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Research Article

Status of Agricultural Mechanization in Ghana: Insight from Farmers' Perception, Population, and Nonagricultural Sector Growth

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The growing human population is a driver for higher food demands with a need to scale agricultural production and maintain security of the food supply chain. Thus, there is a need to increase the adoption and improvement of mechanized systems in agriculture, especially where needed labor is also drifting into nonagricultural production sectors. With this view, the relationship or link between population and employment in nonagricultural sector in Ghana (West Africa) to agricultural mechanization was tested to ascertain any such validity. This formed the primary basis for this study and furthered on to establish the current level of agricultural mechanization within the country through measuring effect of available farm energy sources on farm sizes under cultivation. The methods employed included a structured questionnaire administered to farmers and other agricultural stakeholders to determine the level of mechanization, readiness to adopt/accept mechanization technology, level of usage of mechanization technologies, and ownership of machinery. The Statistical Package for the Social Sciences (SPSS version 20) software was used to model and analyze data obtained including a multiple regression method for the relationship between parameters. The overall level of agricultural mechanization in Ghana was found to be very low with 77.6% of the farm operations being performed manually. The level of the tractor power availability in Ghana was found to have increased from 0.0207 kW/ha in the year 2004 to 0.0588 kW/ha in the year 2020 and is expected to increase to 0.0752 kW/ha in the year 2025. The power availability valued in this study was also found to be low compared with that in other developing countries. Statistically, both employment in the service sector and population growth were significant determinants (Adjusted $- R^2 = 0.9172$) in the variations in the level of mechanization of agriculture in Ghana and policymakers will have to make adjustments in policies to take note of these indicators most often underplayed. Advocacy for higher levels of mechanization of agricultural operations must increase as it is critical to the overall cost of production in agriculture as this study also found out that mechanized operations were between 21.3% and 53.8% cheaper than manual operations.

1. Introduction

Agricultural mechanization is the design, manufacture, distribution, and usage of farm machinery to ensure timeliness and thoroughness of operations leading to the production, handling, and value addition of agricultural products with the overall aim of improving security and sustainability in food systems [1–3]. The evolution of the farming system brought about an increase in and spread of agricultural mechanization, which came with increased levels of use of agricultural inputs. Apart from increased input use, agricultural mechanization also leads to higher labor demand and possible incorporating nonhuman sources of power. Due to the relatively higher initial cost of mechanizing farms to traditional farming methods, employment of mechanization is sometimes limited to certain farming activities and gradually improved to higher levels including labor requirements. Specifically, to Ghana, the use of mechanized systems of land preparation has gained prominence, which has resulted in reduced drudgery, and removed some bottlenecks in agricultural value chains [2, 4]. Land preparation and crop establishment operations have been identified to be the most power-intensive operations in earlier studies [5, 6]. They were also noted as the most critical for crop productivity, as they are time-bound [7].

Due to its unique edaphic qualities and flat geography, Ghana's northern savannah and middle belts are hot spots of smallholder agricultural mechanization [2, 4]. The Sudan and Guinea Savannah vegetation types make up the northern savannah zone, which stretches from the Bono and Ahafo Region's transition zone to the five administrative regions north of Ghana (Upper West, Upper East, Savannah, North East, and Northern Regions). The broad grassland with occasional trees dominates the rather flat area. The northern savannah's soils are mostly ochrosols and groundwater laterites, which are noted for their adaptability for growing food crops. The zone is excellent for tractor-based mechanization because of its unique biological circumstances, particularly the topography and vegetation [4]. The increased demand for mechanized technologies by smallholder farmers in Ghana has resulted in a distinct epoch of agricultural development marked by the introduction of major agricultural development programs such as the Agricultural Mechanization Services Enterprise Centers (AMSECs) and Fertilizer and Certified Seed Subsidy initiatives in the context of the broader agenda of achieving sustainable agriculture for Ghana [4]. As a result of these programs, government-run enterprises have also sprung up to provide farmers with tractor-based mechanized services [8].

