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## Review of Various Harvesting Options for Cassava

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### Abstract

Harvesting plays a critical role in the cassava production value chain. A review of some existing cassava harvesting options is necessary to facilitate the proper adaptation and uptake of improved harvesting methods applicable to farmers from different parts of the globe. In terms of capacity, manual, semi-manual and fully mechanised harvesting options respectively require about 22–51 man-hha-1, 16-45 man-hha-1 and 1–4 man-hha-1. An added advantage with mechanised options is that the field is left ploughed after harvesting with savings on fuel, time and cost. Mechanised harvesters work best on ridged fields with minimal trash or weeds and relatively dry soils (12–16% d.b. moisture content). Earlier attempts at mechanised harvesting have been affected by constraints such as soil characteristics, nature and size of tubers, depth and width of cluster and bond between tubers and the soil, leading to high tuber damage. Though less research attention is given to cassava harvesting mechanisation, that aspect of the global cassava transformation agenda has always been the problem. There is still room for improvement in the provision of appropriate harvesting options for cassava worldwide and a more concerted effort from both the government and private sector is vital.

**Keywords:** cassava, harvesting, mechanised, manual, adoption, improved

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### 1. Introduction

Cassava has become an important food security and the world's third most important crop. The crop is an essential source of food and income throughout the tropics providing livelihood for countless farmers, processors and traders worldwide. Almost 60 percent of world production is concentrated in five countries Nigeria, Brazil, Thailand, Indonesia and the Congo Democratic Republic [1]. In Africa, cassava is the single most important source of dietary

energy for a large proportion of the population living in the tropical areas [2]. According to Tufan [3], no other continent depends on cassava to feed as many people as does Africa, where over 500 million people consume it daily.

Harvesting is one of the serious bottlenecks in the cassava production value chain. Manual harvesting is slow and associated with drudgery and high root damage, especially under arid conditions [4]. This situation tends to increase the total cost of production because more farm hands are usually required to harvest in order to meet industrial and local demands coupled with an increase in cassava prices on the market.

Over the years, various mechanised harvesting options have been developed for use in different parts of the world to overcome these challenges. Earlier attempts at mechanising cassava harvesting have been challenged mainly by inappropriate method of planting, field topography and scale of cultivation. A review of various harvesting options for cassava is crucial to ensure proper adaptation and adoption of improved harvesting methods applicable to farmers from different parts of the globe.

## **2. Cassava harvesting**

The most difficult operation in cassava production is harvesting [5]. This is so because cassava is a highly perishable crop and begins to deteriorate as early as 1–3 days after harvest. It is therefore important to harvest cassava at the right time and in the proper manner. Harvesting too early results in low yield and poor eating quality; on the other hand, when the roots are left too long in the soil, the central portion becomes woody and inedible. It also ties the land unnecessarily to one crop whilst exposing the roots to pests. Cassava is ready for harvest as soon as there are storage roots large enough to meet the requirements of the consumer, starting from 6 to 7 months after planting (MAP), especially for most of the new cassava cultivars [6]. Matured roots are clustered around the base of the plant and extend about 60 cm on all sides. It is for these roots, which contain from 15–40% starch that the crop is cultivated.

Under the most favourable conditions, yields of fresh roots can reach 90 t/ha while average world yields from mostly subsistence agricultural systems are 10 t/ha [7]. Cassava is traditionally harvested by hand lifting the lower part of stem and pulling the roots out of the ground, then removing them from the base of the plant by hand. The upper parts of the stems with the leaves are usually removed before harvest. Levers and ropes can be used to assist harvesting. A mechanical harvester can also be used. Mechanical harvesters, like those developed in Brazil would grab onto the stem and lift the roots from the ground [8]. Harvesting cassava during relatively dry weather is the best since the soil does not stick to the harvesting implement or roots easily [9].

### **2.1. Methods of cassava harvesting**

Mechanisation in terms of harvesting, like most of the other root crops, is still in the development stage with very few commercial technologies in existence. Development of

labour-saving technology for cassava harvesting has become the most critical challenge in the cassava transformation worldwide. Earlier attempts at mechanised harvesting have been affected by constraints such as soil characteristics, nature and size of tubers, depth and width of cluster, and bond between tubers and the soil, leading to high tuber damage. Amponsah et al. [10] stated that farm size and level of root tuber breakage are critical factors that are considered in the selection and adoption of any type of cassava harvesting method. There are basically three cassava harvesting options available to farmers across the globe; manual, semi-manual and mechanised.

