Comparative Field Evaluation of Mechanized and Manual Cassava Production Operations: The Case of Cassava Farmers in Ogun State of Nigeria


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Abstract

In 2015, mechanized technologies for planting and harvesting cassava were introduced to farmers involved in the Cassava Value Chain (CVC) in Ogun State of Nigeria for testing. This study comparatively analysed the profitability of cassava production under mechanized and manual operations. Partial budgeting was used to compare costs and benefits of the new innovations with manual process. The comparison was based on data obtained from farmers involved in an effort to enhance the competitiveness of high quality cassava flour (HQCF). The results revealed that yields from harvested fresh cassava roots on mechanically planted cassava farm plots increased by 38% over the manually planted cassava farm plots. The main gain associated with the mechanized process was the relatively lower costs associated with planting and harvesting operations, which were cheaper over the manual operations by 55% and 59%, respectively. The mechanically and manually planted cassava farm plots have a gross margin of $491/ha and $296/ha, respectively. Comparison of these levels of profitability showed that the mechanized operations were relatively more profitable and exceeded the manual farm operations by 83%. Thus, the study concludes that the mechanization of cassava planting and harvesting, combined with high-yielding variety and complementary agronomic practices, can lead to higher competitiveness and economic break-through for cassava farmers in Africa. Therefore, we recommend increased efforts to scale-up mechanized cassava production operations, including building the capacity of cassava farmers with regards to improved production technologies and crop management practices.

Keywords: Cassava, Mechanized, Manual, Profitability, Partial budgeting, Nigeria

Introduction

Cassava (*Manihot esculenta* Crantz) is one of the most important crops in Africa. It is an important source of energy in the tropics, especially in low-income countries, and will continue to be a vital staple to feed the growing African population. The principal economic product is its roots but the leaves, with protein levels of 18-22% on dry weight basis, are widely processed for human consumption and animal feed (Bokanga, 1999). The stems serve as the planting material for its propagation. The crop is cultivated widely in the tropic and sub-tropic parts of Africa, Asia, and Latin America, between latitudes 30° N and 30° S, and from 0 to 2000 m above sea level (Sharkawy et al., 2012). Cassava serves as the main source of nutrition for approximately half of Africa's 500 million population. Furthermore, it is a major source of income for rural communities; smallholder farmers in Africa who produce more than half the world's cassava, an estimated 158 million tons annually (FAO, 2014). Cassava growers are mostly low income farmers primarily because the crop uses its inherent adaptive mechanisms to produce food during droughts and in low nutrient soils more than cereals and grain-legume crops. The current yield of cassava in Africa is about 10 t/ha, while it is more than 21 t/ha in Southeast Asia and above 40 t/ha in India. With yield of 10 t/ha, African farmers are not competitive in the global market. To be competitive, yield of 25 t/ha or more should be the continent's target. However, to get higher yields and greater economic benefits, improved management practices will be required (Howeler, 2010). Mechanization of the production system, use of fertilizers, control of weeds and the use of improved varieties can increase the yield of cassava beyond 25 t/ha.

The planting and harvesting operations of cassava are usually done manually thereby making it labour intensive and time consuming. Generally, it takes 8-10 persons to manually plant one hectare of land in a day against a two -row mechanical planter that can plant 7-10 ha in a day, which is faster and 50% less expensive than manual planting (Abass et al., 2014). Similarly, manual harvesting is slow and associated with drudgery and high root damage in the dry season (Chalachai et al., 2013; Amponsah et. al., 2014). Manual harvesting of cassava requires between 40 and 60 persons, depending on the season, to harvest one hectare of cassava in a day against the mechanized operated equipment which can lift up to 200 plants per hour while the two-row mechanical harvester can harvest up to 3 to 5 ha cassava farm in a day, depending on the terrain (Abass et al., 2014). Amponsah et al. (2014) observed that mechanical harvesters are needed to break the labour bottleneck associated with cassava harvesting but research in Africa on mechanization of cassava production is very low unlike Asia where there have been some meaningful research attempts made on mechanical harvesting of cassava (Chalachai et al., 2013). In Thailand for example, cassava digger suitable for a 50 hp tractor was developed, while others attempted to integrate cassava digger and conveyer unit. In Brazil and Colombia mechanized planting and semi-mechanized harvesting systems have beenevaluated and models for mechanical cassava planters and harvesters have been adapted to the farming systems and practices (Ospina et al., 2012).

