J ISSAAS Vol. 28, No. 2: 92–99 (2022)

FACTORS DRIVING TRACTORIZATION OF MAIZE FARMS IN THE PHILIPPINES

Hernaiz G. Malanon* and Gigi B. Calica
Socioeconomics and Policy Research Division
Philippine Center for Postharvest and Mechanization (PHilMech), Philippines
*Corresponding author: hgmalanon@up.edu.ph

(Received: April 26, 2022; Accepted: November 1, 2022)

ABSTRACT

Maize farming in the Philippines is generally characterized by relatively slow adoption of mechanization technologies. With the more aggressive effort to promote the extensive use of mechanical power as a means of improving land and labor productivity, information is needed as guide in program implementation. This paper analyzed the factors that influence the decision of maize farmers to adopt machines in land preparation. Using the data gathered by PHilMech and UPLB-AMDP in 2013 from 13 major maize-producing provinces in the country, the determinants of tractor adoption and ownership by 1,018 maize farmers were established by applying logistic regression. Empirical estimates revealed that the farmer's level of education, age, availability of credit, land area and topography influence their decision to use or acquire tractors. Higher education and older age increases the likelihood of tractor adoption while farmers availed credit are more likely to adopt tractors. Moreover, area and land topography are significant variables that affect tractor use and ownership. Farmers with larger landholdings and situated in the lowlands have higher propensity to mechanize their farms. With these findings, it is recommended that mechanization intervention should be more focused in the low-lying areas, increase access of maize farmers to low-cost credit and review policies on land reform, farm consolidation or clustering.

Key words: Adoption, logistic regression, maize, mechanization, tractorization

INTRODUCTION

Maize plays a significant role is sustaining the livelihood and nutritional requirements of significant number of Philippine population. Yellow maize is an essential ingredient in the formulation of animal feeds and raw materials for the manufacture of various industrial products. On the other hand, white maize is a main staple or rice substitute in some parts of Visayas and Mindanao. While maize is widely grown in almost all parts of the country, large number of maize farmers still employs manual labor and animal power (Dela Cruz and Malanon 2017). For decades, mechanization has been limited to land preparation and shelling operations. Planting and harvesting operations have been predominantly performed using manual labor while furrowing and in-field hauling activities are done with the aid of draft animals such as carabao, cattle and horse.

The decision of farmers to mechanize their farm is influenced by various factors but primarily economic in nature, driven by changes in costs of labor relative to capital. The increasing wage rate or rising cost of labor indicates diminishing labor supply and this situation rationalizes the use of labor-replacing technology. The declining local labor supply could be due to ageing population, structural change that caused transfer of farm workers to other sectors of the economy and the waning interest of youth in farming. Moreover, the declining population of draft animals also contributes in the rising costs since there are farm operations that require both human and animal power. The cultivation of idle lots previously devoted for grazing land for animals make it more difficult and costly to maintain farm animals for draft purposes. Another factor is the constrained calendar of farm activities that creates bottlenecks as affected by synchronous planting and scarce labor and/or draft animals. While studies did not indicate the direct effect of tractors on yield, it allows fast/timely completion of farm activities, increase arable land, redress scarce labor amidst the dwindling labor supply and decreasing draft animal population.

In the Philippines, early study showed that large irrigated farms were mechanized first, especially the laborious farm operations such as land preparation (AMIC 1988). The study added that the decision to mechanize farm operation is influenced by farmer's educational attainment, farm size and distance of the farm to the nearest market centers. The study further showed that accessibility of the farm as indicated by the distance of the farm to the market was essential in mechanization, especially for large machines. Amongo et al. (1996) also identified socio-economic factors that affect mechanization of rice farms. These include educational attainment, income, tenurial status, type of irrigation, availability of family labor and access to credit. Education and availability of family labor had negative effect while income had positive effect.

