PLANT SCIENCE TODAY
Vol 12(sp3): 01–12
https://doi.org/10.14719/pst.8234

eISSN 2348-1900

REVIEW ARTICLE

Smart mechanization of tapioca planting: Integrating AI and advanced technologies

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Received: 13 March 2025; Accepted: 08 May 2025; Available online: Version 1.0: 29 May 2025

Cite this article: Shramodaya, Mohankumar AP, Kavitha R, Surendrakumar A, Sivakumar V. Smart mechanization of tapioca planting: Integrating AI and advanced technologies. Plant Science Today. 2025; 12(sp3):01–12. https:/doi.org/10.14719/pst.8234

Abstract

Conventional farming guidelines lack detail, providing crop suggestions without location-based advice. This makes it challenging for farmers to make informed decisions about where to plant crops, affecting their productivity and profitability. The reason for tackling this issue lies in the potential of cassava, a crop that can withstand drought conditions to thrive if the right areas are identified accurately. This evaluation has a look at the way in which advanced technologies as well as artificial intelligence (AI) can be used to revolutionize mechanized cassava planting, with the objective of increasing productivity and sustainability. Cassava, a nutrition base for over 500 million people worldwide, is sourced from India, especially in the Tamil Nadu and Kerala regions. However, its existence is subject to certain problems that are linked to the conventional method of planting, like inconsistency in planting depths, wrong sweating of the stem and clogging of the channel, which all in turn serve to lower yields and increase labor costs. The former factors caused by mechanical devices like two-ploughed and three-ploughed planters have already been close to the economies of scale by achieving better planting efficiencies and consistency, but they are still presenting some difficulties. Some of the latest advances, such as tractor-operated single-row stake cutter-planters and rotary dibble-type planters, provide alternatives that are not only cheaper but also have the highest degree of accuracy when it comes to planters. Furthermore, the introduction of IoT (Internet of Things) and machine learning and the use of big data analytics in farming are the new directions for precision agriculture. This review emphasizes that the research that is continually being carried out, the unbeatable innovation or technological development and the farmer education that is expected to be high enough are crucial for the full realization of smart in cassava cultivation. In this way, we will be closer to a more sustainable type of agriculture and improved food security. By embracing these innovations, agriculture can be modernized, empowering farmers to overcome obstacles and achieve increased productivity. The data and findings highlighted in the review demonstrate the effectiveness of mechanization in revolutionizing practices and bolstering global food security.

Keywords: cassava; mechanization; modern agriculture; planter; sustainability

Introduction

Cassava (*Manihot esculenta Crantz*) is a member of the Manihot genus, which includes around 100 different species of trees, shrubs and herbs. For around five thousand years, cassava has been a primary source of food for many countries around the globe, providing nearly 500 million people with a high-calorie, starchy carbohydrate. Cassava, also known as tapioca, manioc, or mandioca, originated in Latin America over 4000 years ago. It was introduced to India in the 18th century, where it is now cultivated on a large scale. India is the world's leading producer by area cultivated and ranks 25th globally in terms of overall production. In India, cassava is cultivated under both rain-fed and irrigated conditions. Tamil Nadu and Kerala contribute about 80 % of the nation's total cassava production. In 2019, India had 2.28 lakh hectares planted with cassava, yielding 4472.09 thousand tonnes nationwide. Tamil Nadu alone had 81.12 thousand hectares under this crop, yielding 3065.12 thousand tonnes and the state's average productivity was 30.5 tonnes per hectare in 2019-2020. Namakkal district tops all others within Tamil Nadu contributing 20.15 % towards state's total output where approximately 72 % comes from Namakkal, Salem, Dharmapuri, Villupuram and Erode districts. Namakkal District benefits from favorable natural conditions, including well-distributed rainfall and potassium-rich soils, making it suitable for agriculture. In rainfed regions prone to drought, resilient crops like sweet potatoes help mitigate crop failure, ensuring food security and boosting smallholder farmers' incomes (1) (Fig. 1).

Cassava is highly versatile and similar to food grains. It contains easily digestible starch, making it a popular feed for pigs, cattle, sheep and poultry in tropical regions. Fresh cassava tubers are about 30 % starch and sugars, while dried

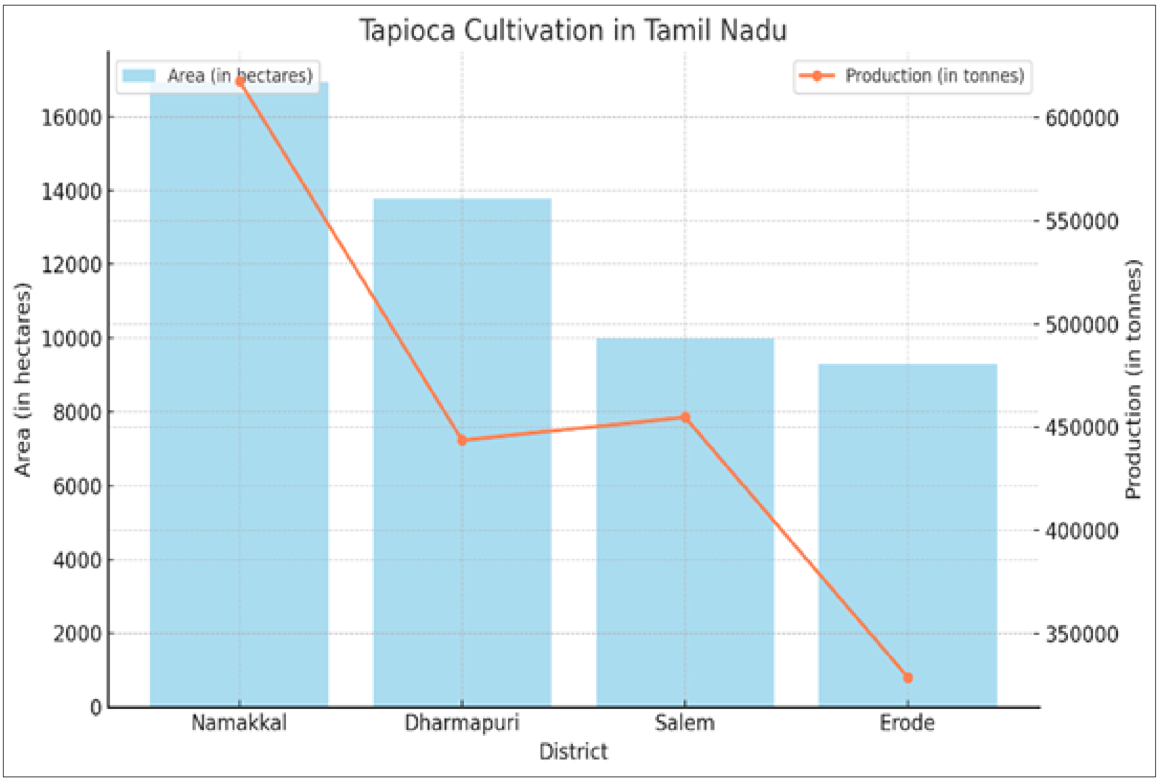

Fig. 1. District-wise area of cassava cultivation and production in Tamil Nadu.

tubers are about 80 % fermentable substances, like rice in terms of producing alcohol. Cassava offers various health benefits; it is good for hair and skin due to its rich nutrient content. For instance, cocoa powder, vanilla and cassava starch can be combined to create an affordable, allergy-free bronzer that is tailored to the needs of various skin tones. Additionally, preliminary research suggests that linamarin, a compound in cassava, may have cancer-fighting properties. Cassava is also rich in vitamin C and calcium, contributing to its medicinal benefits (2).

