Land Conversion and Industrialization and its Impact on Crop Production

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Abstract— *Agriculture, specifically crop production, is a crucial driver of prosperity in the Philippines, contributing to economic growth, employing 36% of the workforce, and ensuring food security. Palay is Central Luzon's most widely grown crop, making it the country's largest producer. Crops like palay do not grow on their own; a variety of factors, such as arable land availability, urbanization, and agricultural mechanization influences them. Therefore, this study examines the effect of selected agricultural input on palay production in Central Luzon from 1970 to 2019, with CobbDouglas production function as its basis. The adopted methodology is the unit root test by the Augmented Dickey-Fuller (ADF) approach, a test for long-run relationship (Johansen cointegration), and the Ordinary Least Squares (OLS) multiple regression method. The study would like to know how the chosen input will affect the output of palay production in the area. The study indicates that the variables are stationary. Land use conversion and Agricultural mechanization show that it significantly affects palay production in the region. Considering that the area is well suited for crop production, the governing bodies should urgently establish and impose policies that cultivate agricultural development to support the country's food security and economic prosperity.*

Keywords— Agricultural Mechanization, Agriculture, Central Luzon, Crop Production, Land Use Conversion, Urbanization.

I. INTRODUCTION

Crop production is one of the main activities classified as agricultural output. It is the process of cultivating crops for both domestic and commercial consumption. Nemethova et al. (2022) further defined it as a branch of agriculture that focuses on growing crops on the land. Factors such as the availability of arable land, agricultural technology, yields, macroeconomic uncertainty, consumption patterns, and crop genetic potential play a significant role (Organisation for Economic Co-operation and Development, 2017). It is critical to understand how to manage these factors in agricultural practices as they play an essential role in ensuring the nation's food security (Kumar et al., 2023). As a developing country, land is a scarce variable that plays a vital role in the nation's advancement. According to De Maria (2019), it is a commodity for almost every output known to humanity. Given the country's soil, tropical climate, and prosperous farming culture, it is best positioned for agricultural activities. Agriculture is the Philippine economy's backbone, contributing significantly to the country's economic output. The crop productivity in the country was 3% in 1970, but has declined to 2.3% in 2020 (Evenson & Sardido, 1986; Philippine Statistics Authority, 2020). In the period 1960s to 1969 it is seen that the agricultural sector contributes most in the Gross Domestic Product (GDP) in the country, with a contribution of 4.2% in the GDP of 4.7% (Briones, 2021). However, as time progresses it placed at the third spot in contributing most in the GDP from 2012 to 2022 (Statista, 2024). The country's population is rapidly increasing, inextricably linked to social and economic services such as housing, health care, educational institutions, recreational facilities, and office buildings (Liu, 2018). As a result, conflict among different industries regarding land use may arise, such as unplanned land use, which impedes the nation's growth.

Azadi et al. (2018) defined land use conversion as the transformation of agricultural land for urban development. It is the process of changing the current physical use of a piece of agricultural land into a non-soil cultivation use. Currently, neoliberalism, a political-economic practice, has spread throughout the country due to structural adjustment programs. It accelerated capital accumulation and dispossession and reshaped land and agrarian relations, promoting economic growth by protecting private property rights, free markets, and free trade (Imbong, 2021). Such ideology frequently serves the interests of foreign and large corporations (Dizon, 2020). Ariola and Park (2014) stated that many agricultural lands in Metro Manila's neighboring regions have been converted to promote economic development and improve infrastructures, adapting to global competition. However, land conversion poses significant challenges because it comes after the loss of agricultural land, threatening the Philippines' palay production and food security.

Central Luzon, the Philippines' rice granary and the major rice producer, is a prime example of rapid land conversion for urbanization and slow land distribution for agricultural farming (German et al., 2022). According to Kajisa et al. (2022), the region's farm size of 2.54 hectares in 1970 has decreased to 1.79 hectares in 2020. With its ideal conditions for maximum development and growth of crops, it contributes 18.7% of the country's rice basket; however, it is the region that has the largest area of converted lands (Navarro, 2023). Also, the region's farmlands are declining by 5% due to land conversion according to Fair Finance Asia, (2021). Currently, the country's largest producer of palay has been regarded as the "next frontiers" of Philippine urbanization, becoming the center of the ongoing development of the roadworks of the Alviera and Clark Green City (CGC) projects despite being ideal for agricultural production (Campos, 2016). Hence, there is an observed misalignment between the supposed land use of Central Luzon and the region's current development trajectory.

In addition, Central Luzon is experiencing rapid urbanization due to Metro Manila's northward urban expansion. According to Harini et al. (2012), such economic activity is increasing in tandem with growth in population, making it difficult to avoid competition for land utilization between farming and other industries. People now require housing as a consequence of these developments. As a result, several real estate developers have been eyeing the region to expand their projects, and they are now taking over Central Luzon. Thus, the conversion of land from agricultural to non-agricultural land use is becoming increasingly prevalent. Such occurrence may result in countless investors looking to profit from non-agricultural development in the region (Cabildo et al., 2017). Moreover, it has improved the economic corridors stretching through Central Luzon's provinces, creating a strategic market access system and boosting regional growth leading to flourishing of business and financial activities (Rosete & Eleria, 2020). However, every economic activity involves a trade-off. For instance, rapid urbanization caused by the desire for economic advancement aggravates the country's limited resources. Land use conversion might be a major factor in reducing agricultural lands in Central Luzon, hampering palay production in the region and potentially contributing to the Philippines' shrinking rice basket and compromising the nation's food security. Similar to the study of Long et al. (2018), Farmland loss poses a threat to food availability because it is the primary resource for ensuring food security.

In the agricultural context, industrialization is defined as the shift to traditional agriculture to modernization through technological progress (Yang & Zhu, 2013). According to Peng et al. (2022), agricultural machinery and tractors utilized as capital assist in transforming ways of farming. Mechanization saves time and effort in farming operations, increasing agricultural efficiency and productivity (Rodriguez and Piadozo, 2016). As a result, farmers carry out their tasks more efficiently and accurately, resulting in lower labor intensity, increased safety and comfort for agricultural workers, and less crop waste. Moreover, utilizing machinery in agricultural activity not only boosts productivity but also alleviates the burdens of manual labor, primarily when fewer people work in agriculture, caused by rural-urban migration and the aging farming population (Dela Cruz & Bobier, 2016).

In Asian middle-income countries, the structure of the agricultural sector is changing rapidly alongside mechanization (Dawe, 2015). Over the past 50 years, Asia has shown substantial progress in agricultural machinery; over the last three decades, a significant correlation between farm power availability and productivity in countries like China, Pakistan, India, and Bangladesh has been observed (Rehman & Khan, 2019). However, mechanization is not happening uniformly across all countries. For instance, the Philippines falls behind since the utilization of machinery is not seen as urgent due to rural landlessness, keeping labor productivity and income for rural workers low (Mataia et al., 2016). It suggests that mechanized farming in the Philippines is emphasized when there is only land to cultivate crops. Thus, it is observed that most machines available in the Philippines were utilized to cultivate rice and corn, the predominant grain crop grown in the country (Dela Cruz & Bobier, 2016).