Compared to rice farms where mechanization of tillage operation is already predominantly practiced with the proliferation of more affordable hand tractors, maize mechanization has been sluggish although tractors were already introduced decades ago. The indivisibility of large capital investment hinders small farmers from acquiring large tractors suitable for maize farms. Moreover, government programs on mechanization focuses on rice as rice farmers are more organized to serve as conduits of government facility assistance.

While studies on the determinants of tractor adoption were already well studied for other crops such as rice, there were limited investigations done for maize, both in terms of focus and geographical scope. This paper aims to provide empirical information on the determinants of tractor adoption by maize farmers. The research findings could provide important insights on how to devise strategies in accelerating the adoption of mechanization technologies as a means of increasing land and labor productivity and ultimately enhance the competitiveness of the maize subsector.

METHODOLOGY

Locale of the study. The study covered 13 major maize producing provinces in the Philippines, representing about 40% of the total national area planted to maize. One province per region was chosen based on the yield of the province that approximates the regional crop average. The areas of the study include the provinces of Pangasinan, Isabela, Tarlac, Ifugao, Occidental Mindoro, Camarines Sur, Iloilo, Leyte, Bukidnon, Davao del Sur, South Cotabato and Agusan del Sur. After the selection of sample provinces, representative municipalities from each provincial district were also chosen based on the provincial average crop yield.

Sampling size and sampling procedure. The total respondent was determined by applying the Yamane equation:

$$n = \frac{N}{1 + N * e^2}$$

Where:

n = Sample size
N = Population size
e = Acceptable sampling error ranging from 1-10%

The respondents composed of 1,018 maize farmers drawn from 1,235 total respondents surveyed using multi-stage sampling. For each province, 95 maize farmers were randomly selected and the sample size for each municipality was determined using proportional allocation.

Data collection and research instrument. Data were taken from the survey conducted by PHilMech and UPLB-AMDP in 2013. Key informant interview, actual field observation and secondary data collection were also done to validate gathered information and gain deeper knowledge on the details of issues surrounding corn mechanization.

Analytical Framework

The Use/Ownership of Tractor General Model. To determine which variables were important in affecting the decision-making process of maize farmers towards the adoption of tractors in land preparation, a binary choice model was applied. These models are generally used when economic decision makers choose between two mutually exclusive outcomes. The farmer's choice of maize land preparation technique is represented by the dummy variable:

$$z = \frac{1 \ \ if maize\ farmer\ uses\ tractor}{0\ if\ maize\ farmer\ still\ use\ draft\ animal\ or\ practices\ zero\ tillage}$$

The probability that a maize farmer adopts tractor can be expressed as:

$$[z = 1] = P_i$$

Drawing from the equation, the probability that the farmer still use utilize draft animal in land preparation or not practice tillage, hence, does not adopt tractor can be illustrated as:

$$[z = 0] = 1 - P_i$$

The specific binary choice model that used was the logistic regression analysis or the logit model. In this model, the probability P_i that the farmer adopts tractor is specified as:

$$P_i = P(z) = f\left(\beta_0 + \sum_{i=1}^{N} \beta_i X_i\right) = \frac{1}{1 + e^{-z}}$$

$$P_i = \frac{1}{1 + e^{-\left(\beta_0 + \sum_{i=1}^{N} \beta_i X_i\right)}}$$

Where:

P_i= probability of adopting tractor in land preparation
Z = measure of the total contribution of all the independent variables used in the model
β_0= constant
N= number of independent variables
β_i= coefficients of the independent variables
X_i= independent variables (factors that influence tractor adoption)
e= base of the natural logarithm

This equation can also be expressed as:

$$P_i = \frac{e^{(Z_i)}}{1 + e^{(Z_i)}}$$

$$Z_i = \beta_0 + \sum_{i=1}^{N} \beta_i X_i$$

Both sides are then multiplied by $1 + e^{(Zi)}$,

$$P_i + e^{(Zi)} P_i = e^{(Zi))},$$

The factor $e^{(Zi)}P_i$ is then transposed and distribution is performed, $P_i = e^{(Zi)} + e^{(Zi)}P_i = (1 - P_i)\, e^{(Zi)}$