Cassava grows best in red lateritic loamy soils that have a pH range of 5.5 to 7.0 and are well-drained. While the rest of the state grows cassava as a rain-fed crop, the districts of Salem, Erode, Dharmapuri and Namakkal in Tamil Nadu are well known for their irrigated cassava cultivation. Growing cassava alone or in combination with coconut is common practice. Co 2, Co 3, CO (TP) 4, MVD 1, H 165, H 226 and other varieties are often planted. Tamil Nadu's cassava planting seasons vary according to the availability of irrigation. It is grown all year round with irrigation. April is the best time of year for crops that are rainfed. Longer duration varieties can yield up to 40 tonnes per hectare, while shorter duration varieties typically yield about 25-30 tonnes per hectare. In order to achieve fine tilth, cultivation practices require extensive field preparation and multiple plowings. Critically important is the vertical planting of sets with the proper spacing (irrigated: 75 x 75 cm or 90 x 90 cm, rainfed: 60 x 60 cm). For best results, regular weeding, earthing up and irrigation (if needed) are required. For standard varieties, harvesting takes place after 10-11 months and for short-duration varieties, it happens after 6-7 months. For the 2019-20 season, India produced 6060 thousand metric tons of cassava. Tamil Nadu is the leading state in cassava production with 3065.14 thousand metric tons, securing the first position nationally (3).

The total cost of cultivating one hectare of cassava is Rs. 32000. The most expensive cost is land preparation, which is valued at Rs. 8000, followed by weeding at Rs. 8000 and harvesting at Rs. 6000. Nursery/planting materials, together with sowing, take up Rs 5000, while plant protection ranks least costly with Rs. 2000 and fertilizers follow closely behind with an amount of Rs. 3000. This cost distribution gives insight into what it takes financially to engage in cassava farming in India. It highlights heavy human resource investment on tasks such as clearing fields before planting, tilling them again after some time so that unwanted plants may die off, thereby reducing competition among crop species and uprooting mature ones when ripe enough for consumption but before seed maturity for preserving eating quality standards through preventing fiber development, which would make root species, Brous, hence unpalatable (3) (Fig. 2).

Cassava, once thought to be unsuitable for large-scale farming due to issues like pest transmission through stem cuttings and low multiplication rates, has undergone an incredible transformation over the last few decades. Despite early skepticism, global cassava production has soared. From 1980 to 2011, the area harvest increased by 44 % and overall output more than doubled. In the last ten years, cassava production growth has picked up even more. By 2012, the global harvest had surpassed 280 million metric tonnes, marking a 60 % rise since 2000. In Africa, cassava production has kept pace with maize, while in Asia, its growth rate has tripled that of rice. The productivity of cassava farming has also seen notable improvements. Since 2000, yields have increased by 1.8 % annually, outpacing the growth rates of potatoes, maize, rice and wheat (Fig. 3). Although the average yields are still below the potential of 23.2 tonnes per hectare that can be achieved with better management practices, the remarkable progress of cassava highlights the power of

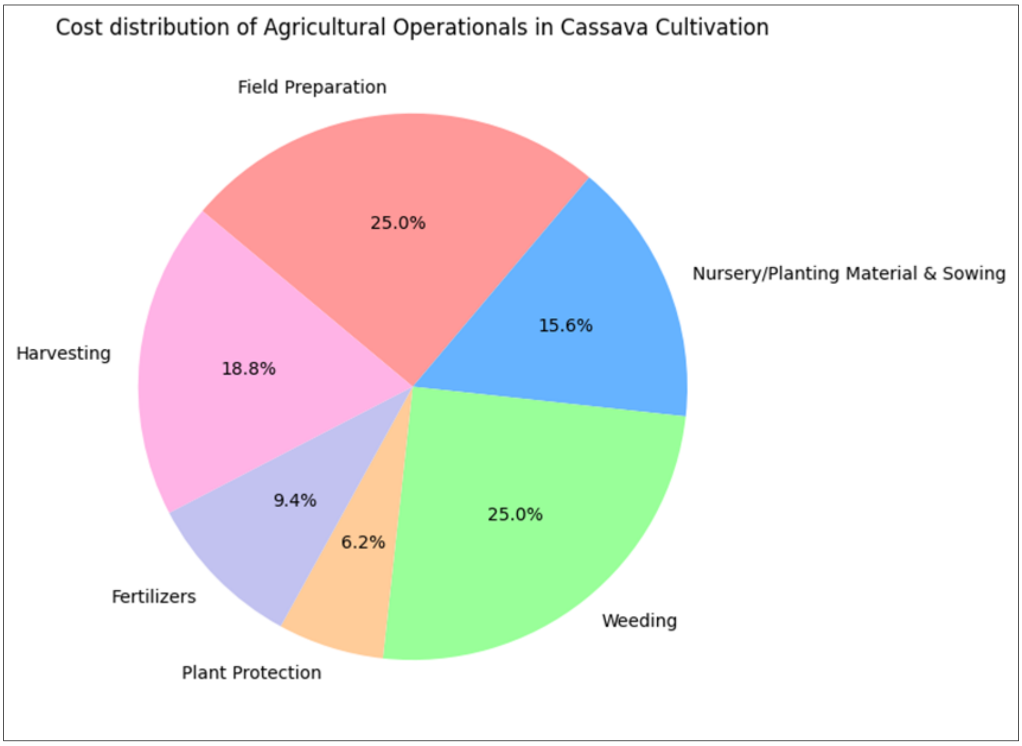

Fig. 2. Cost of cultivation of Cassava.

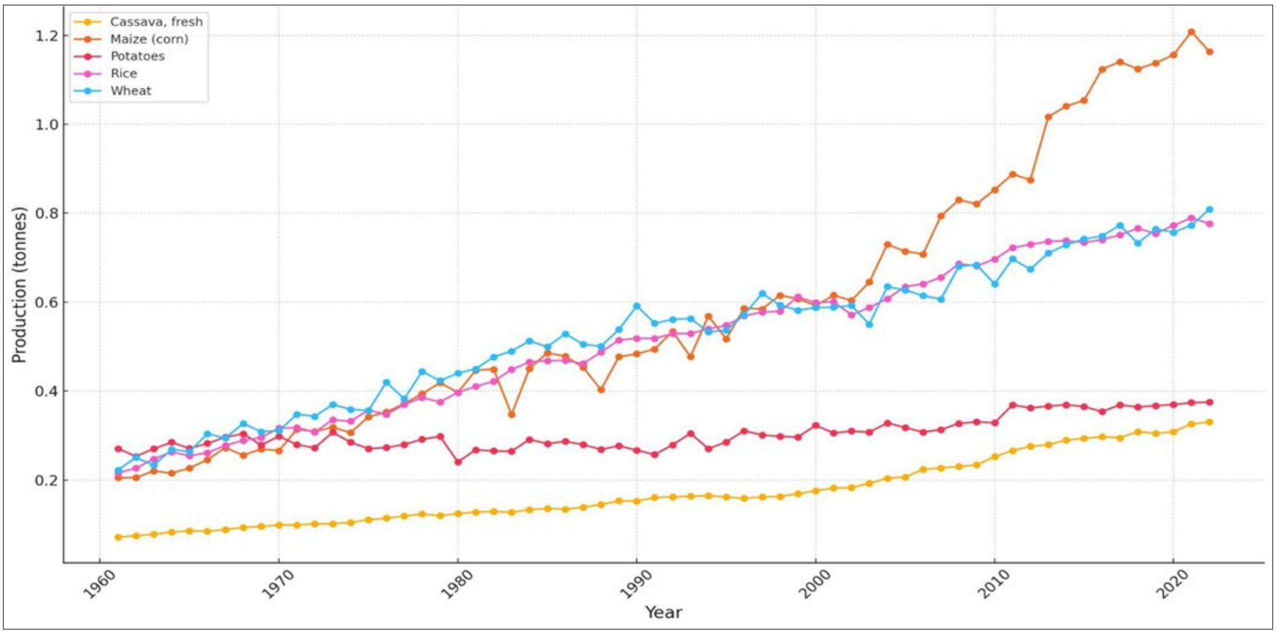

Fig. 3. Growth in world production of major crops, 1960-2022 (index 1980=100) Source: FAO. 2023. FAOSTAT statistical database (http://faostat.fao.org/).

