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Economic impact of high-yielding cassava (*Manihot esculenta*) varieties in Tamil Nadu: Insights on farmer adoption and preferences

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ABSTRACT

The study was carried out during 2022–23 in Salem, Tiruchirappalli, Namakkal, Cuddalore, Dharmapuri and Pudukkottai to examine the socio-economic impact of cassava (*Manihot esculenta* Crantz) production in Tamil Nadu, India based on a survey of 300 farm households. We employed cost-benefit analysis, propensity score matching and a logit regression model to assess the profitability of high-yielding cassava varieties (HYVs) and determine the factors influencing their adoption. Adoption rates were 47.31%, resulting in a 13% increase in yield and a 17% increase in income compared to local varieties. Factors driving adoption of HYVs included higher yield (ME=0.025), technical advice (ME=0.188) and irrigation, with drip (ME=0.193) and flood irrigation (ME=0.394). Farmers reported income growth as the primary motivation, followed by reinvestment in agriculture and loan repayments. The Sree Athulya variety was found to yield the highest net income/hectare. Key challenges included reliance on intermediaries and labour-intensive harvesting. Farmers preferred traits such as high yield, pest resistance, short duration, and drought tolerance. Promoting HYVs can boost the cassava sector and contribute to Sustainable Development Goals, driving economic prosperity and sustainability in the region.

Keywords: Cassava cultivation, Cost-benefit analysis, Logit regression model, Propensity score matching, Socio-economic impact, Sustainability, Technology adoption

Cassava (*Manihot esculenta* Crantz) plays a vital role in global food security, ranking as the fifth most important staple crop after maize, rice, wheat and potato in terms of production and caloric intake (Bokanga 1999, Lebot 2009, FAOSTAT 2022). Over 60% of global cassava production is in Africa and serves as a staple food for more than 800 million people in tropical and sub-tropical regions worldwide (Parmar *et al.* 2017). As a traditional food security crop, cassava provides a high energy yield/hectare with minimal inputs. Due to its adaptability to water stress, ability to thrive on marginally fertile lands, resistance to pests and diseases, flexible growth cycles and capacity to remain in the ground unharvested for extended periods, it is often referred to as the "Food bank" of the poor (Rees *et al.* 2012, Howeler *et al.* 2013). Furthermore, cassava cultivation generates substantial employment opportunities and boosts rural incomes, contributing to the economic stability of cassava-growing regions (Immanuel *et al.* 2024). The importance of cassava as a cash crop is rising, driven by its growing use in various industries, including paper, textiles, plywood, glue, biofuel, animal feed and beverages (Kleih *et al.* 2013, Uchechukwu-Agua *et al.* 2015). In Asia and Latin America, cassava plays a vital role as an industrial raw material and livestock feed for export markets. In sub-Saharan Africa (SSA), cassava is transitioning from a rural staple to a cash crop for urban markets and ultimately, an industrial raw material. Nweke *et al.* (2002) outlined four stages of cassava transformation, from a famine reserve to a rural staple, a cash crop for urban markets and finally, a source of livestock feed and industrial raw materials. While countries like Nigeria and Ghana are in the third stage, others such as Congo, Cote d'Ivoire, and Uganda remain at the rural staple stage, with Asian and Latin American nations having reached the fourth stage. In Africa, nearly 63% of cassava is used as a staple food, with only 2% serving industrial purposes (FAOSTAT 2021). In contrast, in Asia, Europe, and Oceania, significant portions of cassava are directed towards non-food applications, particularly livestock feed and starch production for industrial use.

In India, 94.83% of cassava is used for food, with only 0.06% used as animal feed, and 5.11% attributed to post-harvest losses (FAOSTAT 2021).The southern states of Kerala, Tamil Nadu and Andhra Pradesh contribute 96% of cassava production in the country (GoI 2021–2022). In Tamil Nadu, cassava is an important carbohydrate source,

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particularly in the southern districts and serves as a key raw material for the industrial sector in the northern districts, where extensive cassava processing occurs. Most cassava in the state is processed into starch and sago for both food and non-food industries, with a smaller portion used to produce cassava chips or consumed directly by farmers. Cultivation practices vary across regions, with rainfed production dominating in hilly areas and a mix of irrigated and rainfed systems in the plains. Despite challenges associated with labour-intensive manual harvesting, cassava remains an important contributor to the state's agricultural economy. This study aimed to explore the cassava seed system, analyse farmers' preferences for different varieties, assess the economics of diverse cassava production systems and estimate the impact of high-yielding cassava varieties. Understanding these dynamics is essential for enhancing productivity, profitability and sustainability in the cassava sector, ultimately contributing to rural development and food security in Tamil Nadu.

