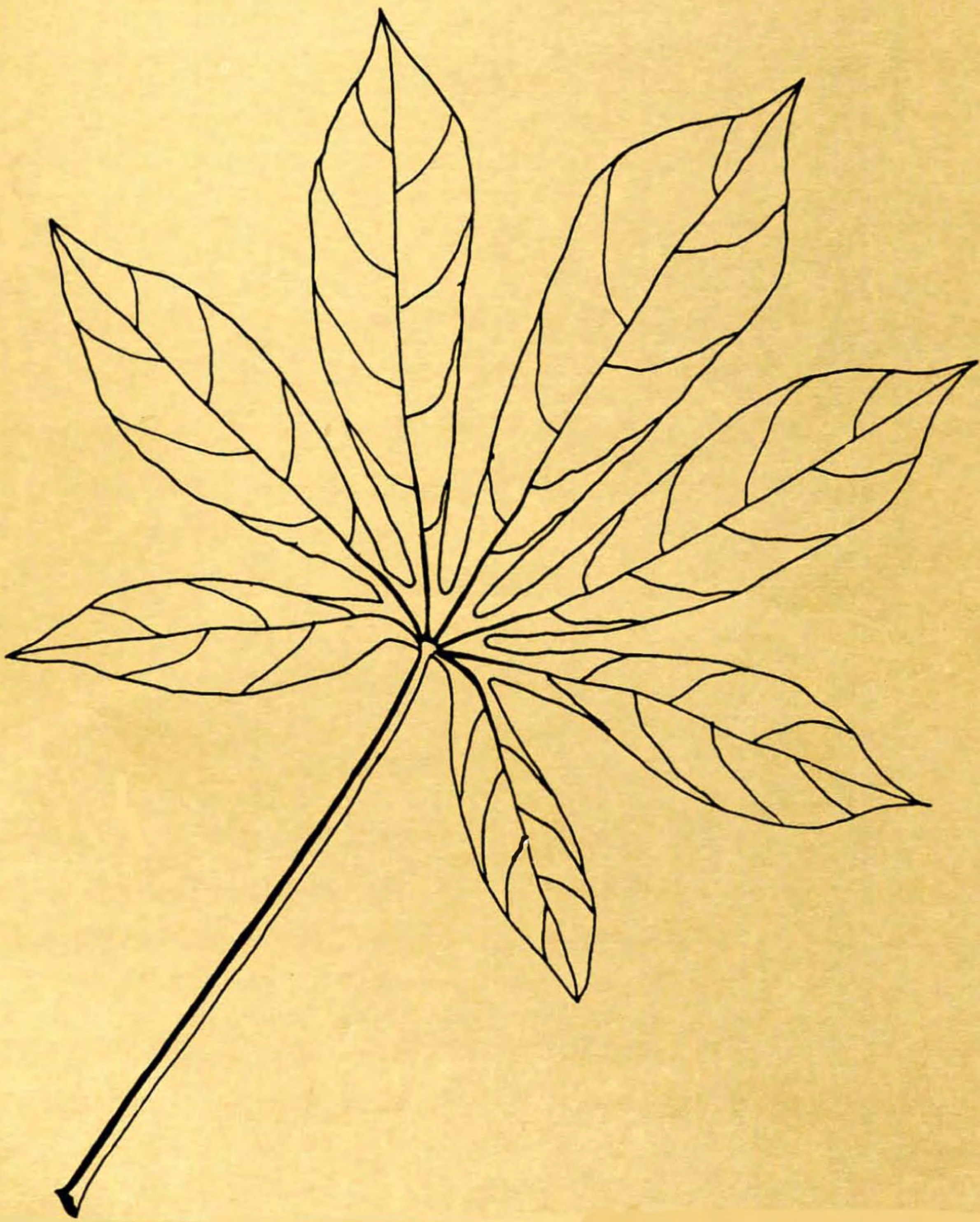
COSCA
Collaborative Study of Cassava in Africa
Working Paper No. 13

13

Cassava Production Prospects in Africa

Felix I. Nweke



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PREFACE

The Collaborative Study of Cassava in Africa (COSCA), is an inter-institutional efforts. The aim is to provide baseline information on cassava over a wide area. Such information is needed to improve the relevance and impact of agricultural research on the crop in Africa in order to realize the potential of cassava in increasing food production and the incomes of the people of Africa.

The COSCA working paper series is published informally by COSCA to disseminate its intermediate output. Publications in the series include methodologies for, as well as preliminary results of the various components and phases of the COSCA surveys. The series is aimed at scientists and researchers working with national agricultural research systems (NARS) in Africa, the international research community, policy makers, donors and members of international development agencies that are interested in cassava. As these papers are not in their final form, comments are welcome. Such comments should be addressed to the respective authors or to the COSCA project leader.

Individuals and institutions may obtain copies by writing to:

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I. Introduction

Since its introduction into Africa in the 16th century, cassava has spread throughout sub-Saharan Africa to become one of the dominant starchy staples in the diet of the people. Although the crop is grown in every country of the continent, cultivation is concentrated in the humid tropical regions. Africa produces 48 million tonnes of cassava annually, which translates into about 200 calories per day for 200 million people (Dorosh 1988). It is the dominant staple, particularly in Central Africa; it constitutes over 50% of the average staple food consumption in Zaire, the People's Republic of Congo, and the Central African Republic. In the coastal regions of West Africa, from Côte d'Ivoire to Nigeria, cassava is as important as yam. Farther along the West African coast, cassava is the second most important staple after rice. In East Africa, although maize is the dominant staple in most countries, cassava is crucially important in Mozambique, Tanzania, Uganda, and Burundi.