research, innovation and farmer adoption in overcoming past challenges (4) (Fig. 3).

The research reveals cassava price patterns over time, demonstrating changes across different locations. The information covers the years 1991 to 2023 and captures significant market developments. The price of fresh items has varied significantly throughout the years, with the highest reported price reaching 23377.35 INR. in Vietnam. These swings might be attributable to seasonal production, transportation costs, regional demand and meteorological circumstances that impact yields. The trendline in the visualisation depicts price increases and decreases, which might imply changes in supply chain dynamics or policy implications on agricultural trade. Sudden price spikes, for example, may occur from supply shortages induced by severe weather events, while decreases may be connected to excess production or trade liberalisation policies. By analysing this data, politicians, farmers and traders may get significant insights into the economic behaviour of fresh product pricing, allowing for improved production, marketing and distribution decisions (4) (Fig. 4).

Challenges faced in cassava plantation

Uneven planting depth

Manual planting frequently struggles to maintain a consistent planting depth, especially in soils with varying conditions, leading to uneven germination and growth, reduced yields and reduced resource use efficiency. Mechanized planters solve this problem by using adjustable-depth controls that adapt to different soil types and conditions. These controls ensure uniform planting depth, promoting even germination

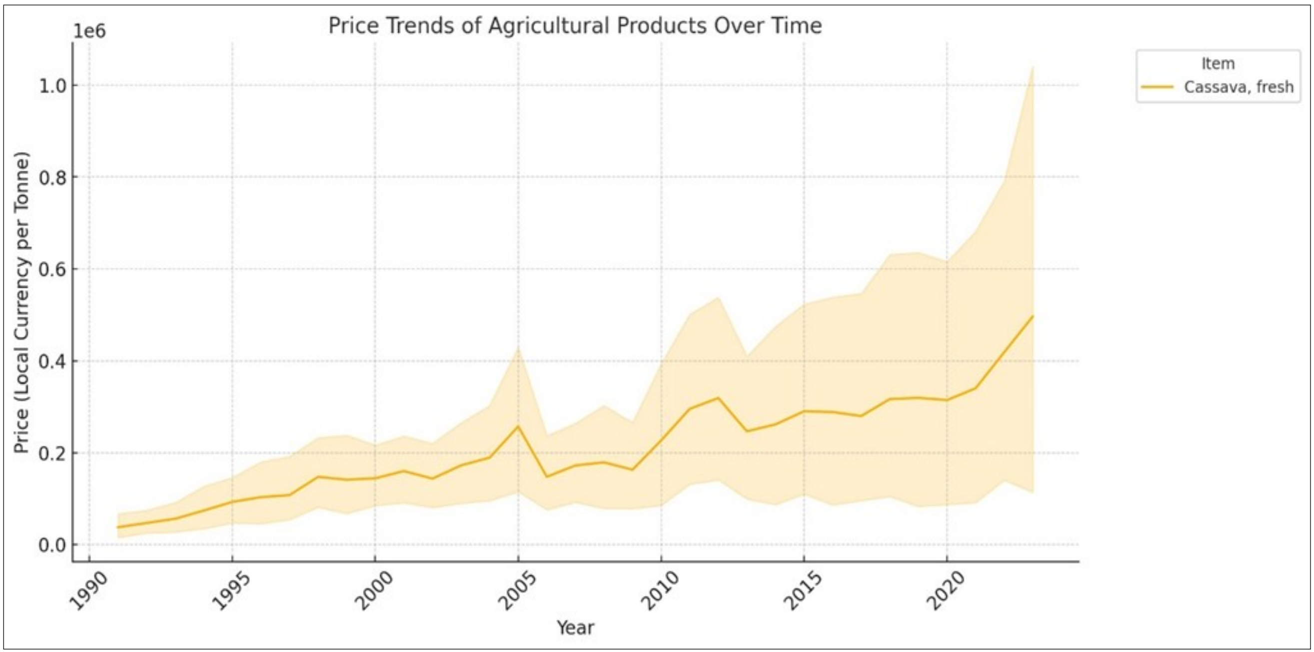

Fig. 4. Price trends of cassava over time. Source: FAOSTAT statistical database (http://faostat.fao.org/).

and growth, thus resulting in higher yields and more efficient resources (5).

Significant patterns in germination time, survival rate and plant height are shown by analysing the effects of planting depth on plant growth. Seeds planted at a depth of 7.5 cm take the longest to achieve 50 % germination, taking around 16 days, while seeds planted at a depth of 15 cm and 22.5 cm germinate more quickly, taking about 13 days. Increased soil temperature variations and moisture loss, which impede consistent germination, are the cause of this delay in shallow planting. Faster germination is supported by deeper planting, especially between 15 and 22.5 cm, which creates a more stable environment with improved moisture retention. The survival rate at 10 months is shown in the second graph, which clearly increases with planting depth. The survival rate of seeds planted at 7.5 cm is the lowest (~65 %), but seeds sown at 15 cm and 22.5 cm have much better survival rates (~85 % and ~90 %, respectively). Increased exposure to environmental stressors including dryness and soil erosion, which may impair root growth and plant stability, may be the cause of the reduced survival rate at 7.5 cm. Plant resilience is increased with deeper planting, which also improves root protection and moisture availability. The third graph, which shows the average height of the plants, indicates that, with plants reaching around 220 cm, the ideal planting depth for maximising growth is 15 cm. Plants at a depth of 7.5 cm grow shorter (around 180 cm), most likely as a result of less water absorption and restricted root growth. It's interesting to note that, while a depth of 22.5 cm promotes greater survival, it causes a tiny decrease in height (~200 cm), maybe as a consequence of delayed emergence from excessive depth. These results suggest that for improved growth and survival, a planting depth of 15-22.5 cm is ideal. While 15 cm depth is better for reaching maximum plant height, 22.5 cm depth is optimal if maximising survival is the top concern. To maximise growth conditions, planting depth modifications should be made in conjunction with proper soil preparation and moisture management (6) (Fig. 5).

Improper stem placement

Inaccurate stem placement during manual planting can hinder root development and decrease yields. Mechanized equipment equipped with precise stem placement mechanisms such as metering devices, vacuum systems, or precision planting units ensures proper positioning of cassava stems in the soil. This accuracy promotes root development and maximizes yield potential (5).