This equates to: $\frac{Pi}{1-Pi} = e^{(Zi)}$

The natural logarithm of both sides is then taken, $\ln \frac{Pi}{1-Pi} = Z_i$

The dependent variable in the formula is represented by the logarithm of the probability that a particular decision was made. Because P_i represents the probability of adopting tractor and $1 - P_i$ represents the probability of using draft animal in land preparation, the ratio $\frac{Pi}{1-Pi}$, also known as the odds ratio will determine whether the farmer would adopt tractor. If P_i is equal to zero, then $\frac{Pi}{1-Pi}$ would also be equal to zero.

The regression probability is:

$$\ln \frac{P_i}{1 - P_i} = z = b_0 + b_1X_1 + b_2X_2 + \cdots + b_nX_n$$

Therefore, variable Z was defined in this study as:

$$Z = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8 + \beta_9X_9 + \beta_{10}X_{10} + \beta_{11}X_{11} + \varepsilon$$

Where:

Z= adoption of tractor in land preparation (1 = using tractor, 0 = not using tractor)
X_1 = age of farmer-respondent, in years
X_2 = farmer's educational attainment: 1 = college level; 0 = below college level
X_3 = membership in farm organizations: 1 = yes; 0 = otherwise

X_4 = attendance to seminars/trainings related to mechanization: 1 = yes; 0 = otherwise
X_5 = credit access: 1 = yes; 0 = otherwise
X_6 = tenurial status: 1 = land owner; 0 = tenant
X_7 = topography: 1 = lowland; 0 = hilly/upland
X_8 = landholding, in hectare
X_9 = cost of prevailing practice to be replaced by machines
X_{10} = labor situation during peak period of planting or harvest: 1 = sufficient; 0 = scarce
X_{11} = ownership of draft animals: 1 = yes; 0 = no
ε= disturbance term

The specific variables included in the adoption or use of agricultural machineries, data measurement and the hypothesized signs are presented and described below. Numerous studies have established significant association between human capital and technological adoption. Higher human capital accumulation as indicated by age of farmer (Bootinger et al. 2010), educational attainment (AMIC 1988; Amongo et al.1996), affiliation in farm organizations, attendance to seminars and trainings and access to credit facilities (Amongo et al. 1996) were hypothesized to increase the likelihood of mechanization technology adoption. These variables were expected to have positive signs. In addition, tenurial status of farmers was included in the model, with owners hypothesized to use or even own machineries (Amongo et al.1996).

Most adoption studies likewise included variable reflecting farm size or volume of production (AMIC 1988; Pingali 2007). Larger farms allow more efficient use of machineries and economies of scale operation. It can also better spread the fixed costs of a given technology over a larger output compared to smaller farmers, thereby lowering average fixed costs. In this study, bigger farms were hypothesized to be more likely to use agricultural machineries. Farm size was measured in hectares and was hypothesized to have a positive sign. Farm characteristics such as agro-ecology and topography were also expected to have positive signs as irrigated farms and farms in lowland plains more likely to utilize or own machineries.

Other factors hypothesized to be influencing use or ownership of machineries were the cost of prevailing practice which machineries replace, labor situation in the area during peak periods and ownership of draft animals (Pingali 2002; Ulluwishewa 1987; Tsuchiya 1972).

For the dependent variable use and ownership of agricultural machineries in corn production, a value of one was assigned for farmers who utilized or own agricultural machineries while a value of zero was assigned for farmers who did not use mechanical power in tillage operations.