The central role played by cassava in the African diet is particularly important because per capita food production in Africa is declining. During the two decades, after most African countries became independent, the continent steadily deteriorated into food import dependence, as cereal imports filled the gap created by unsatisfactory growth in the production of domestic staples. Financing those imports has become increasingly difficult because the balance of trade in African countries has become increasingly negative and the external debt has risen. Declining per capita food production and internal financial liquidity are particularly serious, because an estimated 150 out of 450 million Africans suffer from some form of malnutrition.

The African food problem is commonly traced to inadequate food supplies. Food production has stagnated or fallen. Expansion of cultivation, which is usually in the more marginal agricultural areas, has not been sufficient to keep pace with the rapidly expanding demand for food. Moreover, rising population densities in areas of marginal rainfall has reduced the buffering capacity of subsistence production units against major variations in rainfall, often resulting in substantial shortfalls in food during years when rainfall is especially inadequate. This African food problem is a matter for deep and urgent concern.

Food production in Africa is fundamentally based on rainfed farming. African farming is therefore inherently risky, with marked variations in seasonal and annual food supplies. This highly variable production situation is made even more unstable in areas where land is scarce, because of rapid growth in rural populations which either reduces the farm size or induces migration to more marginal agricultural areas.

Cassava's adaptability to relatively marginal soils and erratic rainfall conditions, its high productivity per unit of land and labor, the certainty of obtaining some yield even under the most adverse conditions, and the possibility of maintaining continuity of supply throughout the year makes this root crop a basic component of the farming system in many areas of Africa. Famine rarely occurs in areas where cassava is widely grown, since it provides a stable base for food production. This indicates that cassava has the potential for bridging the food gap. However, the full realization of the potential depends on obtaining more detailed information about cassava growing conditions, production systems, processing methods, marketing, and urban consumption patterns. Authoritative information on these issues is lacking and even the production statistics that are available are, at best, educated guesses. The COSCA project was initiated to correct these information deficiencies.

Objective of the Report

This report attempts to assess the future trend in cassava production. The key questions addressed are:

- is cassava land area increasing?
- what are the driving forces of the land area expansion?
- is cassava root yield increasing?
- what are the driving forces of the yield increase?

The Collaborative Study of Cassava in Africa (COSCA)

COSCA, funded by the Rockefeller Foundation, aims to collect authoritative information on cassava production systems, processing methods, market prospects, and consumption patterns. This information is needed to improve the relevance of research on cassava by national and international agricultural research centers, in order to realize the potential of cassava for increasing food supply and incomes of the people of Africa. The range of information needed to accomplish this objective is wide and includes information on the importance of cassava, cassava varieties, and production trends.

COSCA commenced in 1989 in six countries: Côte d'Ivoire, Ghana, Nigeria, Tanzania, Uganda, and Zaire. Since then, four additional countries (Burundi, Kenya, Malawi, and Zambia) have begun collaborating with alternative funding.

The COSCA study is executed by a multinational, multi-institutional, and multidisciplinary team. Each collaborating country has a multidisciplinary team of four senior-level scientists from different national agencies within the country, consisting of a breeder, an agronomist, a plant protectionist, and an economist and/or a statistician where available. The collaborating international agencies are the International Institute of Tropical Agriculture (IITA), Centro Internacional de Agricultura Tropical (CIAT), Natural Resources Institute (NRI), Uppsala University, and the Rockefeller Foundation.

COSCA is being executed in three phases as follows:

Phase I involves a broad characterization of the following:

1. Environment (physical, social, economic)
2. Production
3. Processing
4. Marketing
5. Consumption

Phase II deals with cassava production details such as:

1. Yield
2. Land area
3. Utilization (sale/home use, processed/fresh use)
4. Input/output
5. Production practices

Phase III involves detailed studies on postharvest issues:

1. Processing
   - characterization of techniques
   - product quality assessment (nutritional, toxicity, and quality assessment)
2. Marketing
3. Consumption/demand

Phases I, II, and III data collection surveys have been completed in Côte d'Ivoire, Ghana, Nigeria, Tanzania, and Uganda; Phases I and II have been carried out in Zaire, while only Phase I has been conducted in Burundi, Kenya, Malawi, and Zambia.

Method of the COSCA study

Site and sample selection. Climate, human population density, and market infrastructure formed the bases for sampling. Following Carter and Jones (1989), four basic climatic zones were defined from temperature and duration of dry periods within the growing season (table 1).

Information available on all-weather roads, railways, and navigable rivers derived from the 1987 Michelin travel maps was used to divide a market-access infrastructure map of Africa into good and poor zones, according to the density of the roads, railways, or navigable waterways. Human population data from the United States Census Bureau were used to divide a population map of Africa into high demographic-pressure zones with 50 or more persons per km^2, and low, if less.

Table 1. Definitions of climate zones

Climatic zone	Temperature(°C)		Months of dry season
	Daily mean	Range	
Lowland humid	22	10	<4
Highland humid	<22	<10	<4
Subhumid	>22	>10	4-6
Nonhumid	>22	>10	4-9

The three maps of climate, human population density, and market access infrastructure were overlaid to create zones with homogeneous climate, demographic pressure, and market-access conditions. Each climate/population density/market-access zone with less than 10,000 ha of cassava in each country was excluded. The remaining areas were divided into grids of cells 12' latitude by 12' longitude to form the sample frame for site selection. A certain number of the grid cells distributed among the climatic/population density/market-access zones in proportion to the zone size was selected in each country, depending on country size, by a random method. The total for the ten countries is 460 (table 2). One village was selected, by a random method, within each of the grid cells (fig. 1). In each selected village a list of farm households was compiled and grouped into "large", "medium", and "small" farm-holder units with the assistance of key village informants. Farm units which cultivated 10 ha or more of all crops were excluded. One farm unit was selected from each stratum.