The study demonstrates the impact of stem portion and the number of stakes per stand on cassava root yield. In the first plot, it is evident that the top portion of the stem provides the highest yield at 55.2 tonnes per hectare. The middle portion follows with a slightly reduced yield of 50.6 t/ha and the basal portion yields the lowest at 48.7 t/ha. This indicates that the top stem portion is the most effective for achieving higher yields. The effect of the number of stakes per stand on root yield is highlighted. Planting 1 stake per stand results in the highest yield at 58.3 t/ha, while increasing the stakes to 2 per stand reduces the yield to 52.1 t/ha. Further increasing it to 3 stakes per stand decreases the yield even more, down to 49.4 t/ha. This suggests that using a single stake per stand is optimal for maximizing cassava root yield, as multiple stakes can lead to competition for resources, reducing overall productivity. The data emphasizes the importance of selecting the appropriate stem portion and limiting stakes per stand to enhance cassava production efficiency (5).

Clogging and jamming

Debris, soil clumps, or damaged cassava stems can cause clogging and jamming in planters, leading to downtime, reduced efficiency and uneven planting. Mechanized planters are designed to minimize these issues through features like wider tires, improved debris management systems and robust components. These features enable the planters to handle varying soil and debris conditions more effectively, reducing blockages and ensuring smooth operation. By addressing these specific planter problems through mechanization, cassava farmers can significantly improve planting efficiency, reduce labor requirements and achieve more consistent and successful cassava plantations. This mechanization leads to increased

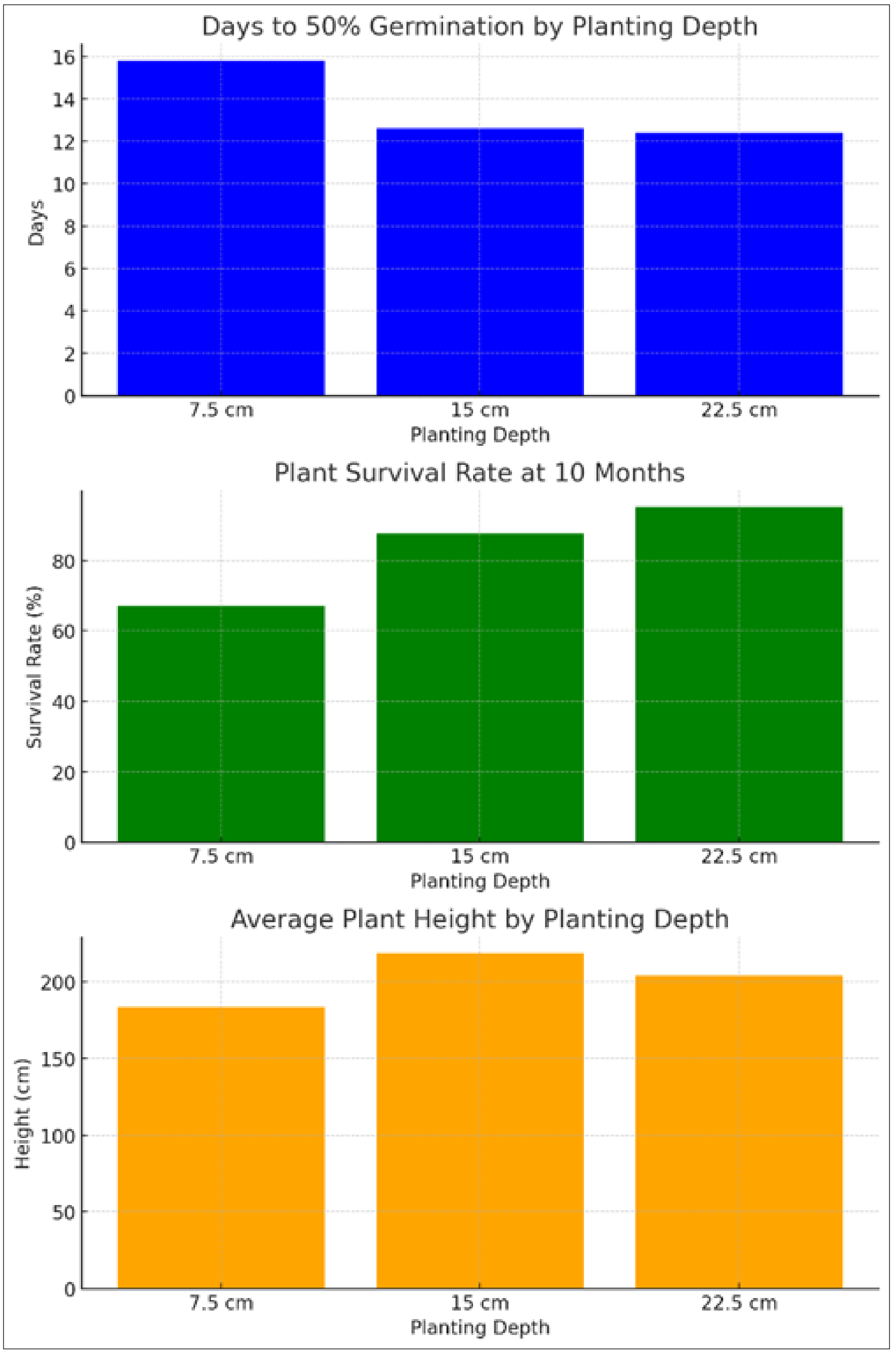

Fig. 5. Effects of planting depth on germination, survival and growth of plants.

productivity and better resource management, benefiting both the farmers and the agricultural sector overall (5).

Managing a commercial cassava plantation is challenging for farmers, as manually planting the entire area requires significant labor. To complete the planting within a set timeframe, the farmer would need to hire multiple workers, ultimately increasing production costs. Additionally, manual planting often results in inaccurately spaced cultivars, leading to lower yield (6). Therefore, mechanization and advancements in planters are essential to improve planting efficiency, reduce labor costs and ensure optimal spacing for higher yields.

Existing plantation methods

There are currently three main technological options for cassava planting that incorporate different degrees of human intervention. The first is a completely manual technique that is popular in many developing nations and involves planting everything by hand. In the second, which is semi-mechanized fertilizer, horizontal stakes are manually inserted into furrows made by chisel ploughing and subsequently filled in with soil. Usually, a tractor pulls the machine. Additionally, some mechanized models incorporate the application of fertilizer during the planting procedure. Evaluated prototypes include:

- The 2-furrow planter (PC-20), which can plant 6.2 hectares per day with a team of three workers. It offers adjustable settings for furrow and plant spacing, stake length and planting depth.
- The 3-furrow planter (PMT-3), which can plant 9.2 hectares per day with a team of four workers. It has a fixed plant spacing of 90 cm and a furrow spacing of 1 m (7).

The 2-furrow planter (PC-20) for cassava is a mechanical device intended to enhance planting productivity and minimise manpower needs in cassava farming. It offers an adjustable row distance ranging from 85 to 95 cm, coupled with plant spacing flexibility inside rows, which may be adjusted from 40 to 100 cm. This versatility guarantees that the planter satisfies varied agronomic demands. The planter is compatible with tractors rated between 60 to 70 hp and employs a hydraulic lifting mechanism for operation. Its notable feature is the automated cutting system, which employs the tractor's wheel rotation to cut cassava stakes consistently. The planter offers a substantial storage capacity, allowing 1.5 cubic meters of cassava stems and 150 kilo of fertilizer, permitting longer operation without regular refills. It also has a facility for managing planting depth, guaranteeing perfect positioning of cassava stakes in the soil. With a field capacity of 5 to 7 hectares per day, the PC-20 greatly exceeds human planting techniques in terms of production. Moreover, it decreases manpower needs, requiring only two persons to load the cassava stems in addition to the tractor driver. This planter offers a significant improvement in automated cassava cultivation, meeting the need for higher efficiency and decreased manual labour in the agricultural sector.