According to [2], the demand for mechanization, particularly for land preparation, is high in Ghana due to a variety of agro-ecological conditions, population density, and nonfarm options. In trying to establish the main drivers for adoption and increase in mechanization levels, Boserup's [9] research work sought to make a theoretical and empirical link between an increase in population and mechanization of agriculture. Boserup argued that agricultural systems' evolution and technology use under various farming systems are endogenous processes in which population growth is the main determinant. She argued that mechanization, which is labor-saving, would be adopted where there is a growing demand for output either because of population growth or because of growth in the nonagricultural sector. She hypothesized that labor-saving technology will be demanded (1) at constant total population growth if labor is moving from agriculture to nonagriculture or (2) with faster population growth and limited food imports, leading to intensification of production. Beneath the concept that demand for mechanization grows as a result of labor scarcity, there is also the counterdemand for workforce in mechanized large farms due to operations, particularly such as weeding and postharvest, which are mostly handled manually in Africa. A source of power is rarely completely displaced by the other, but usually, manual labor, draught power, and tractor power tend to coexist [7]. In a similar fashion, Hayami and Ruttan [10] propounded the theory of induced innovation in technical change aimed at modelling the evolution of agricultural mechanization. In more recent times, Cossar [11] traced the paths of agricultural mechanization and intensification in northern Ghana. The empirical analysis by Cossar [11] found that population growth and travel time to the local urban center explain a significant and large proportion of the variation in machinery used by farmers. There have been other theoretical models developed by Farajian [12] and Ruthenberg [13] for farming systems' mechanization, energy use, and intensification. Farajian [12] used the Box–Jenkins methodology, which is based on a time series analysis to model agricultural consumption of energy for the period spanning from 1988 to 2014. The method has been touted as the most appropriate forecasting method in the area of agriculture (Oguz, 2013).

Many of these previous works have much focused on population growth and to a closer extent travel time to local urban centers as much of the basis for increasing mechanization levels without pointing out more curiously if that population is widely moving out of the agricultural sector and if so to which extent it affects mechanization. From an undefined role of workforce distribution away from the agricultural sector as being a key determinant in the agricultural mechanization drive, the relationship or link between population and employment in the nonagricultural sector in Ghana (West Africa) to agricultural mechanization remains unestablished and unemphatic. Hence, this study focused on ascertaining any such validity and its extent. Again, apart from the use of secondary data to theorize the relationship between agricultural mechanization and other factors such as population and service sector employment, there is the need to consolidate the appreciation of the rate of agricultural mechanization from the perspective of primary stakeholders as farmers. According to Amponsah et al. [15], information on farmer's knowledge and perception of mechanized interventions to modernized agriculture in Ghana is crucial in the development of the agricultural sector. Thus, this study also seeks to focus on the state of agricultural mechanization in Ghana as remarked by farmers. The perception of farmers on agricultural mechanization will help guide relevant stakeholders such as government, nongovernment organizations, the private sector, and engineers on the mechanization intervention that are appropriate for Ghanaian farmers [15, 16].

The objective of this study was to establish theoretical and empirical links between population growth and employment in the nonagricultural sector (also known as employment in the service sector) and the agricultural mechanization level (AML) in Ghana. The study also determined the effect of farm size and type of farm energy source on the level of mechanization in Ghana. The level (status) of mechanization of a country, which is a multifaceted parameter, depends on specific technical factors, agroclimatic factors, economic factors, and social conditions for which government's policy choices have influence. Ghana's few attempts to partner with the private sector to fix market failures along important value chains for some promising manufacturing and agricultural commodities have not been particularly successful [19]. The study will also paint a picture of how the aforementioned factors can be managed to transform the status of mechanization to a higher level for policy formulation.