MATERIALS AND METHODS

The study was carried out during 2022–23 in Salem, Tiruchirappalli, Namakkal, Cuddalore, Dharmapuri and Pudukkottai. These districts were purposively selected because they have been the focus of field interventions with high yielding cassava varieties and they collectively account for more than 65% of the total area under cassava cultivation in the state.

A four-stage sampling procedure was adopted. In the first stage, six major cassava growing districts were selected followed by the choice of 14 blocks in the second stage. In the third stage, 30 villages were identified from these blocks and in the final stage, 300 farmers were randomly selected with an average of 10 respondents per village. The sample distribution was 50 farmers from Namakkal, 120 farmers from Salem, 60 farmers from Dharmapuri, 20 farmers from Pudukottai and 30 farmers from Tiruchirappalli. This ensured representation across the four major production systems in the state, viz. drip irrigated, furrow/flood irrigated, rainfed plains and rainfed hills. Out of the 300 respondents, 151 farmers adopted drip irrigation systems, while 149 farmers cultivated under non drip systems (furrow/flood irrigation, rainfed plains and rainfed hills). Although farmers were not categorized for analysis regarding the information on the subsidies they received. It was observed that majority of the farmers who adopted drip irrigation availed the full subsidy (100%).

The extent of adoption of high yielding cassava varieties was measured using the proportion of farmers adopting each variety, the area under cultivation and cropping intensity. Determinants of adoption were analysed separately using the binary logit model.

The costs and benefits of different cassava varieties and production systems were assessed to estimate their economic viability (Ashok *et al.* 2017). Actual costs included seed/planting materials, fertilizers, manures, herbicides, pesticides, hired machinery, and labour, while costs for own inputs were based on market prices. Gross returns were calculated by multiplying total cassava production by market prices, and net returns were derived by subtracting total costs from gross returns.

Propensity Score Matching (PSM) is a method used to reduce bias in observational studies by matching treatment and control groups with similar characteristics (Aditya *et al.* 2018, Wordofa *et al.* 2021). In this study, the adoption of high-yielding varieties (HYVs) is treated as the intervention (treatment), with farmers using local varieties serving as the control group. The adoption decision is modeled as a binary variable (1 for adopters, 0 for non-adopters), and the propensity score is estimated using either a probit or logit regression model, both common in PSM. The model is specified as:

$$Y_i = \alpha + \Sigma\beta_j X_{ij} + \mu_i$$

Where Y_i is a binary variable for HYV adoption, X_i represents explanatory variables, β_j are the coefficients and μ_i is the error term. The propensity score, ranging from 0 to 1, reflects the likelihood of a farmer adopting the technology based on observable characteristics.

Once the propensity score is estimated, the Average Treatment Effect on the Treated (ATT) is calculated as:

$$ATT = E\{Y_{i1}/(T = 1\} – E\{ Y_{i0}/T = 0\}$$

Where Y_{i1} and Y_{i0} represent the outcomes for adopters and non-adopters, respectively.

The binary logit model was employed to analyse the factors influencing the adoption of high-yielding cassava varieties (Polson and Spencer 1991). This model estimates the probability of a binary outcome (adoption or non-adoption), where the dependent variable takes the value of 1 for adopters and 0 for non-adopters. The model is specified as:

$$P (Y_i = 1 \mid X_i) = \frac{e^a + \sum\beta_j X_{ij}}{1 + e^a + \sum\beta_j X_{ij}}$$

Where $P (Y_i=1)$ represents the probability of adopting high-yielding varieties, X_{ij} are the explanatory variables (e.g. farm size, education, access to extension services, and market access), and β_j are the coefficients showing the effect of each variable on adoption. To enhance the interpretability of the results, marginal effects were calculated instead of odds ratios (Breen *et al.* 2018). Marginal effects indicate the change in the probability of adopting high-yielding varieties given a one-unit change in an explanatory variable, holding other variables constant.

