Hindawi
Journal of Food Quality
Volume 2023, Article ID 9914370, 12 pages
https://doi.org/10.1155/2023/9914370

Research Article

Assessment of Cassava Utilization Patterns, Postharvest Handling Practices, and Productivity Influencing Factors in South and Southwest Ethiopia

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Received 15 April 2023; Revised 19 May 2023; Accepted 24 May 2023; Published 30 May 2023

Academic Editor: Ravi Pandiselvam

Cassava (*Manihot esculenta* Crantz) is mainly produced to supplement food security by providing food for smallholder farmers year round. However, its production is constrained by various factors. Thus, the aim of this research was to assess cassava utilization patterns, postharvest handling practices, and the factors that influence productivity. Data were gathered from primary and secondary sources, and a multistage sampling procedure was used to select 200 HHs. A multiple regression model and descriptive statistics were used to analyze the data. The regression model revealed that the education level, family size, land holding size, cropping system, crop rotation, earthing up rate, maturity, variety type, training, and plant population variables were significantly and positively correlated with cassava productivity. This implies that if any of these variables increases, cassava productivity will increase while the other variables remain constant. Topography and pest variables showed a significant negative correlation, indicating that an undulating topography or being attacked by pests could reduce cassava productivity by 60.00%. The descriptive statistics results for the utilization proportion showed that 51.87% of the farmers utilized for home consumption, 43.68% for the market, and 4.26% for animal feed. The consumption pattern indicated that 46.50% was boiled roots, 15.00% was flour cooked, and 38.50% was boiled roots and flour cooked. As postharvest handling practices showed, 10.00% of the farmers immediately processed to powder, 18.00% immediately processed to sliced (chips), 61.00% left them to root in the soil, and 11.00% did nothing. This indicates that the farmers' consumption patterns and processing methods are very traditional. Therefore, the study suggested that the farmers' different practices should be further supported by research through the generation of multiple food forms, postharvest handling practices, and production technology. Proper attention should also be given to address the identified productivity-influencing factors as well as postharvest handling practices. These could sustain the farming system of the crop and help to increase cassava productivity for smallholder farmers.

1. Introduction

It is apparent that the livelihoods of all rural residents depend on agriculture. Agriculture is also the main route of raw materials for primary industries engaged in domestic food production in Ethiopia [1]. Agriculture has been a significant driver of the Ethiopian economy for many years, and it has contributed about 43% of the country's GDP while also employing almost 85% of the labor force and making up about 90% of the exports [2].

Cassava (*Manihot esculenta* Crantz) originated in South America, but it is now grown in more than 90 countries worldwide [3]. During the 20th century, the crop attained its current level of widespread distribution and food importance [4]. Its superior ecological adaptation, low labor requirements, ease of cultivation, pest tolerance, and high productivity make it more prized than other root crops. As a result, it is frequently regarded as a crucial famine reserve crop in countries with unpredictable rainfall [4, 5]. Cassava was brought to Africa by Portuguese traders. It was first distributed to West Africa through the Gulf of Benin and the Congo River in the second half of the 16th century and then to East Africa at the end of the 18th century [6]. Around the middle of the nineteenth century, the exotic cassava plant (*Manihot esculenta* C.) was introduced to Ethiopia [7]. According to Legese and Gobeze [8], some NGOs introduced cassava to some drought prone Southern Nations, Nationalities, and Peoples' Region of the country, including Amaro, Gamu Goffa, Sidama, Wolaita, and Gedeo, primarily to fill the void left by the failure of other crops due to the drought for subsistence farmers. Farmers typically grow cassava in these areas in scattered plots, either alone or intercropped with common beans, maize, taro, and sweet potatoes [9, 10].

Ethiopia's diverse agroecologies and favorable environments enable the growth of a wide variety of root and tuber crops in many of the country's smallholder farmers' fields [7]. In Ethiopia, the cassava crop has demonstrated outstanding adaptability and growth performance in a range of agroecologies with varying yields [11]. Currently, since its introduction, the crop has been in cultivation, particularly in the South and Southwest parts of the country [7]. According to Tadesse et al. [9], in South and Southwest Ethiopia, cassava is one of the most significant food crops that constitute a considerable portion of the smallholder farmers' daily diet and it is a major source of carbohydrates. The authors added that smallholder farmers grow cassava for food, cash, and livestock feed. Cassava has a great potential to be used in different food recipes. However, in Ethiopia, most cassava products are consumed by boiling the root and flour [9].

Despite its importance and a few research efforts, the national average fresh storage root yield of cassava in Ethiopia ($10.90\,t{\cdot}ha^{-1}$) is still very low, compared to the genetic potential of the crop ($80.00\,t{\cdot}ha^{-1}$) and triple below the productivity per unit area of some South Asian countries, for example, India ($35.60\,t{\cdot}ha^{-1}$) [12]. The low root yield is primarily due to socioeconomic factors, climate variability, a lack of storage for produced products, and biotic and abiotic factors [13, 14]. Furthermore, the authors Markos et al. [10], Mulualem and Ayenew [11], and Zemach [14] reported a lack of reliable data on area coverage and various agronomic practices-related determinants influencing the productivity of cassava crops. The factors that affect cassava productivity can have misleading policy implications. This indicates that, so far, there is very little comprehensive information pertaining to cassava utilization patterns, postharvest handling practices, and the factors that influence the productivity at the national level. Therefore, the generation of information and documentation on cassava utilization patterns, postharvest handling practices, and factors that influence productivity to support the experiences of the producers in relation to their uses, pre- and postharvest management practices, is crucial for future interventions. Hence, the objectives of this study were to (1) investigate the factors influencing cassava productivity; (2) analyze the utilization patterns of cassava products; and (3) examine postharvest handling practices. The study's findings are expected to guide policymakers, researchers, and development actors on where to focus in order to reduce cassava postharvest loss and productivity-influencing factors, as well as the generation and adoption of multiple utilization patterns.