2. Materials and Methods

2.1. Study Area and Survey. The study area comprises sixteen (16) administrative regions of Ghana (West Africa). Ghana is located at the coordinates of 7.9465 N, 1.0232 W with an area of 238,535 km^2. A survey to determine the level of agricultural mechanization based on stakeholders' perceptions in the (16) regions of Ghana was developed. The stakeholder population who were interviewed for the purpose of the survey were farmers, agricultural extension officers, and auxiliary staff within the Ministry of Food and Agriculture (MoFA). In all, the survey was administered to four hundred and eighty (480) respondents throughout Ghana. Thirty (30) stakeholders (people in the agricultural sector) were purposively sampled and interviewed in each of the 16 regions of Ghana. The interview of the stakeholders was carried out with the help of a questionnaire whose questions sought to find out, among other things, cost of some mechanization services, level of usage of mechanization technologies, ownership of machinery, and perceived level of mechanization and the frequency and the challenges associated with the usage of agricultural machinery. Furthermore, the respondent's readiness to adopt/accept mechanization technology was also assessed. The information obtained from the survey was processed using the Statistical Package for the Social Sciences (SPSS version 20) software.

2.2. Selection of Factors and Modelling. Modelling of the availability of tractor power based on factors such as the population and percentage of the population employed in the nonagricultural sector/service sector was done using the multiple regression method. The data for this purpose were obtained from secondary sources such as Statistical, Research and Information Directorate of Ministry of Food and Agriculture of Ghana, Ghana Statistical Service of Ghana, and Published Research Papers. The tractor power availability was determined by a product of the number of tractors in the country and the power rate in kilowatts divided by the total cultivated land area.

The multiple regression analysis method for modelling ensures maximal prediction of the dependent variable from the set of independent variables. This is usually done by least squares estimation. The data obtained from secondary sources were taken through identification (to determine the proper value for model parameters), estimation (to provide a numeric value for model parameters), validation/diagnostic checking (to decide on model adequacy), and forecasting (to get future values of the series) (Asteriou and Hall, 2011).

Mathematically, the level of mechanization of agriculture in Ghana (y) and the two predictors () can be specified using multiple regression analysis as follows:

$$y = \varphi_0 + \varphi_1 X_1 + \varphi_2 X_2 + \cdots + \varphi_k X_k + \varepsilon, \quad (1)$$

where y is the dependent variable; φ_0 is the y-intercept; φ_j are the coefficients of the $j = 1, 2, \ldots, k$ predictor variables; and x is the independent variable.

2.3. Validation of the Model. The model was validated by the level of mechanization computed using data published in past research work in this area of specialization, and secondary data from Statistical, Research and Information Directorate of Ministry of Food and Agriculture of Ghana, Ghana Statistical Service of Ghana. The multiple regression model was used to assess the impact of population growth and employment in the service sector on the level of mechanization of agriculture in Ghana as used by Baudron et al., [7] and Ani et al. [19]. The adequacy (goodness of fit) of the fitted model is assessed based on the adjusted R^2 and the standard error of regression (SER) at a 5% level of significance. All analyses were performed using the Statistical Package for the Social Sciences (SPSS version 20).

Table 1: Farm size and agricultural machinery ownership.

Farm size (acres)	Machinery ownership (%)	
	No	Yes
0–20	70.4	29.5
21–40	65	35
41–60	20	80
61–100	25	75

Table 2: Farm size and agricultural machinery ownership.

Farm size (acres)	Energy source (%)					
	Human	Biomass	Solar	Wind	Fossil fuel	Hydro
0–20	79.50	3.73	5.59	4.35	4.97	1.86
21–40	89.47	5.26	0	0	5.26	0
41–60	25	0	0	25	50	0
61–100	50	0	0	25	0	25

Table 3: Sources of farm energy in Ghana.

Sources of energy	Percentage of farmers using the source of energy
Human	79.1
Biomass	3.6
Solar	4.6
Wind	4.6
Fossil fuel	6.1
Hydro	2.0

Table 4: Percentage of farmers with their rated level of mechanization on farms and its detailed mechanized farming operations.