## 2.2. Manual harvesting

This is the traditional method of harvesting cassava using the bare hands with or without the use of indigenous tools such as hoe, cutlass, mattock, earth chisel etc. Usually, these tools are used to dig round the standing stem to facilitate the pulling of the roots from the soil before detaching the uprooted roots from the base of the plant. **Figure 1** shows various manual cassava harvesting options.

Harvesting cassava manually is laborious especially during the dry season when soil moisture is at lower levels. According to Nweke et al. [11], manual harvesting requires about 22–62 man days per hectare.

Manual lifting of cassava with the bare hands requires about 23–47 man h/ha as compared to the use of a hoe which requires between 42 to 51 man h/ha [4]. The use of manual harvesting tools is preferable on relatively dryer (hard) soils, whereas manual uprooting technique is best suited for soils with relatively higher moisture content. However, best efficiency of manual harvesting is achieved when the upper cassava plant biomass is removed or coppiced before harvesting.

## 2.3. Semi-manual harvesters

Semi-manual harvesters are harvesting aids that usually adopt the lever principle to ensure that little human effort is used in uprooting the cassava. Various harvesting aids can be found in different cassava growing regions across the globe.

The CRI harvester (**Figure 2**) was developed at the CSIR-Crops Research Institute (CRI), Kumasi with the intention of decreasing the toil farmers go through as a result of excessive waist bending when using existing manual harvesting tools. The original design, adopted from the International Institute of Tropical Agriculture (IITA) in Nigeria, has undergone several design modifications to ensure best efficiency is achieved using the implement [12].

The CRI harvester operates according to the “grip and lift” principle and is made up of a frame with a steel plate to which an immovable gripping jaw is fixed. A chisel tip serves as a base which allows for lifting of cassava roots from the soil when using the gripping jaw. It also facilitates the uprooting of cassava especially in hard and dry soils by employing the “dig and lift” principle. This comes in handy where the “grip and lift” principle fails. The harvester has



**Figure 1.** Different manual harvesting options using a hoe (a), bare hands (b), mattock (c), machete (d) and earth chisel (e).

a mechanical advantage of 4.5 when operating under the second class lever principle. With a total weight of 5 kg, even women and children can easily operate and use the tool for harvesting cassava.

Field assessment of the performance of the CRI harvester showed that it is faster harvesting vertically planted cassava though cassava planted slanted offered the least root tuber breakage and drudgery, regardless of cassava variety. **Table 1** presents some performance evaluation results of the CRI harvester according to Amponsah et al. [10].



**Figure 2.** The CRI harvester in use.

The National Centre for Agricultural Mechanisation (NCAM) in Nigeria also developed and commercialised a semi-mechanised cassava lifter/harvester [13]. The NCAM harvester (**Figure 3**), consists of a frame to which a footboard and immovable gripping jaws are attached and a lever (handle) which is hinged to the frame. Both implements have been tested to harvest up to 200 plants per man-hour and can be classified under semi-manual types of cassava harvesters since they require some degree of human effort to be able to use them effectively for harvesting compared to the mechanised types.

The CTCRI cassava harvester (**Figure 4**) was developed at the Central Tuber Crops Research Institute (CTCRI), Kerala, India with the aim of reducing the level of drudgery associated with the use of other manual cassava harvesting tools. The tool, with a mechanical advantage of 3.4 and total weight is 8 kg, operates on the second class lever principle and has a self-tightening mechanism used to grip the cassava stem. The height of the fulcrum at the far end

Parameter	Value
Field capacity (man h/ha)	49.9–156
Root tuber breakage (%)	4.3–19.6
Energy expenditure (W)	470.3–773.7

**Table 1.** Performance evaluation results of the CRI harvester.



**Figure 3.** The NCAM harvester.



**Figure 4.** The CTCRI semi-manual harvester.

of the lever can be adjusted to facilitate uprooting of cassava plants raised on different land preparation methods (flat, mounds or ridges). The CTCRI harvester requires about 16–40 man h/ha and uses 547–639 W of physical energy during cassava harvesting [4].

#### 2.4. Mechanised harvesters

Harvesting cassava mechanically involves the use of a harvesting implement integrally hitched to a tractor to dig out the cassava roots. Manual effort may be needed after cassava uprooting to collect and detach the cassava root tubers. The following field requirements/conditions are also necessary to allow for an optimum mechanical cassava harvesting operation: a field free from hidden obstructions (rocks, roots, stumps etc. down to 40 cm deep) of sizes that can interfere with lifting the tubers; good weed control as weeds block the lifters; Cutting down (coppicing) the cassava plant to a stalk level of about 30 cm prior to harvesting to allow the tractor operator to work in a regular manner. Ridge cultivation of cassava in rows is preferred to facilitate better orientation of stems for tractor operation during harvest.

