Characterization of Mechanized Farming Operations in Butuan City, Philippines

Neil Caesar M. Tado
Department of Agricultural and Biosystems Engineering, College of Engineering and Geosciences, Caraga State University

Reca S. Bautista
Department of Agricultural and Biosystems Engineering, College of Engineering and Geosciences, Caraga State University

https://doi.org/10.5109/5909088

出版情報：Proceedings of International Exchange and Innovation Conference on Engineering & Sciences (IEICES). 8, pp.176-182, 2022-10-20. Interdisciplinary Graduate School of Engineering Sciences, Kyushu University
バージョン：

Characterization of Mechanized Farming Operations in Butuan City, Philippines

Neil Caesar M. Tado[1,2*] and Reca S. Bautista[1]
[1]Department of Agricultural and Biosystems Engineering, College of Engineering and Geosciences, Caraga State University, Butuan City 8600, Philippines
[2]Center for Resource Assessment, Analytics and Emerging Technologies (CReATE), Caraga State University, Ampayon, Butuan City 8600, Philippines
*Corresponding author email: nmtado@carsu.edu.ph

Abstract: *This paper examined the socio-demographic, economic, and mechanization profiles of rice farmers in Butuan City, Philippines. The study was conducted using stratified random sampling survey methodology. In terms of socio-demographics, majority of rice farmers are male and above 50 years old. Furthermore, most farmers lack college degrees. Cost and return analysis show a benefit-cost ratio of 0.36. The average net profit per hectare is only Php 16,211. This paper determine the level of mechanization in terms of hp/ha and power sources. Results showed that Butuan City has a 3.5742 hp/ha, which is significantly still low. It is justifiable because most of the power sources of farmers' operations in the city are performed manually, especially in planting and crop care management. Land preparation and harvesting are done mainly mechanically, with 0.71 hp/ha and 1.85 hp/ha, respectively being the two highest mechanization indices in all rice production operations in Butuan City.*

Keywords: agricultural machinery, level of mechanization, rice farming

1. INTRODUCTION

The productivity and sustainability of rice is a major economic indicator and national security issue in the Philippines. Mechanization increases productivity by reducing the time and labor requirements for each farm operation. While mechanization negative effect on farm labor employment, the income of rice farmers increases with their level of mechanization [1]. However, the budget constraints and high fuel costs discourage Filipino farmers from investing in agricultural machineries [2]. Government support is necessary for farmers to acquire these technologies.

Republic Act 10601 otherwise known as the Agricultural and Fisheries Mechanization (AFMech) Law of 2013 stipulates the strong commitment of the Philippine government towards modernizing Philippine agriculture. The need to mechanize the Philippine rice industry became more apparent when the Rice Liberalization Act was passed and opened the country to free trade. The influx of cheaper imported rice highlighted the need for a more competitive local rice industry. In compliance with this law, the Philippine government have put billions of pesos in funding different agricultural modernization programs to increase productivity and competitiveness.

Several government projects in the past composed of one-size-fits all menu of mechanization technologies that were given to different farmer groups throughout the country. The problem with this approach is the mismatch between the technologies provided, capacity of the recipients, and the suitability of the area. The use of appropriate mechanization technologies plays an important role in achieving high energy-use efficiency in the farm. Good governance and energy-use efficiency are among the performance indicators of sustainable agricultural practices [3].

There are differences in the level of mechanization in rice production systems in the different provinces of the Philippines. Location-specific government programs on agricultural mechanization are important to address the gap in productivity and competitiveness of Filipino rice farmers. Effective government mechanization interventions can only be achieved if policymakers have data on the level of mechanization of a specific commodity and calculate the gaps in each sector.

Figure 1. Map of Butuan City (Source: Creative commons)

This research provides an overview of the state of mechanized rice farming operations in Butuan City, Philippines. Butuan is fast evolving into a smart city and agricultural mechanization would be a vital backbone of its development. One key component of a smart city is the implementation of smart initiatives by centralized leadership [4]. Agricultural infrastructure and mechanization technologies are important to continue this development. The government has already funded six agricultural warehouses that were given to different farmers' associations within the city to support the rice value chain [5].