Level of mechanization on farms (%)	Land preparation	Planting	Weed control	Irrigation	Harvesting	Postharvest
	% of respondents					
80–100	7.0	0.0	0.5	2.3	0.0	1.6
60–79	5.0	3.0	1	3.8	1.5	3.7
40–59	6.1	1.5	5.7	10.0	1.0	5.3
20–39	10.1	10.7	16.6	13.8	12.3	10.6
0–19	71	84.8	76.2	70.0	85.1	78.7

3. Results and Discussion

The survey revealed that the size of farmland cultivated by a farmer is a factor in the decision of a farmer to own machinery or otherwise as shown in Table 1. The results showed that only 30% to 35% of farmers with farm sizes below 40 acres own agricultural machinery, while 75% to 80% of farmers with farm sizes of more than 40 acres own agricultural machinery in Ghana. This finding is consistent with the conclusion of a study by Schmitz and Moss [20], who discovered that there is a positive correlation between farm size and the adoption of mechanized agricultural technologies.

The size of the farm was also a factor in the source of energy used by farmers as depicted in Table 2. The source of energy relied upon by farmers with farm sizes less than 40 acres is largely human energy (between 80% and 90%), but the farmers with farm sizes of more than 40 acres use alternative or modern energy sources such as hydro-energy, fossil fuel energy, solar energy, and wind energy. Zhang et al. [21] in a related study found that farm size affects the amount and type of energy form used by the farmer.

The human energy was found to be the most predominantly used energy source in Ghana with 79.1% of farmers who partook in this study, indicating that they use it as shown in Table 3. The other sources of energy and the percentage usage were found to be fossil fuel energy (6.1%), solar energy (4.6%), wind energy (4.6%), biomass energy (3.6%), and hydro-energy (2.0%).

Results as shown in Table 4 also revealed that land preparation and irrigation or watering of crops were the most highly mechanized farm operations in Ghana with 12% and 6.1% within the high-level mechanized farms rated 60% or more. The least mechanized farm operations within that same levels (60% and above) were found to be weed control and harvesting, which recorded 1.5% each. The results are consistent with those of Diao et al. [2], Malanon et al. [22], and Ahmed and Takeshima [23], whose studies found that land preparation was the most highly mechanized farm operation, while harvesting and crop management were the least mechanized. Again, Baudron et al. [7] found that land preparation and crop establishment were the most mechanized, while weeding and postharvest operations were still heavily performed with hired labor. These results may hinge on the complexity of adopting mechanized weeding systems compared with land preparation, which is timeous and relatively power-intensive.

The overall level of agricultural mechanization in Ghana was found to be very low since averagely 77.6% of the farm operations are largely performed manually (below 20% of farm operations were mechanized). Agricultural policymakers will have to design policies that help modernize agriculture through the transformation of the level from manual systems to highly mechanized systems where averagely more than 60% of the farm operations will be mechanized.

Table 5: Multiple regression analysis statistics.

Model fit statistics	
Measure	Statistics
R-square	0.9283
Adjusted R-square	0.9172
Standard error of regression	0.00344

The modelling of the tractor power availability in Ghana revealed that the number of people in Ghana employed in the service sector and the population in Ghana are key factors that affect the level of mechanical power availability for agriculture in Ghana as shown in Table 5 and Figure 1. The level of tractor power availability increased from 0.0207 kW/ha in the year 2004 to 0.0588 kW/ha in the year 2020 and is expected to increase to 0.0752 kW/ha in the year 2025. These findings were validated by Fashola *et al.* [24] who found that mechanical power availability for agriculture in most of Africa was 0.04 kW/ha, which was consistent with the 0.033 kW/ha obtained in this study. Fashola *et al.* [24] further concluded that power availability in this range was very low and needs to be increased 10-fold in order to achieve meaningful agricultural productivity. The mechanical power availability in Ghana determined in this study was found to be very low when compared to that in India. The projected farm power availability in India was found to be 2.2 kW/ha in the year 2020 compared with that in Ghana (0.0588 kW/ha) in the year 2020 [25]. The value of power availability was also validated by Kansanga et al. [4]. The population of farmers in the Navrongo (Kassena Nankana District in the Upper East Region of Ghana) was determined to be 16844. The population of the farmers was computed by taking the population of Navrongo to be 29993 and the percentage of people who are 15 years old and above to be 70.2%; 80% of them are farmers. The total land cultivated by the farmer in Navrongo was 33688.14 ha, which was computed using the farmer population, and a cultivated area of land per farmer was found to be averagely 2 ha [26]. The total available tractor horsepower was determined using the average power rating of a tractor to be 55 Hp and a tractor population of 46 functional tractors in Navrongo [4]. The calculated available tractor power for Navrongo in the year 2020 was found to be 0.0563 kW/ha, which was consistent with the finding of this study.