A comparison of two mechanical cassava planters (2-furrow and 3-furrow) with manual planting across three sites revealed that the 2-furrow planter achieved higher uniformity in spacing (92.7 %) and stake length (97.7 %) compared to the 3-furrow planter (79.4 % and 95.9 %, respectively). Additionally, the 2-furrow planter caused less mechanical damage to stakes (9.98 %) than the 3-furrow planter (27.9 %). In terms of output, the 2-furrow planter outperformed the 3-furrow planter, with an output of 0.39 hectares per hour and 6.34 hectares per day, versus 0.38 hectares per hour and 6.13 hectares per day for the 3-furrow planter. Manual planting, while achieving the highest uniformity in spacing (97.7 %) and stake length (98.3 %), had the lowest output, with only 0.02 hectares per hour and 1.00 hectares per day (7) (Table 1).

Mechanized planting efficiency ranges from 0.4 to 1.25 hectares per hour, depending on machine type. For instance, Brazil's four-row cassava planter achieves a working efficiency of 13-15 hectares per day, while China's 2CMS-2 cassava planter has an efficiency of 0.4-0.7 hectares per hour. Similarly, cassava harvesting efficiency has improved with innovations in digging shovels and clamping harvesters. Traditional manual harvesting, which dominates in African nations, processes only 0.1 hectares per hour, whereas mechanized harvesters in Brazil and China can achieve 0.4-0.6 hectares per hour. The Chinese 4UMS-1800 harvester uses a clamping mechanism, reducing tuber damage and improving the bright potato rate to over 95%. Manual harvesting in Africa is the least efficient at 0.1 ha/hr, while Brazil's four-row planter achieves the highest efficiency of 1.25 ha/hr. China's vibrating-chain harvester offers a balance between efficiency (0.5 ha/hr) and reduced tuber damage. This highlights the need for increased mechanization in regions reliant on manual labour to improve productivity and reduce cassava losses (7) (Fig. 6).

The 2-row ridging type cassava planter is designed to plant two rows with a row spacing of 0.6 meters. It accommodates chop lengths of 0.49 meters and maintains a planting depth of 0.06 to 0.1 meters. The planter exhibits a productivity range of 0.05 to 0.08 square kilometers per hour and applies fertilizer at a rate of 300-700 kilograms per hectare. The machine requires a tractor with a power output of 67.1-89.5 kilowatts and has dimensions of 2.0 × 2.3 × 1.95 meters, with a total weight of 850 kilograms. Both machines deliver high efficiency in cassava planting, with variations in row spacing, weight and power requirements (Fig. 7).

The CIAE Regional Centre in Coimbatore has designed a tractor-operated single-row cassava stake cutter-planter. The device includes a main frame, a stake cutting system, a stake planting mechanism, a transmission system and a ridger. The cutting system is equipped with two shafts that counter-rotate and have two blades with an equal distance between. The planting mechanism features counter-rotating rubber wheels. Both systems are powered by the appropriate transmission system by the PTO of the tractor. When attached to a 35-40 hp tractor, the equipment forms a single ridge, cuts cassava stems into 24 cm stakes and plants them vertically at 45 cm intervals. The planter has an actual field capacity of 0.18 hectares per hour. The operational cost is Rs. 3125 per hectare, offering 60 % cost savings compared to manual planting. The cost-benefit ratio is 2.06 and the payback period is 4.31 years. The unit costs approximately Rs. 90000 (8).

The metering mechanism in the rotary dibble-type cassava planter is key for achieving precise planting. This

Table 1. Comparing the performance of mechanical cassava planters with manual planting

Parameter	Site 1	Site 2	Site 3	Average	Manual Planting
(A) The 2-furrow cassava planter					
Uniformity of spacing between plants (%)	91.3	92.6	94.3	92.7	97.7
Uniformity of stake length (%)	98.0	97.3	98.0	97.7	98.3
Uniformity of planting depth (%)	94.5	96.6	96.6	95.9	100.0
Mechanical damage to stakes (%)	10.0	10.0	9.6	9.98	0
Output (ha/hour)	0.42	0.39	0.38	0.39	0.02[a]
Output (ha/day)[b]	6.72	6.24	6.08	6.34	1.00
i.e., a 6-fold difference					
(B) The 3-furrow cassava planter					
Uniformity of spacing between plants (%)	74.0	77.0	87.3	79.4	98.1
Uniformity of stake length (%)	96.1	96.1	95.6	95.9	98.6
Uniformity of planting depth (%)	95.6	96.6	97.6	96.6	100.0
Mechanical damage to stakes (%)	36.6	25.0	22.3	27.9	0
Output (ha/hour)	0.37	0.42	0.36	0.38	0.02[a]
Output (ha/day)[b]	5.92	6.72	5.76	6.13	1.00
i.e., a 6-fold difference					

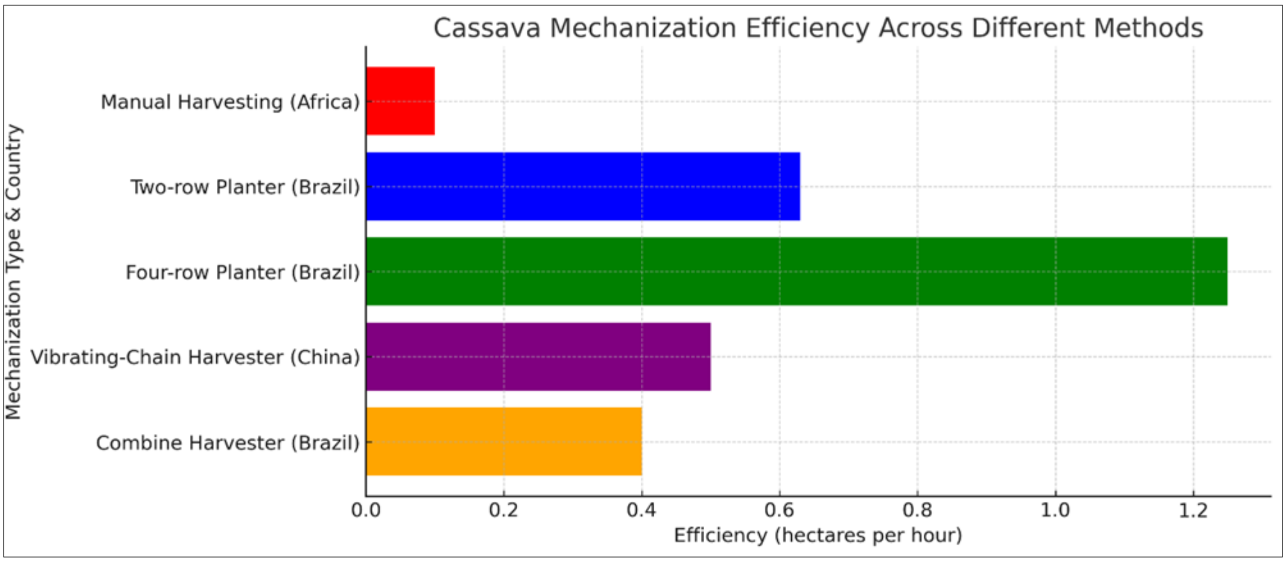

Fig. 6. Cassava mechanization types across different methods.

