State of on-farm maize mechanization in the Philippines

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Abstract: This study addressed the lack of updated information on mechanization as basis of formulating relevant and sustainable programs that could immediately respond to the mechanization needs of the maize farmers. Employing one shot cross-section survey design, interviews of 1,235 maize farmers were carried out in 13 major maize-producing provinces of the Philippines covering crop year, 2012-2013. The status of mechanization was expressed in terms of the percentage of farmers using mechanical power and the total maize area or total harvest using mechanical power for specific major operations, percentage of farmers owning specific machines used in maize, and the total utilization of power from planting to shelling maize. Given the agro-ecological conditions where maize is predominantly grown in the Philippines, the percentage of maize farmers adopting engine-powered machines for land preparation and shelling were 44 and 66 percent of the total number of maize farmers, respectively. About one-fourth of them (26%) owned draft animals and 14 percent had pumps for irrigation. Few of them owned four-wheel tractors (6%) and maize sheller (5%) which was also used for custom servicing. In terms of the total production area prepared or volume of maize produced using engine-powered machines, shelling and land preparation were already considered moderately to highly mechanized with 70 percent of the total volume of harvest passing through mechanical shellers and 49 percent of the maize area prepared by engine-powered machines. Other production activities such as planting, crop care and drying were still done predominantly using manual power with the use of draft animals and/or farm tools. Utilizing combined sources of farm power, namely: human, draft animals and engine-powered machines, the average total power utilized from land preparation to threshing in sample provinces were 172.12 hp-hr ha^{-1}. Sixty-seven percent of this total power has been utilized for land preparation while 20 percent has been utilized in threshing. The remaining power was utilized for harvesting (6%), and the combined power for planting and crop management (7%). Constraints to mechanization were identified and corresponding recommendations were forwarded.

Keywords: maize mechanization, status of mechanization, power utilization, shellers, agricultural machinery, draft animals

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1 Introduction

Modern machineries is usually applied to reduce cost of production, ease drudgery in labor-intensive farm operations, ensure timely completion of farm activities, redress scarce labor during peak periods, allow more precise application of inputs, precision planting, reduce losses and maintain product quality. The benefits derived by using improved inputs cannot be fully realized without increased application of farm power. In situations where land for expansion and other factors of production are not limited, increase in farm power can lead to direct increase in production by increasing the land area cultivated or by increasing the cropping intensity (Rijk, 1989; Clarke, 2000).

While past efforts on agricultural mechanization in less developed and developing countries had received much criticisms because of some negative consequences deemed anti-developmental such as labor displacement, indivisibility problem of capital investments and sustainability of government subsidies arguments, mechanization contributed significantly in the industrialization of the more developed economies (Kishida, 2006). Agricultural mechanization is an essential component of agricultural development, which is, regarded a necessary condition for industrialization.

The state of Philippine agricultural mechanization had

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been characterized by very low mechanization levels and sluggish growth. The gains in agricultural mechanization in the Philippines from 1968 to 1990, as reported by the Regional Network on Agricultural Machinery (RNAM), was a trivial 0.322 hp ha^{-1} (PCARRD, 2002 and 2009). In 1990, the country ranked 9th out of 12 selected Asian countries in terms of agricultural mechanization level with 0.52 hp ha^{-1} while countries such as Japan and Korea already posted 7.00 and 4.11 hp ha^{-1}, respectively. The level of agricultural mechanization was updated by Rodulfo et al. (1998) to 1.68 hp ha^{-1} but since it only covered rice and maize farms in selected areas, the general level of agricultural mechanization at 0.52 hp ha^{-1} is still widely used. In 2016, Dela Cruz and Bobier determined the available farm power to be 2.31 hp ha^{-1} for rice and corn.

As embodied in Philippine laws, the Agriculture and Fisheries Modernization Act (AFMA) of 1997 and Agricultural and Fisheries Mechanization (AFMech) Law of 2012, the country needs to accelerate agricultural mechanization as a means to increase farm income and modernize agriculture. To achieve these goals, one of the strategies adopted by the government is to unify research and development (R&D) efforts and strengthen technology transfer to farmers. Toward these objectives, the conduct of updated and comprehensive review of the status of mechanization and an assessment of machines suitable to farmers and their farm conditions are deemed necessary. A deeper and broader understanding of the multi-faceted aspects of farming is required as mechanization impinges on the specific characteristics of the farmers as well as the agro-ecological, socioeconomic and technical conditions of the production area. The study assessed the status of on-farm maize mechanization in the Philippines and identified the constraints in the adoption and/or utilization of engine-powered machines. Results of this study will provide bases of formulating commodity-based recommendations for appropriate mechanization strategies and baseline information for future evaluation of existing mechanization programs.