Farmer perceptions regarding cassava varieties and their preferred traits were assessed using a structured interview schedule. Respondents were asked to evaluate varieties they cultivate in terms of yield, starch content, pest and disease resistance, drought tolerance, crop duration, ease of harvesting and so on. A five-point Likert scale (1=least preferred, 5=most preferred) was used to quantify the importance of each trait. Trait preferences were analysed by calculating mean scores for each attribute. This allowed

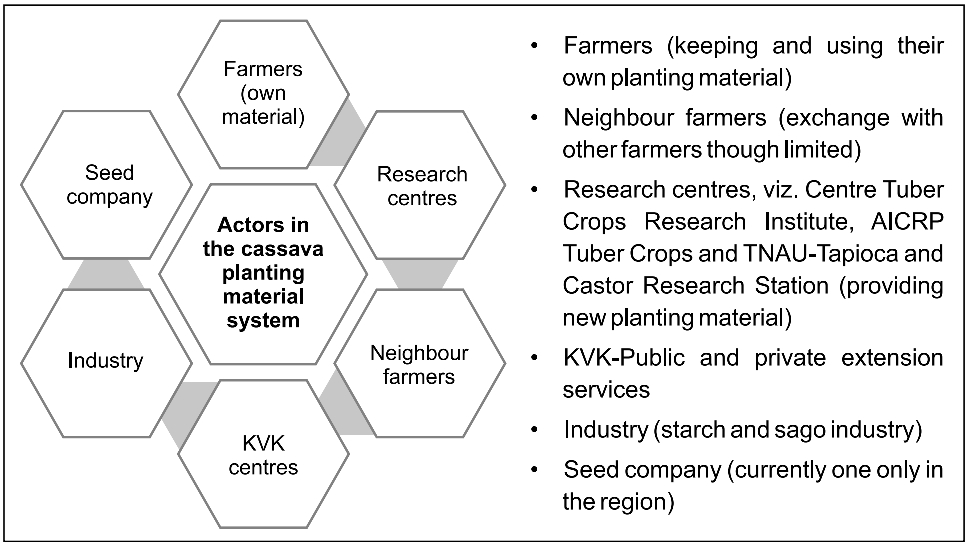

Fig. 1 Stakeholders involved in the supply of cassava planting materials.

identification of the most widely adopted varieties and the key traits driving adoption decisions.

RESULTS AND DISCUSSION

Cassava seed system actors and their variety preference: In the studied region, the cassava planting material system is largely informal, with little formal structure or market for cassava propagation. As a result, cassava cultivation predominantly relies on vegetative propagation through stem cuttings. Several key actors play pivotal roles in the cultivation and dissemination of cassava varieties (Fig. 1) (Giuliani *et al.* 2016).

Most farmers sourced their planting materials from their own stocks or obtained them from other farmers within the same or nearby villages, often through mutual exchanges. Many major varieties cultivated were released over 20 years ago, primarily disseminated by extension agencies and research institutes through progressive farmers. Approximately 60% of farmers used their own planting materials, 30% obtained them from local farmers, 6% accessed them through research institutes (CTCRI), and 5% received them from KVKs/SAUs/AICRP centers. The cassava cropping system varied based on agro-climatic conditions, cropping season, rainfall availability, and market demands. Farmers cultivated 17 cassava varieties, with high-yielding varieties like H165, H226, Sree Athulya, Sree Jaya, Sree Kaveri, Sree Reksha, YTP I and II, and Mulluvadi covering 47.31% of the total area (Table 1). H226 and Sree Athulya were the most prominent high-yielding varieties, occupying 29% of the area, while White Thailand and Kunkumarose were the leading local varieties at 44%. Local varieties remained popular due to their availability, yield, starch content and trader demand, with H226 and Sree Athulya recognized for meeting industrial requirements and drought resilience.

