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Factors of Rice Productivity: A Case Study in Central Luzon, Philippines

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Abstract—Rice is a staple food in the Philippines, with an average daily consumption of 325.5grams. The country's growing population is proof that the need for rice sustainability will be a primary concern in the future. This study identified the significant factors that affect rice production in the Philippines, particularly in Central Luzon, the country's rice capital. Relevant data in the last 16 years, from 2002 to 2017, were analyzed using multiple regression analysis. The results revealed that farm size, pesticide, and irrigation were the most significant contributors to rice productivity, and improvement on other factors or production inputs will not increase the rice yield. Industrialization and urbanization significantly contributed to the decrease in available farmland, and the national and local government units are held responsible for supervising initiatives associated with urban development. The study suggests that the government review the policies and guidelines in farmland acquisition to minimize the rapid trading and transformation of arable lands. Farmers should receive proper compensation to prevent migration as an impact of industrialization. The government should also implement irrigation designs and maintenance projects to improve the irrigation system in the country while allocating appropriate budget for pesticides acquisition and instituting pesticide application training will also aid the farmers. Future researchers may consider investigating the other factors of rice productivity that were not included in the study.

Keywords—rice sustainability, factors of rice production, multiple regression analysis, increased productivity

1. Introduction

Rice is a staple food in many Asian countries, such as the Philippines. Most farmers raise it as a primary crop as it is consumed every day by many Filipinos. Agricultural development in rice farming will always be more beneficial and necessary to ensure that supply will always be available and enough for the consuming public since it is an essential commodity among all income groups [1]. The Philippines' annual rice consumption per capita rose from 93.2 kilograms (kg) in 1995 to 118 kg in 2020, equivalent to daily consumption of 325.5 grams of milled rice for the average Filipino in the last year [2]. With a current population of more than 108 million [3], the country's total annual consumption amounts to 12.9 thousand metric tons (MMT). At present, the rice supply is enough for consumption, but a more abundant rice supply will be required once the country's population increases to 142 million by 2045 [3]. The growing population in the country requires the need for sustainability in rice production.

Urbanization is described as how natural land surfaces are replaced by impermeable ones, brought about by high population increase and economic development [4]. An increase in the human population entails increased urbanization. The contribution of agriculture in the national economy has been observed as declining, and it is largely attributed to urbanization and industrialization, which directly shift agriculture to the service sector [5]. The major rice producers in the Philippines were Central Luzon (18.7%), Cagayan Valley (11%), Ilocos Region (9.8%), Central Mindanao (7.5%), and Bicol Region (6.8%), and while the country is the eighth-largest rice producer in the world, there are still threats to its sustainability [6]. Productivity and farm size happen to have an inverse relationship, as explained by [7]. However, the concept of labor productivity should also be considered. The labor productivity explains that larger farms are more productive than their smaller counterparts when coupled with the right inputs of labor [8]. Despite the

available technology, the World Bank Organization has observed that the Philippine agricultural output had decreased [9]. Other rice-producing countries like Vietnam and Thailand produce 5-8 tons per hectare, while the Philippines only produce 3-6 tons per hectare. [10] stated that growing population, declining land area, poor drainage, and inadequate irrigation facilities are significant factors that affect rice production in the country, while the severe impact of climate change has always been a significant challenge on rice agriculture. While the weather is considered essential in farming, it can also drastically affect crops production [11]. This includes extreme rainfall or droughts, which are both experienced in the country. The tropical cyclones that enter the country produce heavy rains and strong winds [12], which affect crops that more often lead to their destruction. Heavy rains, especially successive ones, cause severe drainage problems in paddy fields where crops are grown. Drainage problems cause significant reduction not just in rice yield but also in quality [6]. The situation is made even worse when irrigation systems, which help in applying controlled amounts of water to land to assist in the production of crops, deteriorate because of the lack of funding for maintenance [13]. Hence, it can be easily said that the typhoon season severely affects rice production in the country since crops are highly vulnerable to heavy rainfall.

Half of the total land area in Central Luzon, Philippines is used for agriculture, accounting for forty percent of the rice demand in the area, and the rest are delivered to other regions [14]. Hence, it was considered the country's rice capital [15]. The available literature on farming in the Philippines has not considered the effects of precipitation level, farm size, fertilizers, pesticides, hired labor, irrigation, and equipment repairs, on rice production. This study accounted these factors to achieve the following objectives: determine how precipitation level, farm size, fertilizers, pesticides, hired labor, irrigation, and equipment repairs affect rice production; identify the effects of these factors on the productivity of rice in Central Luzon; and recommend ways on how to further increase rice production in the province. The findings of this study will be beneficial to research and development institutions in creating projects and programs for more sustainable rice farming in the Philippines. The national government can also utilize this study to review and modify the current agricultural laws.