Although several studies have been conducted on the relationship between land use conversion and agricultural industrialization on crop production, most of these studies have concentrated solely at the national level, with a few focusing on Central Luzon specifically. In addition, only a few studies have considered Central Luzon's (Aurora, Bataan, Bulacan, Nueva Ecija, Pampanga, Tarlac, Zambales) accelerated urbanization due to Metro Manila's northward development and the existence of the Philippines' largest homebuilder in studying the region's crop production index.

The study will be beneficial as it can provide essential information and raise awareness on the current status of the country's agricultural production in light of rapid urbanization in Central Luzon, whether positive or negative. Since Central Luzon is the country's largest rice producer, it is imperative to comprehend the factors that affect it to maintain consistent food security. The study's findings can contribute to future studies, such as the economic and environmental implications of land use conversion among agricultural lands. Moreover, it can provide additional information in the field of academics, which may extend to developing policies that will balance urban expansion and agricultural sustainability. It can also provide the researchers an extensive knowledge about the crop production situation in the region that could be useful in their future studies in the agricultural industry in the Philippines.

The research explores whether the production theory is evident in Central Luzon's agricultural industry. According to Cobb and Douglas (1928), the production theory implies that a change in input results in a change in output units. Hence, the development of the factors of production plays a significant role in the crop production of the region. In addition, using time series data, it investigates the effects of the (IV1) land use conversion to the (DV) crop production of the Central Luzon region, the (IV2) Urbanization Level on Central Luzon region (DV) crop production, and the (IV3) quantity of agricultural machinery and tractors available for the (DV) crop production of the region of Central Luzon with 50 observations. This data analysis will be carried out regionwide to ensure a thorough analysis and conclusion. Specifically, the current undertaking seeks: to investigate the effect of land use conversion on crop production (palay) in Central Luzon; to investigate the effect of the rise of the urbanization level on crop production (palay) in Central Luzon; to investigate the effect of agricultural mechanization and industrialization on crop production (palay) in Central Luzon.

The study will concentrate on the effects of land conversion, urbanization level, and industrialization of agricultural machineries on crop production, specifically in Central Luzon. The study's data will come from secondary sources and publicly available statistics. It will only validate the impact or relationship between the three independent variables, land use, conversion and industrialization, on the crop production index, and will not address the effects or consequences of such independent variables. The survey's focus on palay production in general limits its ability to narrow down to specific crops. Moreover, the data covered in this study spans 50 time periods, commencing from 1970 to 2019.

II. REVIEW OF RELATED LITERATURE

Crop production is heavily reliant on production factors; hence, understanding the factors influencing it is critical for improving and strengthening its role in the country. One theory that addresses this issue is the theory of production. Cobb and Douglas (1928) stated that the theory of production investigates the interdependence of production factors such as land, labor, capital, entrepreneurship, and the yield of goods and services. Increasing an input (factors of production) will result in a corresponding change in output units. As such, this study will focus on two agricultural production factors: land and capital, specifically land use conversion, the expansion of housing projects, and agricultural machinery.

2.1 Crop Production:

The agricultural sector dominates the Philippines' economy, with food crops accounting for two-thirds of total output. According to Nemethova et al. (2022), crop production is the branch of agriculture that deals with crop cultivation on land. It is primarily a farming activity that generates crops for food and fiber. Some of the most popular crops in the country are rice, corn, and sweet potatoes (Cagasan & Dogello, 2021). In the Philippines, fruit and vegetable production has increased significantly; double cropping of rice, corn, and some vegetables is standard in many areas but not universally (Cagasan & Dogello, 2021). As such, it is a staple activity in the Philippine economy, supporting exports and household consumption while also significantly contributing to the country's overall economic growth (Cagasan & Dogello, 2021; Velza et al., 2023). Moreover, crop production is the country's primary source of employment, employing 36% of the total working population (Asian Development Bank, 2016). As a result, it serves as the foundation for the country's economic growth and food security, emphasizing its importance to the country's prosperity (Parreno, 2023).

Palay is the most widely grown crop in Central Luzon, making the region the largest producer in the country (Fair Finance

Asia, 2021). Crops, such as palay, do not grow by themselves; they are influenced by a variety of factors, including arable land availability, macroeconomic uncertainty, and consumption patterns (OECD, 2017). Agricultural inputs such as planting materials, fertilizers, pesticides, and labor availability can also limit harvest volume. Furthermore, the presence of agricultural technology, machinery, equipment, and facilities impacts crop production (Velza et al., 2023). For instance, fuel, fertilizer, land rent, planting season, and land area all impact rice production and technical efficiency in region three (Koirala et al., 2014). With this, ensuring the quality and effective utilization of these factors is critical for successful crop productivity.

2.2 Land Use Conversion:

As the human population continues to grow, the competition for scarce resources such as land has become cutthroat. Calura et al. (2023) reported that Increasing population has caused agricultural lands to significantly shrink due to rapid urban expansion and growing demand for goods and services. Furthermore, this loss in agricultural land is especially severe in developing countries with an estimated reduction of 2.2 hectares in land per person every 12 years. Thus, land conversion in the Philippines is becoming increasingly prevalent to keep up with human growth. Harewan et al. (2023) defined land use conversion as the process of shifting a land's function to another. For instance, agricultural land such as the rice fields in Pampanga has been converted into residential areas. As a result, farm sizes in Central Luzon have decreased from 2.54 hectares in 1970 to 1.79 hectares in 2020 (Kajisa et al., 2022). The primary drivers of land conversion are rapid urbanization, increased population, economic growth, and infrastructure development; however, urban expansion remains one of the most significant contributors to the conversion of agricultural lands, with countless investors eyeing the area for earnings from this non-agricultural development (Mishra et al., 2021; Cabildo et al., 2017). Such urban expansion or rural urbanization is driven mostly by infrastructure developments such as highway construction (Song et al., 2016) and the movement of rural areas into large urban centers such as Metro Manila (Estacio et al., 2021).

While such activities aim to achieve industrial expansion goals and meet the needs of residential communities (Mishra et al., 2021), they come at a significant cost. Converting agricultural lands into residential, commercial, and industrial developments has resulted in a substantial loss of agricultural lands, serious food security concerns, environmental consequences, and social displacement. Furthermore, despite rice being a staple food of three-fourths of the country's population, there is still an inability to meet the Filiino's rice demands. As such, the country has become the world's second-largest rice importer, and nearly 51 million suffer from food insecurity (Food and Fertilizer Technology Center for the Asian and Pacific Region, 2019). Furthermore, the conversion of agricultural lands has resulted in environmental degradation, such as erosion, landslides, climate change, pollution, and social displacement, putting Filipinos' livelihoods at risk (Mishra et al., 2021).

2.2.1 Land Use Conversion on Crop Production:

Crop production heavily depends on production factors such as land, which was established in the early centuries to serve an essential purpose in agricultural activities (Belous, 2022). According to Mf O. et al. (2022), the relationship between production and land size suggests that expanding farm size is another way to boost output. Land is recognized as a critical fixed factor in production and used as a commodity in almost every product known to humanity (De Maria, 2019). However, since areas on the outskirts of Manila are experiencing rapid urbanization and a growing economy, agricultural land has been converted for residential, business, and industrial development purposes, which may impede rural development. This phenomenon is called land use conversion, which is the transfer of land from one use to another, as well as the transformation from its natural state to human use (Phuc et al., 2014; Liu, 2018). Moreover, it is the legal process that changes a land's original use into a completely different purpose (Fulgar, 2023). For instance, the beneficiaries of comprehensive agrarian reform law in the country who acquired land for farming deemed to have a greater economic value if used for other purposes can convert their land into their desired purpose after five years that it is awarded to them (Department of Agrarian Reform, 1998).

