunity improvement over the stagnant yield of paddy 2.84 t/ha in 2015.

Table 4. Summary of the explanatory variables.

Continuous Variable	Unit	N	Mean	Min.	Max.	Std. D.
Paddy price	Kyats/kg	115	237.45	222.74	269.08	12.92
Prilled urea price	Kyats/kg	115	428.47	393.47	484.44	17.19
Paddy yield with UDP	t/ha	115	4.44	1.93	6.75	1.04
Number of total crops grown	Number/ year	115	1.94	1.0	3.0	0.535
Harvested paddy land	hectares	115	3.79	0.61	20.24	3.20
Yield difference with UDP and without UDP (t/h)	t/ha	115	763.35	-917.49	2,436.92	585.43
Harvesting machine cost	Kyats/ha	115	47,048.00	0.00	136,000.00	53,097.70
Number of labor used	Number	115	11.57	0.00	49.40	10.30
Dummy Variable		**N**	**Mean of UDP Yield**	**Min. of UDP Yield**	**Max. of UDP Yield**	**Std. D. of UDP Yield**
Male	t/ha	80	4.607	1.93	6.75	1.021
Female	t/ha	35	4.07	2.42	5.94	1.01
HYVs	t/ha	95	4.603	1.93	6.75	1.024
Local variety	t/ha	20	3.687	2.42	5.20	0.799

Source: Authors' computations.

According to the results of the estimation (Table 5), seven continuous variables and two discrete variables were included in the final model. The value of adjusted R^2 denoted that 56.5% of the variation of the dependent variables, for the sample of 115 crop cuts, can be explained by five significant independent variables. The significant values of F-test and t-statistics show that both the model and each independent variable can help identify the variation. The variance inflation factors (VIFs) of all variables were less than 10, and thus the probability of collinearity was eliminated.

In Table 5, for each continuous variable (X_i), the coefficient is the elasticity of UDP paddy yield with respect to X_i. The lagged price of rice that rice farmers are likely to receive and the lagged price of prilled urea that rice farmers are likely to pay have significant effects on the UDP yield of rice in the rainfed area of the project intervention regions. Also, the *a priori* signs of all the variables are met. From Table 5, it was found that the lagged price of prilled urea is statistically significant at 0.05 as the probability value (0.037) is less than 5% and exhibits the right *a priori* expectation. A 1% decrease of the transformed value of prilled urea can increase UDP paddy yield by 1.219% (for more exact calculation, by $1.01^{1.233} - 1 = 1.219\%$) (Wooldridge, 2013), holding other variables fixed.

There is a direct relationship between the farm-gate price of rice and paddy yield, but it is not significant. If farmers apply fertilizers more efficiently and effectively in the paddy field without UDP, the yield difference between with UDP and without UDP would be reduced. A 1% increase in the yield difference between UDP and non-UDP yield can increase significantly (at 1% level) the UDP paddy yield by 0.097%.

Ceteris paribus, if farmers diversify or grow more crops per year, the UDP yield will increase significantly at 1% level. The sampled farmers received higher gross margin from practicing three crops (wet paddy followed by oilseeds and dry paddy or wet paddy followed by gram and dry paddy), especially in UDP paddy fields

(Figure 5B). The calculated coefficient 0.356 implies, with UDP, when the number of crops grown increases by 1%, it will lead to a 0.356% increase in the yield of rice.

Based on the results in Table 5, the calculated coefficient for harvested paddy area was 0.047% having a negative sign, and this was significant at 10% level. The data indicate that when a farmer increases his or her field of rice by 1%, it will lead to 0.047% reduction of UDP paddy yield. Insufficient credit and poor knowledge of fertilizers and their application lead to low and imbalanced fertilizer application and low yields, and this problem increases when a farmer increases his or her field. There is limited opportunity for crop land expansion in the project regions. Increased output of rice must come from the adaption of modern technology to improve yield rather than area expansion.

It was found that there was an increase in yield as the cost of harvesting (machine) and the number of hired labor increased, but it was not significant. With adequate machinery and labor, all farming activities and critical cultural practices, such as sowing, weeding, pesticide application, UDP fertilizer application, and timely harvesting, can be carried out in a timely manner, and this will lead to an increase in yield.

For the dummy independent variable of gender (D_1), when D_1 shifts from 0 (female) to 1 (male), the UDP yield will increase significantly at 5% level by 32%, keeping other explanatory variables constant. If the dummy variable of variety (D_2) changes from 0 (local variety) to 1 (HYV), the UDP yield will increase by 11%, but it is not significant.

Table 5. Results of the log-linear multivariate regression estimation.