This study assessed the level of mechanization in Butuan City in terms of hp/ha and power sources. Furthermore, it also determined the impact of the Rice Liberalization Law by performing a cost and return analysis of the production cost in rice production systems

2. METHODOLOGY

2.1 Process Flow

The process flow of the study is shown in Figure 1. The questionnaire was developed through consultations and review of existing studies related to agricultural mechanization. The survey questionnaire was then pilot tested at adjacent municipalities before it was implemented in the study. The data gathering was conducted through face-to-face interview with the selected respondents. The data collected was validated through phone call to ensure consistency and accuracy of the survey results.

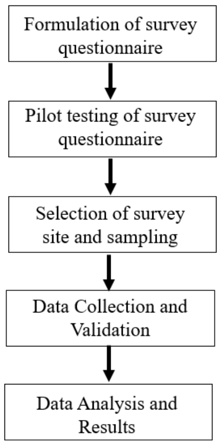

Figure 2. Process flow of the study

2.2 Research Design

This study used a stratified random sampling methodology, and the sample size was calculated using Cochran's equation using 90% confidence interval. The two-stage sampling design (stage 1= barangay; stage 2= farm level) was considered to determine representative samples of farmers in different barangays in proportion to the rice production area. The selection of samples was done using random stratified sampling to minimize the error in estimation. Furthermore, the respondents were selected from the database of the Registry of the Basic Sectors in Agriculture (RSBSA). The sample size allocation for the selected barangays is shown in Table 1.

Table 11. Sample size selection

Barangay	Number Of Respondents
Ambago	2
Ampayon	2
Antongalon	16
Banza	6
Baobaoan	7
Bitan-agan	3
Bobon	2
Bonbon	1
Libertad	2
Maguinda	8
Taguibo	7
Tiniwisan	6
Villa Kananga	2
TOTAL	**64**

2.2 Socio-economic data

Basic demographics and production performance data were included in the survey questionnaire to present the profile of the rice farmers in Butuan City. These data were subjected to frequency analysis and other descriptive statistics tools. They will be useful in policymaking decisions of government agencies that are mandated to promote agricultural development in the city. Furthermore, gender roles and educational level were also determined because they play important roles in ability to adopt new technologies.

2.4 Cost and Return Analysis

The cost of rice production was examined according to the product's condition and the supply chain's stakeholders, such as wet palay (farmer's level), dried palay (trader's level), and milled rice (miller's level). The farm level cost includes all expenditures associated with land preparation and produce hauling from the field to the farm road. It included farm-level, handling, and drying charges at the trader level. The miller's cost includes all prior expenditures in addition to milling costs.

In Butuan City, there were no operations performed by only one power source in the farm, it is either conducted with a combination of man-animal or man-machine power sources or any combination of the two power sources. Hence, a separate treatment was conducted to determine the costs of the combined operations. The contribution of each operation in the supply chain was calculated by taking the weighted average of the costs associated with the various power sources used. Net returns were computed by subtracting total costs from gross returns. Dividing the net profit by the total cost to obtain the net profit cost ratio. Two cost analyses were conducted for two different planting methods: rice transplantation and broadcasting.

2.3 Level of Mechanization

This study expresses the level of mechanization in terms of the hp/ha and the power sources. The power sources in the farm are divided into man, man-animal, and man-machine combinations. The Modified Agricultural Mechanization Index equation (Eq 1) developed by Amongo [6] used to quantify the power utilized in the farm considering different parameters such as windows for each operation, operation per hour per day, and source of power for each operation.

$$\mathrm{MAMI} = \frac{\Sigma(\mathrm{HPs\ x Ns + Nw\ x\ HPm}}{\Sigma \mathrm{At}} \quad (1)$$

$$At = C\ x\ t\ x\ W \quad (2)$$

where:

MAMI = Modified Agricultural Mechanization Index of the operation, hp/ha
Ns = number of sources of power
HPs = Power source, hp
HPm = Power of man, hp
Nw = Number of workers
At = Total coverage area, ha