2 Methodology

2.1 Research design and sampling of respondents

The project employed one shot cross-sectional research design. It included 13 regions in the country and focused on the on-farm activities of maize farmers in 13 maize-producing provinces. The survey covered farmers' operations for the previous two cropping seasons; second cropping of 2011 and first cropping of 2012.

The total respondents of 1,235 maize farmers were determined by applying the Slovin's formula, using a three percent margin of error. The sample provinces were selected using multi-stage sampling. The study limited the sampling frame on the key maize areas identified by the Department of Agriculture on the premise that government efforts on mechanization are concentrated on these areas. Majority of the selected provinces representing each of the 13 regions, comprised at least 40 percent of the total regional physical area planting maize. After the selection of sample provinces, representative municipalities from each provincial district were chosen based on the provincial average crop yield. The sample size for each municipality was determined using proportional allocation and the sample respondents were selected at random. The provinces covered were: Pangasinan, Isabela, Tarlac, Ifugao, Occidental Mindoro, Camarines Sur, Iloilo, Cebu, Leyte, Bukidnon, Davao del Sur, South Cotabato, and Agusan del Sur.

2.2 Data collection

Data were primarily collected through personal interview using structured questionnaires. Pre-testing of survey instruments was done to determine the effectiveness and ascertain the reliability and validity of the questionnaires. Key informant interview, actual field observation and secondary data collection were also done to supplement gathered information and gain deeper knowledge on the details of issues surrounding agricultural mechanization. Key informants included staff from the Regional Field Units of the Department of Agriculture specifically the Regional Agricultural Engineering Group (RAEG) and Maize Coordinators, Provincial Agriculture Offices, Municipal Agriculture Offices and other entities involved in agricultural mechanization.

2.3 Analytical procedure

Descriptive statistics such as percentages, frequency distribution, cross tabulations and measures of central tendency were used in analyzing the information gathered

applying the Statistical Package for Social Sciences (SPSS). Computations of the different indicators of level of mechanization were done using the following equations which were adopted from the methods utilized by the Agricultural Machinery Development Program (AMDP), University of the Philippines, Los Baños:

a. Percent area mechanized (%) = [area mechanized (ha)/ total area (ha)] × 100

This refers to the portion of the respondents' total farm area that was accomplished or completed by using mechanical power. This is also termed as mechanization degree or extent of mechanization in several studies.

b. Percent farmer-user (%) = [(number of user of a specific machine)/total number of respondents)] × 100

This refers to whether the farmer-respondent uses machines (e.g., tractor, pump set, thresher, etc.).

c. Level of power utilized = nominal power of engine used (hp) × efficiency factor × number of units × number of hours used per ha

This refers to the total hp-hr ha^{-1} utilized from three sources of power: human, man-animal and man-machine for all on-farm operations. The total hp-hr ha^{-1} per operation were derived based on the following assumptions:

The specific nominal horsepower values utilized by the respondents were adjusted for standard efficiency values. These efficiency values were established by Agricultural Machinery Testing and Evaluation Center (AMTEC) and were considered as standard values for the country.

Eff_e = Prime mover efficiency at 0.80

Eff_t = Transmission efficiency at 0.80

Eff_b = Belt efficiency at 0.95

Eff_{PTO} = Power take off (PTO) efficiency at 0.90

Eff_{db} = Drawbar efficiency at 0.75

Eff_e, Eff_t and Eff_b were used for machineries such as hand tractor (all types), combine harvester, reaper, pump set, thresher and sheller while Eff_e, Eff_t, Eff_{PTO} or Eff_{db} were applied for four-wheel tractors, depending on the attached implement.