Where β_{is} are estimated coefficients and X_{is} are the independent or explanatory variables. The logistic coefficient is interpreted as the change in the log-odds associated with one unit change in the independent variable. The coefficients do not measure marginal effects of independent variables but only show if any variable has significant influence on the dependent variable. The significance of the estimated coefficients may be shown in terms of Wald Statistic, t-ratios, correlation coefficients or $E(\beta_i)$, i.e exponentiation value of β_i. Among these, $E(\beta_i)$ gives a more direct interpretation of β_{is} and it is derived by rewriting the equation in terms of odds rather than log odds as follows:

$$\frac{Prob\ (event)}{Prob\ (noevent)} = e^{\beta 0+\ \beta 1X1+\cdots+\ \beta nXn}$$

Now, e raised to the power β_i is the factor by which the odds change when the $_ith$ independent variable increases by one unit. If β_i is positive, $E(\beta_i)$ is more than1 which means that the odds are increased. If β_i is negative, $E(\beta_i)$ is less than1 which means that the odds are decreased. If $\beta_i = 0$, $E(\beta_i) = 1$ which leaves the odds unchanged**.**

RESULTS AND DISCUSSION

Characteristics of maize farmers. The profile of maize farmers revealed that adopters and non-adopters of tractors did not differ in terms of age but varied significantly in terms of education and experience in maize farming (Table 1). Moreover, majority of adopters were owners of the land they planted with maize while high percentage of non-adopters were tenants. While membership to farm organizations were almost the same for adopters and non-adopters of tractors, lesser numbers of non-adopters were not members of farm organizations. This was also noted for the attendance to seminars and trainings. Meanwhile, about two-thirds of adopters applied for loans used for maize farming compared to 52% for non-adopters.

Table 1. Characteristics of maize farmers in 13 major producing provinces, Philippines

Item	Adopter	Non-Adopter	*Mean Difference*
Age	49.09	49.06	*0.03*^{ns}
Education, years	9.19	8.16	*1.03****
Farming experience, years	21.31	22.97	*1.66***
Tenurial status			
Owner	66%	62%	
Tenant	21%	29%	
Leaseholder	13%	9%	
Membership to farm organizations			
Yes	51%	41%	
No	49%	59%	
Attendance to trainings or seminars related to mechanization			
Yes	49%	41%	
No	51%	59%	
Availed credit			
Yes	66%	52%	
No	34%	48%	

***Significant at 1%
**Significant at 5%
^{ns} Not significant at 10%

Farm characteristics. Generally, the adopters of the tractors operated larger farms, with an average of 2.25 hectares (Table 2). This was significantly larger than their non-adopter counterparts. Most of the farms of adopters were also located in the lowlands and near riverbanks while 38% of non-adopter maize farms were in the uplands. Both adopters and non-adopters reported that they encountered problem on scarcity of labor during the conduct of labor-intensive maize farm operations. This was mentioned as primary reason in the adoption of tractors. While non-adopters also recognized the need to mechanize their farms, barriers to adoption are more difficult to overcome so they continue to utilize traditional method of land preparation.

Table 2. Characteristics of maize farms, 13 major producing provinces, Philippines

Item	Adopter	Non-Adopter	*Mean Difference*
Area of farm, ha.	2.25	1.88	*0.37***
Land topography			
Plain/lowland	83%	62%	
Slopping/upland	17%	38%	
Labor availability			
Sufficient	84%	84%	
Insufficient	16%	16%	
Cost of land preparation, Php/ha.	1,671.54	1,922.75	*251.21**

**Significant at 5%
*Significant at 10%

Determinants of tractorization in maize farms. The model was fitted for the use of land preparation machineries in maize production. Important variables include topography, area, credit access, education and age (Table 3). The result suggests that corn farms in the plains, lowland and gently sloping areas are more likely to use tractors by 3.08 times compared to farms in hilly areas with more steep gradients. In terms of area, a one-hectare increase in farm area cultivated increases the likelihood of tractor adoption by 1.35 times. This is consistent with the findings of Pingali (2007) and AMIC (1988).

Availability of credit is another significant variable influencing use of machines for land preparation. It should be noted that tractor rental is usually paid on a cash basis, hence, farmers lacking capital but can easily borrow money from various sources are more likely to avail tractor services to cultivate their farms. Farmers who availed credit are more likely to use tractors by 1.51 times compared to farmers with no source of loans or borrowings.