The level of mechanization in terms of the power source was also determined using Eq 3. The level of mechanization each operation was calculated based on the considering the service area and the number of farmers using the power source. There are three types of systems or sources of power considered are: human, man-animal, and man-machine.

$$Ps = \left(\frac{Ap}{At}\right) x100\% \qquad (3)$$

Where: Ps = Mechanization level by power source
Ap= Farm area by power source
At = Total coverage area

3. RESULTS AND DISCUSSION

3.1 Demographic Profile of Rice Farmers

Sixty-four respondents from different associations members of the Registry System for Basic Sectors in Agriculture (RSBSA) in Butuan City were interviewed. Table 2 shows the profile of rice farmers in Butuan City in terms of gender, age, education, occupation, and farm size. The data shows that rice production is still a male-dominated industry with 67% of the respondents are male. Farm management roles for women include cooking for hired laborers, farm visitation and supervision [7]. Furthermore, women are also active in seedling preparation and manual transplanting. The drudgery of farm operations makes it more suitable for male labor in the field. However, women exercise greater control over household income may have a relatively higher participation and influence in household decisions [8].

Table 2. Demographic profile of rice farmers

Variables	Distribution
Gender	
Male	33%
Female	67%
Age	
>30	2%
30-39	13%
40-49	17%
50-59	33%
60-69	30%
70<	5%
Educational Attainment	
Elementary Undergraduate	14%
Elementary Graduate	25%
High School Undergraduate	11%
High School Graduate	27%
Vocational Graduate	3%
College Undergraduate	9%
College Graduate	11%
Main Occupation	
Government Official/Employee	13%
Full-time farmer	84%
Others	3%

The data on age distribution reflects the issue on aging farmer population in Asian farms [9]. The results show that 68% of farmers are more than 50 years old. It is alarming that the only 2 percent of farmers are below 30 years old. This shows grave disconnect of the youth in rice farming. The common explanations for the decline in young people's involvement in farming include migration to work in factories and difficulty in obtaining land, and the generally low profitability of farming [10]. The youth should be encouraged to engage in agriculture by promoting modern farming technologies that decrease the drudgery of farm operations.

The educational background of rice farmers also shows dismal results with only 11% of the respondents are college graduates. The high school graduates and undergraduates comprise most farmers. Higher levels of educational attainment can help farmers in farm management and adoption of technology. This can be achieved if more young people pursue agriculture-related degrees and engage in farming and agribusiness upon graduation.

3.2 Farm Size

In terms of farm size, rice farmers generally have small landholdings. Figure 2 shows the farm size distribution. The data shows that 89% of farms are less than 2.0 ha. Furthermore, only 2 percent of respondents' have farm sizes of more than 4 ha. This is a major obstacle to adopting mechanization technologies as small farm areas would result to lower field efficiencies of machineries. The government intervention programs provide tractors and combine harvesters that are more suitable to bigger parcels of farmlands. Hence, the production costs are not optimized, and farmers are more vulnerable to fluctuations in fuel prices. One possible solution to this is to have a paradigm shift to consolidated farmlands for more efficient mechanized operations.

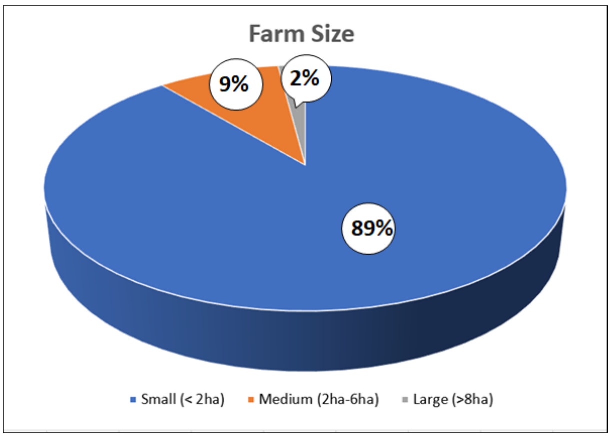

Figure 3. Farm size distribution

3.3 Production cost

Rice production costs were primarily composed of the following: specific input supply; rental costs for land, animals, tools, and machinery; utility costs, including irrigation; and farm labor. The specific inputs included food; agricultural inputs such as seeds, fertilizer, herbicide, insecticide, molluscicide, rodenticide, as well as fuel and oil. Rentals and fees were paid in cash or in kind. On the other hand, farm laborers were made up of family members and hired laborers.