2. Methodology

The data utilized in this study were taken from public data available in various government institutions such as the Philippine Statistics Authority (PSA), Department of Agriculture (DA), and Department of Science and Technology - Philippine Atmospheric, Geophysical and Astronomical Administration (DOST-PAGASA). The data gathered did not indicate the specific rice variety and farming method applied, therefore, it is assumed that the study has considered only one rice variety and the traditional farming method. Figure 1 illustrates the framework of the study that was conceptualized from the studies of [16], [17], and [18].

Climatic, physical, economic, and technological factors are the key components affecting the productivity of rice production. Climatic factors refer to the level of water or rainfall and temperature that can cause either growth or destructiveness to rice productivity [16]. Although temperature affects rice production [19], it was not considered in the model since the temperature data is consistent throughout the region [12]. The physical factors are the farm size and soil type, which can affect the rice yield [18].

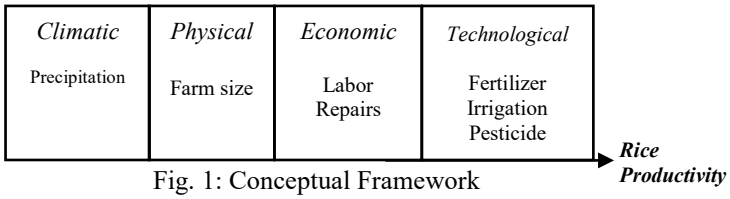

Fig. 1: Conceptual Framework

Although soil properties control lowland rice fields, [20] stated that the soil type in Central Luzon is constant all over the region, with soils having less than 3.8% organic matter due to the relatively low precipitation. Since the soil type is consistent throughout the region, the difference in their type is almost negligent. Therefore, only the farm size will be considered the physical factor in this study. Rice productivity brought about by economic factors varies with the cost of direct production. Labor refers to the total annual cost of hired labor [18] while repairs indicate the total annual cost of repairs on machineries [18]. The

technological factors such as the number of fertilizers used, the number of machineries rented, and total man-days represent the technology adopted and the applied level [18]. Urbanization determines the area of land converted to urban use. As urbanization increases, rice production decreases [21].

The data covered in the study was from 2002 to 2017. IBM SPSS Statistics Software 25was utilized to identify the factors of rice productivity using multiple regression analysis. The dependent variable, y, is the annual rice production of the region and is measured in metric tons, while the independent variables, x_1, x_2,…x_m, are the factors of rice productivity. $\beta 0$ represents the y-intercept, βn is the slope coefficient of the nth independent variable, and ε is the error of the residuals. Equation 1 shows the regression model.

$$y = \beta 0 + \beta 1X1 + \beta 2X2 + \cdots + \beta nXm + \varepsilon \quad (1)$$

Table I. presents the factors of rice productivity considered in the study. These factors include precipitation, farm size, fertilizers, pesticides, labor, irrigation, and repairs. The precipitation is the annual average rainfall, measured in millimeters (1mm = 1L of water per square meter). Farm size is the total rice farm size in hectares. Fertilizers are the average quantity of fertilizers applied per year, measured in bags of fifty kilograms. Pesticides, considered the average quantity of pesticides applied per year, are measured in bags of fifty kilograms. Labor is the total cost of hired labor, measured in Philippine peso per hectare. Irrigation is the total annual cost of irrigation, measured in the Philippine peso per hectare. Lastly, repairs are the total annual cost of repairs, measured in the Philippine peso per hectare.

Table 1: Factors of Rice Productivity

Factor	Description	References
Climatic	Precipitation – the annual average rainfall	[16]; [17]
Physical	Farm size – the total rice farm size	[18]; [22]
Economic	Labor – the total annual cost of hired labor	[18]
	Repairs – the total annual cost of repairs	[18]
Technological	Fertilizers – the average quantity applied per year	[18]
	Irrigation – the total annual cost of irrigation	[16]; [17]; [18]
	Pesticides – the average quantity applied per year	[18]

The study posited the following hypotheses:

H1: Precipitation significantly affects rice productivity.

H2: Farm size significantly affects rice productivity.

H3: Labor significantly affects rice productivity.

H4: Repairs significantly affect rice productivity.

H5: Fertilizers significantly affect rice productivity.

H6: Irrigation significantly affects rice productivity.