Land supply scarcity and finite nature foster fierce land-use competition between agricultural and non-agricultural sectors, resulting in agricultural land conversion (Rondhi et al., 2018). The competition for land for other purposes, leads to a very limited potential for expansion of agricultural land (Eitelberg et al., 2014). Rapid urbanization and population growth are the primary driving forces for land use conversion, as well as environmental, geographical, and socioeconomic factors and the shifting from a rural to an urban society (Hassan, 2016; Van Vliet et al., 2015). For instance, the National Irrigation Authority (NIA) reported that Central Luzon had the most converted lands, with 111,079.46 hectares of formerly irrigated land converting to other purposes between 2012 and 2022. Worse, aside from the expansion of large urban centers and metropolitan areas, peri-urbanization and the spread of villages that consume more land per person has added as the culprit for larger amount of agricultural land loss which further constraints the capacity of the growing population to produce food (Van Vliet et al., 2017).

Converting agricultural land for development leads to forcing farmers to abandon farming, losing stable livelihoods and income (Zhang, 2014; Taer, 2024). In addition, conversion of farmlands to other uses has substantially depleted agricultural land and decreased crop production. The conversion of lands used for agricultural activities to urban use due to economic growth has resulted in a drastic decrease in crop production and a change in the agricultural landscape of the Metropolitan Manila area and urban fringes (Bravo, 2017). Since most cities are distributed on the neighboring agricultural lands, converting agricultural land into urban centers may cause land use and food conflicts in the future (Magsi et al., 2017). Moreover, these land use changes reduce arable land productivity by reducing the size of farms and decreasing the efficiency of the country's agricultural sector, resulting in a slow improvement in food security. (Ye et al., 2022; Lagare 2021). In addition, the loss of cultivable land due to land use conversion will pose a significant threat to crop production and food security (Dela Cruz & Bobier, 2016). Especially if the region is densely populated and there is less land available for farming, it would lead to food insecurity (Giller et al., 2021). Furthermore, it demonstrates that having less available land impedes agriculture and crop production (Nilsson, 2018). These losses of agricultural land due to conversion had also resulted in loss in crop production as a continued decline in crop production is seen because of the transitions that occurred (Skog & Steinnes, 2016; Ge et al., 2018). The selling of crops is the bread and butter of the farmers so when farmlands are shrinking so is the produced crops, resulting in a declining agricultural income (Noack & Larsen, 2019). Similar to the study of Giller et al., (2021), where it is discussed that shrinking arable land constrain agricultural production and income. Increased arable land availability has significantly improved grain yields, demonstrating that arable land availability influences agricultural productivity, specifically crop yields (Su, 2022; Dait, 2023).

In contrast to these studies, the spatial transition of farmlands can gradually create a spatial pattern that optimizes grain production and might also have some positive effects on conserving nearby farmland as new residents create new business opportunities for local producers (Ge et al., 2018; Qiu et al., 2015). Land use conversion having a positive or no effect on the crop production in the area might be because land is not the only factor involved in crop production. For instance, a more significant quantity of farm size is not the only factor influencing yields; factors such as irrigation and pesticides are also necessary in achieving crop productivity (German et al., 2022). Furthermore, not only does land size affect production, but so do highly industrialized methods that now have more extensive tracts of land to raise a narrow range of crops (Spangler, 2020). Moreover, the spatial transition of farmlands can gradually create a spatial pattern that optimizes grain production and might also have some positive effects on conserving nearby farmland as new residents create new business opportunities for local producers (Ge et al., 2018; Qiu et al., 2015).

2.3 Urbanization:

Urbanization has resulted in the depletion of arable land (Wang et al., 2019). As cities grow, competition for land between urbanization and food production (agriculture) increases (Van Vliet et al., 2017). Urbanization reduces the availability of land, which has a negative impact on staple crop production and yields. This urbanization is expected to continue, claiming millions of hectares of cropland (Andrade et al., 2022). Worse, rural areas are gradually urbanizing due to population growth and industrialization demands, causing farming activities to stagnate and agricultural output to decline (Yamagishi et al., 2021).

This is evident in the Philippines, which has undergone rapid urbanization, transitioning from an agrarian to an urban-centered society in just fifty years, and the effects of urbanization in the country have not produced the expected positive results compared to neighboring countries (Rob & Talukder, 2013). Furthermore, in the Philippines, urbanization is defined as expanding existing urban areas by transforming or converting neighboring agricultural lands into non-agricultural uses (Chaves et al., 2020). The ongoing urbanization and industrialization of the Philippines' provinces surrounding Metro Manila has resulted in a persistent decrease in productive agricultural land due to extensive conversion for industrial, commercial, and residential development (Estacio et al., 2021). Additionally, it increases commercial centers, residential subdivisions, and industrial and technological facilities, creating job opportunities and income sources for residents. However, it also puts pressure on agricultural lands, challenging locals to balance their basic needs while adapting to land use conversion and population growth (Bragais, 2022).

In Central Luzon, prime lands for agricultural activities must be sacrificed to satisfy the thirst for urban development (Tinio, 2013). According to Quimba and Estudillo (2021), the spread of urbanization forces in the region has significantly benefited its constituents by creating more employment opportunities outside the farming sector. However, since non-farm activities are now more appealing farming now becomes a non-primary source of income putting agricultural production in danger.

2.3.1 Urbanization on Crop Production:

Urban development is an antecedent to agricultural land conversion since it requires accommodating population growth and expanding cities. It is also driven by housing, infrastructure, and commercial space demand (Juarez et al., 2022). This is similar to the study of Dadi et al. (2016), where they indicated that agricultural land conversion mostly takes place to cater to infrastructure development and residential expansion. Liu (2018) stated that the rapid expansion of urban regions represents more than just a significant shift in land usage globally but also has significant impacts on rural areas that must be observed as it exacerbates issues associated with rural diseases that contribute to the depletion of agricultural land and occasionally has irreversible consequences. Thus, by 2030, it is projected to cause a decrease in global croplands, wherein Asia will encounter the most significant absolute decline in cropland (d'Amour et al., 2017). According to Yamagishi et al. (2021), rural areas gradually urbanize as development demands rise.

For the past two decades, urbanization in the Philippines has plateaued, with a slow pace indicating a higher rate of growth in the rural population than in the urban population (Bravo, 2017). Hence, urbanization in rural areas has resulted in a significant loss of arable land and depletion of high-quality farmland (Li & Song, 2019). It also coincides with rural settlements, which have a negative impact on cropland productivity because they frequently result in the construction of houses (Song & Liu, 2014). Similar to the study of Wang et al. (2018), in which the total amount of land used for rural settlements increased as demand for improved housing conditions increased. This results in the fact that urban development planning and execution in the Philippines have excessively prioritized housing (Navarro, 2016). Thus, intense urbanization, specifically residential expansion, directly impacts the capability to produce food (Gardi et al., 2014).