The costs of various rice field operations are summarized in Table 2. In Butuan City, planting operations are typically commenced through direct contracting. The fees for land preparation, drying, and milling are paid in cash, harvesting operations are taken as a percentage of total harvested grains. The range of values provided in Table 2 represents the variability of the production costs among the respondents. Furthermore, family labor is costed using the minimum wage allowed by the labor department for uniformity of assumptions and calculations.

Table 3. Unit cost for different components of the production system

ITEMS	UNIT COST
Family/Hired Labor	Php 350-P 400/day
Man-Animal Fee	Php 500-P 700/ day
Tractor	Php 1500-P 3000/ha
Irrigation	Php 500/cropping
Planting-Harvesting Fee	Php 4,000-P 6,000/ha
Harvesting Fee	8%-10% of the harvested grains (wet basis)
Hauling	Php 15-P 30/sack
Drying	Php 70-P 75/sack
Milling	Php 100-P 110/sack
Interest Rate	5%-10% per cropping

Table 4 shows the average production cost per hectare for transplanted rice. The data shows that planting and harvesting operations make up most of the production cost. Furthermore, these operations also require the highest amount of labor. Furthermore, fertilizers and pesticides have the highest cost of input. It is important to note that with the passage of the Rice Liberalization Program, rice farmers are provided with free seed subsidy by the Philippine Rice Research Institute. Hence, there is no input cost for the seedling preparation. Moreover, the labor and machine rentals (Php 29,348) comprise 66% of the production costs as compared to the 34% cost of agricultural inputs. This shows that the competitiveness of rice farmers can greatly be improved if we can reduce the cost of labor and machine rentals.

Table 4. Total production cost per ha for transplanted rice

OPERATION	AMOUNT	
	Labor/Rentals Php/ha	Inputs Php/ha
Seedling Preparation	4,050	-
Irrigation	-	500
Dike Repair	900	-
Land Preparation		
Plowing	2487	2,000
Harrowing	1,714	2,000
Leveling	700	-
Planting	8,000	-
Crop Care		
Fertilizer Application	400	5,000
Insecticide Application	400	1,599
Herbicide Application	400	2,500
Harvesting	8,000	-
Hauling	2,297	-
TOTAL	29,348	15,599

The average yield of the respondents was computed at 4,100 kg/ha at 24% moisture content. The average farmgate price of palay is at Php 14.88 per kg. This would result in a gross return of Php 61,159 per ha. The cost and return analysis for rice production is shown in Table 5. The total production cost per hectare is Php 44,947. This would give a benefit-cost ratio (BCR) of 0.36. Although a BCR of 0.36 for a season of production may look good on paper, this does not mean that rice farming is profitable. The production season for rice would last four months. The net return for each farmer is only Php 16,211. This means that a farmer tilling one hectare would only get Php 4,052 per month. The small farm size and high production costs eats up the returns of each farmer. Hence, there should be more government interventions to our farmers to mitigate this situation.

Table 5. Cost and return analysis

ITEM	AMOUNT	
	PhP/ha	PhP/kg
Gross return	61,159	14.88
Total cost	44,947	10.94
Inputs	15,599	3.80
Labor/rentals	29,348	7.143
Interest	-	
Net Returns	2,000	0.488
Net profit-cost ratio	16,211	3.94
	0.36	0.36

This problem can also be addressed if the average yield of famers is increased. The average yield of about 4.1 t/ha is below the potential yields of the varieties that are being used in Butuan City. The yield levels in major rice producing in the Philippines can be more than 5 t/ha. Farmers should be educated on modern rice production techniques, such as balanced fertilization, integrated pest management, and other technologies that would increase yield and reduce production cost. The approach should be both on the agronomic and mechanization aspects of production.