Cost of cultivation and profitability analysis of cassava varieties and production systems: The estimated economic benefits at the farm level from different cassava varieties revealed noteworthy patterns. The variety White Thailand saw the highest adoption, being cultivated by a majority of farmers (71), followed by Kunkumarose (65), H226 (50), and Sree Athulya (42). In terms of yield, Sree Athulya stood out with the highest recorded production at 34.26 tonnes/ha, surpassing Burma (31.96 tonnes/ha) and YTP 1 (28.73 tonnes/ha). Similarly, Sree Athulya commanded the highest price (₹9128/ tonnes) among the varieties, attributed to its notably high starch content. This was followed by Kunkumarose (₹ 9035/tonnes) and YTP II (₹ 9017/tonnes). Interestingly, despite its higher yield, Burma received one of the lowest prices (₹ 7761/tonnes), possibly due to its comparatively lower starch content. The higher yields of Sree Athulya played a pivotal role in reducing the unit cost of production and, consequently, increasing overall profitability. In terms of net income, Sree Athulya emerged as the most lucrative variety, yielding the highest net income/hectare at ₹ 219,383, followed by Burma with ₹ 179,460/ha and Black Thailand with ₹ 169,176/ha.

The average cassava yield exhibits notable variation across different production systems: 29.47 tonnes/ha in the drip system, 27.63 tonnes/ha in flood-irrigated systems, 19.35 tonnes/ha in rainfed plains and 15.56 tonnes/ha in rainfed hills (Table 2). The rainfed system represents a low-input cassava production approach. In the drip system, fertilizers are precision-applied through drip irrigation directly to the root zone. The cost of cultivation spans from ₹0.97 lakh/ha in the drip system to ₹ 0.61 lakh/ha in rainfed hills. In the drip system, the primary cost components are human labour, followed by the amortized cost of drip installations. Human labour consistently constitutes 45–60% of the total cultivation cost across all production systems. Price per tonne of tubers varies from ₹ 9513–₹ 8523 depending on the starch content of tubers and also suitable for consumption. The net income is estimated at ₹ 1.78 lakh in the drip system,

Table 1 Diffusion of cassava varieties in Tamil Nadu

Particulars	Frequency	% adoption
High yielding varieties (H165, H226, Mulluvadi, Sree Athulya, Sree Jaya, Sree Kaveri, YTP I, YTP II, Sree Reksha, CO4)	156	47.31
Local varieties (Black Thailand, Burma, Kunkumarose, M4, White Thailand, Nattu Vella, Nattu Burma)	180	52.69

*Multiple response

Table 2 Economics of different cassava production systems

Costs/returns	Drip irrigation#		Flood irrigation		Rainfed plains		Rainfed hills	
	Value (₹)	%	Value (₹)	%	Value (₹)	%	Value (₹)	%
Land preparation	12012	16.26	13991	17.24	11327	16.47	6606	10.74
Stem cuttings	2659	3.6	2656	3.27	2188	3.18	1910	3.11
Sett making and planting	4993	6.76	4805	5.92	5293	7.7	4726	7.69
Organic manures	5906	7.99	7390	9.1	4958	7.21	6219	10.12
Inorganic fertilizers	19987	27.05	22033	27.14	17719	25.76	16649	27.08
Irrigation	3620	4.9	4275	5.27	-	-	-	-
Herbicides	965	1.31	1035	1.28	1517	2.21	733	1.19
Pesticides	2383	3.22	1287	1.59	2646	3.85	1531	2.49
Intercultural operations	21354	28.9	23698	29.2	23130	33.63	23105	37.58
Total cost (₹/ha)	73878	100	81170	100	68777	100	61479	100
Average yield (t/ha)	29		28		19		16	
Price of tubers$ (₹/tonnes)	8523		8557		8971		9513	
Gross returns (₹/ha)	251515		237750		169741		149221	
Net returns (₹/ha)	177636		156580		100964		87741	

#, Small farmers can benefit from a 100% subsidy upon producing a small farmer certificate, while larger farmers are eligible for a 75% subsidy. Given that drip systems are provided free of cost to the majority of farmers in the study area, the cost of drip installations was not included in the total cost. $, Cassava price varied according to starch content and depends on the variety and production systems. This is the net price received by farmers after deducting harvesting and transportation charges, hence these expenses are not included in the total cost.

₹ 1.56 lakh in the flood irrigated system, ₹ 1.0 lakh in the rainfed plains and ₹ 0.88 lakh in the rainfed hills. These results are consistent with Ashok *et al.* (2017), who reported 32 tonnes/ha yields in drip systems whereas 21 tonnes/ha in rainfed hills, cultivation costs between ₹ 1.09 lakh/ha and ₹ 0.59 lakh/ha and net income from ₹ 1.20 lakh–₹ 0.57 lakh, with labour accounts 50–60% of costs.