The urban expansion around Metro Manila will impact nearby regions like Central Luzon (Valerio, 2020). Central Luzon, located on the outskirts of Manila, has become a haven for real estate, commercial, and infrastructure development, but at the expense of farms and rice lands (Arceo-Dumlao et al., 2021). This owes to urbanization expanding to fertile areas that are great for farming; hence, direct competition for land arises between crop production and urbanization (d'Amour, 2017; Thebo et al., 2014; van Vliet et al., 2017). Urbanization causes cities to expand, leading to a need for enough housing to accommodate the growing urban population. As economic development increases, so does the demand for housing (Lall, 2015). This is observed with Central Luzon. During the year 2010, the region ranked third highest in population at 10,137,737 among the other regions, and in connection with this, the region ranked fourth highest in urbanization due to population at 51.6% (Navarro, 2016). Worse, residential expansion, such as housing areas, often has a negative impact on agricultural areas (Ahmed & Jackson-Smith, 2019). Residential expansion and infrastructure development are the main reasons for converting agricultural land, which reduces the size of cultivated land and crop production (Dadi et al., 2016). Existing residential zones frequently attract new housing developments, often surrounded by agricultural areas (van Vliet et al., 2013). Farmland conversion has reduced income sources due to farmers who till the land have been displaced for residential developments (Tufa & Megento, 2022). It also caused significant changes during the farmland requisition process, such as a transition from farmhouses to urban apartments, a shift in identity from peasants to urban residents, a shift in occupation from farming to non-farming jobs, and a change in resident structure from a single village to several. Such socio-spatial changes have gradually faded in urban areas as people move from rural villages to urban housing districts (Tufa & Megento, 2022).

In addition, these developments for both residential and commercial use have harmed farming and food production, resulting in a decline in agricultural activity (Osumanu & Ayamdoo, 2022). Furthermore, access to urban and rural farmlands is critical for food security, as prices are low when agricultural lands are plentiful (Tacoli., 2019). According to Waseem et al. (2019), crop production has been reduced due to the loss of agricultural land due to housing development. This may result in increased food prices due to reduced crop production. Less availability of agricultural land can further limit the food and crop production capacity (van Vliet et al., 2017). Crop production has decreased significantly as agricultural lands have been converted to residential areas (Cai et al., 2023). Similar to this, Wang et al. (2021) found that converting farmlands into residential areas reduced total crop production, leading to food insecurity and potential social unrest.

On the other hand, urbanization negatively affects agriculture as it takes over farmlands reducing food security and the expansion of the market allows cheaper options that hurt local farmers' produce and profits. Wang et al. (2021) indicated in their study that crop production increases with urbanization because urbanization has the potential to release rural land areas that were once occupied for residential use or housing. Moreover, a study by Omotoso et al. (2022) revealed that crop yields are higher in rural areas with developed infrastructure than those with less developed infrastructure. Additionally, such an occurrence may also result in economic benefits, such as many investors looking to profit from the region's non-agricultural development (Cabildo et al., 2017). Furthermore, the development of transportation infrastructure is not solely due to investments made by individual states/provinces. Furthermore, (Qiu et al., 2015) found that new residents create new business opportunities for local producers, which benefits the conservation of nearby farmland. Other research, however, has revealed a variety of perspectives on the impact of urbanization on crop production. According to Li and Li (2019), urbanization has both a positive and negative impact on agriculture. It was explained that urbanization positively impacts crop production because it brings scientific and technological advancements that help improve seeds, increase crop yields, and enable efficiency. These enable the movement of agricultural products from rural to urban markets and provide farmers with more opportunities to increase their income.

2.4 Agricultural Mechanization and Industrialization:

Agricultural mechanization is a critical component for running farm operations efficiently and productively. According to Zou and Qui (2017), introducing automated agricultural machinery in agricultural powerhouse countries such as China represents societal progress in meeting growing agricultural demands. Incorporating agricultural automation is an effective way to increase productivity, lower costs, and improve product quality in agricultural production. Furthermore, mechanization positively impacts the cost, output values, income, and return rate of all crops, as seen in Chinese agriculture (Peng et al., 2022). However, it's important to note that using agricultural mechanization is a complex process. While it is expected to increase agricultural output, it also leads to a decrease in other agricultural inputs, such as employment, as machines outperform humans in tasks (Rodriguez & Piadozo, 2016). Moreover, application of mechanization differs between developing and developed countries, wherein developing countries apply mechanized farming in order to alleviate challenges they face in their economy such as food security for a growing population (Emami et al., 2018).

Considering the Philippines' agricultural nature, adopting mechanization holds significant potential for reaping numerous benefits. However, the country's current mechanization levels are classified as low (Suministrado, 2013). Recognizing the importance of a mechanized agricultural sector, the Philippine government has started promoting its development by enacting the Agricultural and Fisheries Mechanization (AFMech) Law (Bautista et al., 2017). This shift towards mechanization has improved labor productivity, efficiency, cropping intensity, and global market competitiveness, lowering labor requirements and production costs through timely operations (Mataia et al., 2016).

Despite being referred to as the 'Rice Granary of the Philippines,' Central Luzon is falling behind in farm mechanization compared to other regions. By 2022, the region is expected to have a farm mechanization rate of 2.62 horsepower per hectare (hp/ha), mirroring the national trend of declining farm mechanization (Lagare, 2023). The primary reason for this is the lack of access to such machinery, which most farmers are hesitant to acquire due to the high costs of purchase and maintenance, as well as the need for more knowledge and training.

2.4.1 Agricultural Mechanization on Crop Production:

Mechanization is not just a tool but a key driver of global competitiveness in the agricultural sector. The deficiency in mechanization or technical support leads to decreased cultivated land and delayed agricultural production, creating a substantial loss in agricultural products (Mashkov et al., 2019). For instance, Ukraine's economy observed a decrease or loss of agricultural machinery, leading to a significant loss in their agricultural sector (Navrotskyi & Petrov, 2023). This underscores the crucial role of mechanization in the extension services offered to farmers or agricultural workers, directly impacting agricultural yield (Rodriguez & Piadozo, 2016).

Tractors, as one of the primary examples of agricultural mechanization, demonstrate the practical benefits of this technology. It is at the forefront of farm machinery and stands out arguably as the most crucial agricultural instrument employed in farming as it is versatile in performing various tasks which makes it the best implement in modern agriculture (Munar et al., 2021). With their positive impact on agriculture, the farming industry is recommended to preserve the existence of this agricultural machinery and increase its number of units (Peng et al., 2022). Specifically, tractors revolutionize labor efficiency, reduce dependency on human labor, and streamline agricultural operations such as plowing, cultivating, and smoothing, resulting in increased harvesting efficiency and the abolition of archaic farming methods (Turky et al., 2023).

The utilization of agricultural machinery such as tractors positively affects crop production in general agricultural production as observed in improved crop yields in Uganda (Epule et al., 2018). However, its effects may differ depending on the crop, as only rice crops benefit from mechanization (Takeshima et al., 2020). Singh (2015) similarly stated that the degree of mechanization to be utilized varies depending on which crop type is to be grown. With agricultural technology development playing a critical role in enhancing crop yields in agriculture, its vital application is necessary among agricultural countries such as the Philippines.