2. Materials and Methods

2.1. Descriptions of the Study Area. The research was conducted in six major cassava growing districts in two administrative zones (Figure 1). The Dawuro zone, whose districts are Loma Bossa, Zaba Gazo, and Disa, in the Southwest Ethiopia Regional State, and the Wolaita Zone, whose districts are Kindo Kosha, Kindo Didaye, and Gasuba, in the Southern Nations, Nationalities, and Peoples' Region state. The Dawuro zone is located at latitudes 6°59′–7°34′N, longitudes 36°68′–37°52′E (Figure 1), and elevations ranging from 550 to 2820 meters above the sea level [15]. The Dawuro zone has a bimodal rainfall pattern, with light rains from February to May and heavy rains in the months of June and September. Rainfall is 1705.4 mm on average every year, with a temperature of 20°. The majority of the districts are mountainous, with orthic acrisols and well-drained brown soil (Nitosols) that has mild weathering. The area is known for its mixed crop-livestock farming system, in which the cultivation of maize, bread wheat, faba bean, field pea, teff, potato, sweet potato, cassava, enset, mango, banana, and common bean are the major crops [16]. The Wolaita zone is situated between 06°57′–07°04′N and 037°35′–037°58′E (Figure 1), and the region has a bimodal rainfall pattern, with light rains from March to May and heavy rains in the months of July and August. It is located between 700 and 2900 meters above the sea level [17]. The average annual rainfall is 1580.0 mm, and the average annual temperature is 20.1°C. The area is primarily part of the midhighland agroecological zone. Due to the area's varied topography, its soils vary [18]. According to the reports by Laekemariam et al. [17], the zone's dominant soils are nitonic, which are sesquioxides, and moderately to strongly acidic. The main food crops cultivated in the zones are maize, common beans, sweet potatoes, ensete, Irish potato, tef, coffee, ginger, and cassava [18]. The production of cassava in these two zones was largely concentrated among smallholder farmers whose farming conditions were diverse [9].

2.2. Sampling Method and Sample Size Estimation. This study employed a multistage sampling procedure. In the first stage, a purposive sampling procedure was used to select the two administrative zones of the study areas. The selections of the two zones were made with the help of experts from the Agricultural and Natural Resources Bureau in the Southern Nations, Nationalities, and Peoples' Region. A high production potential, a long history of production, and

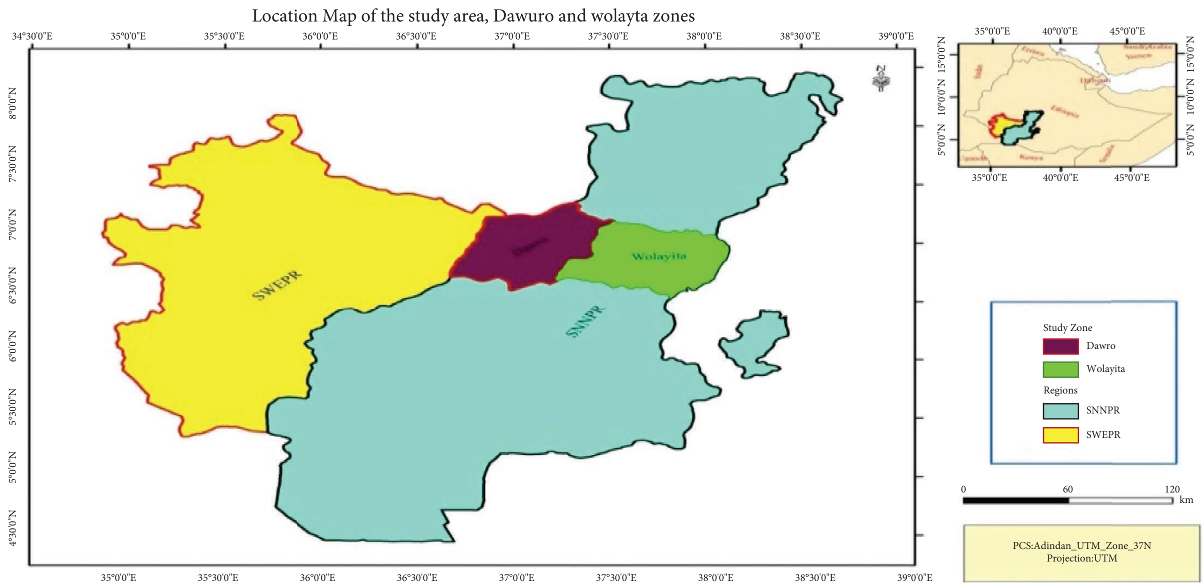

Figure 1: Location map of the study areas (Dawuro and Wolaita zones).

management systems for cassava based on farmers' traditional knowledge were considered the basis for the selection of the study zones. In the second stage, a random sampling procedure was used to sample six districts from the two zones. In the third stage, a random sampling procedure was used to sample ten kebeles (PA) from the six districts. Finally, 200 cassava producer farmers' households were randomly selected based on a probability proportionate to the size sampling procedure from the sampled kebeles and the formula proposed by Yamane [19] at a 95% confidence interval, 5% variability, and 7% precision (Table 1). Due to the population being uniform in terms of cassava production, a precision level of 7% was chosen for this study in order to avoid incurring additional costs and requiring more time to gather the same set of data on various smallholder cassava producer farmers.

$$n = \frac{N}{1 + N(e)^2} = \frac{9118}{1 + 9118(0.07)^2} = 200\,\text{house holds}, \quad (1)$$

where n is the size of sample, N is the total household size (the population size), and e is the level of precision.