Farmers are either not aware of the mechanical methods available for the planting and harvesting of cassava, or access to the mechanized production technologies are constrained by the relatively high initial investment. Although new commercial, medium-scale cassava farmers are beginning to emerge in some cassava growing countries, such as DRC, Ghana and Nigeria, most of them use only some and not all available modern techniques that can increase the yield of cassava. The availability of mechanical planters and harvesters, for example, is still very low and can be found within few localities in few countries like DRC, Ghana, Nigeria, Tanzania and Zambia. Where these machines exist, there are many factors that inhibit their use that could affect the final financial outcome and use-conveniences, depending on the knowledge or competences to use them, which may exist locally. The factors include: loss of cassava root in the field, working width, root breaking losses, greater power requirement, and stringent field cleaning requirements (Chalachai et al., 2013). Thus, full benefits of using improved inputs, such as improved varieties, fertilizers, and herbicides in boosting cassava production, cannot be fully achieved without mechanization of the production operations. Inability to apply modern technologies in a holistic or consolidated manner for the production and processing operations of cassava reduces the prospect to maximize profit (ICS-Nigeria, 2003).

In 2015, "Enhancing the Competitiveness of High Quality Cassava Flour project" introduced mechanical planting of cassava stems and harvesting of fresh cassava roots to farmers in the four innovation platforms in Nigeria. The adoption of these mechanised planting of cassava stems and harvesting of fresh cassava roots were expected to reduce production costs, increase cassava output and the overall relative profitability of cassava production compared to manual process. In addition, they could enhance farmers' willingness to adopt the improved mechanized production technologies, particularly new use of mechanical cassava planters and harvesters, which can expand production of cassava and increase its productivity.

The study was aimed at comparing the costs and benefits of using the new mechanical planting and harvesting innovations against the traditional manual practices in terms of cost-effectiveness, profitability and competiveness of the production operations.

Methodology

2.1 Farmers' Organization in Innovation Platforms

The study was carried out at Joga Orile (N 7.146°; E 3.053°) in Ogun State of Nigeria, comprising farmers in an out-grower arrangement for production of fresh cassava roots for sale to the processing factory (**Fig. 1**). Data were collected on average yields results obtained from 5 cassava farm plots that used mechanical planting and harvesting compared with the average yield results obtained from another 5 cassava farm plots that used manual planting and harvesting methods.

Strong linkage between the out-grower farmers and the HQCF factory was developed through contractual arrangements to increase farm yield through mechanization and other improved production methods.

The aim was to show how to put in-place functional institutional arrangements for out-grower schemes that could present economic success for the farmers. The HQCF plant served as the node to build the model of competitive cassava root production, utilizing best agronomic practices, improved varieties, and farm mechanization.

2.2 Planting and Harvesting Methods

Farmers were grouped in two categories, a group adopting mechanized planting and harvesting and a second group using traditional production system where the use of mechanical planter or harvester were not involved. A total of 34 ha of cassava was planted by the out-growers using two main varieties. These were TMS 419 (well-adaptable to mechanical planting) and TMS 30572. Farmers were trained on fertilizer application and weed management by using boom sprayer for herbicide application.