In the case of manual horsepower or power derived from manual labor, standard horsepower values were 0.10 hp for males and 0.075 hp for females. In the case of draft animals, standard horsepower value of 1.0 hp was used Stevenson and Wassersug, 1993).

d. Ownership of draft animal = (number of farmers with draft animal/total number of farmers responding) × 100

This refers to whether the farmer-respondent owns draft animals (carabao, cattle or horse).

e. Ownership of engine-powered machine = (Number of farmers with specific machine/total number of farmers responding) × 100

This refers to whether the farmer-respondent owns a specific machine (e.g., hand tractor, pump set, thresher, etc.).

3 Results and discussion

3.1 Characteristics of maize farmer-respondents

The mean age of maize farmers is 49.12 years old (Table 1), majority of whom have not attended seminar or training (60%) about maize for the last five years, and not a member to any farmers' organizations (58%). Most of them are owners of the maize area that they cultivate (67%), have access to credit either from formal or informal sources (67%), and plant maize twice a year (63%). In terms of available farm labor, majority of them have 1-2 members of the household that could help in farming operations (63%). When asked about the adequacy of labor during peak periods of planting and harvesting, more than three-fourth (78%) mentioned that labor is still adequate.

3.2 Maize farmers mechanizing farm operations

Across all provinces, 44 percent of the maize farmers have been mechanizing their land preparation (Table 2). More than half (56%) of the maize farmers are not using engine-powered machines in land preparation. The study of Gerpacio et al. (2004) could shed light on the results taken. Of the 24 villages from eight major maize-growing regions covered by their study, 91 percent of the maize areas were situated in upland plains (33%) and/or rolling-to-hilly areas (58%). Only 17 percent were situated in the rainfed lowlands. The agro-ecological conditions where maize are generally produced, like upland plains and rolling-to-hilly areas do not permit the effective utilization especially of high-powered machines.

Table 1 Characteristics of maize farmer-respondents, Philippines, 2012-2013

Characteristic	Value
1. Age, yr	49.12
2. Attendance to seminar or training related to maize, % reporting	
Yes	40
No	60
3. Membership to farmers' organization, % reporting	
Yes	42
No	58
4. Access to credit, % reporting	
Yes	67
No	33
5. Land tenure, % reporting	
Owner	67
Leaseholder	9
Share-tenant	24
6. Maize area planted/farmer, % reporting	
≤1.0 ha	50
1.1-2.0 ha	26
2.1-5.0 ha	17
>5.0 ha	7
7. No. of maize cropping/year, % reporting	
Once	29
Twice	63
Thrice	8
8. Available family labor, % reporting	
None	19
1-2	63
≥3	18
9. Local labor available for hire during peak of planting or harvesting, % reporting	
Adequate	78
Scarce	22

Table 2 Percent of maize farmers adopting engine-powered machines for different farm operations, selected maize-producing provinces, Philippines, 2012-2013

Province	Operation				
	Land Preparation[1]	Crop Est. /Care[2]	Harvesting	Shelling[3]	Drying[3]
Pangasinan	93	0	0	78	0
Isabela	86	0	0	97	1
Tarlac	89	0	1	92	0
Mindoro Oc.	81	0	0	99	0
Cam. Sur	10	0	0	88	10
Ifugao	40	0	1	83	0
Iloilo	7	0	0	80	5
Cebu	22	0	0	1	0
Leyte	4	0	0	4	2
Bukidnon	61	0	0	93	0
Davao Sur	0	0	0	54	3
Cotabato So.	43	0	0	58	0
Agusan Sur	42	0	0	37	0
All	44	0	<1	66	2

Note:[1] Plowing and harrowing; [2] Seeding, fertilizer application, weeding and spraying; [3] Percent volume.

More number of maize farmers (>80 percent) from the provinces of Pangasinan, Tarlac, Isabela, and Mindoro Occidental have adopted engine-powered machines in land preparation while the percentage of maize farmers mechanizing land preparation was lowest in Davao del Sur, Leyte and Iloilo. It is implied that draft animals are still largely used or zero-tillage is being practiced in these areas. Table 4 shows that farmers owning draft animals are highest in Leyte (62%) and fairly high in Cebu and Davao del Sur.