2.3. Sources, Methods, and Tools of Data Collection. A combination of secondary and primary sources was used to collect the data. Using a pretested semistructured questionnaire survey, primary data were gathered from the sampled farm families in ten rural kebeles through individual farmer interviews, farm field observations, and 10 key informants' group discussions guided by open-ended or unstructured questions. Furthermore, for secondary data, the Zonal Agricultural and Natural Resources Department in each zone and six districts' Agricultural and Natural Resources offices were visited during the fieldwork.

2.4. Data Analysis. Using Stata software, the collected data were analyzed through descriptive statistics and analytic econometric models. Descriptive statistics such as mean, percent, and frequency were used to describe socioeconomic characteristics, utilization patterns, and postharvest handling practices of cassava products. Multiple linear regression models were then used to identify factors influencing the development of cassava productivity among smallholder farmers in the study area. Undoubtedly, the most popular econometrics tool is multiple linear regression models and their estimation using ordinary least squares (OLSs). Ordinary least squares are used when all sampled households are involved in cassava production. A continuous dependent variable and its relationship with a group of dummy, categorical, or continuous explanatory variables can be estimated using the following formula adopted by Belayneh et al. [20]. The multiple linear regression models are specified as follows:

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 \ldots \beta_{16} x_{16} + \varepsilon, \quad (2)$$

where the dependent variable (Y) = the level of cassava productivity (storage root yield) measured in tons, and the explanatory variables are as follows: X_1 = education level of the household head, 1 if he/she learned in formal school (who can read and write at any grade level), and 0 otherwise, X_2 = the sex of the household head, 1 if male and 0 otherwise, X_3 = the age of the household head in years, X_4 = the number of the household head's family in a single dwelling, X_5 = the household head's landholding size in hectares, X_6 = the cropping system of the household head, 1 if intercropped and 0 otherwise, X_7 = crop rotation of the household head, 1 if rotated and 0 otherwise, X_8 = the number of earthing up rates of the household head, X_9 = the household head's years of cassava production experience, X_{10} = cassava variety maturity period in months, X_{11} = the

Table 1: Description of the sampled district and the sample size.

Zones	Districts	Districts' cassava producers HHs	Districts' cassava producers Kebeles (PA)	Kebeles (PA)	Cassava producer HHs	Sample sizes
Dawuro	Disa	1368	6	Shota chawula	235	22
	Loma Bosa	1459	9	Adis bodari	178	17
				Afuki woro	212	20
	Zaba Gazo	1094	6	Buri	202	19
Wolaita	Kindo Didaye	1732	10	Zaro	198	19
				Fatata	211	20
	Kindo Koyisha	1641	11	Moltícho	218	20
				Manara	196	18
	Ofa	1824	11	Busha	247	23
				Seresha	232	22
	Total	9118			2129	200

Key: PA = peasant association, HHs = household.

topography of the household head's cassava farm, 1 if undulating and 0 otherwise, X_{12} = pest occurrence on the household head's cassava farm, 1 if pests appeared and 0 otherwise, X_{13} = the type of variety used by the household head, 1 if improved and 0 otherwise, X_{14} = the cassava product market price of the household head, 1 if low price and 0 otherwise, X_{15} = participation in training of the household head, in number, and X_{16} = plant population density, plants per hectare, and ε = pooled error (residual term). The types of variables, definitions, measurement, and anticipated effect on productivity are presented in Table 2.

3. Results and Discussion

3.1. Socioeconomic Characteristics of the Respondents. The descriptive statistics for continuous and dummy variable results are presented in Table 3. The result showed that the mean age of the household head respondents was 45.89 years, while the age ranged from 25.00 to 75.00 years among the 200 household head respondents. This implies that cassava production in the study areas is dominated by young and economically active individuals. The mean family size of the household head in a single dwelling was 5.55, with a minimum of one and a maximum of ten. This finding is supported by Shah et al. [21] and Belayneh et al. [20] who reported larger family sizes, implying that it was above the average household size of the national 4.70. It emphasized the relevance of larger families participating in agricultural production, especially when all household members contribute to the family's economy through increased productivity and the provision of services [22].

The average landholding size of the household head was 2.22 hectares, with the minimum and maximum landholding sizes being 0.63 and 6.50 hectares, respectively. For countries like Ethiopia, where the agriculture sector is the backbone of the economy, the land is the most valuable natural resource [23]. This implies that agricultural operators with larger landholdings would have a higher farm income if there was enough family labor available, and this increases the demand for children who can work on the farm [24]. The study also revealed that the average earthing up frequency was 2.07. The average cassava production experience was 12.07 years with large variation, and the average maturity period was 14.34 months. The average training participation rate was 2.18, and the plant population density per hectare was 42,955.56 plants (Table 3).