Table 2. Number of survey units by country

Country	Number of Villages	No. of households		No. of fields Phase II
		Phase II	Phase III	
Côte d'Ivoire	40	120	222	267
Ghana	30	90	180	297
Nigeria	65	195	359	975
Tanzania	39	131	252	543
Uganda	37	120	240	359
Zaire	71	108	-	264
Burundi	39	-	-	-
Kenya	34	-	-	-
Malawi	67	-	-	-
Zambia	38	-	-	-
Total	460	764	1253	2705

Data collection. Leaders in cassava research in the national agricultural research systems in each country administered survey questionnaires to local farmers and took various measurements. They were knowledgeable in the cassava production systems of their respective countries and hence well qualified to collect the information.

A rapid rural appraisal technique was employed to collect village-level information in the Phase I survey. Farmer groups consisting of men and women of various ages were constituted and interviewed in each village. Structured questionnaires were used to collect qualitative information. This survey was conducted in 1989–1991.

Phase II survey was carried out at field level. Field size was determined by measurement with a compass, a tape, and ranging poles. Yield estimation was made for fields which were 9 months or more old, except when the farmer harvested at less than that age. The estimation was based on a representative sample plot of 40 m^2, except when the field was too small, in which case a 20 m^2 plot was used. There were one or two plots per field depending on the size and heterogeneity of the field in terms of soil and toposequence. The field level information was collected in 1991.

Phase III survey was at the household level. Relevant male and female household members were interviewed using structured questionnaires. The household information was collected in 1992.

Statistical analysis. Different analytical models were used in the various sections as necessary; they include frequency count, simple average, analysis of variance (ANOVA), and econometric models used to identify forces which drive cassava land area and root yield. Wherever it was carried out, the econometric analysis is presented under theoretical and empirical models, empirical results, and discussions. A reader who may not be interested in analytical procedures can read only the discussions.

Plan of the report

Section II defines relevant variables which form the bases of the various analyses. Section III discusses major issues in cassava land area expansion. Issues in root yield are discussed in section IV. Section V summarizes key observations.

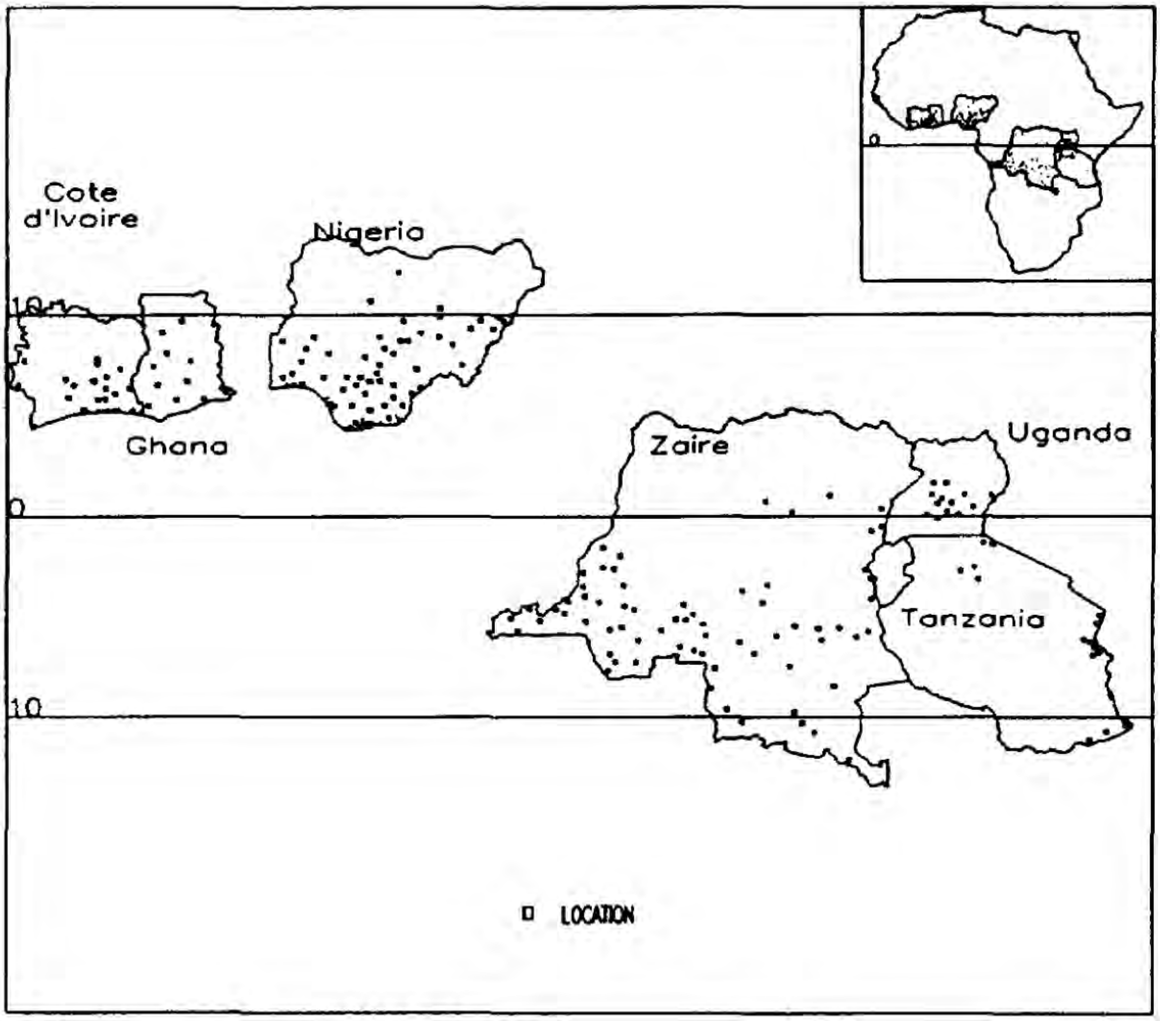

Fig. 1. Location of survey sites.