Age is also an important variable influencing adoption or use of tractors. As farmers grow older and their physical strengths start to decline, labor-replacing technologies become a necessity. As the age of maize farmer increases by a year, the likelihood of using tractor increases by 1.01 times. This finding is contrary to most literatures asserting that technology adoption decreases with age, as older farmers are usually more reluctant to change (Bootinger et al.2010, Awotide et al.2014).

Another significant variable affecting farmers' decision to adopt tractor is the farmer's level of education. This implies that farmers with college level education are more likely to adopt tractors by 1.09 times compared to farmers with no college education.

Meanwhile, other variables such as tenurial status, membership in farm organizations, attendance to trainings and seminars related to corn mechanization, cost of land preparation using draft animals, ownership of draft animal dummy and labor situation dummy do not influence the decision of maize farmers to use tractors. It is important to note that landowners make all farm decisions including the use of farm power. Moreover, there was limited number of cooperatives or farm organizations engaged in maize production and marketing so the data did not show large variations in terms of cooperative membership. This was also observed for trainings or seminars related to maize production, postharvest or mechanization.

The Hosmer and Lemeshow goodness-of-fit p-values of 7.843, with 8 *df* is not significant, indicates that the model fit the data well.

Table 3. Regression results showing determinants of mechanizing land preparation by maize farmers in the Philippines

Independent Variables	β_i	*S.E.*	$E(\beta_i)$
Age	*0.011**	*0.006*	1.011
Educational attainment	*0.084****	*0.023*	1.088
Tenurial status	*-0.087*^{ns}	*0.140*	0.917
Membership in farm organizations	*0.202*^{ns}	*0.141*	1.223
Attendance to seminars/trainings	*0.127*^{ns}	*0.141*	1.135
Credit access	*0.413****	*0.142*	1.511
Area	*0.299***	*0.136*	1.349
Topography	*1.125****	*0.161*	3.080
Man-animal land preparation cost	*0.000*	*0.000*	1.000
Owned draft animals	*-0.077*^{ns}	*0.143*	0.926
Labor situation during peak periods	*0.168*^{ns}	*0.190*	0.183
Hosmer and Lemeshow Test			
χ^2		7.843^{ns}	
df		8	
Nagelkerke Pseudo R^2 = .140			

*Significant at 10%
**Significant at 5%
***Significant at 1%
^{ns}Not significant

Determinants of agricultural machinery ownership. For the ownership of agricultural machinery model, important determinants are topography, area of the farm, education and age (Table 4). Farmers with farms situated in the lowlands are more likely to purchase agricultural machinery by 1.92 times compared to farmers in the uplands. For an enterprising farmer, investment in agricultural machineries such as tractors in the lowland areas has higher potential of faster recovery of capital as low-lying areas are more productive because of higher cropping intensity and generally better yield. Moreover, the area of the farm is significant variable influencing ownership or purchase of agricultural machineries. One-hectare increase in farm area cultivated increases the likelihood of acquiring farm machinery by 1.35 times.

For demographic variable age of farmers, a one-year increase in the age of farmers increases the likelihood of purchasing agricultural machinery by 1.014 times. This is even more essential for farmers who are already old, who can no longer perform tedious activities. With regard to education, rice farmers who obtained higher education are more likely to purchase agricultural machines by 1.65 times compared to farmers with low level of education. While education is considered influencing productivity by affecting farmers' ability to understand the complicated information related to different technologies and to adjust quickly to new practices, educated farmers are more likely to have higher or other sources of incomes so they have the capability to buy or invest in agricultural machineries.

The Hosmer and Lemeshow goodness-of-fit p-values of 4.466, with 8 *df* is not significant, hence, the model fit the data well.

Table 4. Regression results showing determinants of tractor ownership by maize farmers in the Philippines.