H7: Pesticides significantly affect rice productivity.

Several statistical tests were also performed such as test for normality and test for multicollinearity.

3. Results and Discussion

3.1. Statistical Analysis

The test for normality is needed to ensure that there is unbiasedness, consistency, and minimum variance in estimators [23]. The study applied the Shapiro-Wilk test, which considers the null hypothesis that the data came from a normally distributed population. The generated p-value of 0.445 indicates that the null hypothesis is not rejected, and the data tested are normally distributed. Multicollinearity is the existence of more than one exact linear relationship among some or all the independent variables in a regression model

[23]. The Variance-Inflating Factor (VIF) values were computed to test for multicollinearity and measure the speed with which variances and covariances increase. The value of 9.96 for mean VIF suggests no multicollinearity exists in the model since it is less than 10 [23].

3.2. Factors of Rice Productivity in Central Luzon

Table II presents the summary of regression analysis. It can be observed that farm size, irrigation, and pesticides factors have significant contributions to rice production, with p-values of less than 0.05. Thus, hypotheses H2, H6, and H7 are accepted.

Table 2: Result of Final Regression Model

Factors	Coefficients	p-values
precipitation	-107.315	0.948
farm size	7.036	*0.048*
labor	-6.347E-5	0.729
repairs	0.000	0.209
fertilizer	1.775E-5	0.844
irrigation	0.003	*0.030*
pesticide	-0.004	*0.016*

Farm size plays a critical role in agricultural sustainability. Contrary to the prior expectation of a previous study that farm size should take a negative sign because of the inverse relationship of farm productivity and farm size as explained by [7], farm size in the final regression model surprisingly took a positive sign in the case of Central Luzon. An increase in labor will not increase the rice yield if there is an insufficient land area to cultivate [8]. Fertilizers, meanwhile, can only be applied up to a certain amount. Over-application of fertilizers can be detrimental to crops and even increase rice susceptibility to pests and diseases [24]. Like the findings of [25], pesticides also significantly affect rice productivity. Although pesticides do not guarantee the increase of yield, it prevents the destruction of crops due to pests and diseases [24]. Consequently, this preventive action enables the farmers to minimize the possible damages and losses brought abought by pests and crop diseases. However, extensive pesticide use by farmers should be avoided to minimize environmental risks for soil, water, and air [26] and various health issues in human beings [27]. Equation 2 presents the final regression model. From the correlation results, the R-squared value of 0.948 indicates a strong relationship [28].

$$\textit{rice productivity} = 881240.285 + 7.036\ \textit{farm size} + 0.003\ \textit{irrigation} - 0.004\ \textit{pesticides} + 158003.831 \quad (2)$$

Since farm size, irrigation, and pesticides have been identified as significant factors in increasing rice production in Central Luzon, it is essential to recognize the existing and potential problems affecting each factor. This can help address the problems and further discover opportunities to increase rice yield. Industrialization and urbanization are the primary reasons for the decrease in available farmland in the Philippines and other countries. Industrialization occurs when a country transitions from an agrarian economy to manufacturing goods for individual and business consumption [29]. It includes societal change, such as when farmers leave jobs for other occupations due to unsustainable incomes. [30] reported that the study of the National Economic and Development Authority (NEDA) revealed that most agricultural workers in Central Luzon have permanently migrated to pursue jobs in other industries to gain a more stable income, resulting in a decrease in farm laborer and rice production as well. As urbanization takes place, the cities begin to expand when the high-density urban population spreads to lower-density suburban areas, and when this happens, lands used for agriculture are converted to residential use. This land reclassification also entails the need for more infrastructure, such as recreational buildings and roads, where even more agricultural lands are compromised to accommodate the expansion. Hence, any increase in urbanization decreases rice production [21]. Adjustments on salary wage should be made to properly compensate and prevent the continuous decline of agricultural workers. The daily wage of farmers who are usually situated in provinces should be comparable with the legislated daily minimum wage in the National Capital Region (NCR) to motivate the