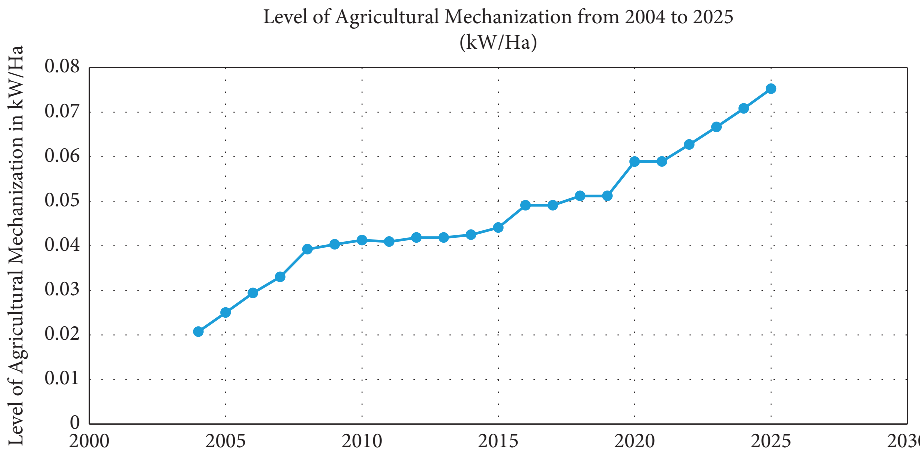

Figure 1: Level of agricultural mechanization from 2004 to 2025 in kilowatts per hectare.

Table 6

ANOVA	*df*	*SS*	*MS*	*F*	*Significance F*
Regression	2	0.001989432	0.000995	84.11125	3.6497E-08
Residual	13	0.000153741	1.18E-05		
Total	15	0.002143172			

Table 7

	Coefficients	Standard error	t Stat	p value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	−0.096106	0.01876991	−5.12023	0.000197	−0.1366562	−0.05556	−0.13665622	−0.0555564
ESS	−0.002467	0.00085844	−2.87355	0.013054	−0.0043213	−0.00061	−0.00432132	−0.0006122
Pop	9.56 *E*-09	1.98808 *E*-09	4.80886	0.000341	5.2654 *E*-09	1.39 *E*-08	5.2654 *E*-09	1.3855 *E*-08

Table 8: Cost of farm activities (northern and middle belts of Ghana).

Activity	Manual		Mechanized	
	Cost (Ghs/acre)	Time spent (hr/acre)	Cost (Ghs/acre)	Time spent (hr/acre)
Ploughing	165	10	136	0.6
Weed control	200	12	130	0.8
Harvesting	220	12	150	1

Policymakers in Ghana should consider diversifying employment opportunities away from the service sector while encouraging more growth in the agricultural sector [26, 27, 28]. Further to this, measures to bring in more tractors while the population of the country is growing should be consciously pursued to help increase the mechanical power availability to levels that can bring about sustainable productivity [27, 28].