Despite being an agricultural country, the Philippines faces significant challenges, such as low productivity, which strains and hinders agricultural production (Cagasan & Dogello, 2021). Thus, the Philippine government has been dedicated to modernizing the country's agriculture, specifically the rural sector, where most originates (Calibuso et al., 2021). As part of the Philippine government's efforts to modernize its agricultural sector was to implement Republic Act 10601 or the Agricultural and Fisheries Mechanization Law of 2013 (AFMech Law), which aims to promote the adoption and utilization of agricultural mechanization technologies in order for the country's agricultural sector to be in line with its Association of Southeast Asian Nations (ASEAN) neighbors (Amongo & Larona, 2015). Enactments such as this presented an opportunity for technological innovation and paved the way for a transformative shift in the country's agricultural sector. Machineries as one of these technical innovations generated benefits such as increased crop yields (Cagasan & Dogello, 2021).

In 2011, 77% of the farm power utilized for rice production was supplied by mechanical power, playing a crucial role in the advancement of the country's rice industry (Dela Cruz & Bobier, 2016; Bautista et al., 2023). This is due to the fact that rice is a significant crop in the Philippines and that enhancement done on the productive and post-production systems is achieved through agricultural mechanization technologies (Amongo et al., 2018). Thus, farm machinery was found to be one of the incorporated inputs that increase the possibility of higher rice yield potential (Bautista & Minowa, 2010). It was reported that the two-wheel single tractor axle (2WT) is commonly produced and utilized in the Philippines (Singh, 2015). However, despite the mechanization in the Philippines, much is still to be improved. Although the Philippines produces 2WT tractors, as mentioned, the country still imports tractors from other countries (Singh, 2015). Despite the supposed positive effect of mechanized farming, the opposite or no effect may manifest as it may not be compatible with the farming conditions. Mendoza (2016) mentioned that the country imports numerous machinery that is not usually compatible with the country's local farming conditions as most farms are small and are usually situated on slopes that require smaller machines, yet the imported machines are large, which makes it unsuitable and may need necessary adjustments on its tires.

However, some studies disagree with the positive effects of machinery or mechanization on crop production. Such agricultural machinery has no significant effect on agricultural productivity, but rather farm size, pesticide application, and irrigation influence rice productivity (Ojiya et al., 2017; German et al., 2022). Moreover, similar to what was mentioned earlier, tractors are also a double-edged sword. Tractors influence environmental pollution by emitting exhaust gasses, which release harmful substances (Lovarelli & Bacenetti, 2019). Thus, implying that as tractors instigate the deterioration of the environment, it may create various challenges that may hinder optimal crop production.

Moreover, it's claimed that highly mechanized farms make greater profits than conventional farms because their output and income per hectare increase with mechanization degree (Rodriguez, 2016). Despite increased yield and thus a greater demand for harvesting and threshing these machines pose a danger to human capital because they decrease the amount of manual labor input, leading to comparatively steady person-days in this activity (Rodulfo Jr. et al., 2021). People may be more reluctant to enter the farming industry, and if farming is not thoroughly studied before employment, it could impede crop output.

Furthermore, the study by Parvin et al. (2022) shed light on another perspective of mechanization's impact, revealing that agricultural machinery can adversely affect soil quality specifically, how exertion of loads, pressure, and vibrations during machinery operations may lead to soil degradation, thus posing a significant concern for the productivity of growing crops. Similarly, Khafizov et al. (2021) mentioned in their study that the propeller of tractors causes soil compaction and, as a result, reduces crop yield. Additionally, a study by Ojiya et al. (2017) indicates that agricultural machinery yields no substantial impact on agricultural productivity. This finding from the study implies that adopting machinery may not lead to the expected increases in crop yields or overall agricultural output, as mentioned in other studies.

Crop production is a farming activity heavily dependent on labor, capital, entrepreneurship, and land. Several studies and scholarly articles confirm that certain factors influence crop production and that if the necessary conditions are met, crop production may be slow. For example, studies have shown that as the human population rapidly increases, so does the intense competition for finite resources such as land between urbanization and food production (Van Vliet et al., 2017). As a result, agricultural land for development purposes such as urbanization and residential expansion has become common throughout the country. This phenomenon is defined as land use conversion or the process of shifting a land's function to another. For instance, agricultural land such as rice fields in Pampanga had been converted into residential areas leading to the depletion of arable land (Wang et al., 2019; Harewan et al., 2020).

Land use conversion may be conducive to economic growth, but it can also reduce agricultural productivity, making the country's economy unsustainable. According to Mishra et al. (2019), agricultural land conversion has a cost, including significant land loss, serious food security concerns, environmental consequences, and social displacement. However, some studies show that land use conversion has little to no effect on crop production in the area, possibly because land is not the only factor in crop production. For example, larger farm sizes are not the only factor influencing yields; irrigation and pesticides are also required for crop productivity (Germna et al., 2022).

In addition, capital, such as agricultural mechanization, is required for farms to run efficiently and effectively. It is primarily found in leading agricultural nations, such as China, where the adaptation of agricultural machinery represents societal progress toward meeting agriculture's growing demand (Zou & Qui, 2017). This is because agricultural machinery has been shown to improve crop yields (Epule et al., 2018). Given the Philippines' agricultural nature, mechanization has the potential to provide numerous benefits. Moving toward mechanization increases productivity, efficiency, crop frequency, and competitiveness (Mataia et al., 2016). Notably, given that Central Luzon is the Philippines' rice granary, mechanization in farming is essential. Bautista and Minowa (2010) noted that incorporating farm machinery can help increase rice yields. As a result, this emphasizes the significance of studying land use conversion and agricultural mechanization in Central Luzon.

2.5 Theoretical Framework:

The theoretical framework in this study will be constructed on the CobbDouglas Production Function to illustrate how changes in the inputs affect the quantity of output produced.This production function illustrates the relationship between input and output, in which the input determines the output.According to Sinha (2023), CobbDouglas production in the sense of agricultural production encompasses crop production being dependent on variables such as the quantity and quality of land and agricultural technologies. In this study, the quantity of farmlands left due to land use conversion and urbanization and the quantity of available agricultural machinery are considered for the palay production of the region.

Based from the studies by Sinha (2023) and Singh et al. (2017), the Cobb-Douglas Production Function is as follows:

$$Q = AL^{\alpha}K^{\beta} \text{ or } Y = A_0 f(K^{\alpha}, L^{\beta}, N^{\gamma}) \tag{1}$$

Where Q or Y is the output, which in this case is the palay production. On the other hand, the inputs such as farm size, urbanization level, and agricultural mechanization are represented by $L, K,$ and N. Its elasticity is then represented by $\alpha, \beta, and\ \gamma$, which when summarized equates to 1 (Singh et al., 2017).The constant value of A or A_0 is for the total factor production. Taking into account that this may be a level of technology which is known as the "Total Factor Productivity" or the "Solow Residual" (Singh et al., 2017).

Kamanga et al. (2000) stated that choosing a function and deciding which factors to utilize involves some judgment, such as choosing the inputs that affect the output for a production function. Therefore, the production function needs to be simplified depending on the study. Thus, the Cobb-Douglas Production Function in this study will be transformed to a general form:

$$Y = AX_1^{a1}\, X_2^{a2}, X_3^{a3}, \ldots X_n^{bn} \tag{2}$$

Where Y is the quantity of output, which in this case is the palay production in Central Luzon. On the other hand, X_i are the inputs or the vector of variable resources with $i = 1,2,3, \ldots, n$. It is the levels of inputs (land conversion, urbanization level, and mechanization in the form of tractors) that affect the level of corresponding output or crop production. Moreover, the estimation of elasticity of the input X_i is estimated with A and a_i with i = 1,2,3,...,n.