farmers to stay and continue land cultivation in the province. Although [31] reported that increasing the minimum wage for farmers could increase rice prices if the agricultural employment rate is to be kept constant, [32] however, claimed that this negative impact could be offset if the supply of workers in other industries decreases due to the decrease in migration of agricultural workers and this can eventually lead to an increase in labor cost. Although urbanization cannot be prevented, the local government should also ensure that policies on farmland conversion are appropriately implemented to minimize the rapid trading and transformation of arable lands. Central Luzon can also increase its rice production by addressing the existing problems on current irrigation systems. According to [33], rice production in the Philippines is lower than in neighboring countries in Southeast Asia. This low productivity is attributed to the underutilization of land brought about by water supply issues and the low efficiency of existing irrigation systems. The same study also indicated that most of the existing irrigation systems in the country are already old and deteriorated and suffer from inappropriate designs and poor maintenance. Another reason is the damages brought by extreme weather conditions, where, unfortunately, irrigation facilities are not rehabilitated immediately due to the lack of funds [33]. Hence, it is suggested that the national government formulate strategies and programs that would address the various issues such as irrigation design and maintenance, training of farmers on proper irrigation systems, and improvement of water supply on rice lands. The government should also allocate appropriate budget for pesticides to financially aid the farmers in controlling pest and harmful diseases to crops. In addition, farmers should also be oriented and trained on the proper application of pesticides since excessive amount could harm both the environment and the human health.

4. Conclusion

The growing population of the Philippines requires the conduct of a rice sustainability study. A 16-year data on various factors such as precipitation, farm size, fertilizers, pesticides, labor, irrigation, and repairs were gathered from various government institutions to identify the significant factors that affect rice productivity. The multiple regression analysis results indicate that farm size, irrigation, and pesticides are the most critical factors that affect rice production in Central Luzon. The study also revealed that industrialization and urbanization significantly influence the decrease in farmland and migration of farmers. The rapid population and economic growth bring about the conversion of arable lands into commercial and residential spaces. Farmers migrate and look for other jobs that could give them a more stable income, nonwage benefits, and better working conditions, which are not readily available in the agriculture industry. The study proposes an increase in farmers' daily wage rate and makes it comparable to the wage rate in urban areas such as the NCR to encourage them to remain and continue land cultivation in the province. In addition, to minimize the impact of urbanization in the agriculture industry, the local government should also ensure that policies on farmland conversion are properly implemented to minimize the rapid trading and transformation of arable lands. Appropriate budget allocation for pesticides, training farmers on proper pesticide application, and instituting projects and improvements on the current irrigation systems in rice farming are also recommended to improve rice productivity. Future studies on rice productivity at a national level may be conducted using other theories or methods and may consider other factors not included in the study, such as rice farming and harvesting methods, machinery, pesticides, climate season, and other factors.

5. References

[1] N. Y. Tibao, “Why does the Philippines Import Rice: A solution to the Rice Shortage,” National Chung Hsing University, n.d.

[2] M. Layaoen. “Rice Supply Adequate for 2020”, Department of Agriculture, 2020. Retrieved April 2, 2021, from: https://www.da.gov.ph/rice-supply-adequate-for-2020

[3] Philippine Statistics Authority (PSA), “Ten Regions Expected to Grow Faster Than the National Average,” 2015.

[4] Y., Chen, B. Huang, & H. Zeng, “How does urbanization affect vegetation productivity in the coastal cities of eastern China?”, Science of The Total Environment, vol. 811, 152356, 2022. Doi. https://doi.org/10.1016/j.scitotenv.2021.152356

[5] M. Yokohari, A. Murakami, Y. Hara, & K. Tsuchiya. “Sustainable Landscape Planning in Selected Urban Regions”, Springer, 2017.

[6] J. Maclean, B. Hardy, & G. Hettel. “Rice Almanac”, 2013.

[7] D. Gollin. “Farm Size and Productivity”, IFAD, Oxford University, 2018.

[8] S. M. Helfand & M. P. H. Taylor. “The Inverse Relationship between Farm Size and Productivity: Refocusing the Debate,” Food Policy, vol. 99, 2021. Doi: https://doi.org/10.1016/j.foodpol.2020.101977

[9] J. D. Caro, J. “Why is there a Rice Crisis in the Philippines?, CNN, 2018. Retrieved April 1, 2021, from: https://cnnphilippines.com/business/2018/09/07/rice-crisis-explainer.html

[10] E. Hernandez. “Innovative Risk Management Strategies in Rural and Agricultural Finance,” Food and Agriculture Organization of the United Nations, 2017.

[11] Department of Agriculture and Fisheries Information Division (DAAFID), “Flood Tolerant Rice Varieties: A Steadfast Partner Towards Achieving Food Security Amidst Climate Change,” 2018.

[12] Department of Science and Technology - Philippine Atmospheric, Geophysical and Astronomical Administration (DOST-PAGASA), “About Tropical Cyclones,” 2021.

[13] T. Facon, “Water Management in Rice in Asia: Some Issues for the Future,” FAO Regional Office for Asia and the Pacific, n.d.

[14] R. A. Cuyco, “NNC Region III Profile,” 2020.