Fig. 7. 2 Row ridging type cassava planter (21).

device attaches to a tractor via. a three-point hitch and uses a ground-driven system to carefully place cassava stalks. Equipped with 12 cups on a rotating shaft, the mechanism moves as the tractor advances. The ground wheel's motion turns the shaft, allowing the cups to pick up cassava stalks from a supply box and drop them into planting furrows at regular 45 cm intervals. This design ensures high uniformity, minimizing variations in planting depth and spacing and making the cassava planting process more efficient and effective (9).

The measuring mechanism of a cassava planter is a critical aspect that helps in ensuring the whole exercise of planting is accurate and efficient. The cassava planter, fitted with a rotary dibble-type metering mechanism, is connected to a tractor through a three-point hitch. This mechanism consists of a rotating shaft with 12 stalk cups that move in a circular motion as the tractor moves forward due to the ground wheel's rotation. Cassava stems are cut to 150 to 200 mm in length. Placed in a stalk box, during operation, the tractor's movement drives the ground wheel, which in turn drives the rotary dibble-type metering device Stalk Cups: Each stalk cup on the rotating shaft picks up a single cassava stalk from the supply box. As the cups rotate, they carry the stalks to a discharge point. Once the cassava stalk reaches the discharge point, it falls due to gravity into a guide groove, which ensures the stalk is correctly positioned into the planting furrow. The mechanism ensures that the cassava stalks are planted at a consistent spacing of 45 cm. This is highly critical for uniform crop growth and optimal yield. The stalk cups are designed such that their height is 200 mm to accommodate the cassava stalk. The diameter of the stalk orifice is optimized to ensure smooth discharge, considering the rotational displacement of the stalks. The rotational speed of the metering device is calibrated such that it allows for uniform planting speed and spacing.

The metering mechanism saves much of the manual, which mostly acts as the limiting factor in cassava planting. This mechanized approach will ensure that the timely planting of cassava is done and will, therefore, maintain the quality and quantity of the cassava tubers. The metering mechanism in a cassava planter ensures that cassava stalks are planted with proper spacing and at the right depth. Through mechanization, it saves time and provides very accurate spacing; hence, it promotes efficiency in planting, reduces labor dependency and contributes to better crop management and yield (10).

The cassava stem cutting unit was designed in line with the existing practices of the cultivation of the cassava plant. It allows for variable cutting lengths between 150 and 300 mm and horizontal cutting of cassava stems with variable diameters. The said cutting unit will be attached to the planting unit of a cassava planter so that it can continuously cut and deliver stakes into the planter's delivery tube. A cam mechanism and bottom plate were developed for this purpose and a circular saw was adopted as the cutting blade due to its versatility and local availability, particularly for wood. The stem cutting unit, which was designed, fabricated and tested for collecting data to be used in developing the cassava planter, consists of a circular saw blade, cam mechanism, bottom plate, electric motor and motor gear, which are mounted on the main frame. The unit cuts cassava stems of all diameters and varieties horizontally with minimum power consumption. The cutting length can be set between 150 and 300 mm by adjusting the bottom plate. It was high in capacity and efficient with uniform feeding. When the camshaft operates at 50 rpm. A minimum cutting capacity of 5034 stakes per hour with an 83.91 % cutting efficiency was reached. Under the said conditions, the stems incurred no damage, which is sufficient for germination. Results of tests showed that the best cutting quality was obtained with a 60-tooth circular saw operating at a cutting speed of greater than 1200 rpm and a camshaft speed of less than 50 rpm (11).

The implement-type cassava planting machine aims to reduce labor requirements and increase cassava planting output. This machine was evaluated based on various performance metrics, including actual field capacity, planting and ploughing efficiency, percentage of hills missed and fuel consumption rate. The results of the performance test and cost analysis indicated that the machine is economically viable and easy for farmers to operate and maintain. The machine requires two operators to plant cassava stalks effectively. During the development of the implement-type cassava planting machine, several factors were considered to ensure its practicality and cost-effectiveness. The machine was designed to be manufactured using locally available materials to keep production costs low. It was also made simple and easy to operate, ensuring that farmers could use it without difficulty. Additionally, the component parts were designed to be easily fabricable. The development and performance evaluation of the implement-type cassava planting machine proved successful, with an increased planting efficiency of 91.39 % and an operating speed of 2.28 km/h. Although the efficiency decreased with higher operating speeds, the machine's overall performance and cost analysis confirmed its economic viability, making it a valuable tool for cassava farmers (12).

A power-operated portable cassava set cutter was designed and developed. India is considered to be the highest producer of tuberous roots in the world, with a production rate of 27.6 t/ha. It has been cultivated in an area of about 0.2 million ha with the production of 5.5 million metric tonnes of tuberous roots. Tamil Nadu and Kerala are named to produce 80 % of the total average of crop production in India. Due to the increase in population, growth of urbanization and increased use of cassava products in livestock, the demand for cassava has increased. A sett cutter requires 0.5 HP power and is capable of cutting 650 setts per hour. The most used varieties in Tamil Nadu regions are Mulluvadi and Kumkum rose. The length of Mulluvadi was around 1.2 to 3 m and Kumkum Rose variety was 1.2 to 2.8 m. The cost varied from Rs. 16200/- to Rs. 17000/- and output capacity was found to be 9600 sets per hour (13).

The 2CM-2B cassava intercropping machine is examined, showing its operational efficiency under field conditions. Currently, the machine relies on a manual-assisted seed release mode, which can lead to seed leakage due to untimely seed release. This drawback emphasizes the need for transitioning from mechanization to automation, where automatic seed metering systems can replace manual seed release, thereby reducing labour requirements. Several challenges persist in mechanized planting, including wear and tear of the seed-cutting mechanism, failures in seed metering and chute jamming, all of which contribute to inefficient seed placement (Fig. 8).

Addressing these issues requires research into intelligent seed leakage detection systems and automation in seed metering mechanisms. Moreover, the development of intelligent control algorithms can enhance the precision and reliability of cassava planting equipment. To improve the automation level of cassava planting, researchers must focus on smart technologies, such as real-time monitoring systems and automated adjustments for seed depth and spacing. The integration of sensors and AI-driven control mechanisms could further optimize the planting process, reducing waste and ensuring consistent seed distribution. These advancements will play a crucial role in the development of intelligent cassava planting systems, ultimately enhancing productivity and sustainability in cassava farming (12) (Fig. 9).