3.4 Power Sources

Table 6 shows the distribution of farm power source per operation. The farm operation conducted solely by human labor include seedling preparation, planting, fertilizer application, weeding, and pesticide application. Plowing and harrowing are fully mechanized with the use of combination of two-wheel and four-wheel tractors. Leveling is done using man-animal power source with the use of a carabao drawn wooden plank. Crop protection activities, such as weeding and pesticide application, are done manually. In general, manual weeding consumes more energy than spraying [11].
Harvesting and threshing is mostly done using a combine harvester. This would lead us to conclude that the agricultural mechanization technologies that have been adopted the most are tractors and combine harvesters. Land preparation and harvesting are among the most labor-intensive components of the rice production system. Furthermore, the respondents have signified reduction in harvesting costs when using combine harvesters as compared to the traditional manual harvesting and mechanical threshing. The combination of human, animal, and mechanical power sources play an important role in energy efficiencies. Bautista [12] found that manual direct seeding coupled with mechanized

operations provide the highest energy efficiency in irrigated rice production systems.
On the other hand, the adoption of the mechanical rice transplanter did not go well as observed by the 100% manual planting method applied. This could not be attributed to the lack of available machines as the government had already distributed transplanters throughout the region. During the survey interview, farmers noted that the wide row spacing and difficulty in seedling preparation are the main reason for not adopting the mechanical transplanter. There is a gap in the knowledge transfer on this technology that should be addressed by agricultural extension programs.

Table 6. Distribution of farm power sources

OPERATION	POWER SOURCE	
	Man & Man-Animal (%)	Man-Machine (%)
Seedling Preparation	100.0	
Irrigation and Drainage		57.81
Dike Repair	100.0	
Plowing	12.40	87.60
Harrowing	5.55	94.45
Leveling	100.0	
Planting	100.0	
Fertilizer Application	100.0	
Weeding	100.0	
Insecticide Application	100.0	
Herbicide Application	100.0	
Rodenticide Application	100.0	
Molluscicide Application	100.0	
Harvesting	1.32	98.68
Threshing		7.92

Table 7 shows that respondents' perception on labor availability. Most respondents believe that there is adequate labor available for rice farming. Hence manual operations can still be attained. Furthermore, we should be prudent in switching to fully mechanized farm operation to prevent massive labor displacement and loss of income.

Table 7. Farmer's Perception on Labor Availability

Labor Availability	Number of Respondents
Enough	41
Abundant	6
Insufficient	17
TOTAL	64