II. Cassava Production Circumstances

Areas of cassava production

The importance of cassava in comparison with other staples in terms of field area, decreases from the humid through subhumid to non-humid climatic areas sampled (fig. 2). Cassava is by far the most widely grown of all the staple crops in the humid zone. Maize is also widely grown in this zone since it is found in 25% of the major staple crop fields. The third and the fourth crops in importance, rice and banana/plantain each occupies about 10% of the staple crop land area. Areas in the humid climate zone where cassava occupies less than the largest field area are found in Uganda, where cassava competes with banana and also in parts of Côte d'Ivoire and Ghana, where

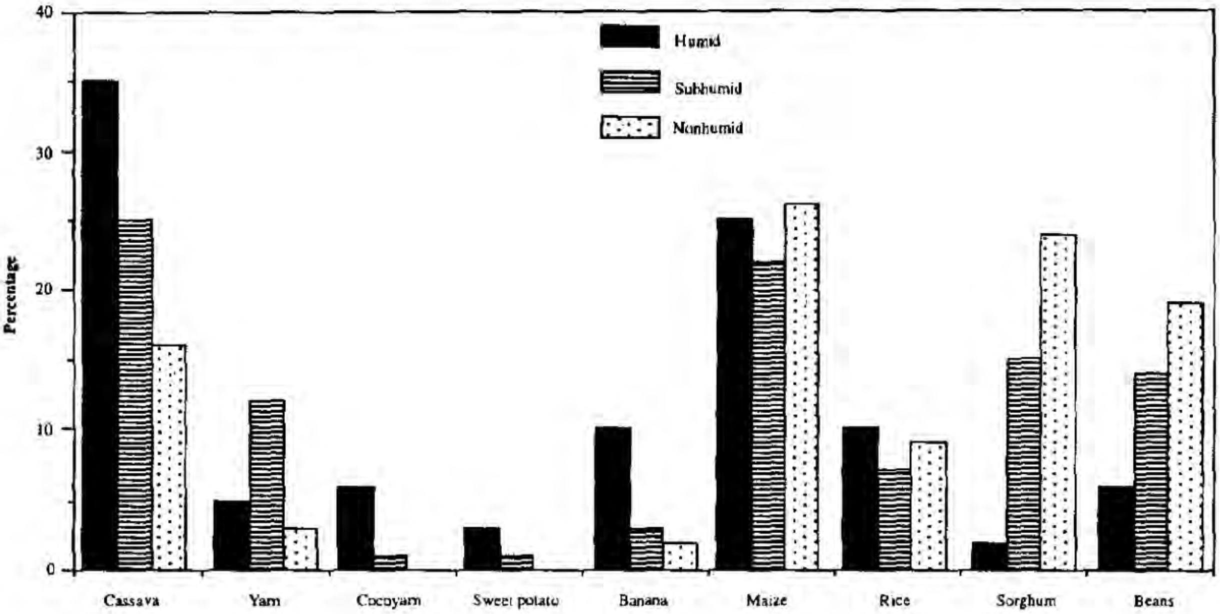

Fig. 2. Relative importance (field area) of staple crop by climatic zone

Note
Banana=banana and plantain, Sorghum=sorghum amd millet, Bean=beans and peas

rice and maize are important staples. Cassava production appears to be driven more by population than by market pressure in the humid zone. The relative importance of cassava is higher in high than in low population areas (fig. 3); it is however lower in areas around market centers than in areas remote from the market centers.

Although cassava is relatively more important in the humid than in the subhumid area, it is still the most important staple crop in the subhumid zone, occupying 25% of staple crop land area.

The subhumid areas where cassava occupies less than the largest land area among the staples are located mostly in Nigeria, where yam is a major crop (fig. 4). Such areas also exist in the other West African countries (Côte d'Ivoire and Ghana) as well as in Tanzania where maize is an important staple.

Within the nonhumid area, even though sampling was biased in favor of cassava, its relative importance is only fourth, following maize, millet/sorghum, and beans/peas. However, cassava occupies the largest field area among all staple crops in some nonhumid areas. Cassava production appears to be driven more by market than by demographic pressure; the relative importance of cassava is higher in areas around market centers, than in areas which are remote from market are