Independent variables	β_i	***S.E.***	$E(\beta_i)$
Age	*0.014******	*0.004*	1.014
Educational attainment	*0.503******	*0.133*	1.653
Tenurial status	*0.108*^{ns}	*0.099*	1.114
Membership in farm organizations	*-0.049*^{ns}	*0.101*	0.952
Attendance to seminars/trainings	*0.005*^{ns}	*0.101*	1.005
Credit access	*-0.118*^{ns}	*0.099*	0.889
Area	*0.299***	*0.136*	1.349
Topography	*0.653****	*0.106*	1.921
Owned draft animals	*-0.011*^{ns}	*0.102*	0.989
Labor situation during peak periods	*-0.105*^{ns}	*0.114*	0.900
Hosmer and Lemeshow Test			
χ^2		4.466^{ns}	
df		8	
Nagelkerke Pseudo R^2 = .103			

**Significant at 5%
***Significant at 1%
^{ns}Not significant

CONCLUSION

This study provides empirical information concerning the factors that determine the adoption of tractors by maize farmers in the Philippines. The adoption of tractors is higher among older farmers and with higher level of education. As the age of farmers increases, the likelihood of using tractors also increases.. Availability of credit also increases tractor adoption, as farmers who are able to avail of loans are more likely to use tractors. As the area of the farm increases, the likelihood of tractor adoption also increases. Moreover, corn farms in the plains, lowland and gently sloping areas are more likely to be mechanized compared to farms in hilly areas with steep gradients.

With the findings, it is recommended that the factors and barriers to adoption be considered in devising intervention and promotion strategies to stimulate wider adoption of mechanization technologies such as tractors. The Department of Agriculture should intensify maize mechanization efforts in order to allow small farmers to collectively own tractors. However, the physical attributes of maize farms should be considered in the development and promotion of machines suitable for the hilly areas. The provision of low-cost credit is also important to increase adoption of tractors. Furthermore, there is a need to reconsider early consolidation or clustering efforts to enable small fragmented farms to avail of capital intensive machines and allow economies of scale operation.

ACKNOWLEDGEMENT

The authors are grateful to Dr. Renita Dela Cruz for the research supervision; Ms. Zeren Lucky Cabanayan, Ms. Joanne Ceynas and Engr. Philip Foronda for their assistance in data gathering and Ms. Joyce Lauren Lavapie for encoding the data.

REFERENCES CITED

AMIC [Agricultural Mechanization Inter-Agency Committee]. 1988. Handbook on Agricultural Mechanization. UPLB. College, Laguna. 13 p.

Amongo, R.C.; V.A. Rodulfo, JR.; A.C. Del Rosario and M.V.L. Larona. 1996. Farm mechanization study and machinery ownership analysis in Region IV. AMDP, CEAT, UPLB. Paper presented during the 44th PSAE Annual National Convention, Cagayan de Oro, Philippines.

Awotide, B.A, Andoulaye, T., Alene, A. and V.M. Manyong. 2014. Assessing the extent and determinants of adoption of improved cassava varieties in South-Western Nigeria. Journal of Development and Agricultural Economics. 6(9):376-385.

Böttinger, S., Doluschitz, R., Volz, R., Paterson, R. and C. Jenane. 2010. World trend and evolution of agricultural machinery manufacturing sector. Paper presented at International Conference on Agricultural Engineering. Clermont-Ferrand, France.

Dela Cruz, R.S. and H.G. Malanon. 2017. State of on-farm maize mechanization in the Philippines. Agricultural Engineering International: CIGR Journal, 19(4): 20-28.

Pingali, P. 2007. "Agricultural mechanization: Adoption patterns and economic impact." In Handbook of Agricultural Economics.Vol.3, edited by R. Evenson and P. Pingali. Amsterdam: North Holland.

Tsuchiya, K. 1972. Mechanization and relationships between farm, non-farm, and government sectors. In: Farm Mechanization in East Asia. Ed. H. Southworth. The Agricultural Development Council, Inc. New York. 196 p.

Ulluwishewa, R. 1987. Factors affecting the mechanization of the tillage operation of fields in Sri. Lanka: A Geographical Perspective. International Journal of Physical, Biological, Social, and Economic Geography and Applications in Environmental Planning and Ecology. GeoJournal 15.4: 393-398