[15] M. M. R. Tinio, “Nueva Ecija: An Urbanizing Rice Granary,” 2013.

[16] A. Bowen & J. Pallister, “Understanding GCSE geography: For AQA Specification,” 2006. A. Harcourt Education Limited.

[17] V. P. Dek, T.D. Xuan, & T.D. Khanh, “Influence of Climate Factors on Rice Yields in Cambodia,” AIMS Geosciences, vol. 3, issue 4, pp. 561-575, 2017. doi: 10.3934/geosci.2017.4.561

[18] S. Wong & E. Geronimo-Kue, “Variations of factors Affecting Rice Productivity in Central Luzon,” Geojournal, vol. 6, pp. 469-476, 1982. doi: https://doi.org/10.1007/BF00185350

[19] N. Korres, K. Norsworthy, N. Burgos & D. Ooesterhuis, “Temperature and Drought Impacts on Rice Production: An Agronomic Perspective Regarding Short- and Long-term Adaptation Measures,” Water Resources and Rural Development, vol. 9, pp. 12-27, 2016. doi: 10.1016/j.wrr.2016.10.001

[20] J. Magahud, R. Bayados & P. Sanchez, “Soil Properties of Major Irrigated Rice Areas in the Philippines,” Asia Life Sciences, vol. 25, issue 1, pp. 291-309, 2016.

[21] G. F. Winfield, “The Impact of Urbanization on Agricultural Processes,” The ANNALS of the American Academy of Political and Social Science, vol. 405, issue 1, pp. 65–74, 1973. doi:10.1177/000271627340500108

[22] C. Ren, S. Liu, H. Van Grinsven, S. Reis, S. Jin, H. Liu, & B. Gu, “The impact of farm size on agricultural sustainability,” Journal of Cleaner Production, vol. 220, pp. 357-367, 2019. https://doi:10.1016/j.jclepro.2019.02.151

[23] D. N. Gujarati & D. C. Porter, “Basic Econometrics,” 5th Edition, McGraw-Hill Irwin, 2009.

[24] International Research Rice Institute (IIRI), “Steps to Successful Rice Production,” ISBN 978-971-22-0313-8, 2015.

[25] M. J. Mariano, R. Villano, & E. Fleming, “Technical efficiency of rice farms in different agroclimatic zones in the Philippines: an application of a stochastic meta-frontier model,” Asian Econ. J., vol. 25, issue 3, pp. 245-269, 2011.

[26] G.-P.-P. Govindharaj, B. Gowda, R. Sendhil, T. Adak, S. Raghu, N. Patil, A. Mahendiran, P. C. Rath, G. A. K. Kumar, & C. A. Damalas, “Determinants of rice farmers’ intention to use pesticides in eastern India: Application of an extended version of the planned behavior theory,” *Sustainable Production and Consumption*, vol. *26*, pp. 814–823, 2021. doi: https://doi.org/10.1016/j.spc.2020.12.036

[27] M. F. Jallow, D. G. Awadh, M. S. Albaho, V. Y. Devi, & B. M. Thomas, “Pesticide knowledge and safety practices among farm workers in Kuwait: results of a survey,” Int. J. Environ. Res. Public Health, vol. 14, p. 340, 2017.

[28] J. F. Hair, G. T. M. Hult, C. M. Ringle, & M. Sarstedt, “A Primer on Partial Least Squares Structural Equation

Modeling (PLS-SEM)," SAGE Publications Ltd, Thousand Oaks, CA, 2014.

[29] E. E. Opoku & O. A. Aluko, "Heterogeneous Effects of Industrialization on the Environment: Evidence from Panel Quantile Regression," Structural Change and Economic Dynamics, vol. 59, pp. 174–184, 2021. doi: https://doi.org/10.1016/j.strueco.2021.08.015

[30] K. Ocampo, "Where Have PH Farmers Gone," Inquirer, 2019. Retrieved July 14, 2021, from: https://newsinfo.inquirer.net/1190760/where-have-ph-farmers-gone-neda-tracks-7-yr-dip-in-agri-labor
S. Dludla, "Agriculture Warns of Devastating Impact of Minimum Wage, 2021.

[31] M. Fan & A. A. Pena, "Do Minimum Wage Laws Affect Those Who are not Covered?: Evidence from Agricultural and Non-agricultural Workers, PLoS ONE, vol. 14, issue 10, e0221935, 2019. doi: https://doi.org/10.1371/journal.pone.0221935

[32] Asian Development Bank, "Country Partnership Strategy: Philippines," 2011.