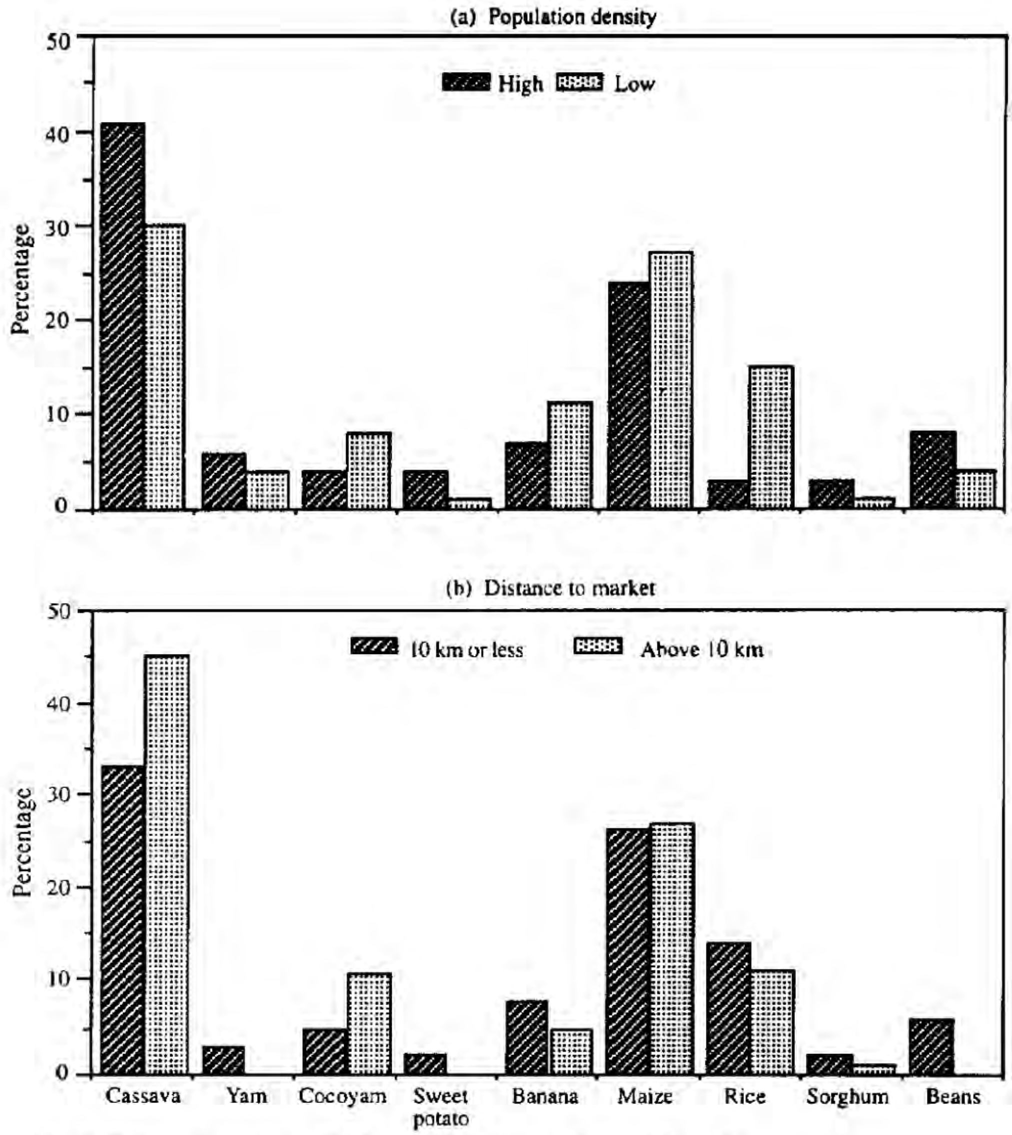

Fig. 3. Relative importance (field area) of staple crops in humid zone by (a) population density and (b) distance to market.

Note: Banana = banana and plantain, Sorghum = sorghum and millet, Bean = beans and peas.

centers (fig. 5). In general, sub-Saharan Africa can be broadly divided into two food zones: the moist zone where the starchy staples dominate and the drier zones where grains and grain legumes are the dominant staples. Cassava predominates over all the other starchy staples in the moist zones. Yam, which is cultivated mainly in the subhumid zone, is an exception to this trend. Although the relative importance of maize or rice appears equally distributed across the three zones, in the humid and subhumid zones maize is grown mainly in intercrop with cassava or yam, where it is often the minor crop. In those systems, maize is often harvested green and used as vegetable, while grain maize production is concentrated outside the humid zones.

This proportion of staple field area does not adequately represent the relative importance of banana/plantain since it does not include those grown in compound gardens, or those grown or protected in tree crop or fallow fields. The distribution, by climate, of the relative importance of the staples based on field area does not necessarily correspond with the farmers' ordinal crop ranking (fig. 6). For example, the relative importance of cassava based on the farmers' ordinal corp ranking is estimated at 35% in the humid, 27% in the subhumid, and 32% in the nonhumid