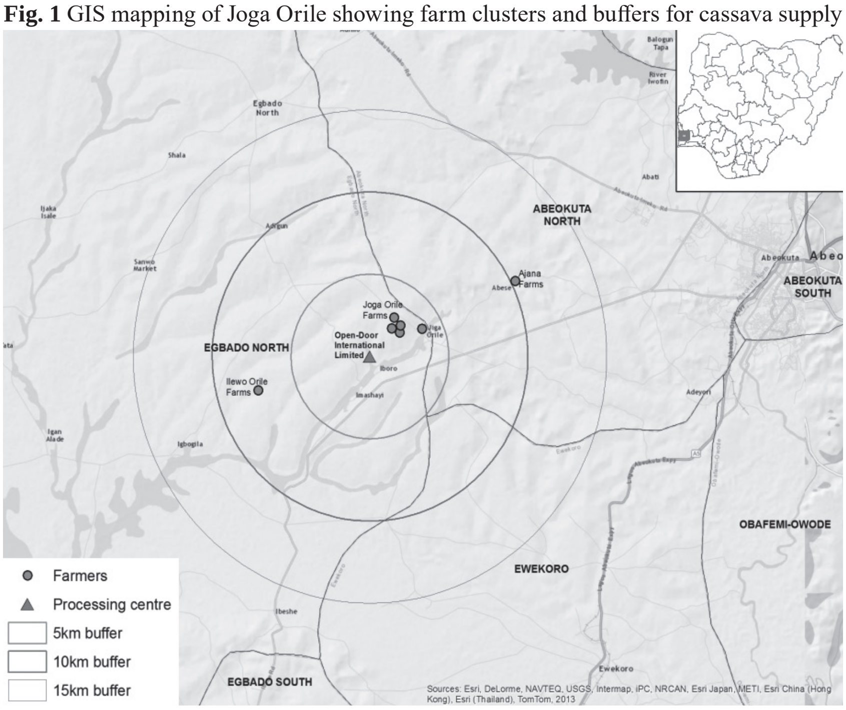
The farmer's group using the traditional planting method planted their cassava during the main rainy season (May-July, 2015). Mechanical land preparation involving field operations such as ploughing, harrowing and pre-emergence herbicide application were done in August, 2015. Planting was done at the beginning of the dry season in October, 2015, a timing that was unusual to the farmers based on the farming practices in the area but scientifically satisfactory since the area has humid climate and the cassava could utilize the small residual soil moisture and the small last rains to initiate root development (Ospina et al., 2012).

Traditional manual planting practices involved 15-20 cm long stakes planted at slanting position on ridges or flat land at a depth of about 10 cm. The direction of bud growth was often not known nor considered when planting by the locally available labour.

The two-row planter used was BAZUGA NCM 8432.31.90 which was designed to plant cassava on flat ground had a planting rate of 0.5-0.8 ha/h at 700 mm row spacing. The two-row cassava planter as shown in **Fig. 2** was drawn by a 60 hp (44.76 kW) tractor. The stalk length for the planted cuttings was 18 cm. Stakes were cut with a power-take-off (PTO) driven circular saws. The planter plants the cuttings at uneven planting distance that ranged from 80 cm to 100 cm which is as a result of the unleveled harrowed land. Planting depth ranging between 60 and 100 mm below soil surface was maintained. No ridges was made for the cassava plot. Planting was done in October 2015 at the end of the rainy season. The farms were managed by the out-grower farmers. Irrespective of the planting method, all the farmers maintained manual weeding in combination with the use of herbicides until the roots were ready for harvesting at 12 months after planting.

Harvesting of the cassava farm plot was done using a Cassava Up-

Fig. 1 GIS mapping of Joga Orile showing farm clusters and buffers for cassava supply



rooter Model P-900 NCM 8432.29.00 harvester, equipped with front disk and depth control wheels. The mechanical harvester as shown in **Fig 3** was driven by an 80 hp (59.68 kW) four-wheel-drive (4WD) tractor at a forward speed which ranged from 2.1 to 6.7 km/h and at a digging depth that ranged from 300 to 400 mm. Manual planting and harvesting were done by hired labour sourced from the area.

2.3 Data Collection

Key Informants Interview (KII) and partial budgeting techniques were used to examine the cost-effectiveness, profitability and competitiveness of cassava production operations. The KII was held with farmers that used mechanical planter and harvester to assess their perceptions. The partial budgeting was used to compare costs and benefits of the new innovation against the manual planting and harvesting. The comparison was based on cassava production operations data from farmers that used mechanized or manual planting and harvesting techniques.