Use of smart mechanization

Smart agriculture has been revolutionized by the fusion of the Internet of Things (IoT) and data analytics, which provides farmers with valuable information for decision-making. With the combination of IoT technology and data analysis techniques, farmers are able to know things like the state of their crops, weather patterns, market trends, or even surveillance on land use. By using information collected from sensors, cloud platforms and other sources stored in databases, people involved in the agriculture industry will be empowered to carry out best practices that will lead to high productivity levels through making informed decisions. Big data acts as a cornerstone towards the success of precision agriculture as it creates room for economic empowerment within the farming community. Its ability to harness large datasets makes it possible

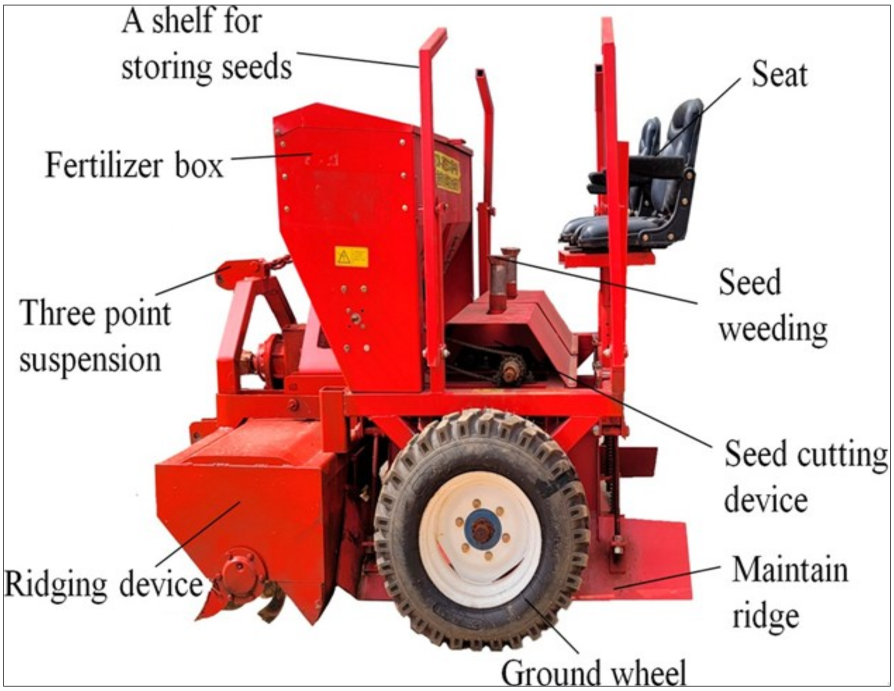

Fig. 8. 2CM-2B ridging cassava combine planter (21).

(**a**) Zhanjiang, Guangdong | (**b**) Guiping, Guangxi | (**c**) Congzuo, Guangxi

Fig. 9. 2CM-2B cassava intercropping machine in action during partial field operations (21).

for farmers to optimize resource utilization, thereby achieving sustainable agricultural practices that yield more with less input. Normally, smart farming system architecture is divided into three layers, namely the front end, gateway and back end. This kind of setup helps in gathering farm data, which is later processed to provide insights for decision-making by the farmer (14).

The 2AMSU New Ridging/Flat Type Cassava Planter is an advanced mechanical planting equipment developed to increase the efficiency and accuracy of cassava farming. Developed by TAGRM, this planter is very adaptable, capable of performing well in both ridged and flat field settings. One of its most prominent qualities is its multi-functional capabilities, enabling it to execute numerous jobs concurrently, including ditching, fertilizing, cutting cassava stems, sowing, soil covering and vibration pressure processing. By merging these operations into a single operation, the planter considerably lowers the need for several field passes, hence reducing time, labor and fuel expenses. Designed for large-scale cassava production, the 2AMSU planter boosts planting efficiency, making it a great solution for commercial farmers wishing to mechanize their operations. Its tolerance to many climatic circumstances, including the moist tropical areas of Southeast Asia and the dry temperatures of Africa, making it a dependable tool for numerous agricultural settings. Despite scant research papers or extensive performance assessments, the planter's design and characteristics imply that it is a highly efficient alternative for upgrading cassava cultivation. For a better understanding of its functioning, a demonstration film exhibiting its operation is accessible online, offering insights into how it advances automated cassava planting.

An IoT-based automatic sugarcane seed cutting machine, integrating sensor-based automation for precision cutting. The system employs infrared sensors to detect the exact length of the seed cane and triggers servo motors for precise cutting. Additionally, a programmable logic controller (PLC) governs the operation, ensuring accuracy and efficiency. The results demonstrate that the automatic seed cutting machine significantly improved precision, reducing seed waste and ensuring uniformity in seed size; it increased operational efficiency, reducing labour dependency and increasing processing speed by 30 % compared to manual cutting; it demonstrated a 95 % accuracy in detecting and cutting the sugarcane stalks at the predefined length; and it integrates sensor-based automation for precision cutting by using infrared sensors to detect the exact length of the seed cane and triggering servo motors for precise cutting; additionally, a programmable logic controller (PLC) governs the operation, which ensures accuracy and efficiency (15).

An advanced machine vision-based automation system for precise seed cutting is presented by a new design of machine vision-based sugarcane seed cutting systems. To find the best places to cut sugarcane stalks, the system combines high-resolution cameras with image processing algorithms. Based on real-time image analysis, the automation uses servo motors and a programmable logic controller (PLC) to make precise cuts. According to the findings, the machine vision-based seed cutting system considerably increased processing speed by 40 %, decreased seed waste by 25 % and enhanced cutting accuracy by 97 % when compared to traditional techniques. The system also made adaptive cutting adjustments and real-time monitoring possible, which improved overall accuracy and efficiency (16).

Trends in the development of cassava stem planters offers a perceptive examination of developments in automated cassava planting. It persuasively argues for mechanized solutions by highlighting the disadvantages of conventional manual planting, including its inefficiency, uneven planting depth and high labor costs. Examining different planter designs-from partially automated to fully automated systems-is especially helpful in comprehending how cassava planters have evolved technologically. The conversation about automation, sensor integration and metering systems illustrate how precision agriculture is influencing cassava production. Additionally, the well-structured economic analysis that contrasts manual and mechanized planting techniques supports the long-term advantages of mechanization in spite of initial investment challenges. Although the paper notes issues with affordability, it could look more closely at ways to make it more accessible to smallholder farmers. All things considered, the study offers insightful information about modernizing cassava planting and emphasizes the necessity of ongoing innovation to increase effectiveness and adoption (17).

Sugarcane Stem Node Detection and Localization for Cutting Using Deep Learning aims to improve sugarcane harvesting precision by detecting stem nodes with deep learning-based techniques. It explains the problems with traditional cutting methods, such as inefficient harvesting and material waste due to inaccurate node detection. The study investigates various neural network models to improve node localization accuracy, resulting in precise cuts that increase yield while reducing processing losses. The incorporation of machine vision and artificial intelligence into agricultural machinery is discussed as a step toward automation, which reduces manual labor while increasing efficiency. The method is useful for modernizing sugarcane harvesting, but factors such as model training, adaptability to different lighting conditions and computational requirements remain challenges. While the study effectively demonstrates the potential of AI in precision agriculture, more work on real-time implementation and affordability would improve its applicability (18).

The effect of different planting methods on growth and yield looks closely at how different planting techniques affect the growth and productivity of cassava. The comparison of traditional manual planting, ridge planting and mechanized planting methods, focusing on how they affect germination rates, plant health and final yield. It shows clear experimental data that highlight the benefits of optimized planting techniques, especially regarding uniform plant spacing, better root development and increased nutrient uptake. The results highlight how mechanized and ridge planting are better than traditional manual methods, especially when it comes to increasing yield and improving labor efficiency. The paper also talks about environmental and soil factors that affect planting success, providing useful insights for improving cassava cultivation. The study is detailed, but it might have looked deeper into cost-benefit analyses for various methods to assist farmers in making informed choices. The research gives important insights that can help enhance the efficiency of cassava farming by adopting better planting practices (19).