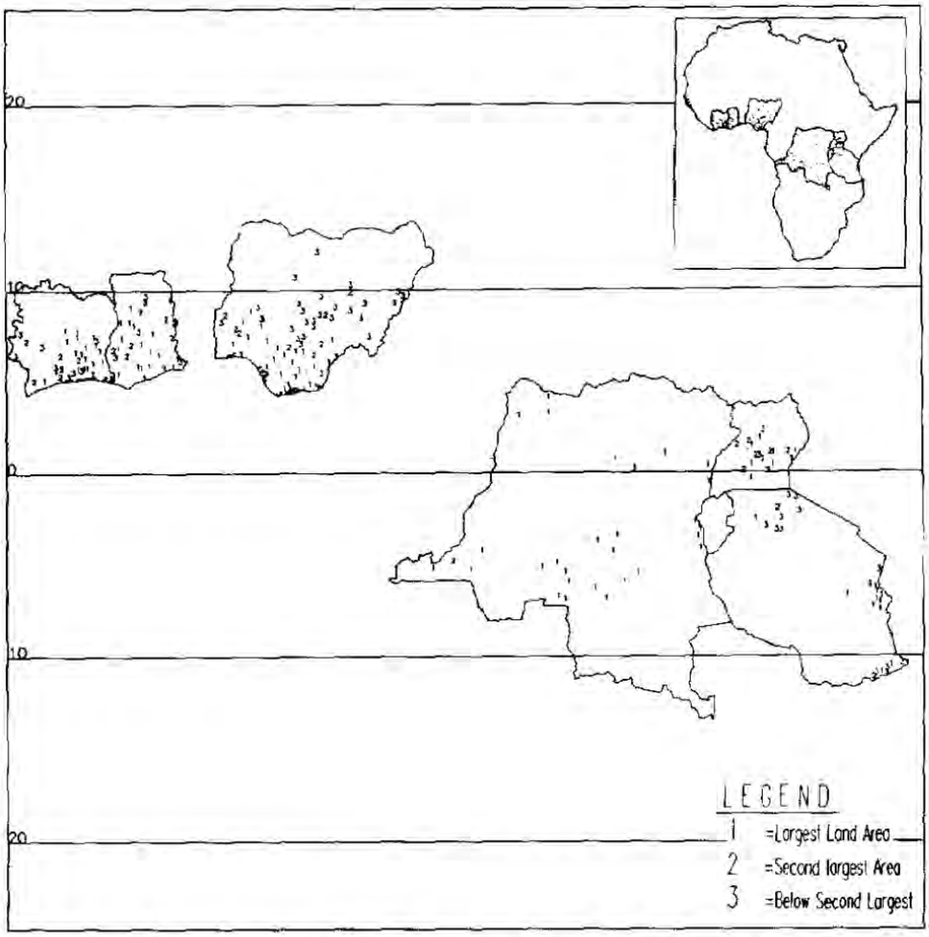

Fig. 4. Distribution of survey sites by relative size of cassava land area.

areas. The relative importance estimate based on the farmers' ordinal crop ranking reflects the food security value of cassava. Hence, the relative importance of the crop is high in the nonhumid zone, which is more susceptible to food shortages.

The midaltitude zone is not sufficiently represented in the COSCA survey because the sample design was directed to major cassava producing areas. The relative importance of cassava estimated on the basis of field area is lower in the midaltitude zone, about 25% of the arable land, than in the low altitude zone where cassava occupies an average of nearly 30% of arable land. Midaltitude villages where cassava occupies more land than any other arable crop are mainly high population villages.

Cassava was a dominant staple crop among villages which did not experience famine (table 3). Rice, maize, and yam are relatively more important in areas prone to famine than in areas not so prone. Put differently, areas where rice, maize, or yam are the main crops are more likely to be famine prone. In contrast, areas where cassava is the main crop are less likely to be famine prone. Cassava's adaptability to a wide range of climatic and edaphic conditions, including tolerance to drought, pests, and disease relative to other crops, confers a comparative advantage on cassava over other crops under conditions of famine. Cassava's tolerance of adverse conditions, and its flexibility with respect to the timing of both planting and harvesting, make it ideal for famine situations (Fresco 1993). Romanoff and Lynam (1992) argue that cassava plays

