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Machinery ownership model for effective smallholder mechanized rice production in Ghana

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Abstract
Rice is a major staple in Ghana and there are constant efforts to increase its production locally. As of 2020, local rice production figures were 987,000 tons, an increase of about two hundred thousand tons from 721,465 tons in 2017. This shows a very promising trend in ensuring the local production of rice. However, the major rice producers are smallholder farmers whose processes are riddled with drudgery. In addition to ensuring continued production, smallholder farmers are being introduced to conservation agriculture farming methods. Though they are gradually adopting conservation agriculture methods of production, the level of drudgery in their production still poses major problems for their agenda to increase production sustainably. This study was formulated on the premise that if smallholder rice farmers can own/access machinery easily, it will increase their productivity. As such the study aims at providing a machinery ownership model for smallholder farmers that is economically feasible and sustainable. This was done by first evaluating the level of mechanization through a survey of 150 rice farmers in both the southern and northern sectors of the country. The field data collected from rice production centers in the northern and southern parts of Ghana showed that aside from the major issues with rice production mechanization, only specific processes along the value chain receive attention regarding mechanization. Based on technical specifications, the study provided the full set of equipment (13hp power tiller, drum seeder, knapsack sprayer, mini combine harvester) required to mechanize smallholder rice farming and then further developed economic models around ownership of the machinery. The net present value and cost-benefit-ratio analysis of the business models developed show that the best model is where farmer cooperatives own machinery and hire it out to members.

Keywords: rice, mechanization, sustainable, economic, business model.

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Introduction
One major agricultural product that most Ghanaian families consume greatly is rice. The ease and the variety of dishes that can be prepared with this staple crop abound in the country. This has created a growing demand for rice which exceeds the country's total production capacity. In effect, about 55% of the domestic rice demand is met through import, resulting in a huge cost to the economy as well as depriving the local farmers of the needed revenue (Angelucci et al., 2013).
In an attempt to ensure that the country can produce enough to meet its local demand and ease the economic burden the importation of rice places on the economy, Governments have implemented projects that seek to ensure the country produces all the rice that is consumed locally. One of such program is the National Rice Development Strategy which was launched in 2008 to double the domestic production of rice by the year 2018 (Angelucci et al., 2013). With funding from the

government and its donor partners, these programs, together with other government initiatives like METASIP, FASDEP, etc., have led to an increase in strategic interventions for the rice-producing sector. Improved rice varieties, education, the implementation of extensive irrigation systems, and others were among the initiatives. Both the favorable effects of these initiatives and the constant rise in rice production have been realized. In 2020, there were 987,000 tons of rice produced locally, up around 200,000 tons from 721,465 tons in 2017 (MoFA, 2022; FAO, 2019).

Despite this, there are still significant issues with the rice production sector that go beyond introducing major production schemes, improving rice varieties, etc. that may aid Ghana in fully cultivating the existing rice-growing area and boosting the productivity of the current fields. The primary strategy for achieving increased production and productivity in the rice sector is the adoption of mechanical methods of production. All facets of rice production, from tillage through to the packaging of quality rice for the market, are impacted by mechanization. However, a review of the available research on rice mechanization reveals that each rice production farm has a specific demand for mechanization (Hernaiz & Renita, 2018; Muazu et al., 2014; Umesh, 2012). It is crucial to identify the types of mechanized machinery needed for increased rice production in Ghana by assessing the level of production, the size of the rice farms, and the required preference of the end rice product by customers. Earlier studies only focused on the level, intensity, and profitability of mechanization on rice fields in Ghana (Angelucci et al., 2013; Apiors et al., 2016; Diao et al., 2018; Kuwornu et al., 2017), without proceeding to determine the needed mechanization inputs to fully mechanize the specific rice production activities in Ghana.

As such, this study will propose the mechanization inputs required by local rice farmers to ensure full mechanized production. In addition, the study will evaluate the economic viability of different ownership models and propose the best ownership model with the most promising economic output for smallholder rice farmers in Ghana.