Moreover, Kamanga et al. (2000) wrote in their study that in order to figure out the values for the constants (coefficients) to further understand the extent of how one influences the other involves transforming the general Cobb-Douglas production model into a linear equation will result to a logarithmic linear function as follows:

$$log\, Y = log\, A + a_1 logX_1 + a_2 logX_2 + a_3 logX_3 + \ldots + b_n logX_n$$

Or

$$log\, Y = B_0 + B_1 logX_1 + B_2 logX_2 + B_3 logX_3 + \ldots + B_n logX_n \tag{3}$$

The above general linear Cobb-Douglas production function will be tested for a multiple linear regression analysis to estimate the coefficients from the equation. Moreover, it will also be utilized since it is similar to the Double Logarithmic multiple linear regression.

As for the elasticities, in reference to the study by Singh et al. (2017), it can be done from the logarithmic form where the data set are converted to the natural logarithmic (base e = 2.71828…) or base 10. With this the value of A is $A = e^{B0}$. Similar to this, the values of a_1, a_2, a_3 are as follows: $a_1 = e^{B1}, a_2 = e^{B2}, a_3 = e^{B3}$.

Values of B_1 B_2 B_3 can be measured by getting the output elasticity of each inputs where $B_1 = (dY/dX_1) * (X_1/Y)$, $B_2 = (dY/dX_2) * (X_2/Y)$, $B_3 = (dY/dX_3) * (X_3/Y)$.

III. METHOD

Cobb and Douglas' (1928) production theory states that there is a relationship between the units of factor production and the units of output of goods and services. It is also demonstrated that if the number of inputs used changes, the units of output produced will undoubtedly change. The positive sign on the variable Agricultural Tractors (IV3) signifies a positive relationship between it and the dependent variable (Crop production). The negative sign on the Land Conversion (IV1) and Urbanization Level (IV2) denotes a negative relationship with the dependent variable (Crop production).

With the production theory as a foundation, the proposed research framework investigates the relationship between land conversion, agricultural tractors, urbanization level, and crop production. It would use the production function to investigate how independent and dummy variables influence crop production in the Philippines, specifically in Central Luzon.

3.1 Data:

The data used from 1970-2019. Data for the IV1 or the Land Conversion measured through Farm Size (Hectares) and the IV3 or the Industrialization/Mechanization measured through Adoption of New Technologies (%) were collected from the Central Luzon Loop Survey by the International Rice Research Institute (IRRI) Emerging-Economy State and International Policy Studies. Data for the IV2 of the Urbanization measured through Urbanization Level (%) were collected from the Urban Transition, Poverty, and Development in the Philippines journal by the Ateneo de Manila University, the Urban Population in the Philippines report by Philippine Statistics Authority (PSA), and Central Luzon Quickstat by PSA. The DV or the Crop Production measured through Palay Production (Metric Tons) was collected from the PhilRice website by the Department of Agriculture wherein data sources are from Philippine Rice Information System, PSA, PalayStat, World Bank, and DOST-FNRI.

3.2 Research Design:

This study utilized quantitative methods and time-series analysis to examine the impact of land use conversion for non-agricultural purposes and residential development on crop production in Central Luzon. It will also look into the impact of urbanization in the region and agricultural mechanization on crop production.

3.3 Research Method:

This study examined the relationship between palay production and land use conversion, urbanization, agricultural mechanization, and industrialization in Central Luzon. Therefore, the researchers used the following econometric model:

$$CP = \beta 0 - \beta 1LC - \beta 3U + \beta 2AM + e \quad (4)$$

where *CP* refers to Crop Production, *LC* refers to land conversion, *U* refers to urbanization and *AM* refers to agricultural mechanization. Land conversion and urbanization are expected to negatively impact crop production, while agricultural mechanization is expected to positively affect crop production.

With this, the researchers will use quantitative method analysis and time-series analysis to assess the long-term impact of variable land use conversion, the urbanization level, and agricultural mechanization and industrialization. Moreover, analysis on these variables will also serve to allow understanding of the complex interactions between them.

3.3.1 Unit Root Tests:

The study by Ojiya et al. (2017), which investigated the effect of agricultural input on agricultural productivity and is similar to the current study, will serve as a reference for the tests that will be conducted. This study will employ a time series test, specifically the Augmented Dickey-Fuller Test, which can detect and correct for nonstationarity in a time series. It will determine whether crop production is constant or varies over time. This test will examine the relationship between the independent and dependent variables during the period. Furthermore, since it yields consistently good results for time series with a higher number of observations, it will be employed for this investigation as a trustworthy unit root testing technique (Arltova & Fedorova, 2016).

Johansen Cointegration will also be used to determine whether the variables in the dataset have a long-term relationship with one another as stated in the study by Ojiya et al. (2017). Johansen's methodology takes its starting point in the vector autoregression (VAR) of order p given by:

$$y_t = \mu + A_1 Y_{t-1} + \ldots + A_p Y_{t-p} + \beta \chi_t + \varepsilon_t, \quad (5)$$

where A stands for the autoregressive matrices and Y_t is a vector of endogenous variables. The parameter matrices are represented by B, and the deterministic vector is X_t.

3.3.2 Ordinary Least Square Model:

After doing the augmented dickey fuller test, this study will now use an ordinary least squares model, specifically a multiple linear regression. According to Muraya (2017), establishing a production function is required to determine the individual or combined contribution of inputs to outputs. The general neoclassical production function: Y = F (X1, X2, X3,….Xn) or Y = F (LC, U, AM) for this study where Y is the output level, Xs are the inputs; in this study it is the land conversion, urbanization, and agricultural mechanization, respectively.

Furthermore, according to Muraya (2017), in order to eliminate the bias in the Cobb-Douglas production function, the formula can be converted by taking the logarithm of both sides. The transcendental logarithmic function (trans-log) is more flexible than the Cobb-Douglas production function. Thus, it is more suitable when estimating a complex production relationship. The ordinary least squares (OLS) technique can estimate this transformed function. The model can now be estimated using ordinary least squares (OLS) because its parameters are linear. With all of the variables in logs, this becomes a double log model which is as stated in the theoretical framework.

Furthermore, based on the theoretical framework, a double logarithmic regression will be utilized. By means of this, it will verify the percentage increase and decrease of the output or DV for every given 1% increase in the input or IV. Thus, the double logarithmic regression will be as follows:

$$\text{Log Crop Production} = \beta 0 - \beta 1 \log LC - \beta 2 \log U + \beta 3 \log AM + e \quad (6)$$

where log *CP* refers to log Crop Production, log *LC* refers to log land conversion, log *U* refers to the log urbanization and log *AM* refers to log agricultural mechanization. The log land conversion and log urbanization are expected to negatively impact the lpg crop production, while the log agricultural mechanization is expected to positively affect the log crop production.

3.3.3 Post Diagnostic Test:

Suphannachart and War (2011), who investigated the effects or impact of inputs on agricultural production or productivity, similar to the current study, used the autocorrelation test to validate the regression analysis. Autocorrelation will be determined by assuming that the model has no serial autocorrelation and that the alternative hypothesis is that the model has serial autocorrelation. If the value exceeds the p-value, then the null hypothesis is accepted. If the value is less than the p-value, the null hypothesis is rejected, while the alternative hypothesis is accepted. Autocorrelation will be tested to verify that the errors in the model are unrelated or that the error for one observation does not influence the error of another observation (Burton, 2021). Durbin-Watson is the most commonly used test for autocorrelation. However, the Breusch-Godfrey test has been shown to be superior to other autocorrelation tests for models with lagged dependent variables (Uyanto, 2020).