2.4 Partial Budgeting

Partial budgeting is a planning and decision-making tool used to compare the costs and benefits of alternatives available to a farm business. This tool allows comparison of marginal costs and marginal benefits of small, specific changes - without having to financially analyse the entire farm (Rabin, 2012). The simplicity of partial budgeting facilitates decision making by estimating profitability of a given change. It focuses only on the changes in income and expenses that would result from implementing a specific alternative. Thus, all aspects of farm profits that are unchanged by the decision can be safely ignored. Partial budgeting allows better handling on how a decision will affect the profitability of the enterprise, and ultimately the profitability of the farm itself.

Partial budgeting was used to determine and compare profitability in cassava production using mechanized planting and harvesting compared with manual planting techniques. The process provided actual information on farm-input use and costs, output and prices, and farmers' gross margins. The gross margin budget examines the returns to the farmers' resources, which consist mainly of labour used, capital inputs such as fertilizer, chemicals and other production inputs. The procedure involved the estimation of the costs and returns based on 2015/2016 cassava production season.

In developing the gross margin, estimates of production cost and gross revenue from cassava output were collected from the farmers that implemented mechanized techniques and manual planting and harvesting in Joga Orile in Ogun State of Nigeria. In estimating the production cost, family labour cost that were not paid for by the farmers, was estimated as its opportunity cost by using the prevailing market wage rate for labour in the area. The gross margin from cassava production activities is the gross value of cassava output less all the variable costs incurred during the production period.

Fig. 2 Tractor drawn mechanical planter

Fig. 3 Tractor drawn mechanical harvester

The gross margin was estimated as:

$$GM = \sum piqi - \sum rjxj$$

where,

GM = Cassava gross margin

pi = Unit price of output i

qi = quantity of output i

rj = unit cost of the variable input j

Xj = quantity of the variable input j

The use of partial budgeting is quite an appropriate technique to assess profitability in crop production as there is often limited or negligible use of fixed inputs by smallholder farmers (Amaza and Olayemi, 2002).

Results and Discussion

3.1 Partial Budgeting Comparison

The results for partial budgeting comparison of mechanized and manual planting and harvesting of cassava are summarized in **Table 1**. The components of variable cost under mechanical planting comprises of land preparation, stem cuttings, mechanical planting, pre-emergence herbicide and its application, post-emergence herbicide and its application, fertilizer and its application, weeding cost, harvesting and transportation of fresh roots and other miscellaneous costs. On the contrary, some of these variable costs were not incurred by farmers who planted cassava manually. The costs that were not incurred are: pre-emergence herbicide and its application, fertilizer or second weeding costs.

The yield from harvested fresh cassava roots on mechanically planted farm had increased by 38% over the manually planted cassava farm (**Table 1**). The cassava stem yields and its corresponding value were not measured under both mechanical and manual planted farms. Similarly, as the farmers face the same market prices, revenue obtained from sales of fresh cassava roots had also increased by 38% on the mechanically planted cassava farm over the manually planted cassava farm.

Generally, mechanization of farm operations, including mechanized planting can increase yield through timelier performance of operations and higher quality performance of operations (Bloom, 1979). Because there is an optimum time to perform operations, crop yields tend to be highest where critical operations such as planting and harvesting are carried out closer to the optimum time (Goering, 1992). Mechanized planting unlike manual planting of cassava stems allows for deep tillage whereby the hard pan in the ground are loosened up. This facilitates the development of larger roots with increased number of principle roots, thus greater surface contact between root and soil. Consequently, the improved root system gives the crop better possibility to increase the intake and conservation of soil and mineral, which eventually leads to increase in yield and total production (Bloom, 1979).

The cost associated with land preparation for manual operation is higher by 7% compared with that of mechanical operation. There was 34% increase in the cost of cassava stems; as greater amount of cassava stems were planted under mechanized planting compared to manual planting. Herbicides and its application had increased by 256% on the mechanical operation. The relatively lower costs of purchased inputs for manual operation were possible because the farmer did not fully use some of the inputs purchased, especially fertiliser and herbicides.