Material and Methods

The research region was divided into two groups: farmers producing in the northern sector (NS) and farmers producing in the southern sector (SS) due to the distinct nature of the level of production in the northern and southern sectors of the country. In general, Ghana has two seasons: the rainy (April to November) and the dry (November to April) season, which differ in severity from the south to the north.

A total of 150 farmers were interviewed from both sectors. The questionnaire made of 136 data points was used to gather both basic demographic data and statistics on the degree of mechanization along the entire value chain.

The data from the questionnaire were coded and entered into the SPSS software before being statistically analyzed. Based on the farm size and level of machinery used, the study analyzed different types of machinery ownership. The final analysis was to determine the scenario/model that is the most economically viable for a farmer to adopt. This was determined to be the model with the best (positive) benefit-cost ratio (BCR).

Results and Discussion

Demographics

The major distribution of the farmers in terms of their demographics was analyzed. The distribution of male to female as well as the level of education amongst respondents is presented in table 1.

The questionnaire was used to obtain specific information on the level of mechanization along the production value chain. From the collated data (fig 1), it was seen that aside from land preparation and threshing, most of the other farm operations were not fully mechanized. This means there exists a major mechanization gap that needs to be fixed.

Sustainable strategy for mechanizing smallholder rice production

The analysis takes into account the complete mechanization of production. As a result, the total amount of machinery needed is for the entire production value chain, from land preparation to harvesting and rice threshing. The machinery selection is affected by the average land size found

during the study's field survey, which ranges from 2 to 5 Ha. The machinery chosen for complete mechanization of small-scale rice farms' productivity based on the technical features seen during fieldwork and the machines' technical specifications is listed in table 2.

Table 1. Analyzed field data

Parameter	NS Values	SS Values
Gender of respondents (%)		
Male	66	63
Female	34	37
Average Age (years)	43 ± 8	43 ± 11
Education status (%)		
No formal education	50	16.7
JHS	24	47
SHS	27	27
Degree /Diploma	3	9
Average farm size (Ha)	4.5±1.9	2.3±1.4
Land tenure		
Owned	84	0
Leased	16	100
Fund for farming (%)		
Loan	29	77
Personal	68	23

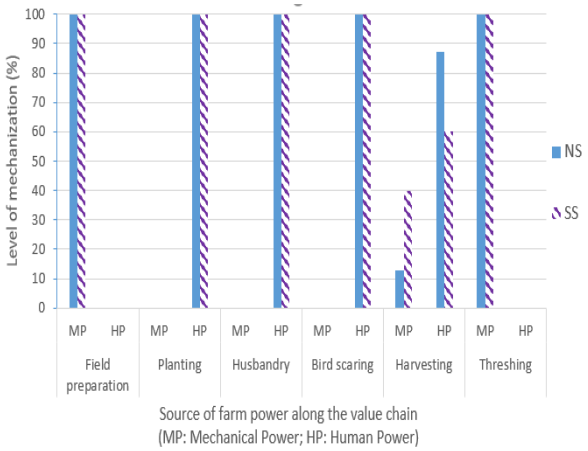

Fig 1. Level of mechanization

The machinery was chosen to provide the smallholder farmer with the best equipment possible given the current technologies. Before making a decision, an economic analysis of the machine's ownership in terms of operating costs was also performed (Table 4).

Table 2. Proposed machinery for activities

Field Activity	Machinery
Field preparation	13hp power tiller
Planting	Drum seeder
Husbandry activities	
Weed control	Knapsack sprayer
Fertilizer	
Bird scaring	Human labour
Harvesting	Mini Combine
Threshing	Thresher

Table 3. Models for machinery ownership and utilization

Model	Description
FHM-B	The farmer hires all the machinery used for
FHM-T	production
FOM-B	The farmer owns all the machinery used for
FOM-T	production
FOHM-B	The farmer owns all the machinery used for
FOHM-T	production and operates hiring services
COM-B	The farmer cooperative owns all the
COM-T	machinery used for production
FOHM-2B	A farmer owns all the machinery used for
FOHM-2T	production, operates hiring services and crops twice in a calendar year

*Cropping under broadcasting (B) and Transplanting (T) methods.