Uyanto (2020) presented the Durbin-Watson equation as follows:

$$d = \frac{\Sigma_{t=2}^{n} (\hat{u}_t - \hat{u}_{t-1})^2}{\Sigma_{t=1}^{n} \hat{u}_t^2} \quad (7)$$

Here the $\hat{u}_t^2$ represents the errors from the model in different times and the Durbin-Watson compares how these errors vary from one time to another. The squared difference compares the overall size of the errors. The value of d will always fall between 0 and 4. Values close to 2 means no autocorrelation in the model or errors are independent. Values close to 0 means positive autocorrelation or that the errors are related. Values close to 4 means negative autocorrelation or that the errors move in opposite directions.

Uyanto (2020) also presented the Breusch-Godfrey equation as follows:

$$Y_t = \beta_1 + \beta_2 X_t + u_t \quad (8)$$

The test figures out if the errors in the regression model are related to each other over time by running a secondary regression through this auxiliary regression:

$$u_t = a_1 + a_2 X_t + \hat{p}_2 \hat{u}_{t-2} + \ldots + \hat{p}_p - \hat{u}_{t-p} + \varepsilon_t \quad (9)$$

The above auxiliary regression will be done to obtain R^2 or the squared regression which is similar to calculating in any standard OLS regression wherein R^2 = 1 - (RSS/TSS). RSS is the residual sum of squares and TSS is the total sum of squares (Erickson, 2014). Asymptotically, once the R^2 is obtained, it can demonstrate the following equation below:

$$(n-p)R^2 \sim X_p^2 \tag{10}$$

The normality test adopted the Jarque-Bera statistics using the skewness and kurtosis of the derived ordinary least squares model.

The equation will be as follows:

$$JB = \frac{n}{6}(S^2 + \frac{(K-3)^2}{4}) \tag{11}$$

It will determine whether the dataset in the regression model follows a normal distribution. The normality will be determined by assuming the null hypothesis has normal residuals and the alternative hypothesis has non-normal residuals. If the value exceeds the p-value, then the null hypothesis is accepted. If the value is less than the p-value, the null hypothesis is rejected, while the alternative hypothesis is accepted.

Also, to ensure that the regression analysis was valid and reliable. Heteroskedasticity will be determined by whether the null hypothesis states that the model is homoscedastic or not, and the alternative hypothesis states that the model is heteroskedastic. If the value exceeds the p-value, the null hypothesis will be accepted. If the value is less than the p-value, the null hypothesis is rejected, while the alternative hypothesis is accepted. This test is applied to the study as heteroskedasticity determines the spread or variability of error, which can cause an error on the OLS done. Hence, there is a need to validate whether the model has heteroskedasticity or homoscedasticity to ensure reliability and efficiency in estimating the relationship of the variables (Mills, 2014).

Mills (2014) presented the heteroskedasticity equation as follows:

$$V(u_i) = E(u_1^u)\sigma^2 \tag{12}$$

Classical linear regression assumes that the spread of errors should be the same for all data points. This is what is known as homoscedasticity. If this is false and the spread of errors varies, then it is what is known as heteroskedasticity.

Furthermore, Sanaullah et al. (2020), utilized the Variance Inflation Factor (VIF) in testing multicollinearity in their study. The equation are what follows:

$$VIF = \frac{1}{1-{R_j}^2}; \tag{13}$$

$$VIF = \frac{1}{1-0.235642} \tag{14}$$

The R_j is the coefficient of multiple correlation between j and other regressors. When the variable is not correlated with other variables, the minimum value will be at 1.0. According to Neter, Wasserman, and Kutner (1990), a number larger than 10 is often interpreted as a value that suggests a significant degree of collinearity. Thus, it is recommended to check the biggest VIF as a diagnostic value for collinearity.

Suphannachart and War (2011) also used the Ramsey test for functional form misspecification (RESET) in their study. Thus, this test will also be used in the current study. The null hypothesis has no specification error, while the alternative hypothesis has one. If the value exceeds the p-value, then the null hypothesis is accepted. If the value is less than the p-value, the null hypothesis is rejected, while the alternative hypothesis is accepted. This test will be utilized to verify if the model being tested is indeed linear as nonlinearity may occur caused by various factors such as nonlinear relationship between variables or presence of outliers (Prabowo et al., 2020).

Prabowo et al. (2020) presented the Ramsey RESET equation as follows:

$$Y_i = \lambda_1 + \lambda_2 X_i + u_i \tag{15}$$

Starting with the original regression model, there's a pattern and there's suspicion the model needs improvement. To improve the model, new forms of the predicted values are added, such as squaring or cubing $\hat{Y}$ in order to validate if it explains the data better:

$$Y_i = \beta_1 + \beta_2 X_i + \beta_3 \hat{Y}_i^2 + \beta_4 \hat{Y}_i^3 + u_i \quad (16)$$

After, comparison of performance of the original model with the improved model is done using Ftest. If the new model is significantly better, reject the idea that the original model was enough, meaning that the model might be nonlinear.

$$F_{hit} = \frac{(R^2_{model2} - R^2_{model1})/k}{(1-R^2_{model2})/(n - p_2)} \quad (17)$$

IV. RESULTS AND DISCUSSION

TABLE 1
JOHANSEN COINTEGRATION (LINEAR AND DOUBLE-LOG) TEST RESULTS

Rank	EigenValue	Trace Test	p-value	Lmax test	p-value
0	24858	29.037	0.7667	14.004	0.8175
1	0.17132	15.033	0.7811	9.208	0.8131
2	0.10485	5.8252	0.7183	5.4276	0.6902
3	0.008083	0.39768	0.5283	0.39768	0.5283

The conducted Johansen Cointegration test for the linear and double-logarithmic model acquired the same results. Both models revealed that the alternative hypothesis is accepted at all ranks, wherein cointegration exists. It implies that the variables in the model exhibit a long-run relationship. Moreover, this implies that even if shocks were to occur in the short run and may affect movement individually, the variables would converge in time.

TABLE 2
ADF (LINEAR AND DOUBLE-LOG) TEST RESULTS

Variable	t-statistics	Prob.*
(First-Difference) Land Conversion	-6.80372	1.11E-09
(First-Difference) Agricultural Mechanization	-6.82516	9.73E-10
(First-Difference) Urbanization	-7.0336	2.69E-10
(First Difference) Crop Production	-9.48524	1.45E-17

To begin the long-run regression analysis, the study begins with unit root tests for stationarity of each model variable using Augmented Dickey-Fuller (ADF). The unit root test, conducted using the Augmented Dickey-Fuller (ADF) test, revealed that both models acquired the same results. The test revealed that there were no variables that were non-stationary across levels, and therefore the null hypothesis of non-stationarity across levels could not be rejected. Therefore, variables do not change when it encounters a shift in time and space.