3.5 Level of mechanization

The level of mechanization was calculated using Eq 3 developed by Amongo [13]. The power rating of human, man-animal, and man-machine systems were calculated for each operation. Table 8 shows the summary of the results of the level of mechanization expressed in terms of hp/ha. The farm operations with the highest hp/ha are the land preparation and harvesting since these activities use tractors and combine harvesters. This is in contrast with the low calculated hp/ha for crop care activities, such as chemical application and fertilization. Crop care activities are done manually with only 1-2 persons doing the operation per hectare. In the case of manual transplanting, 8-20 persons are needed to finish the activity in one day. Threshing only contributes 0.048 hp/ha since there are only small number of farmers who still use mechanical threshers instead of combine harvesters. Harvesting machinery are important because manual harvesting methods fail during the rainy season. This problem is also encountered in other commodities such as in cassava production [14].
The operations with the lowest hp requirements are typically those that include the application of chemicals such as insecticides and other pesticides. These are primarily carried out by farmers using knapsack sprayers. Only 1.6 percent of farmers engage in drying and milling operations, indicating that they have ceased drying and milling their palay following harvest and instead sell it directly as wet palay. Drying and milling of rice are accomplished using a flatbed drier and multi-pass rice milling, respectively.
Despite the widespread use of machinery by farmers for harvesting, plowing, and harrowing, most operations are still conducted by human labor. This could indicate that human labor is still sufficient, as shown in Table 7, where 64.06% of farmers perceive labor availability as adequate, followed by 26.56% who perceive labor as insufficient, and only 6% who perceive labor as excessive. Most farmers (87.5%) obtain labor locally, while 12.5% obtain labor from other cities or barangays. The two major drivers of agricultural mechanization are labor shortage and the need to lower production costs [15]. Hence, it is inevitable that the demand for agricultural machinery would continue to increase within the next few years.
The level of mechanization of Butuan City is calculated at 3.57 hp/ha. This shows an increase in the level of mechanization versus the data published by PhilMech in 2013 wherein the average level of mechanization in the Philippines was only 1.23 hp/ha. The governments' aggressive agricultural mechanization programs and private sector adoption of agricultural machineries hastened the increased in the level of mechanization. However, the results of this study are only focused on the farm-level operations and did not consider further processing applications after harvesting.
The data for drying and milling operations in Table 8 came from a small number of respondents who had their palay dried and sold as milled rice. However, most farmers in Butuan City sell their palay fresh to traders and millers right after harvest. Hence, the cost and return analysis only considered the costs up to the harvesting operation. There is still a big economic opportunity for farmers in drying, milling, and marketing of milled rice as the value adding can increase their profit margins.
The hp/ha profile demonstrates that mechanized processes generate more hp than manual ones. For the time being, rice combine harvesters, floating tillers, and tractors are prevalent in harvesting, harrowing, and

plowing operations or in land preparation in rice production systems. The rise in available hp/ha is a result of the increased use of these machinery in the rice field.

Table 8. Level of mechanization, hp/ha

OPERATION	Power Utilized hp/ha
Seedling Preparation	0.0133
Irrigation and Drainage	0.0721
Dike Repair	0.0133
Plowing	0.7097
Harrowing	0.3554
Leveling	0.1444
Planting	0.1875
Chemical Application	0.0074
Weeding	0.0048
Harvesting	1.8505
Threshing	0.0480
Hauling	0.1032
Drying	0.0066
Milling	0.0581
TOTAL	3.5742

Even though some operations are mechanized, intensive work such as planting and leveling is still performed manually. If a rice transplanter is used, it may improve the farmers' hp/ha availability.

The change from manual to mechanized rice farming operations cannot be completed quickly. That is why, in addition to providing free seeds and machinery, the Rice Liberalization Law provide support to farmers for five years in the form training and seminars on how to operate such machines. And, as evidenced by their adoption of machine harvesting, plowing, and harrowing, farmers in Butuan City are receptive to and willing to use mechanized activities.

4. CONCLUSION

This study was able to characterize the rice farming operations in Butuan City. In terms of demographics, male farmers comprise most of the respondents. Furthermore, the rice industry is in danger of losing its rice industry due to its aging farmers. There is a need for the government and private sector to engage the youth in agriculture and revitalize the city's aging farming sector. Another issue that needs to be addressed is the lack of formal education in most rice farmers. This can be a cause of concern, especially in their ability to adopt new technologies.

Cost and return analysis show a BCR of 0.36. However, farmers on the average earn Php 18,211 per hectare per season. This translates to only Php 4,052 per month, which is barely enough for the needs of his family. This low productivity needs to be addressed by increasing the yield and lowering the production cost.

The level of mechanization was also determined in this study. The results revealed that among rice mechanization operations, land preparation and harvesting had the highest mechanization rating. Butuan City's rice mechanization index was still significantly lower (3.5742 hp/ha). Although most land preparation and harvesting procedures are performed mechanically, most operations, particularly planting, are performed manually. Farmers were provided rice transplanters throughout the planting operation; however, they did not use them due to various specifications. However, the fact that most farmers perform land preparation and harvesting mechanically indicates that they are willing to adopt the technology. To improve the level of mechanization in Butuan City, the recommendation is to have a study, particularly on the rice transplanter, to design and develop a suited transplanter for the farmers.