The provinces with 80 percent or more of the farmers adopting engine-powered machines for shelling operation are Isabela, Tarlac, Mindoro Occidental, Bukidnon, Ifugao, Camarines Sur and Iloilo. Minimal proportion of the maize farmers in Cebu and Leyte used machines for shelling primarily because their produce are for home consumption where shelling could be done in small quantities as the need arises. This finding is also in conformity with the previous findings of Gerpacio et al. (2004) more than a decade ago.

3.3 Types of machines utilized by maize farmers

The popularity for four-wheel tractors for land preparation is clearly shown in Table 3 as 72 percent of the maize farms are plowed and 57 percent are harrowed using four-wheel tractors. This popularity is due to the dry land culture of maize and the concern for timeliness of operation which is very important in the rainfed areas where maize is generally planted. More than one-fourth (28%) and 43 percent of those mechanizing plowing and harrowing used two-wheel tractors, respectively. There were areas where plowing is done by four-wheel tractors and the succeeding operations of harrowing and furrowing are done using draft animals.

For mechanized threshing, farmers in all areas mainly used maize shellers powered by gasoline or diesel engines with power rating ranging from 5-16 hp.

3.4 Ownership of draft animals and engine-powered machines

Out of the 13 maize-producing provinces, only six percent of the maize farmers own four-wheel tractors (Table 4) which suggest that only few farmers had the capability to invest in capital-intensive facilities like large tractors or that present maize farm situations do not warrant the use of large-capacity machines. This resulted

in low mechanization level of some maize farms as farmers were contented with using draft animals and some even resort to zero tillage practice. Maize farmers who mechanized land preparation mostly depend on custom service providers.

Table 3 Type of machines used by farmers in mechanizing maize farm operations, Philippines, percent reporting, 2012-2013

Province	Plowing		Harrowing		Shelling	
	Two-wheel tractor	Four-wheel tractor	Two-wheel tractor	Four-wheel tractor	Engine rating (hp)	Percent reporting
Pangasinan	5	95	78	22	12.5	61
Isabela	8	92	0	100	12.5	49
Tarlac	35	65	92	8	16.0	55
Mindoro Oc.	9	91	92	8	16.0	98
Cam. Sur	10	90	0	100	5.0	42
Ifugao	10	90	0	100	16.0	68
Iloilo	100	0	100	0	8.0	54
Cebu	50	50	50	50	16.0	100
Leyte	100	0	100	0	8.0	67
Bukidnon	10	90	0	100	10.0	48
Davao Sur	-	-	-	-	12.0	44
Cotabato S.	-	100	0	100	12.0	40
Agusan Sur	3	97	0	100	10.0	19
All	28	72	43	57		

Table 4 Ownership of draft animals and farm machineries, maize-producing provinces, Philippines, 2012-2013

Province	Ownership of draft animals and farm machines			
	Draft animal	Four-wheel tractor	Irrigation pump	Maize sheller
Pangasinan	14	9	35	4
Isabela	41	12	12	8
Tarlac	17	20	67	2
Mindoro Oc.	24	7	60	11
Camarines Sur	18	10	-	12
Ifugao	23	10	1	10
Iloilo	27	6	-	12
Cebu	38	2	1	1
Leyte	62	1	-	1
Bukidnon	9	2	-	4
Davao Sur	29	0	-	0
Cotabato So.	16	2	-	2
Agusan Sur	24	0	1	0
All	26	6	14	5

On the average, about one-fourth (26%) of the maize farmers still own draft animals. These draft animals are used to plow, harrow, furrow, cultivate and haul. Relatively higher proportion of farmers maintain draft animals in Leyte, Isabela, Cebu, Iloilo, and Davao del Sur while lower percentage of farmers have draft animals in Bukidnon, Pangasinan, South Cotabato, Tarlac and Camarines Sur. Some farmers also own irrigation pumps (14%). Nine out of the 13 sample provinces purely rely on rain for corn irrigation.

Despite the highly mechanized shelling operation of maize farms in most areas, few maize farmers own shelling facilities. This shows that most maize farmers depend on custom service providers for their shelling needs or they depend on manual labor to shell.