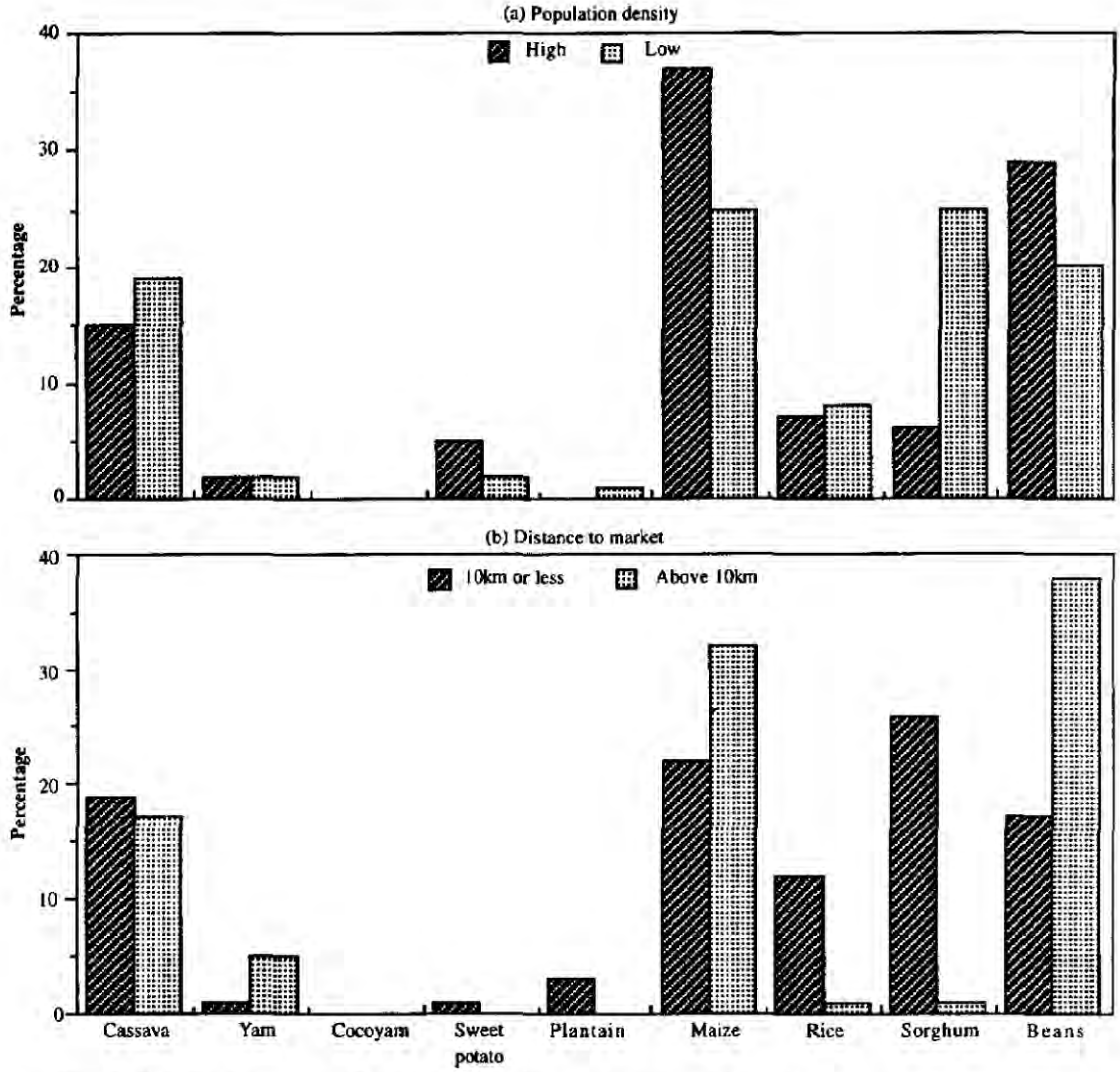

Fig. 5. Relative importance (field area) of staple crops in nonhumid zone by (a) population density, and (b) distance to market.

Note: Banana = banana and plantain, Sorghum = sorghum and millet, Bean = beans and peas.

a famine prevention role; where cassava is widely grown, famine rarely occurs because cassava provides a stable base to the food production system.

Cropping system in cassava growing areas

Multiple crops were produced in multiple fields by each farm household. The mean number of staple crops per farm household was 6.5, the range was 1 to 15. Cassava, yam, sweet potato, plantain, cooking banana, maize, and rice were among crops frequently observed. Sweet potato and cooking banana were not widely grown in West Africa, yam was not widely grown in East Africa while rice was not commonly grown in Ghana and Uganda. Cassava and maize were widely grown in all countries (table 4). The average farm size was 1.57 ha/household, the range was 0.01–9.54. ha. The distribution of the mean by major crops is presented in table 5.

The crops were sometimes grown sole and sometimes as intercrop. When crops are grown in mixed culture, farmers distinguish, based on their production objectives such as food security and income generation, which is the major and which is the minor crop in the mixture. Rice, yam, and cassava were grown more frequently as major crops in intercrops. Bean/peas, sweet potato,

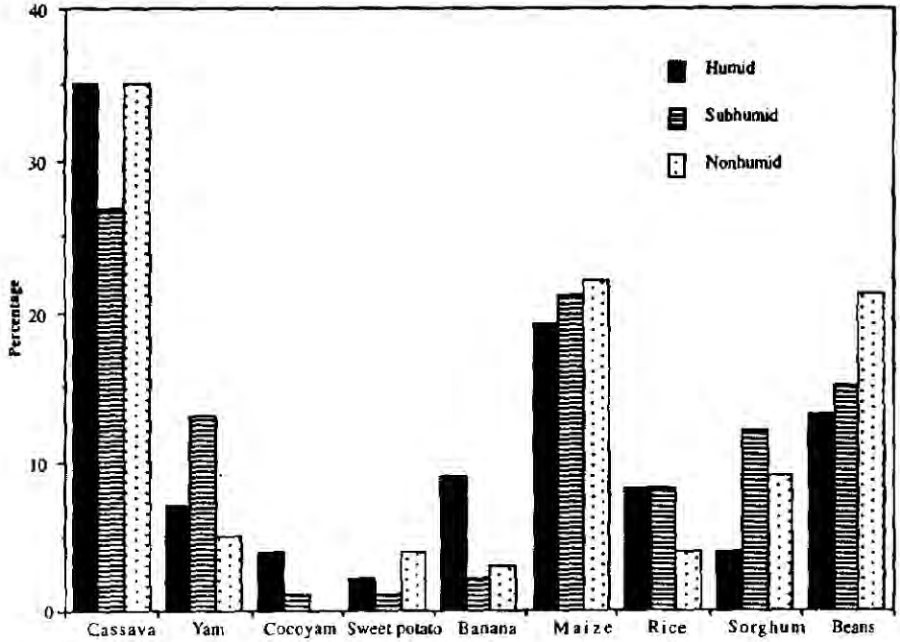

Fig. 6. Relative importance of staple crops by farmers' ordinal crop ranking by climatic zone.

Note
Banana = banana and plantain, Sorghum = sorghum and millet, Bean = beans and peas.