As indicated in Table 3, 33.00%, 13.00%, and 2.50% of the respondents learned primary, secondary, and tertiary level education, respectively, with a cumulative of 48.50%. The findings showed that, less than average, farmers received a formal education, which made it easier for them to understand agricultural instructions from extension agents. The result is consistent with the findings of Asfaw and Admassie [25], who reported that education plays a significant role in agricultural productivity and income. Investment in production techniques and technology should be matched by an equal investment in human capital to achieve agricultural development. This is because farmers need information and knowledge to adopt technology, obtain input, modify their ways of doing things, and market their products [26]. About 59.00% and 76.50% of cassava crops had been intercropped and rotated, respectively, with other crops (Table 3). This result showed that a large number of households employed intercropping and crop rotation practices for cassava production. This implies that to improve soil fertility and increase the productivity of cassava, intercropping and rotation practices have been used by smallholder farmers. However, there was still a significant gap in their adoption and practices, requiring much attention from extension workers in the selection of an appropriate crop for intercropping or rotation, shortening the rotation period, and maximizing their utilization.

According to the topography variable results, 19.00% of the respondents planted cassava in a plain or level topography, while the rest (81.00%) planted it in undulating farmland with valleys, hills, plateaus, and mountainous topography (Table 3). This implies that undulating topography is one of the major factors influencing the cassava yield because of its high vulnerability to soil erosion, difficulty in tillage operation, and low nutrient content in the soil. As a result, cassava productivity was largely influenced by the topography factor. Bakker et al. [27] reported that the

Table 2: Definition, measurement, and the predicted effect of the variables.

Variables	Types of variable	Measurements and definitions	Anticipated effects on productivity
Productivity	Continuous	Dependent variable cassava productivity in tons	
Education level of the HH head	Dummy	Independent variables 1 if learned formal school and 0 otherwise	+
Sex of the household head	Dummy	1 if male and 0 otherwise	±
Age of the household head	Continuous	Year	−
Family size	Continuous	Number	±
Landholding size	Continuous	Hectare	+
Cropping system	Dummy	1 if intercropped and 0 otherwise	+
Crop rotation	Dummy	1 if rotated and 0 otherwise	+
Earthing up rate	Continuous	Number	+
Cassavas production experience	Continuous	Year	+
Maturity period	Continuous	Month	+
Topography	Dummy	1 if undulating and 0 otherwise	−
Pests	Dummy	1 if pests appeared and 0 otherwise	−
Variety type	Dummy	1 if improved and 0 otherwise	+
Product market price	Dummy	1 if low price and 0 otherwise	±
Participation in training	Continuous	Number	+
Plant population density	Continuous	Plants per hectare	±

Table 3: Descriptive statistics for continuous and dummy variables.

Variables	*Mean*	*Std. dev.*	*Minimum*	*Maximum*
Age of the household head in years	45.89	11.39	25.00	75.00
Family size in number	5.55	1.85	1.00	10.00
Land holding size (ha)	2.22	1.28	0.63	6.50
Earthing up rate in number	2.07	0.62	1.00	4.00
Cassavas production experience in years	12.07	8.06	2.00	37.00
Maturity period in months	14.34	3.71	8.00	24.00
Training participation in number	2.18	0.95	0.00	3.00
Plant population density in number of plants ha^{-1}	42895.56	17168.01	10000	83333.33
Education level of the HH head			*Frequency*	*Percent*
Learned formal school			97	48.50
Not learned formal school			103	51.50
Sex of the household head				
Male			178	89.00
Female			22	11.00
Cropping system				
Intercropped			118	59.00
Pure stand			82	41.00
Crop rotation				
Rotated			153	76.50
Not rotated			47	23.50
Topography				
Undulating			162	81.00
Not undulating (level/plain)			38	19.00
Pests				
Pest appeared			87	43.50
Pest not appeared			113	56.50
Variety type				
Improved			73	36.50
Not improved			127	63.50
Product market price				
Low price			89	44.50
Not low price			111	55.50

Source: own computation result, 2022.

cultivation on steep topography could cause soil erosion, resulting in reduced crop productivity. About 43.50% of respondents' cassava farms were affected by pest infestations, and 36.50% of the respondents grew cassava using improved varieties (Table 3). The finding indicated that a high number of the respondents grew cassava using local varieties. The major reasons given by the respondents for using local varieties were that improved varieties were not accessible.

3.2. Analysis of Influencing Factors. The variables influencing the productivity of cassava were identified using multiple linear regression models (Table 4). For parameter estimation to be effective, the assumptions of the classical linear regression model must be maintained. Thus, the hypothesized explanatory factors were tested for multicollinearity using appropriate test statistics. The multicollinearity test result showed that explanatory variables are uncorrelated with the error term because the average VIF value was found to be 1.82. Furthermore, the analysis of the coefficient of determination (R^2) result showed that the dependent variable was explained in 75.45% of the fitted data in a regression model. This implies that explanatory variables account for about 75.45% of the total variation in cassava productivity. Thus, the R^2 value suggests a better fit for the model. This finding is in line with that of Zemach [14] and Monica and Okorji [28], who reported that the coefficient of determination was used to assess the regression model's goodness of fit in the cassava production determinants study.

The results from the multiple linear regression models on the determinants of cassava productivity are presented in Table 4. Accordingly, 16 explanatory variables were used to identify factors influencing cassava productivity on the farmland of smallholder farmers. Among these variables, 12 variables were found statistically significant at a 5% level of significance, while four variables were nonsignificant at a 5% level of significance. In addition to this, of the total independent variables, twelve variables were found to have a positive relationship with cassava productivity, whereas four variables were found to have a negative influence on cassava productivity. The details are as follows.