Yield and income gains from adoption of high yielding cassava varieties: Evidence from the t test and propensity score matching: Differences between adopters of high yielding varieties and non-adopters of local varieties in cassava cultivation were systematically compared through t-statistics across various parameters, including input costs, yield, price, and net income. The results unequivocally illustrate the advantages associated with adopting high yielding varieties or technologies. Adopters experienced a per-hectare increase in input costs by ₹ 8083. Furthermore, adopters demonstrated substantial advantages in both yield and income, with 2.57 tonnes/ha and ₹ 25713/ha, respectively, compared to non-adopters. While the t-statistic emphasizes the clear differences due to adoption, it's important to note that the estimated impact may lack precision as the test doesn't account for factors influencing the adoption decision. To address this limitation and provide a more accurate estimation of the direct causal effect of technology adoption, a counterfactual framework was employed. Farmers who adopted high yielding varieties exhibited higher input costs, yield, and net income compared to non-adopters (Table 3). The Propensity Score Matching (PSM) results revealed that the adoption of high-yielding

Table 3 Effect of high yielding varieties: PSM results

Treatment-effects estimation		Number of observations = 299	
Estimator: propensity-score matching		Matches: Requested = 1	
Outcome model : Matching		Minimum =1	
Treatment model: logit		Maximum =2	
Particulars	ATET (Impact)	Standard error	P value
Input cost (₹/ha)	9963.16***	2440.12	0.000
Yield (tonnes/ha)	3.29***	1.28	0.010
Price (₹/tonnes)	78.63	228.48	0.731
Net income (₹/ha)	26182.07**	11071.84	0.018

cassava varieties led to a 13% increase in yield and a 17% increase in income. These results were consistent with the view that adopting improved cassava varieties enhances both yield and income (Olusayo *et al.* 2019, Acheampong *et al.* 2022). The estimates obtained through the matching procedure are considered more reliable, as it control for various factors influencing the adoption decision, providing a clearer understanding of the impact of technology adoption on cassava cultivation.

Determinants of adoption of high yielding cassava varieties: Evidence from a logit model: The analysis identified several significant factors influencing the adoption of high yielding cassava varieties, based on logit estimates. Yield, access to technical advice, district, and irrigation dummies were key determinants, while all other variables in the model were found to be non-significant (Table 4). The marginal effects indicated that for every additional tonne increase in yield, the likelihood of adopting high yielding varieties rises by 2%. Acheampong *et al.* (2022) reported positive and significant impacts on the yields of adopters compared to non-adopters. Access to technical advice significantly boosts the probability of adoption by 18.8%. Similarly, Onyemauwa (2012) found that extension services and awareness programme significantly influenced the likelihood of adopting improved cassava varieties. The significance of district dummies, particularly for Namakkal and Tiruchirappalli, suggests that adoption decisions are influenced by local factors such as soil type, rainfall, and cropping patterns. Furthermore, irrigation dummies show that the availability of irrigation facilities, such as drip and flood irrigation, increases the likelihood of adoption, with both having a statistically significant impact.

Table 4 Determinants of technology adoption: Logit estimates

Explanatory variables	Coefficient		P value
Age (years)	0.0004	(0.002)	0.873
Education (years)	-0.003	(0.006)	0.655
Family size (no)	-0.019	(0.019)	0.320
Ln_farm size (ha)	0.060	(0.043)	0.164
Yield (tonnes/ha)	0.025***	(0.010)	0.008
Access to technical advice (1/0)	0.188***	(0.049)	0.000
District 1 (1=Salem, 0=otherwise)	-0.032	(0.074)	0.669
District 2 (1=Namakkal, 0=otherwise)	0.417***	(0.097)	0.000
District 4 (1=Pudukkottai, 0=otherwise)	0.105	(0.174)	0.548
District 5 (1=Tiruchirappalli, 0=otherwise)	0.593***	(0.076)	0.000
Irrigation 1 (1=Drip, 0=otherwise)	0.193***	(0.073)	0.008
Irrigation 2 (1=Flood, 0=otherwise)	0.394***	(0.075)	0.000

Figures in parentheses are standard errors; ***, indicates significance of z statistics at 1% level.