The main gains associated with mechanized planting of cassava is its relatively lower costs of planting and harvesting. Planting cost was cheaper under mechanized planting than manual planting by over 55%. The cost for manual planting of cassava was US$29/ha while it was US$13 for mechanized planting. Manual planting accounted for 9% of the total cost as mechanized planting accounted for 4% of the total cost. The cost of production using manual method was $328/ha representing US$20.5/ton of roots, while the cost of production using mechanical method was US$367/ha representing US$16.68 per ton of roots. In a similar study done in Colombia in 2000, Ospina et al. (2012) obtained US$635.1/ha as cost of production for using manual operation. In this same study carried out by Ospina et al. (2012), US$517/ha and US$490.4/ha were the cost of production obtained for mechanical operation using a two-furrow and three-furrow planters, respectively. The planting cost which is a proportion of the total operation cost was found to be 8.8% for manual operation, 5.1% for mechanized operation with two-furrow prototype planter and 4.7% for mechanized operation with three-furrow prototype planter.

According to Ospina et al. (2012), harvesting is the most difficult cassava production operation to mechanize. It is also the most expensive operation under the smallholder production systems in Nigeria due to the rudimentary nature of the harvesting tools used by the farmers combined with the limitations that result from the shape and distribution of roots in the soil, the depth of the roots in the soil, the removal and careful collection of stakes, and the

Table 1 Slicing Performances with respect to the rotating speed of the cutting disc

	Manual Operations	Mechanized Operations	Increase/ Decrease	% Increase/ Decrease
Yields[1]				
Fresh roots ton ha^{-1}	16	22	6	38
Cassava price (US$/ton)	39	39	0	
Revenue from Output (US $)	624	858	234	38
Variable costs (US $) ha-1				
Stem cuttings	85	56	-29	-34
Land Preparation	87	81	-6	-7
Herbicide and application	16	57	41	256
Planting	29	13	-16	-55
Fertilizer and application	0	61	61	
Manual weeding	19	39	20	105
Harvesting	61	25	-36	-59
Miscellaneous and roots transportation	31	35	4	13
Total Variable Costs	328	367	39	12
Total variable cost (US$ per ton of roots)	21	17	-4	-19
Margin (US$ per ha)	296	491	195	66
Margin at farm gate (US$ per ton)	19	22	3	21

Note: The average exchange rate of N310 = 1 USD for September 2016 was used for calculations adherence of sometimes hard soil to roots. The farmer decides when to initiate the harvesting operation depending on the productivity, root size or maturity (months of the cassava after planting) of the plant, the roots' starch content, food needs of the family, culinary properties and other actors such as possibility of disease onset, onset of fibrousness in the roots, or market opportunity that may present itself. This period may coincide with the dry season when the soil is hard.

Results obtained in the study carried out by Ospina et al. (2012) revealed that harvesting cost was lower under mechanized system by 59% compared with manual system. Meanwhile a reduction of 42.8% was obtained in Colombia under the same production operations. Harvesting cost was US$61/ha under manual operation and US$25/ha under mechanized operation. Harvesting cost which is a proportion of the total cost was found to be 18.6% for manual operation and 6.8% for mechanized operation. This is to say that similar to the cost structure found in Colombia, where harvesting cost was reduced by 6% in the relative cost of labor to total production cost per hectare, the reduction obtained in Nigeria was 11.8%.

The difference in the total variable costs between the two categories of cassava farm plots is only US$39, which represents 12% for the manually planted cassava farm compared with the mechanically planted cassava farm. The achieved gross margin in cassava production from the two production systems revealed that both mechanized and manual cassava production systems are profitable. The mechanically and manually planted cassava farm plots have a gross margin of US$491/ha and US$296/ha, respectively. However, comparison of these levels of profitability, showed that the mechanized planted cassava farm plots relatively is extremely very profitable and exceeded the manually planted cassava farm plots by 66%. This finding agrees with Benin (2014), who stated that mechanization can contribute to increasing the production, productivity and profitability of agriculture improving the timeliness, quality, and efficiency of operations. Along with yield and the agronomic benefits, farmers who used mechanization for more services were more technically efficient than farmers who used mechanization for fewer services (Itodo and Dauda, 2013; Shamsudeen et al., 2013).