3.2.1. Education Level of the Household Head. The education level of the household head influenced cassava productivity positively, and it was found significant at a 1% level of significance. This means that as the respondent enters a formal school, i.e., can read and write at any grade level, cassava productivity increases by 1.117 $t{\cdot}ha^{-1}$ more than farmers who have not learned a formal education. The probable reason for this is that the farmers who have a better educational background are assumed to be in a better position to adopt different technologies like fertilizer, improved seed, irrigation, and better farm management systems, thereby increasing the productivity of their crop. In Nigeria, a similar study was conducted on the cassava crop by Itam et al. [3], who reported that farmers' education had a positive relationship and it was vital for productivity. Furthermore, in Nigeria, other studies by Monica and Okorji [28] found that education would increase productivity by 1.24 $t{\cdot}ha^{-1}$ in comparison with farmers who had not learned a formal education, while Anigbogu et al. [29] reported that the increase education of one grade would increase the output by 50.80 kg.

3.2.2. Family Size. The number of families that attend cassava production was statistically significant at a 1% level of probability, and it was positively correlated with cassava productivity. The coefficient suggests that an increase in the number of family sizes by one person would increase cassava productivity by 0.408 $t{\cdot}ha^{-1}$. This implies that households that attend cassava production with a large number of family sizes contribute a large labor force to the farm activity, resulting in the increased productivity of the cassava crop. This finding is consistent with the findings of Inoni [30], who reported that the family size can positively affect productivity by providing labor for farming. Furthermore, studies by Zemach [14] reported that each additional family member would increase cassava productivity by 1.6 $t{\cdot}ha^{-1}$, while Gebre et al. [31] reported that a 10% increase in the family size would increase maze productivity by 7.5%.

3.2.3. Landholding Size. The landholding size variable had a positive influence on the productivity of cassava in the study area, and it was statistically significant at a 5% probability level. The coefficient indicates that a one-hectare increase in landholding could increase cassava productivity by 0.398 $t{\cdot}ha^{-1}$. This means that farmers with larger landholdings had higher productivity in cassava farming. The reason could be that farmers with large landholding may have employed fallow land management practices, which are accompanied by better soil fertility maintenance, better labor productivity, and a tendency to use more modern technology than farmers with small landholding for cassava production, resulting in the increased productivity. The earlier study by Adamopoulos and Restuccia [32] suggests that larger farms have higher productivity due to their higher labor productivity and better use of production technology than small farms. Similar studies by Obasi et al. [33] reported that increasing the farm size by 1 hectare would increase productivity by 31.50%; Anigbogu et al. [29] found that a hectare increase in the farm size would boost farmers' output by 23.30 kg; and Olukunle [34] reported that increasing the farm size by 10% would increase cassava productivity by 4.80%.

3.2.4. Cropping System. The cropping system had a positive correlation with cassava productivity, which was found statistically significant at a 1% level of significance. The positive coefficient shows that smallholder farmers who intercrop cassava with other crops would increase the storage root yield by 1.364 $t{\cdot}ha^{-1}$ compared to farmers who do not practice intercropping cassava with other crops. This implies that the farmers who intercropped cassava with other crops would increase cassava productivity per unit

Table 4: Multiple linear regression analysis for variables predicting the productivity of cassava crop.

Variables	Coef.	Std. error	t-stat	Sig.	Tolerance	VIF
Constant	−3.685	1.816	−2.03	0.044		
Education level of the HH head	1.117***	0.398	2.81	0.006	0.741	1.35
Sex of the household head	−0.013	0.621	−0.02	0.983	0.765	1.31
Age of the household head in year	−0.006	0.022	−0.27	0.790	0.444	2.25
Family size in number	0.408***	0.129	3.17	0.002	0.512	1.95
Land holding size in a hectare	0.398*	0.157	2.53	0.012	0.714	1.40
Cropping system	1.364***	0.287	4.76	0.000	0.656	1.52
Crop rotation	0.851*	0.385	2.21	0.028	0.680	1.47
Earthing up rate in number	0.854**	0.329	2.59	0.010	0.699	1.43
Cassavas prod. experience in years	0.028	0.029	0.99	0.325	0.543	1.84
Variety maturity period in months	0.409***	0.057	7.17	0.000	0.650	1.54
Farm topography	−0.609**	0.242	−2.52	0.013	0.304	3.29
Pests	−0.608***	0.214	−2.84	0.005	0.286	3.50
Variety type	1.249***	0.393	3.18	0.002	0.808	1.24
Product market price	0.600	0.413	1.45	0.148	0.685	1.46
Training participation rate	0.585***	0.214	2.74	0.007	0.564	1.77
Population density in the number of plants per hectare	0.0003*	0.001	2.12	0.035	0.570	1.75
Number of observations	200					
F (16, 183)	35.14					
Prob > F	0.000					
R-squared	0.7545					
Adj R-squared	0.7330					
Mean VIF						1.82

Source: own computation result, 2022.

area when compared to pure-stand-cultivated cassava. Cassava is intercropped mainly with taro, maize, haricot beans, and sweet potatoes [9, 10]. The explanation may be that farmers who intercropped tall or short plant components more effectively used sunlight through their aerial parts, while shallow- or deep-rooted below ground plant components would have better water and nutrient use efficiency than sole cropping, which ultimately increased cassava productivity. This finding is in agreement with the work of Karlidag and Yildirim [35], who stated that intercropping is becoming increasingly important in terms of increasing crop productivity. In the other study, the wheat yield increased to 39.43 quintals per hectare after intercropping wheat and chickpea [36].