The fitted multiple regression model (MRM) to the level of mechanization of agriculture in Ghana uses pop and ESS as predictors. Results in Table 5 show the model is statistically significant (F value = 84.11, p <0.05) and the model accounts for at least 90% (Adjusted – R^2 = 0.9172) of the variations in the level of mechanization of agriculture in Ghana. Moreover, model predictions for the future level of agricultural mechanization will be very precise due to the relatively small standard error of regression of 0.00344. Thus, the level of agricultural mechanization in Ghana forecast will be within acceptable limits. Both ESS and pop are statistically significant (p <0.05) for determining the level of mechanization of agriculture in Ghana (see Tables 6 and 7).

There is also the need to embark on public education of stakeholders in agriculture in Ghana to let them understand that the cost of mechanized tillage operations is cheaper than that of manual methods of tillage as shown in Table 8. This study discovered that the cost of mechanizing ploughing, weed control, and harvesting was 21.3%, 53.8%, and 46.6%, respectively, lower than that of manually carrying these operations (Table 8) [27, 28].

4. Conclusion

The evolution of the farming system brought about agricultural modernization came with increased levels of use of agricultural inputs and labor demands. Beyond many research papers that have situated the increasing mechanization of farming operations on population growth demands and scarcity of labor, this study went on to further establish the significance of labor employment away from the agricultural sector within that growing population in Ghana. This study determined links between population and employment in the nonagricultural sector to mechanical power availability in agriculture in Ghana. The study also determined the effect of farm size and the type of farm energy source on the level of mechanization in Ghana.

Significantly, employment in the service sector and population growth determine variations in the level of mechanization of agriculture in Ghana. On this, national policy direction will have to focus on attracting more labor required along the broad spectrum of the agricultural production and value chain as mechanization drives expansion and has room to offer many economic opportunities. The overall level of agricultural mechanization in Ghana was found to be very low with 77.6% of the farm operations being performed manually. However, on high-level mechanized farms (rated 60% or more) in Ghana, land preparation and irrigation were the most mechanized by farmers. The other farming operations will have to be targeted consciously by government programs and policies for holistic modernization. Agricultural policymakers will have to design policies that can help modernize agriculture through the transformation of the level from manual systems to highly mechanized systems where averagely more than 60% of the farm operation will be mechanized. The level of tractor power availability in Ghana was found to have increased from 0.0207 kW/ha in the year 2004 to 0.0588 kW/ha in the year 2020 and is expected to increase to 0.0752 kW/ha in the year 2025. These power availability values were also found to be comparatively low.

The agricultural sector ministry and agencies must champion a collective drive including private sector players with policies aimed at increasing the tractor population as the human population grows in order to increase the tractor power availability in the country. The increased mechanization of agricultural operation will help lower the cost of production since this study found that mechanized operations were between 21.3% and 53.8% cheaper than manual operations.

Data Availability

All relevant data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Authors' Contributions

Gilbert Ayine Akolgo, Duke Nii Darko Quaye, Abdul-Rauf Malimanga Alhassan, Killian Asampana Asosega, Ebenezer Nunoo, Akimsah Osman A. Jedaiah, Michael Elorm Deho, and Thomas Atta-Darkwa initiated the conceptualization and design of the research work. Gilbert Ayine Akolgo, Duke Nii Darko Quaye, Abdul-Rauf Malimanga Alhassan, Killian Asampana Asosega, Ebenezer Nunoo, Akimsah Osman A. Jedaiah, Michael Elorm Deho, and Thomas Atta-Darkwa did data collection and analysis of the research work. Gilbert Ayine Akolgo, Duke Nii Darko Quaye, Abdul-Rauf Malimanga Alhassan, and Killian Asampana Asosega did the drafting, revision, and final approval of the research work. Gilbert Ayine Akolgo, Duke Nii Darko Quaye, Abdul-Rauf Malimanga Alhassan, Killian Asampana Asosega, Ebenezer Nunoo, Akimsah Osman A. Jedaiah, Michael Elorm Deho, and Thomas Atta-Darkwa agreed to be accountable for all aspects of the research work.

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