Innovative approach to agricultural planning through the use of remote sensing and machine learning, focusing on developing a predictive model to identify suitable areas for cassava cultivation in the Nakhon-Phanom province of Northeastern Thailand during the dry season. The scientists made use of satellite images coupled with soil properties data in coming up with a predictive model through artificial intelligence, from which it was realized that height above sea level combined with Ferric Acrisols (Af) type soils were the most important factors indicating suitable areas for cultivation. The study employed a two-class boosted decision tree algorithm that had 88.6 % accuracy and 74.6 % F1 score as the best performing one. Researchers advise the adoption of this decision support system by farmers and extension workers for improved crop planning while suggesting further studies to consider more diverse soil types alongside varying crop attributes so as to enhance its precision levels even further into the future. Transformative machine learning can be applied within agriculture by underscoring its ability not only to increase yields but also to ensure food security globally. With advanced technological tools, this investigation has practical implications for smallholder household incomes but also serves as a foundation upon which more research in agricultural technology can be built, with the goal of improving productivity under adverse growing conditions (20).

The implementation of IoT and big data analytics in precision agriculture poses several challenges, such as data unavailability, accuracy of predictions based on available information and high initial costs associated with setting up these technologies, among others, like equipment failure rates because they are still relatively new systems. This can only be addressed through education at all levels of the sector; they include coming up with frameworks that bring together both methods (internet of things and data analytics), proposing new technologies for better results, selecting appropriate Wireless

Sensor Network (WSN) technologies and dealing with implementation challenges. The aim is to make sure that these studies contribute not only towards knowledge creation but also towards sustainable agriculture development, thus profit generation (14).

Future prospects of cassava planters

The incorporation of modern sensor technologies into the cassava planter holds enormous potential for boosting its efficiency, precision and adaptability. Sensors like proximity sensors, ultrasonic sensors and load cells can be included to monitor crucial parameters, including planting depth, seed spacing and soil conditions, in real-time. For example, proximity sensors can assure precise stalk placement by detecting anomalies in stalk flow, while ultrasonic sensors can check planting depth by monitoring soil disturbance throughout the planting process. Load cells can be used to measure the weight of stalk material in the hopper, ensuring continuous measurement without pauses. Furthermore, IoT-enabled sensors may transfer real-time data to cloud-based systems, allowing for remote monitoring, predictive maintenance and data-driven decision-making, minimizing downtime and enhancing overall productivity.

In comparison, modern planters used in crops such as maize, wheat and rice have already embraced similar technologies, displaying considerable increases in operating efficiency and reduced labour dependency. These planters feature GPS-guided precision systems for automatic row alignment and variable-rate seeding, which maximize resource utilization and boost yield potential. Adapting this proven technology to cassava planters can transform the planting process by solving the unique constraints of root crop cultivation. Additionally, this innovation can contribute to promoting sustainable agriculture practices by minimizing seed wastage, reducing energy usage and enhancing the uniformity of plant establishment, ultimately leading to improved production and profitability for farmers.

Conclusion

Implementing advanced technologies and AI in cassava planting offers a game-changing solution for farmers, enhancing efficiency and profitability. By using smart mechanization, farmers can optimize resource use, streamline planting processes and boost their income. This innovative approach not only improves operational efficiency but also promotes sustainable farming, providing both financial benefits and higher yields for cassava growers. Embracing these advancements modernizes agriculture, helping farmers achieve greater productivity and success in their fields. Through AI and advanced tools, the future of cassava farming looks brighter, more efficient and more sustainable.

Acknowledgements

We are grateful to Tamil Nadu Agricultural University for their ongoing support in the form of regular workshops that help us with writing review.

Authors' contributions

S wrote the original manuscript. APM conceptualized the manuscript and reviewed the manuscript. RK and AS reviewed the manuscript. SV reviewed and edited the manuscript. All authors read and approved the manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

References

1. Shankar RG, Rajesh R, Selvam S. A study on resource use efficiency and economic returns for Tapioca in Namakkal district of Tamil Nadu, India. The Pharma Innovation Journal [Internet]. 2021;(9):400–4. http://www.thepharmajournal.com
2. Jegan S, Raj RA, Elakkiya M, Madan P. Automation in cassava plantation. International Journal of Scientific & Technology Research [Internet]. 2020;9(03):2035–7. www.ijstr.org
3. Senthilkumar T, Ganeshamoorthy J, Annamalai SJ, Mohanraj E. Development and evaluation of tractor operated cassava stake cutter planter. 2023;13-8.
4. FAO. Save and grow: Cassava [Internet]. [cited 2025 Feb 3]. https://www.fao.org/faostat/en
5. Marechera G, Muinga G. Value chain approaches to mechanization in cassava cultivation and harvesting in Africa. 2017;375–98.
6. Ogundare SK. Effect of depth of planting, methods of planting and animal residues application on the growth and yield performance of cassava in Ejiba, Kogi state, Nigeria. 2016.
7. Ospina Patiño B, Fernando Cadavid LL, García M, Alcalde C. Mechanized systems for planting and harvesting cassava (*Manihot esculenta* Crantz). 2012.
8. ICAR-CIAE Modernizing agriculture through engineering interventions [Internet]. 2020. www.ciae.icar.gov.in
9. He F, Deng G, Cui Z, Li L, Li G. Development of a rotary dibble-type cassava planter. Engenharia Agrícola. 2022;42(5).
10. Dinesh Pandi M, Asokan D, John Gunasekar J, Vallal Kannan S. Assessing suitability of fluted roller metering mechanism for cassava sets planter. Int J Curr Microbiol Appl Sci. 2019;8(05):1951–7.
11. Lungkapin J, Salokhe VM, Kalsirisilp R, Nakashima H. Development of a stem cutting unit for a cassava planter. 2007.
12. Benigno Engr JL. Design and development of a prototype implement-type cassava planting machine. International Journal of Scientific and Research Publications (IJSRP). 2021;11(4):165–70.
13. Dhananchezhiyan P, Sathish Kumar N, Sindhujaa J. Design and development of power operated portable cassava sett cutter for small farmers. An International Refereed, Peer Reviewed & Indexed Quarterly Journal in Science, Agriculture & Engineering. 2020.
14. Vikranth KP. An Implementation of IoT and data analytics in smart agricultural system - a systematic literature review. International Journal of Management, Technology and Social Sciences. 2021;41–70.
15. Yang L, Nasrat LS, Badawy ME, Wapet DEM, Ourapi MA, El-Messery TM, et al. A new automatic sugarcane seed cutting machine based on internet of things technology and RGB color sensor. PLoS One. 2024;19.
16. Zhou D, Fan Y, Deng G, He F, Wang M. A new design of sugarcane seed cutting systems based on machine vision. Comput Electron Agric. 2020;175:105611.

17. Ale MO, Manuwa SI, Olukunle. Effect of forward speed and drive wheel on the performance of a semi-automatic cassava planter [Internet]. Vol. 4, Original Research. 2023. www.achieversjournalofscience.org

18. Wang W, Li C, Wang K, Tang L, Ndiluau PF, Cao Y. Sugarcane stem node detection and localization for cutting using deep learning. Front Plant Sci. 2022;13.

19. Narmilan A, Puvanitha S. The effect of different planting methods on growth and yield of selected cassava (*Manihot esculenta*) cultivars. Agricultural Science Digest - A Research Journal. 2020.

20. K Mbugua J, Suksa-ngiam W. Predicting suitable areas for growing cassava using remote sensing and machine learning techniques: a study in Nakhon-Phanom Thailand. Issues in Informing Science and Information Technology. 2018;15:043–56.

21. Guojie LI. AI4R: The fifth scientific research paradigm [J]. Bulletin of Chinese Academy of Sciences. 2024;1.

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Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

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