Socio-economic impact of high yielding cassava varieties: The socio-economic impact analysis reveals significant improvements in household income, family welfare and creditworthiness, primarily due to the adoption of high yielding varieties developed by ICAR-Central Tuber Crop Research Institute. Notably, 94% of households experienced an increase in total income of up to 15%, which led to several positive outcomes. Some households invested in new items (5%) and were able to afford better food, clothing, or jewelry (14%), while 7% could perform important social functions. In terms of family welfare, 56% of households reinvested their additional income into agriculture, enhancing long-term sustainability, while 8% used it for significant social obligations like a child's marriage. Additionally, 12% invested in children's education, and 14% saw improvements in health. The increased income also positively impacted financial security, with 15% of households reporting an enhanced ability to repay loans. According to Rusike *et al.* (2010) and Prakash *et al.* (2023), the adoption of improved agricultural technologies increased household income, which in turn led to greater reinvestment in agriculture, higher expenditures on health and education, job creation, improved food security and living conditions and overall economic growth.

Cassava marketing system: Cassava marketing operates through intermediaries, typically brokers or middlemen, who play a crucial role in connecting farmers with the industry. These intermediaries facilitate the process by taking tuber samples from farmers' fields to assess starch content and determine prices. Additionally, they coordinate the labour needed for harvesting and the transportation of tubers to the industry. However, the cassava harvesting process presents challenges. It is a labour-intensive activity, constituting over 50% of labour costs. Farmers often grapple with labour shortages, particularly during peak harvesting periods. A significant majority, over 90%, of farmers identify labour scarcity as a prominent and pressing issue. Some farmers also express concerns about the synchronization of robust demand with the harvesting period, highlighting the need for better alignment between market demand and the timing of harvesting activities. Addressing these challenges is crucial for enhancing the efficiency and effectiveness of the cassava marketing system. The major constraints and opportunities for cassava production and marketing in Tamil Nadu as perceived by both farmers and industry stakeholders are outlined in Table 5.

Perception of farmers on cultivation of cassava varieties and their trait preferences: White Thailand is the most widely adopted cassava variety, accounting for 25% of the cultivated area, primarily due to its 28% starch content, which reduces rat-induced tuber damage. Its ease of uprooting is favourable, despite challenges like lodging and mealybug susceptibility. Kunkumarose is preferred in hilly areas, with moderate yield, medium height, and good drought adaptability, though it faces issues with rat damage and yield variability. It is also valued for consumption,

Table 5 Constraints and opportunities for cassava production and marketing in Tamil Nadu

Stakeholders	Opportunities	Constraints
Farmers	• Well suited to local and climate conditions • Requires relatively low inputs (fertilizer, water, etc.) • High productivity potential	• Price fluctuations • Competition from maize • Low starch content in some varieties • Labour shortage especially at harvest
Industry	• Cassava starch can be modified for multiple uses without chemicals • Strong demand from sago and starch industries	• Limited and irregular tuber supply • Tubers highly perishable • Competition from maize starch

attracting traders. H226, known for high yield and 28% starch content, performs well under drought but is vulnerable to mealybugs. Sree Athulya is a high-yielding variety with over 30% starch content, reduced mealybug susceptibility, and strong market value. Farmers prioritize high tuber yield, pest and disease resistance (particularly to mealybugs and red spider mites), and high starch content. CMD is not a major concern, but short crop duration and drought resistance are valued. Ease of harvesting is important, while storability traits are less emphasized.

The study concludes that the high yielding cassava varieties cover 47.31% of the area, while local varieties make up 52.69%, with White Thailand and Kunkumarose comprising 44% of local adoption. Sree Athulya stands out, yielding the highest income/hectare. Varietal choices significantly impact economic outcomes, with drip irrigation systems achieving the best yields, showcasing the benefits of precision farming. High-yielding varieties are driven by better yields, extension support, and irrigation access, though adoption is limited because of pests, especially mealybugs and red spider mites, and restricted credit and insurance. Propensity Score Matching shows that adopting high-yielding varieties boosts yield by 13% and income by 17%. Farmers prioritize high yield, pest resistance, starch content, and drought tolerance. Policy recommendations include developing short-duration, pest-resistant varieties, creating a starch meter for quality-based pricing, strengthening seed systems to promote high yielding varieties and expanding drip irrigation to enhance productivity and profitability. This study provides important insights and opens avenues for future research, particularly in mapping and analyzing the value chain of cassava.

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