3.2.5. Crop Rotation. As indicated in Table 4, it was found statistically significant at a 5% level of significance with an anticipated positive correlation. The coefficient indicates that cassava rotation with other crops could increase productivity by 0.851 $t{\cdot}ha^{-1}$ when compared to households that do not rotate cassava with other crops, while all other variables remain constant. It is hypothesized that farmers who rotate their crops could better maintain soil fertility, minimize soil erosion, keep soil healthy, break the disease-pest life cycle, and enhance nutrients available for cassava crops, thereby increasing cassava productivity compared to farmers who are not engaged in crop rotation on their farmland. This finding is in line with the previous work by Bowles et al. [37], who reported that diversified crop rotation increased crop yields and brought significant economic benefits for smallholder farmers. In the Loess Plateau of China, Han et al. [38] carried out a crop rotation experiment with various combinations of alfalfa after cultivation and discovered that after sowing rapeseed during the winter, the mean yield increased by 44.40% in comparison to continuous cropping rapeseed, and the wheat yield increased by 42.90% in comparison to continuous cropping wheat. Another study, by Wang et al. [39], reported that in comparison to continuous maize farming, maize-potato rotation reduced soil water consumption rates by 16.81–24.83% and boosted maize productivity by 15.5–23.40% over a three-year period.

3.2.6. Earthing Up Rate. This variable was significant at a 1% level of significance, and the correlation had a positive sign with cassava productivity. According to the findings, adding one earthing up would increase productivity by 0.854 $t{\cdot}ha^{-1}$. This implies that the earthing up technique on cassava farms could bring a high income for smallholder farmers. Earthing up means piling soil around the stalk of a growing crop; in this case, cassava usually combined with weeding. The most likely reason is that earthing up keep the soil loose and gets rid of weeds. This could, therefore, provide a favorable environment for root expansion and microbial activity in the soil, increasing nutrient availability and water infiltration into the root zone, thereby enhancing the productivity of the cassava crop. Caruso et al. [40] in Italy, Tafi et al. [41] in Iran, and Nebiyu et al. [42] in Ethiopia reported that earthing up potato crops created a favorable environment for more rapid tuber initiation and a greater number of tubers formed, resulting in increased productivity when compared to no earthing up potato. This finding is also consistent with Gutema's [43] who reported that earthing potatoes up to three and two times increased the total tuber yield by 24.7% and 15.5%, respectively, over the control.

3.2.7. The Maturity Period of a Variety. This variable influenced the productivity of cassava positively and significantly with a 1% probability. The result shows that as the maturity period of the cassava crop increases by one month, the cassava productivity increases by 0.409 $t{\cdot}ha^{-1}$, while all other variables remain constant. This implies that the late-maturing cassava variety could produce more storage root yield per unit area. The probable reason is that the crop's extended harvest time may help to accumulate more dry matter because a prolonged growth and development period creates a chance to make better use of growth resources, which, consequently, increases the productivity of the cassava crop. A similar report by Monamodi et al. [44] stated that time had a positive effect on dry matter accumulation, resulting in the increased root yield, which increased with the harvest time. Muli and Agili [45] added that the root yield and dry matter increased as more time was allowed for root growth and development.

3.2.8. The Farm Topography. This variable had a negative correlation with cassava productivity, and it was found significant at a 5% significance level. The result shows that planting cassava in valleys, hills, plateaus, and mountainous topography could decrease its productivity by 0.609 $t{\cdot}ha^{-1}$ compared to cassava growing by hectare in plain topography. This suggests that topographical features like valleys, hills, plateaus, and mountains are vulnerable to erosion, which would reduce crop yields. So far, researchers have shown a negative relationship between topography and crop productivity. For instance, Kryzanowski and Kutcher [46] reported that the lowest crop yields were measured on steep slopes or steep topography, while the highest yields were measured on lower slopes or plain topography. They added that steep topography was characterized by being prone to erosion, having shallow surface horizons, having higher carbonate levels, having lower organic matter levels, and having low moisture in the soil. In a study conducted in Laos, farmers identified cultivating on steep land or steep topography as the essential factor that caused severe erosion and reduced yields [47].

3.2.9. Pests. The pests' variable had a negative coefficient, and it was significant at the 1% significance level. The results show that pests could reduce cassava productivity by 0.608 $t{\cdot}ha^{-1}$ compared to pest-free cassava farms. The most likely reason is that the respondent's cassava farm may be damaged by pests such as insects, wild animals, and domestic animals, thereby reducing productivity. The study suggests that cassava farms should be protected from wild and domestic animal attacks through fencing. Additionally, farmers should apply integrated pest management technology for insect infestations. This finding is in line with a study by Uwagboe et al. [48], who reported that pests have significantly led to a 25–30% decrease in cocoa productivity in Nigeria. Similarly, Paul et al. [49] research study was conducted in Malawi, Tanzania, and Uganda. They reported that cassava productivity was reduced by 50% due to pests compared to noninfested farms among smallholder farmers.

3.2.10. Variety Type. Choosing and using improved varieties of cassava planting material increased productivity positively at a 1% significance level. The finding shows that if the farmers grow improved varieties, cassava productivity could increase by 1.249 $t{\cdot}ha^{-1}$ compared with those who have used a local variety. Improved varieties offer higher and more stable yields and higher tolerance or resistance to diseases, insect pests, drought, heat, cold, parasitic weeds, and other stress factors, while local varieties have characteristics of low yield, less stable yield, and being susceptible to biotic and abiotic factors. This finding is supported by Monica and Okorji [28] and Odii [50] who stated that using improved cassava varieties would increase productivity. In Kugbei's [51] study in Afghanistan, the improved wheat seeds produced a 33% higher yield in comparison to the local seed. Also, this finding is in line with Gebre et al. [31], who reported that improved seeds have a positive and significant relationship with productivity. As a result, a 10% increase in the use of improved maize seed would result in an increase in the output of 5.33%.