There are several factors that plausibly influenced the exceedingly higher level of gross margin; however two factors clearly stand out. First, the population density in terms of number of roots and root weight. The average number of roots found on mechanically planted cassava stems was 34 which is more than double that found on manually planted cassava roots which stood at 14. Similarly, the average weight of roots was significantly higher at 58 kg for mechanized planting compared to only 14 kg obtained for manually planted stems. Hence, introducing mechanized planting and harvesting to cassava production operations increased the economic benefits to farmers through the higher weight of harvested roots per unit area as a result of increased yield or due to the mechanical harvester's ability to remove more roots than the traditional harvesting systems involving the use of human labour. Secondly, some variable inputs, especially fertilizer, post-emergence herbicide and second weeding operations were not applied on the manually planted cassava farm. This tend to have negative effect on the quantity of harvest cassava roots in kg/ha. For instance, fertilizers are known to be a major yield enhancing input in the sense that it improves the productivity of existing land by increasing crop yields per hectare as well as well spread difference in gross margin (Amaza et al., 2006).

3.2 Perceived Advantages and Disadvantages of Mechanized Planting and Harvesting

Farmers were asked to give their perceptions on the relative advantages and disadvantages of mechanized planting and harvesting. The results of their perceptions are summarized as follows:

Advantages

a) Increased Plant Population: - The plant population density using mechanized planting is considerably high compared with manual planting. This has effect on the yields of fresh cassava roots, stems and cassava leaves which all have economic value.

b) Increased yield of fresh roots: - The population density was relatively high using mechanized planting which effectively increased the yield per unit area when compared with manual planting.

c) Loose soil: - As a result of the ploughing and harrowing operations carried out which was close to the end of the rainy season, made the soil to be well ventilated and the soil structure was loose for a longer time, thereby creating good conditions for planting and root development.

d) Weed control: - Weeds were more efficiently controlled due to subsequent seizure of rains stifling the growth of weeds that could have competed for nutrients with the germinating cassava. Hence there was a consequential reduction in the cost of weeding for mechanical operation compared with manual operation.

e) Saves time: - Mechanical planting saves time which can be released for other activities.

f) Reduced drudgery:- Mechanical planting and harvesting removes drudgery that characterizes manual planting and harvesting of cassava.

Disadvantages

a) Scale of Operation:- Mechanical planting and harvesting of cassava may not be ideal for the small-scale farmers, where the size of farms are relatively small. Hence, land consolidation may be needed, possible through cooperative system, which is possible under out-grower arrangements in which the farmers are assured for selling their roots collectively to a reliable buyer

b) Limited availability of technologies:- Mechanical planters and harvesters are relatively new technologies that may not be available when needed.

c) Knowledge of the technologies:- The fact that the technologies used for planting and harvesting are relatively new and emerging, most farmers are unware and may need to be educated on their advantages and cost-effectiveness by out-scaling the approach tested in the study.

In addition to all these, the partial budget analysis supports most of the perceptions held by the farmers with respect to the advantages and disadvantages of cassava production mechanization.

Conclusion and Recommendations

The results of the partial budgeting have clearly shown that mechanized method of cassava production is highly profitable and cost effective. The yield obtained from mechanized operation almost doubled the manual operation, while the costs associated with planting and harvesting using mechanized operation is less than 50% of the cost spent by manual operation. Such cost reduction and higher root output from mechanical operation signify increased competitiveness of cassava production system; increased economic benefits and food availability for the farmer.

In order to enhance the competitiveness of the cassava value chain in Nigeria and elsewhere in Africa, we recommend the following:

a) An integrated system of production and processing in which farmers within the same locality are formed into out-growers around a reliable buy or buyers of fresh cassava, forming a platform that allows business deals and agreements to be made in ways that link the growers with the buyer (market) and opportunities for land consolidation and mechanization of the production operations can be practiced.

b) Extension and other scaling institutions should intensify efforts to create awareness among cassava farmers with regards to the adoption of mechanized operation in cassava production.

c) There should be increased efforts to scale-up the promotion and dissemination of mechanical planters and harvester among cassava farmers to improve the competitiveness of cassava operations and build the capacity of cassava farmers with regards to using mechanization implements and improved crop management methods.

d) Extension institutions should identify and create awareness among entrepreneurs that can provide mechanized planting and harvesting services for interested farmers. Such entrepreneurs should be linked to credit institutions and equipment leasing companies.

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