The dominant agro-ecologies where maize is planted would explain the trend of technology adoption among maize farmers. Maize is generally grown in rainfed lowlands, upland plains and rolling-to-hilly agro-ecologies (Gerpacio et al., 2004). Large engine-powered machines for land preparation would not be practical on rolling-to-hilly areas where significant areas are planted to maize. Gerpacio et al. (2004) also reported that these agro-ecologies are almost totally dependent on rainfall or from water pumped from ground or surface water sources or from government supplied shallow tube wells. This would explain the relatively greater number of maize farmers that are maintaining draft animals and irrigation pumps.

3.5 Percent of maize area or volume of maize harvest mechanized

For maize farms, land preparation that includes plowing and harrowing were considered fairly mechanized as the 13 provinces reported mechanization level of 49 percent based on total area planted to maize (Table 5). The provinces of Pangasinan, Isabela, Tarlac and Occidental Mindoro were already highly mechanized, with extent of mechanization higher than 75 percent. Maize areas from these provinces could be classified as rainfed lowland where machines for land preparation could be used effectively.

The findings of Gerpacio et al. (2004) could shed light on the relatively lower degree of mechanization in land preparation in maize farms. Their research team reported that maize in the Philippines is largely grown in the rainfed lowland, upland plain and rolling-to-hilly agro-ecologies. In the rainfed lowlands, exemplified by four villages in Isabela and Mindoro Occidental in the study they conducted, the extent of farm mechanization during land preparation was 70-95 percent. This finding

conforms with the recent findings on the degree of mechanizing land preparation. They also reported that only plowing was mechanized in the upland plains with harrowing and furrowing being done using animal draft power. Land preparations in the rolling-to-hilly areas were done manually or with the use of draft animals. The use of large engine-powered machines for land preparation especially in rolling-to-hilly areas is not feasible not only because of the rugged terrain but also due to the absence of access roads to the inner production areas.

Table 5 Percent of maize area or volume of harvest mechanized, selected maize-producing provinces, Philippines, 2012-2013

Province	Operation				
	Land preparation[1]	Crop Est. /Care[2]	Harvesting	Shelling[3]	Drying[3]
Pangasinan	97	0	0	91	0
Isabela	96	0	0	97	1
Tarlac	92	0	1	93	0
Mindoro Oc.	76	0	0	100	0
Cam. Sur	19	0	0	88	9
Ifugao	52	0	1	85	0
Iloilo	6	0	0	91	5
Cebu	22	0	0	6	0
Leyte	8	0	0	6	0
Bukidnon	63	0	0	75	0
Davao Sur	0	0	0	67	0
South Cotabato	48	0	0	73	6
Agusan Sur	60	0	0	30	0
All	49	0	<1	70	2

Note: [1] Plowing and harrowing; [2] Seeding, fertilizer application, weeding and spraying; [3] Percent volume.

For operations such as planting, weeding, spraying and harvesting, manual power is still applied by using implements such as maize seeder or jabber and knapsack sprayer.

Shelling registered the highest mechanization degree (70% of the total volume of harvest) in all the provinces. The provinces of Occidental Mindoro, Isabela, Tarlac, Pangasinan and Iloilo recorded mechanization degree higher than 90 percent. Other provinces with highly mechanized shelling operation were Camarines Sur, Ifugao, Bukidnon, South Cotabato and Davao del Sur. Meanwhile, the provinces of Cebu, Leyte and Agusan del Sur reported lowest mechanization degree from among the 13 provinces. Maize farmers in these areas mainly use manual shelling. It is important to note that most farm holdings in these areas were below one hectare and farmers were growing white maize for home consumption.

Mechanical drying of maize has been practiced in three provinces with Camarines Sur leading in the volume of maize dried through mechanical dryers. The grain drying centers established in the maize-producing villages of Camarines Sur could have helped in the dissemination and/or increased utilization mechanical drying technology. Harvesting of maize in this province falls during the wet season, requiring the use of mechanical dryers to effectively dry maize.

3.6 Level of farm power utilization

Across all locations and major on-farm operations, the average power utilized from land preparation to shelling is 172.12 hp-hr ha^{-1} (Table 6). Mindoro Occ. and Tarlac provinces registered highest power utilization at 196 hp-hr ha^{-1} while maize farmers in Cebu reported lowest power usage at 145 hp-hr ha^{-1}. High power utilization indicates use of mechanical power and/or multiple applications of the different power sources. Some farmers, especially the owners of machines tend to cultivate their farms more often for more thorough land preparation.