3.2.11. Training Participation Rate. The results (Table 4) also revealed a positive and significant association between training and productivity. The model result showed that increasing the farmer's training by one would increase cassava productivity by 0.585 $t{\cdot}ha^{-1}$. This implies that farmers who receive practical training can increase the productivity of cassava since the training improves their understanding and skills in its management, including the application of different inputs. Furthermore, the data showed that a high number of educated farmers received training, which could help farmers record training documents and easily understand new approaches to production technology and its adoption, resulting in increased productivity compared to noneducated farmers. According to Mariyono et al. [52], agricultural training equips farmers with technical know-how and useful information. In Bangladesh, the research conducted by Schreinemachers et al. [53] found that trained farmers would increase net household income by about 48%, and 31% initially adopted the technology over nontrained farm households.

3.2.12. Plant Population Density. This variable had a positive coefficient, as predicted, and it was found to be significant at a 5% significance level. This means that as plant population density approaches an optimum, cassava productivity per unit area tends to increase, assuming all other factors remain constant. Optimizing plant population density may increase cassava productivity per unit area because it increases light interception and use efficiency for the crop's leaf photosynthetic potential. This finding is consistent with that reported by Jiang et al. [54] who reported that the efficiency of water consumption and solar radiation absorption is enhanced by maximizing plant population density, which also helps to increase biomass production, canopy photosynthetic capacity, Ceotto et al. [55] yield, and water productivity [56].

3.3. Cassava Utilization and the Consumption Pattern. The cassava utilization pattern is presented in Table 5. The result indicated that the average utilization proportion of the farmers was 51.87% for home consumption, while the minimum and maximum home consumption were 5.00% and 100%, respectively (Table 5). The next large proportion was about 43.68% of what the farmers used for the market, with the range of values being the lowest (0.00%) and the highest (93.00%). The results also indicated that the mean animal feed proportion of the farmers was 4.26%, whereas animal feed utilization ranged from 0.00% to 10.00% among the 200 respondents. This implies that the highest proportion of cassava goes for family use, followed by the market, while the least percentage is utilized for animal feeding. However, only a small number of farmers fully utilize it for home consumption or a large percentage goes to the market without sharing for animal feed.

Farmers' cassava consumption patterns are presented in Figure 2. The test statistics for equal proportions result showed that the difference between the mean farmers' cassava consumption patterns was highly significant ($P \leq 0.0001$). This indicates that the null hypothesis is false or should be rejected. Hence, 93 farmers (46.50%) consumed cassava as a boiled root, 30 farmers (15.00%) consumed cooked flour, and 77 farmers (38.50%) consumed boiled root and cooked flour (Figure 2). The result shows that only a small number of farmers would have consumed cassava products in the form of processed products such as flour or sliced cooked cassava. As a result, farmers utilize cassava products for a short period of time for family feeding and may experience high postharvest losses of the product. This study also shows that those farmers' practices in terms of processing methods and forms of consumption are very traditional. Therefore, the study suggests that the researchers should focus on developing multiple food forms through a participatory research approach or adopting technology from other countries by importing it with minimal modification. This finding is in line with the earlier work by Tadesse et al. [9], who stated that most of the cassava produced in Ethiopia was consumed by boiling the root and cooking the flour. However, in various countries, cassava was adopted in multiple food forms and was primarily produced as fermented and unfermented products [57, 58]. Fufu, lafun, akyeke, agbelima, and gari are examples of fermented products, whereas tapioca, chips, pellets, unfermented cassava flour, and unfermented cassava starch are examples of unfermented products. Cassava flour is one of the latest food applications (e.g., bread and biscuits) appearing in products with decreased or no gluten [58].

Table 5: Descriptive statistics for cassava products' utilization proportion.

Nos.	Utilization proportions (%)	Mean	Min-max	Std. deviation
1	Home consumption	51.87	5.00–100.00	27.55
2	Market	43.68	0.00–93.00	27.52
3	Animal feed	4.26	0.00–10.00	2.62

Source: own computation result, 2022.

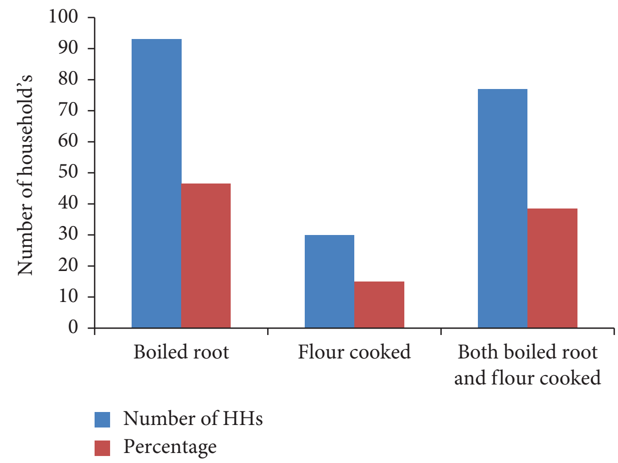

Figure 2: Respondents' distribution for the cassava products' consumption pattern. Note: number of observation = 200, $\chi^2 = 32.17$, DF = 2, Pr > ChiSq (χ^2) ≤ 0.0001.