Mechanised harvesters can be classified into semi-mechanised and fully mechanised. Whereas all processes from digging of roots, lifting of uprooted roots onto soil surface to transport are mechanically done in fully mechanised harvesters, only the root digging process is mechanised in the case of semi-mechanised harvesters.

The digging, lifting and transport of cassava root cluster into a windrow have been demonstrated under Ghanaian condition using a prototype fully mechanised cassava harvester developed at the Leipzig University, Germany [14]. The harvester reduces the heavy physical work involved in manual cassava harvesting using the hoe and cutlass, especially in the dry season. Design goals for the Leipzig mechanical harvester prototype were, cutting of soil, digging of soil, raising of soil containing the cassava root cluster, transporting the cassava root cluster into windrow behind the tractor to ease manual tuber detachment from stem, reducing the number of moving parts, improvement in the flow of soil and residue to prevent blockade and fuel conservation during seedbed preparation for next cropping. The structural arrangement of the harvester consists of a digging share rising into a conical shaped mould-board between two legs, a frame of digging tool, a stem guiding device, a frame for stem pulling device and hydraulically operated belt pulling elements. The 1 m wide harvester which is a fully mounted implement operates according to the “dig and pull” principle. It cuts and loosens the growth area of the root cluster by two vertical beams, and a share attached to the base plate.

**Figure 5** shows the Leipzig mechanical harvester prototype. The cassava root cluster is loosened carefully, lifted to about 20 cm and delivered to the transport unit made of two belts and a set of steel/plastic press rollers. The windrowed root clusters are then detached with hand or cutlass and finally collected. The harvesting process produces a well pulverised field, thus effectively eliminating the tedious and energy intensive conventional primary tillage operation. Additional advantages for using the harvester include, lowering of the total production



**Figure 5.** The Leipzig mechanical cassava harvester.

cost, increase in labour productivity and considerable decrease in harvesting losses and root damage.

The harvester was introduced into Ghana in 1991. However, field testing only started in 1993. As a result, it could not be evaluated extensively and further investigation on the performance of the harvester was expected to be conducted in other agro-ecological zones of the country. **Table 2** shows the summarised performance evaluation results after testing the Leipzig mechanical cassava harvester prototype on the TMS 30572 cassava variety for some agro-ecological zones in Ghana according to Bobobee et al. [14].

The Latin American and Caribbean Consortium to Support Cassava Research and Development (CLAYUCA) conducted some research on the adaptation and evaluation of semi-mechanised harvesting systems for cassava in Columbia. This evaluation process became important due to the excessive cost of manual harvesting. A semi-mechanised cassava harvester prototype developed in Brazil was imported and its performance was evaluated under specific conditions in the main cassava growing regions of Columbia [15].

The prototype harvester has a front cutting disk that facilitated the harvesting process and was able to work even on dry soils where manual harvesting was not possible [15]. For a smooth operation, however, it required the cutting of cassava stems prior to harvesting to a height of 20–40 cm. **Figure 6** shows the CLAYUCA mechanised harvester model P600.

Parameter	Value
Draft requirement (kN)	11.94–16.2
Working depth (cm)	25
Soil moisture content (% d.b.)	3.5–5.8
Soil bulk density (g/cm <sup>3</sup> )	1.82
Cone Index (MPa)	0.88–2.5
Average fuel consumption (l/ha)	40.3
Working speed (km/h)	2.4–4.1
Field capacity (ha/h)	0.25–0.38
Tractor power requirement (kW)	55–80

**Table 2.** Performance evaluation results for the Leipzig mechanical cassava harvester.



**Figure 6.** The CLAYUCA mechanised harvester model P600.

The technical and performance characteristics of the CLAYUCA harvester prototype is presented in **Table 3**.

The main effect of the use of the harvester is the improvement in the efficiency of labour. Under the traditional system, in which the cassava roots are harvested by hand, a good performance for a worker is around 500 kg roots/day [15]. With the use of the harvester Model P600, CLAYUCA has been able to measure the harvest of around 1100 kg roots/day. In more developed cassava producing systems, such as those found in South Brazil, a good performance using mechanical harvesters is around 1500 kg roots harvested/day. The economic importance of the use of mechanical harvesters is in the reduction in the number of workers that are needed to harvest a cassava field. Ospina et al. [16] reiterated that the introduction of the CLAYUCA harvester prototype allows a reduction of 53% in labour cost for harvesting resulting in a reduction of 43% of the cost of harvest, and a further reduction of 12% of the total production costs.