Land preparation (plowing, harrowing and furrowing), registering 114.98 hp-hr ha^{-1}, is the most power-intensive operations constituting 66.8 percent of the total power utilized from land preparation to shelling. A big portion of the power utilized for land preparation is utilized for plowing (43.6%) while the remaining power is used for harrowing (32.1%) and furrowing (24.3%). The average power utilized in plowing ranges from 40.86 to 63.08 hp-hr ha^{-1}, with Tarlac, Pangasinan and Isabela farmers reporting highest power utilizations.

Next to land preparation, shelling is the second most power-intensive operation utilizing an average of 35.15 hp-hr ha^{-1}. The power utilized for shelling is almost similar in all areas. Small variations noted were mainly due to rating of engines used and the number of laborers involved in threshing operation. In Cebu, white maize farmers reported an average of 18.76 hp-hr ha^{-1} as they only employ manual method of shelling their harvest.

Based on the existing practices and available

technologies currently in use in the maize production areas, planting and harvesting are the two most labor-intensive farm operations where manual labor is still employed. Weighted power utilization for planting is 7.34 hp-hr ha^{-1} (range of 5.03 to 9.94 hp-hr ha^{-1}) while harvesting has 9.77 hp-hr ha^{-1}.

Table 6 Level of farm power utilized, production operation, maize production areas, Philippines, 2012-2013

Province	Land Prep.*	Planting	Fert. App	Spray-ing	Weed-ing	Harves-ting	Shell-ing	Total
	(weighted hp-hr ha^{-1} per season)							
Pangasinan	134.77	7.87	4.05	0.24	0.44	10.49	34.64	192.50
Isabela	120.88	7.82	3.02	0.84	1.27	8.58	36.23	178.64
Tarlac	136.05	7.61	2.99	0.56	0.84	10.66	37.66	196.37
Occ. Mindoro	133.70	5.48	3.69	0.71	1.26	10.86	40.80	196.50
Cam. Sur	107.52	6.54	4.11	0.81	1.83	8.95	35.36	165.12
Ifugao	100.92	7.58	3.54	1.16	1.14	8.70	37.35	160.39
Iloilo	99.62	7.94	3.41	1.33	0.90	8.06	36.94	158.20
Cebu	109.63	5.03	3.06	0.47	0.44	7.84	18.76	145.23
Leyte	120.51	8.02	2.03	0.34	0.56	11.24	39.26	181.96
Bukidnon	114.74	8.10	2.14	0.35	1.45	12.47	35.96	175.21
Davao Sur	99.40	6.74	2.73	0.54	2.67	8.49	30.54	151.11
South Cot.	110.58	6.81	2.41	0.37	0.97	9.86	34.19	165.19
Agusan Sur	106.39	9.94	3.09	0.69	0.96	10.80	39.26	171.13
All	114.98	7.34	3.10	0.65	1.13	9.77	35.15	172.12

Note: * Land preparation includes plowing, harrowing and furrowing.

Detailing the power utilized in all sample provinces, plowing (29%), harrowing (22%), shelling (20%) and furrowing (16%) are the major operations where 87 percent of the total power has been utilized (Figure 1). The trend in mechanizing production operations in maize followed the trend observed in rice where the most power intensive operations were mechanized first (Bautista, 2003).

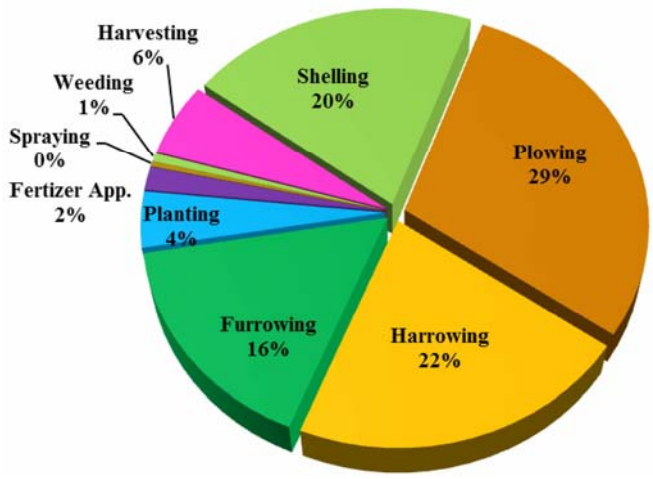

Figure 1 Percent of total power utilized in different on-farm production operations of maize, Philippines, 2012-2013

3.6 Constraints in agricultural machinery adoption

High proportion (50%) of maize farmers cultivates one or less than one hectare of maize area. This situation limits adoption of most mechanization technologies, especially the large machineries. As shown in several studies, area planted is an important variable influencing use and ownership of agricultural machineries.