3.4. Postharvest Handling Practices. In the present study, the chi-square test for equal proportions result showed that the difference between the mean of various postharvest handling practices among farmers were highly significant ($P < 0.0001$). As a result, we would reject the null hypothesis. In total, 20 respondents (10.00%) reported that fresh storage roots were immediately processed into powder or flour, 36 respondents (18.00%) were immediately processed into slices or chips, 122 respondents (61.00%) were left in the soil, and 22 respondents (11.00%) did not know anything about the postharvest handling practice of the storage root yield (Figure 3). Because of the root's rapid physiological deterioration after harvest, postharvest management of freshly harvested cassava roots is critical. Our finding indicates that large numbers of smallholder farmers are managing postharvest loss by leaving roots in the soil. This means that farmers hold the harvest until the crop is needed, which is the easiest and cheapest method to preserve the root yield of cassava. This is one of the most significant characteristics of the crop when utilized for food security because it allows flexibility in harvesting. The respondents said this type of handling practice allows the storage root to stay in the soil for 5–7 months. However, this handling practice is criticized by the scholars because of its drawbacks. Since there is a peak harvesting period for cassava roots, after which the yield declines, the roots become woody, and there is a risk that pathogens will infest the roots during soil storage [59]. According to the study, extension services should focus on immediately processing the root yield into slices or powder to prolong utilization and minimize the cassava product loss, thereby improving food security, and soil handling practices should be researched further. This result is supported by Oluwatusin [60], who reported that postharvest loss handling practices in Nigeria were reduced by allowing roots to stay in the soil for 3-4 months and processing roots to chip and "fufu."

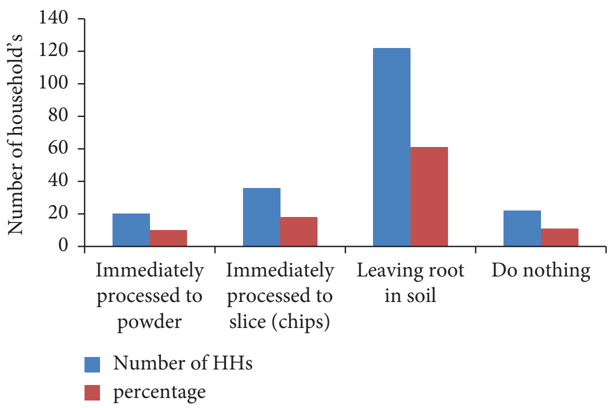

Figure 3: Distribution of the respondents for postharvest loss handling practices of cassava products. Note: number of observation = 200, $\chi^2 = 141.28$, DF = 3, Pr > ChiSq $(\chi^2) \leq 0.0001$.

4. Conclusion and Policy Implications

Cassava is an important food crop produced in the study area mainly to supplement food security. It is an essential food crop for smallholder farmers, especially during times of food scarcity (in storage and on the market) and shocks. The cassava crop's main characteristics are its ability to provide year-round harvesting, resistance to heat or dry season stress, and role in filling the seasonal food gap. However, different factors such as socioeconomic, biophysical, and farming management were identified as the major determinants influencing the productivity of cassava crops. The results of the regression model show that the education level, family size, land holding size, cropping system, crop rotation, earthing up rate, maturity, variety type, training, and plant population variables affect cassava productivity significantly and positively, while topography and pest variables show a significant negative correlation with cassava productivity. The findings show that smallholder farmers grow cassava with traditional crop management practices, poor postharvest handling practices, and very few methods adopted in its utilization as food and for other purposes, which are also other constraints hindering the production and productivity of cassava.

Based on the present findings, the following recommendations are important for enhancing cassava productivity and sustaining its production among smallholder farmers. Potential intervention areas include the following: in the study area, about 81% of the farmers planted cassava on steep topography, suggesting that farmers' attention must be focused on implementing appropriate physical and biological conservation activities. The study showed that about 37% of the farmers cultivated cassava using improved planting materials; hence, there was a large gap in their use, suggesting the need for attention from extension agents and stakeholders' efforts to ensure their adequate provision and adoption. The education sector should focus on adult learning programs for not-literate households, while the agricultural office has to promote and strengthen crop rotation, intercropping, farmer training, and earthing up activities to improve soil fertility and sustain productivity. For better results, extension services need to be strengthened with a focus on encouraging farmers to adopt fully packaged new technologies, such as improved planting materials, chemicals, and technologies to harvest, process, and utilize the yield. Our data found that cassava has received minimal research interest from the scientific community and it is trailing other root crops because of the crop's perennial nature. Therefore, the study suggests that the farmers' different practices should be more supported by research through the generation of multiple food forms, postharvest handling practices, and production technology. Additionally, the national root tuber crop research program and other international organizations that mandate cassava research should collaborate to assure adequate records and proper transfer of cassava research findings to farmers. Furthermore, policymakers and local planners are expected to develop strategies that include adopting technologies or extension services that could help address the identified productivity-influencing factors, utilization options, and postharvest handling practices, thereby increasing the productivity of cassava and ensuring food security among smallholder farmers.

Data Availability

The datasets used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

Berhanu Bilate carried out the field work, performed the statistical analysis, and drafted the manuscript. The rest of the authors coordinated the study, supervised the fieldwork, and contributed to the writing of the manuscript. All authors have read and given their approval for the final manuscript to be submitted.

Acknowledgments

Jimma University and Wolaita Sodo University are acknowledged by the authors for providing funding for the study. The authors are also pleased to acknowledge Jimma and Hawassa Agricultural Research Centers and International Institute for Tropical Agriculture for providing planting materials used for the study.

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