According to Oni [17], the National Centre for Agricultural Mechanisation (NCAM) in Nigeria developed a mechanised cassava harvester which was adapted for use in most farming communities in Nigeria. The harvester consists of a combination of a standard chisel plough preceding a serrated disc plough, both mounted on a tractor-drawn toolbar. The harvester has a field capacity of 0.8–1.2 ha/h. **Figure 7** shows the NCAM tractor-drawn cassava harvester.

Odigboh and Moreira [18] reported that mechanisation of cassava harvesting has attracted a great deal of research attention but with very modest successes achieved. Catalogues of agricultural machines produced by Brazilian manufacturers contain no cassava harvesters. What exists in Brazil, as elsewhere in the world, are few models of cassava harvesting aids in limited production and on trial use by a few farmers. Also, there are many problems associated with cassava harvesting. Some of these problems are as a result of the serious difficulties created by the random growth patterns of the roots and the equally random branching of the stems. In addition, cassava does not have a specific harvesting season. According to Odigboh and Moreira [18], an effective harvester must therefore be able to operate in the parched hard soils of the dry season, the drenched muddy soils of the tropical rainy season,

Parameter	Value
Working width (m)	2.4
Working depth (cm)	30–40
Harvester weight (kg)	200
Average working speed (km/h)	7
Field capacity (ha/h)	0.63–1.1
Tractor power requirement (kW)	67

**Table 3.** Performance evaluation results for the CLAYUCA cassava harvester.



**Figure 7.** NCAM semi-mechanised cassava harvester [15].

as well as in soils the consistencies of which vary between those two extremes. Agbetoye et al. (2000) reported that most of the experimental cassava harvesters in literature are based on the elevator digger principle whereby the share cuts through the soil 0.3–0.4 m deep and 0.7–0.8 m wide and handling about 0.23 m<sup>3</sup> or about 500 kg of soil to harvest a plant. All these unique characteristics must be appropriately considered to design an effective harvester for cassava.

The TEK mechanical cassava harvester was developed and manufactured at the Department of Agricultural and Biosystems Engineering, Kwame Nkrumah University Science and Technology, Kumasi. This harvester was developed after the Leipzig to suit local prevailing field conditions. However, unlike the Leipzig which was fully mounted with a hydraulic transport system, the TEK harvester did not have that. One thing that was evident during the field evaluation of the Leipzig was that most tractors found on farmer's fields were not able to support the hydraulic system of the harvester. This necessitated the disabling of the hydraulic transport system in the design of the TEK mechanised harvester. The TEK cassava harvester (**Figure 8**) basically has the following parts; digger, shakers consisting of a slatted mould conical mouldboard, the linkage points and the vertical support.

The TEK mechanical harvester, though semi-mechanised, is a fully mounted implement which operates according to the 'dig and pull' principle. Having met the necessary field conditions prior to harvest, the implement hitched to the tractor is gently lowered to set the required depth of penetration (depending on root depth of the cassava variety to be harvested). As the digger goes through the soil, the roots are brought onto the surface for collection and detachment facilitated by the inclination of the slatted conical mouldboard (B). Due to the large quantity of soil and trash that is dug out together with the roots, there is often an increase in the resistance behind the tractor leading to increased fuel consumption. When the soil is moist and sticky, the slatted conical mouldboard serves as shakers to sieve the soil clods and reduce adhesion. This helps to accelerate the harvesting process resulting in an increase



*A – Beam to which digging unit is attached  
C – Top link hitching point  
E – Vertical support  
G – Slatted rods for shaking off soil*

*B – Conical mouldboard  
D – Digger  
F – Lower link hitching points*

**Figure 8.** The TEK mechanical cassava harvester.

in the efficiency of the tractor and harvesting implement. **Table 4** presents the field evaluation results of the TEK mechanised harvester.

An added advantage after mechanical harvesting of cassava is that the land is ploughed for subsequent crop establishment. Only harrowing and ridging may be needed, thus total cost of production for the subsequent season is reduced. Careless use of machinery for harvesting however, can damage tubers, resulting in rapid deterioration that will lower the value of the end product.

Parameter	Value
Working width (m)	1
Working depth (cm)	23–29
Harvester weight (kg)	300
Average working speed (km/h)	5
Field capacity (ha/h)	0.4–0.52
Draft power requirement (kN)	10.33

**Table 4.** Performance evaluation results for the TEK cassava harvester.

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