The results of this study show limited utilization of agricultural mechanization technologies particularly in transplanting and crop care. There should be follow-up research on the causes of low technology adoption and development programs and interventions to address this issue.

5. REFERENCES

[1] D. J. Rodriguez and M. E. Piadozo, "Characterization of Farm Mechanization Among Lowland Rice Farmers in Laguna, Philippines," Journal of Economics, Management & Agricultural Development, vol. 2, no. 2, pp. 97-108, 2016.

[2] M. J. Mariano, R. Villano and E. Fleming, "Factors influencing farmers' adoption of modern rice technologies and good management practices in the Philippines," Agricultural Systems, vol. 110, pp. 41-53, 2012.

[3] R. Mungkong, S. Sitthikitpanya, R. Chaichana, K. Bamrungwong, Y. Santitaweeroek and N. Jakrawatana, "Measuring sustainability performance of rice cultivation in Thailand using Sustainable Rice Platform indicators," International Journal of Agricultural Sustainability, 2022.

[4] M. H. Kim, "Transition of Initiative from Ubiquitous City to Sustainable Smart City by Korea: Focusing on the Case of Songdo City," Proceeding of International Exchange and Innovation Conference on Engineering & Sciences (IEICES), vol. 5, pp. 111-115, 2019.

[5] P. D. Sanchez, K. Amar and M. Rayoso, "Profiling and Technical Evaluation of Existing Agricultural Warehouses in the Agusan Provinces, Caraga Region, Philippines," Proceeding of International Exchange and Innovation Conference on Engineering & Sciences (IECES), vol. 5, pp. 129-135, 2021.

[6] R. Amongo, M. Onal, M. Larona, A. Fajardo, C. Ilao, G. Lalap, A. Borja, C. Deniega and J. Sumague, "Level of Agricultural Mechanization in Oriental Mindoro, Laguna and Quezon, Philippines Using the Modified Agricultural Mechanization Index for Lowland Rice," Philippine Journal of Agricultural and Biosystems Engineering, vol. 14, no. 2018.

[7] T. Paris, T. Chi, M. Rola-Rubzen and J. Luis, "Effects of out-migration on rice-farming," Gender, Technology and Development, vol. 13, no. 2, pp. 169-198, 2009.

[8] R. Maligalig, M. Demont, W. J. Umberger and A. Peralta, "Off-farm employment increases women's empowerment: Evidence from rice farms in the Philippines," Journal of Rural Studies, vol. 71, pp. 62-72, 2019.

[9] J. Rigg, M. Phongsiri, B. Promphakping, A. Salamanca and M. Sripun, "Who will tend the farm?

Interrogating the ageing Asian farmer," The Journal of Peasant Studies, vol. 47, no. 2, pp. 306-325, 2019.
[10] J. Rigg, A. Salamanca and E. C. Thompson, "The puzzle of East and Southeast Asia's persistent smallholder," Journal of Rural Studies, vol. 43, p. 118–133, 2016.
[11] P. Soni, C. Taewichit and V. Salokhe, "Energy consumption and CO2 emissions in rainfed agricultural production systems of Northeast Thailand," Agricultural Systems, vol. 116, pp. 25-36, 2013.
[12] E. G. Bautista and T. Minowa, "Analysis of the Energy for Different Rice Production Systems in the Philippines," Philipp Agri Scientist, vol. 93, no. 3, pp. 322-333, 2010.
[13] R. Amongo, V. Rodulfo, R. A. M. Larona, J. Ramos, A. Castalone, M. Eusebio, A. Borja, J. Amongo, E. Repoldo and M. & Idian, "Determination of agricultural mechanization level in the production-post production systems," 2013.
[14] S. Chalachai and A. Soni, "A Critical Review of Mechanization in Cassava Harvesting in Thailand," International Agricultural Engineering Journal, vol. 22, no. 4, pp. 81-93, 2013.
[15] P. Soni, "Agricultural Mechanization in Thailand: Current status and future outlook.," Agricultural Mechanization in Asia, Africa & Latin America, vol. 47, no. 2, pp. 58-66, 2016.