Independent Variable	B[a]	ΔY%[b]	Std. B	t	VIF
Constant	8.032*		4.466	1.799	
Lagged paddy price (*X_1*)	0.067	0.066	.417	0.160	1.145
Lagged prilled urea price (*X_2*)	-1.233**	-1.219	.575	-2.148	1.803
Yield difference with UDP & without UDP (*X_3*)	0.098***	0.097	.028	3.480	1.128
Wet paddy harvested land (*X_4*)	-0.048*	0.047	.028	-1.726	1.132
Total crop grown/year (*X_5*)	0.358***	0.356	.080	4.498	1.722
Harvest machine cost (*X_6*)	0.027	0.026	.048	0.586	1.164
Total labor used (*X_7*)	0.015	0.0149	.023	0.630	1.715
Gender (*D_1*) (male=1, female=0)	0.126**	32.53	.044	2.835	1.071
Variety (*D_2*) (HYV=1, local=0)	0.045	11.45	.067	0.679	1.345
N=115					
Adjusted R^2 = 0.566					
F value = 8.839***					

*Note: Dependent Variable: LN UDP yield (t/ha), a: *, ** and *** imply significant at 10%, 5% and 1% level respectively. b: Percentage of paddy yield changes due to a 1% increase of X_i by 100*(1.01^B – 1) and due to value of D_i shifting from 1 to 1 by 100*(e^B -1).*

Conclusions

Agricultural advisory services play a crucial role in promoting agricultural productivity and farm income. Extension can bridge the gap between potential and actual yield by addressing the technology gap and management gap (Anderson and Feder, 2003). Alternative extension models rather than traditional public extension services including local partners or NGOs and agro-dealers are applied in transferring

UDP technology and the best farm management practice (balanced and efficient use of fertilizers, use of good seeds, etc.). The paper presents the outcomes of extension activities and evaluates the gap between farmers' yield with UDP and without UDP in rainfed lowland production system in the target areas of Yangon, Bago, and Ayeyarwady regions.

The UDP yield of rice in the study area was found to change significantly with fluctuations in area harvested for rice, prices of fertilizer, crop intensification (or number of crops grown per year), yield difference or technology gap, and gender of rice farmers. Of the overall variations observed in UDP rice yields, 56.6% were explained by the independent variables in the model. Wet season paddy yield with UDP has an increasing relationship with the number of crops grown per year, technology gap, and gender of rice farmers. This could be attributed to the purchasing power of farmers and the affordability of inputs for non-UDP paddy fields, which would be increased with crop intensification with gram, oilseeds, and dry season paddy. There is also an indication that women's participation in extension education and training should be promoted as the increases in GM due to technology were more than 100%. Also, yield has an inverse relation with harvested area; thus, when harvested area increases, yields would decrease, likely due to the challenge in accessing the input and cost of fertilizer, insufficient cash required for balanced fertilizer application, and low access to credit.

To meet the national and export rice market demand, the yield potential for cultivating high-yielding rice varieties with UDP should be fully exploited as a first option. The evidence from our empirical analysis further suggests that increased and focused government efforts are needed toward promoting the use of efficient soil and fertilizer management technologies, such as UDP, and promoting crop intensification practices among farmers in the lowland rainfed rice cropping system in Myanmar to achieve higher yields and profits from limited expansion of cropping land.

References

Anderson, J.R., and G. Feder. 2003. "Rural Extension Services," World Bank Policy Research Working Paper 2976, World Bank, Washington, D.C.

Central Statistical Organization. 2016. *Myanmar Statistical Year Book 2015-2016*, Ministry of National Planning and Economic Development, Nay Pyi Taw, Myanmar.

Coelli, T.J., D.S.P. Rao, C.J. O'Donnell, and G.E. Battese. 2005. *An Introduction to Efficiency and Productivity Analysis,* 2^{nd} ed., Springer: Berlin, Germany.

Denning, Glenn, Kye Baroang, and Tun Min Sandar. 2013. "Background Paper No. 2: Rice Productivity Improvement in Myanmar," Michigan State University and MDRI, Yangon, Myanmar.

Department of Planning. 2015. *Myanmar Agriculture at a Glance 2015*, Ministry of Agriculture and Irrigation, Nay Pyi Taw, Myanmar.

Nin-Pratt, A., B. Yu, and S. Fan. 2008. "The Total Factor Productivity in China and India: New Measures and Approaches," *China Agric. Econ. Review*.

Raitzer, David A., Larry C.Y.Wong, and Jindra Nuella G. Samson. 2015. "Myanmar's Agriculture Sector: Unlocking the Potential for Inclusive Growth," ADB Economic Working Paper Series, No. 47, Asian Development Bank, Manila.

Settlement & Land Record Department. 2010. *Myanmar - Agricultural Census 2010*, Ministry of Agriculture and Irrigation of Myanmar.

U.S. Department of Agriculture, Foreign Agricultural Service. 2016. *GAIN Report Number BM 6002*.

USAID. 2013. *Feed the Future Agricultural Indicators Guide*.

Wooldridge, J.M. 2013. *Introductory Econometrics: A Modern Approach*, 5th International Edition, South-western Cengage Learning, Mason (Ohio, USA).

World Bank. 2016. *Myanmar Economic Monitor*.

Yu, Bingxin, and Shenggen Fan. 2009. "Rice Production Response in Cambodia," Contributed paper prepared for presentation at the International Association of Agricultural Economist Conference, Beijing, China.