TABLE 3
MULTIPLE OLS ON CROP PRODUCTION, LAND CONVERSION, URBANIZATION, AND AGRICULTURAL MECHANIZATION (1975-2019)

Variable	Coefficient	Std. Error	t-ratio	p-value
Const	0.0419833	0.019499	2.153	0.0374**
Land Conversion	0.559446	0.295141	1.896	0.0653*
Agricultural Mechanization	0.234659	0.137793	1.703	0.0963*
Urbanization	0.0097553	0.245462	0.03974	0.9685
Crop Production	-0.338355	0.138537	-2.442	0.0191**
● R-squared: 0.235642				
● Adjusted R-squared: 0.159207				
● F-statistics: 0.026472				

Log Crop Production $=\beta 0 - \beta 1$ log LC - $\beta 2$ log U + $\beta 3$ log AM + e (18)

The result of the regression analysis is shown in Table 3, illustrates the effect of land use conversion, urbanization level, and agricultural mechanization on palay production in Central Luzon between 1970 and 2019. The p-value of 0.0374 of the model, which is less than the alpha of 0.05, shows that the model is significant. Moreover, variables land conversion, agricultural mechanization, and crop production have resulted in 0.0653, 0.0963, and 0.0191 respectively, indicating that the variables are significant to the model. On the other hand, the variable urbanization level acquired a result of 0.9685, which tells us that it does not have significance to the model. In a nutshell, land conversion and agricultural mechanization can bring significant changes on palay production in Central Luzon, unlike the variable of urbanization level Specifically, land conversion decreases the palay production in Central Luzon which supports the studies by Bravo (2017), Dela Cruz and Bobier (2016), Nilsson (2018), Skog and Steinnes (2016), and Ge et al. (2018) that the conversion of agricultural land significantly reduced land available which impedes agriculture and results to decreased crop production. Because of this land use and food conflicts will rise (Magsi et al., 2017) and risk of food insecurity will grow (Ye et al., 2022; Lagare 2021, Dela Cruz & Bobier, 2016; Giller et al., 2021). However, mechanization has shown to increase the palay production in Central Luzon which supports the study by Epule et al. (2018) that the use of agricultural machinery, such as tractors, generally boosts crop production and leads to improved crop yields. As for the urbanization level, it shows that it is insignificant or that it has no strong effect on the palay production in Central Luzon.

This model also reveals that for every hectare of land being converted for non-agricultural activities, the palay production will experience a decrease of 0.05594 metric tons. Every one-percent increase in agricultural mechanization will correspond to a 0.2347 metric ton increase in palay production in the region. The OLS results revealed that the hypotheses that the increase in land conversion and the increase in agricultural mechanization will increase crop production have been proven correct. Hence, the hypotheses of both variables of the study were accepted.

TABLE 4
DIAGNOSTIC TEST ON CROP PRODUCTION, LAND CONVERSION, URBANIZATION, AND AGRICULTURAL MECHANIZATION (1975-2019)

	Normality Test	Breusch-Godfrey Test	Durbin Watson Test	White's Test	Breusch Pagan	RESET Test
Test Statistic: Chi-square (2)	6.67032	0.857489	2.12876	6.49452	3.97946	0.52118
p-value	0.0356089	0.360137	positive: 0.6877777 negative: 0.312223	0.889134	0.4008793	0.598003

Diagnostic tests serve as crucial to assessing the model involved to yield unbiased and non-misleading outcomes. The model was then tested for normality, serial correlation, heteroscedasticity, and stability (Table 4). In terms of the econometrics test, the p-value of the normality of residuals observed at the table is less than the alpha of 0.01, thus there is non-normality of residuals. Also, the p-value of the Breusch - Godfrey Serial Correlation LM test is greater than the alpha of 0.05, indicating that there is no significant first-order autocorrelation detected in the regression output. Moreover, the p-values of the Durbin Watson Test are both greater than the alpha of 0.05 showing that there is no significant autocorrelation, either positive or negative, detected in the regression output. This entails that the errors or residuals in the model are independent of each other (Burton, 2021). The p-value of the White's test is greater than alpha of 0.05, indicating that the model in the study is homoscedastic or there is no heteroskedasticity. Similar results were observed with the Breusch Pagan Heteroskedasticity test as the p-value is greater than the alpha of 0.05 which indicates that the model in the study is homoscedastic or there is no heteroskedasticity. This entails that the variance of error or residuals in the model is constant among all levels of the independent variables (Mills, 2014). Lastly, since the p-values of the RESET test are greater than alpha of 0.05, then there is no misspecification error in the regression output. This entails that the results of the model is more likely valid and likely that there are no nonlinear relationships between the variables (Prabowo et al., 2020).

TABLE 5
MULTICOLLINEARITY TEST (LINEAR AND DOUBLE-LOG MODEL)

Crop Production	1.011
Land Conversion	1.001
Urbanization	1.006
Agricultural Mechanization	1.005

The conducted multicollinearity test on the linear and double-logarithmic model accepts the null hypothesis that the model has no multicollinearity. Specifically, the model has low multicollinearity or is moderately correlated since VIF values are more significant than one but less than five.

V. CONCLUSION

Despite the Philippines slowly shifting its main contributor to Gross Domestic Product (GDP) from agrarian to service sector, the agricultural sector still plays a vital role in the country's economic position. Crop production has an integral role in the Philippines' economy. Agriculture has been the country's backbone for centuries, with Central Luzon as its leading contributor, earning the title "Rice Granary of the Philippines." It is responsible for employing 36% of the Filipino workforce, providing a continuous income stream, and allowing individuals access to their needs. Furthermore, the country is experiencing a growing population, which entails growing demands. Hence, the agricultural sector is vital to securing food security for this concern.

The main objective of this study is to investigate the effect of variables such as land use conversion, urbanization level, and agricultural mechanization on palay production in Central Luzon. Specifically to validate that the persistent land use conversion and urbanization in the Philippines negatively affect the crop production in Central Luzon. Moreover, it also aims to validate that the addition and utilization of mechanized farming positively affects crop production in Central Luzon. Furthermore, the study employs the Cobb-Douglas production function in another approach, wherein the production inputs to be utilized will substitute the traditional inputs on the function and instead have input factors such as land conversion, urbanization, and agricultural machinery.

The variables estimated through multiple regression analysis demonstrated that the decreasing farm size input, which results from land use conversion and the amount of available agricultural machinery, significantly impacts the growth of palay production in the region. The continuous land use conversion has negatively affected the palay production. On the other hand, the increasing availability of agricultural machinery has positively influenced the production of palay in the area. However, results showed that despite the region experiencing rapid urbanization, it does not significantly affect palay production.

Since Central Luzon is the country's major rice producer, the governing body should boost agricultural development in the region. Through establishing and enforcing land-use policies and zoning regulations that prioritize the protection of agricultural lands, as well as fostering collaboration among urban planners regarding sustainable urban development to prioritize the preservation of existing farmlands and reduction, or better, the avoidance of negative impacts on agricultural lands. It is also noted that adopting more mechanized farming positively affects the palay production. Hence, the adoption of agricultural machinery should be supported through subsidies or incentives among farmers to increase their productivity and efficiency to boost the production of crops and secure food for the growing population. These measures hold the promise of a more sustainable and productive agricultural future for Central Luzon. Moreover, the study provides future researchers knowledge to find strategies to balance the preservation of agriculture and the growing urbanization in rural areas. It may also create more nuanced knowledge and examine land conversion's effects on crops and geological areas. This could also extend to future researchers assessing how well different land management techniques preserve agricultural land and productivity in the face of increasing urbanization.

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