According to the economic analysis, for either of the two chosen discounted rates, owning the full complement of small-scale machinery is not a smart mechanization strategy from an economic standpoint. However, a 10% discount rate makes it economically feasible for farmers to personally own their equipment and offer hiring services. This shows that this concept can be implemented by development organizations that can get farmers low-interest loans. Considering the scalability of this idea, nations with extremely low-interest rates can provide their farmers with such machinery models.

At both discount rates, the cooperatively owned machinery with a shared initial investment capital outlay for the machinery acquisition appears to be economically viable. As such, this economic model for machinery ownership is the best recommended for the Ghanaian rice farmer. Since there is only one planting every year, this strategy will be most beneficial for rice farmers in both the northern and southern sectors.

Therefore, FOHM-2B and FOHM-2T are the most suitable models for anyone who wants to start small-scale rice production. Additionally, this implies that they may purchase equipment, lease it to other farmers, and then schedule their production to guarantee two crop cycles every year. The

farmers near the government irrigation sites may also be the ideal candidates for these models. Hence, farmers using irrigated areas are urged to possess their own equipment, while farmers away from irrigation locations where twice-yearly output is impractical can organize small farm cooperatives and buy equipment for their operations (that is the COM model).

Table 4. NPV and BCR for the proposed mechanization models

	FHM		FOM		FOHM		COM		FOHM	
	FHM-T	FHM-B	FOM-T	FOM-B	FOHM-T	FOHM-B	COM-T	COM-B	FOHM-2T	FOHM-2B
Fixed Cost										
Cost of machinery	-	-	43,000.00	43,000.00	43,000.00	43,000.00	2,150.00	2,150.00	43,000.00	43,000.00
Recurring cost										
Cost of farm input	6,627.00	5,956.00	4,525.00	3,854.00	4,525.00	3,854.00	4,525.00	3,854.00	9,050.00	7,708.00
Total Cost	**6,627.00**	**5,956.00**	**47,525.00**	**46,854.00**	**47,525.00**	**46,854.00**	**6,675.00**	**6,004.00**	**52,050.00**	**50,708.00**
Benefit Cost										
Revenue from farm produce	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	20,000.00	20,000.00
Revenue from machinery hire	-	-	-	-	2,000.00	2,000.00	-	-	2,000.00	2,000.00
TOTAL Benefits Cost	**10,000.00**	**10,000.00**	**10,000.00**	**10,000.00**	**12,000.00**	**12,000.00**	**10,000.00**	**10,000.00**	**22,000.00**	**22,000.00**
NPV* at 10% discount rate	**20,725.62**	**24,848.63**	**-5,449.40**	**-1,326.40**	**6,839.73**	**10,962.73**	**31,686.96**	**35,809.96**	**40,481.23**	**48,727.24**
BCR* at 10% discount rate	**1.51**	**1.68**	**0.92**	**0.98**	**1.10**	**1.17**	**2.06**	**2.40**	**1.43**	**1.56**
NPV at 22% discount rate	**13,232.90**	**15,865.36**	**-13,766.47**	**-11,134.01**	**-5,920.10**	**-3,287.64**	**19,717.14**	**22,349.60**	**15,559.34**	**20,824.25**
BCR at 22% discount rate	**1.51**	**1.68**	**0.74**	**0.78**	**0.89**	**0.93**	**2.01**	**2.32**	**1.22**	**1.32**

*NPV (Net present value) and BCR (Benefit cost ratio) at the time period of 10 years.

To ensure that the models are effective when applied, further studies have to be done on aspects such as equipment availability, spare parts availability, ready market for farmers' produce, etc.

Conclusions and Outlook

The study evaluated the level of mechanization for rice production and based on the field data and technical specifications, the study provided the full set of equipment (13hp power tiller, drum seeder, knapsack sprayer, mini combine harvester) required to mechanize smallholder rice farming. Cooperative ownership of machinery was the best however other personal ownership models proved viable under various conditions.

For the models provided in this study to be fully operationalized, additional research on the variables influencing the decisions made by local farmers, the limitations on local output, and the availability of equipment is essential.

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