The study found that most farmers continuously utilize old and inefficient machines due to lack of capital to acquire new facilities. Usable life of machine or engine is often extended through constant repair or reconditioning. Inventory of facilities validated that commonly used machineries are already beyond their economic or useful life. This often results in high energy, repair and maintenance costs, delayed activities due to frequent breakdowns and inefficient operations, high postharvest losses and detrimental effect to the environment due to excessive emissions of harmful gases.

Result of the study showed that there are areas that encounter problems on shortage of labor but some areas also reported sufficiency of labor even during peak periods. Introduction of technologies that will reduce the utilization of labor such as combine harvesters and mechanical planters in these areas would likely encounter social repercussion.

Some farmers in Isabela, Ifugao and other maize-producing areas are practicing zero tillage to cut down land preparation costs and/or make use of residual soil moisture. Planting maize without thorough land preparation lowers productivity.

Poor and/or absence of irrigation facilities and access roads impede mechanization especially the less favorable or far-flung areas. Certain areas are difficult to mechanize due to agro-ecological or topographical constraints. For example, large machineries such as tractors and combine harvesters require wide and semi-permanent access roads.

Many farmers, especially in remote areas have not seen or even heard about new technologies that could enhance their farm operations. Most machinery distributors in some areas only handle popular machineries usually procured by farmers.

4 Conclusion and recommendations

There is considerable room for improving mechanization of maize in the Philippines based on the present status of on-farm mechanization. Considering the farmers' present practices and preferences, general conditions of the production areas and the limited number of units, more number of scale-appropriate engine-powered land preparation equipment are apparently needed.

As 50 percent of maize farmers have areas of one or less than a hectare, smaller machines that would facilitate operations and reduce drudgery are needed. For example, medium-sized four-wheel tractors (<50-hp rating) or two-wheel tractors should be prioritized in the rainfed lowlands or upland plains as this would be more appropriate not only to larger number of farmers but to the existing agro-ecological conditions of production areas.

Moreover, the prevailing agro-ecological conditions where maize are planted extremely necessitates the provision of equipment for irrigation water which include pumps and/or shallow tube wells, or other appropriate water-delivery equipment like the construction of ram pump in areas situated near streams of water.

The provision of mechanization technologies should not be limited on providing new or emerging technologies but also include replacement of old and inefficient machines that are continuously being used by farmers. The needs for replacing old inefficient maize shellers have been observed in most of the production areas.

The practice of maize cribbing using plastic-covered tunnel type rain shelters could be pilot tested in areas where harvesting falls during wet season. This practice can prevent or reduce mechanical damage due to wet shelling.

While majority of the production areas considered that labor during peak of planting and harvesting operations is still adequate, selective placement of mechanical planters and combine harvesters for demonstration and creation of awareness can be started especially in the production areas that are located near urban centers and where the scarcity of farm labor has already been felt. Scale-appropriate mechanical planters and harvesters can be provided by the government as pump-priming strategy in areas with problem on availability of labor, where there is control on irrigation water and where prevailing weather situation during harvesting season would permit combine harvesting. For example, mechanical planters can be adopted in areas where there is sufficient control of irrigation water and combine harvesters are generally used where maize are sufficiently dry during harvesting seasons.

The strategy of selective mechanization can partly address the issue of reduced labor utilization. Moreover, there is a need to provide alternative livelihood options for affected farmers. This was already done in some areas affected by growing popularity of combine harvesters in rice.

To address the constraint of small farm holdings, small machines should also be developed or promoted for individual or small group use. The use of smaller machines can reduce drudgery and may be more sustainable in areas that are less productive because of limited water.

Infrastructures such as irrigation and farm access roads are preconditions for mechanization, hence, the need to expedite implementation of these programs.

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