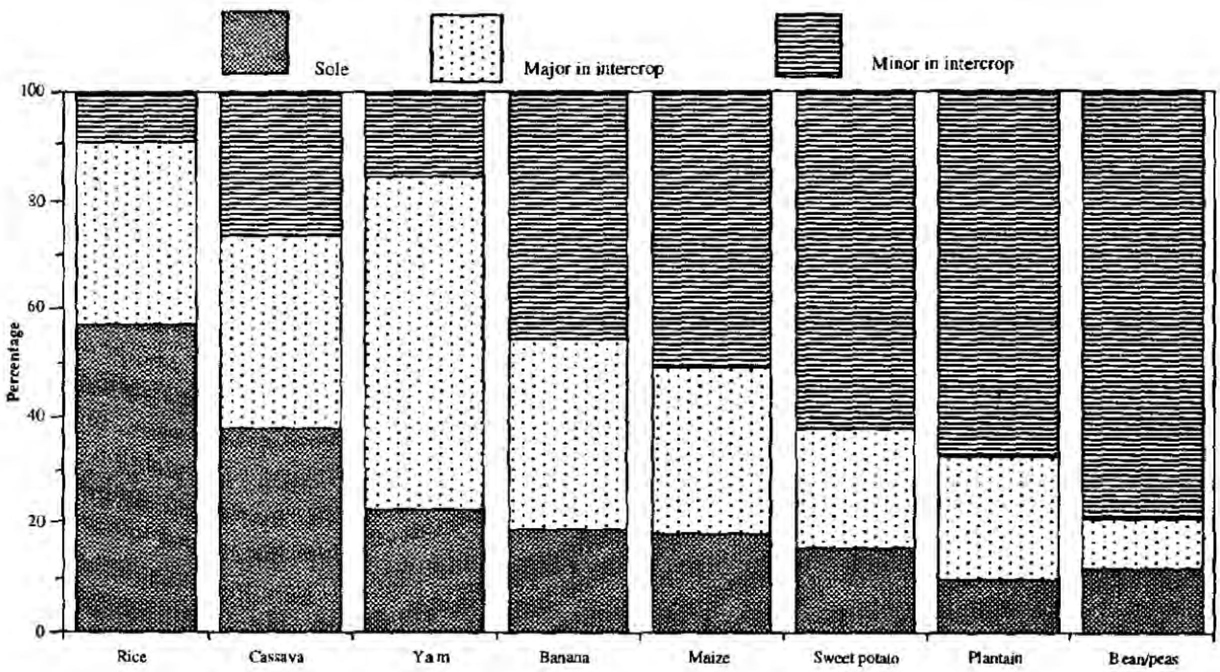

Fig. 7. Percentage distribution of fields of major crops by cropping patterns.

plantains and bananas, and maize were grown more frequently as minor crops than as sole or major crops in the intercrop (fig. 7). In this report, a field is designated for a crop if that crop was grown sole or as the major crop in an intercrop.

Distinction is often made between near (compound) and distant (outer) fields (Lagemann 1977 and Dvorak 1993), based on the distance from residential area. Near fields are close to the

residential areas, distant fields are, in contrast, further away from residential areas. The fields surveyed, 25 were located near and 75% distant in relation to the residences of the farmers (table 6).

Table 3. Relative importance (percent) of staple crops, estimated by field area and by farmers' crop ranking by famine experience of representative villages

Staple crops	Field area		Farmers' crop ranking	
	Famine	No famine	Famine	No famine
Cassava	26	34	29	37
Yam	8	7	9	7
Cocoyam	3	2	2	2
Sweet potato	2	2	2	2
Banana/plantain	6	3	7	3
Maize	24	24	20	21
Rice	9	4	6	8
Millet/sorghum	11	11	8	5
Beans/peas	11	14	17	15
Total	100	100	100	100

Table 4. Percentage distribution of surveyed households by production of main crops by country

Main crop	Côte d'Ivoire	Ghana	Nigeria	Tanzania	Uganda
Cassava:					
producing	100	100	92	95	100
not producing	0	0	8	5	0
total	100	100	100	100	100
Yam:					
producing	62	80	73	7	11
not producing	38	20	27	93	89
total	100	100	100	100	100
Sweet potato:					
producing	7	3	28	60	92
not producing	93	97	72	40	8
total	100	100	100	100	100
Plantain:					
producing	73	54	49	12	44
not producing	27	46	51	88	56
total	100	100	100	100	100
Cooking banana:					
producing	1	8	5	46	51
not producing	99	92	95	54	49
total	100	100	100	100	100
Maize:					
producing	76	97	100	100	85
not producing	24	3	0	0	15
total	100	100	100	100	100
Rice:					
producing	43	14	40	50	12
not producing	57	86	60	50	88
total	100	100	100	100	100

In the major food crop fields, 30% of the seedbeds were nontill, 29% plowed flat, 24% were ridged, and 17% were mounds (table 7). The seedbed type is frequently a reflection of the physical characteristics of the soil in the area. If the soil is shallow or if the water table is high, farmers often plant on large mounds to enhance drainage and soil aeration. If, on the other hand, the soil is deep, or the water table is low enough farmers plant on flat.The crops were transported home, where processing and storage were often carried out, from about 85% of the fields. The crops were transported direct to the market or selling points from 10% of the fields, and to processing sites outside the residence from 5% of the fields.

Table 5. Summary of field area (ha) per household by crop

Crop*	Mean	Minimum	Maximum	Std. Deviation	No. of Households
Cassava	0.62	0.00	6.48	0.93	720
Yam	0.11	0.00	5.26	0.74	720
Sweet potato	0.02	0.00	0.96	0.19	720
Plantain	0.03	0.00	2.81	0.17	720
Cooking banana	0.03	0.00	1.18	0.13	720
Maize	0.28	0.00	8.52	1.19	720
Rice	0.14	0.00	4.71	0.99	720
Overall	1.57	0.01	9.54	1.54	720

Note: * field in which a crop was minor in an intercrop was counted.

Table 6. Percentage distribution of arable fields by location (near or distant) relative to the farmer's residence

Crops	No. of fields	Near	Distant	Total
Cassava	1161	24	76	100
Yam	170	9	91	100
Sweet potato	77	63	37	100
Plantain	55	74	26	100
Cooking banana	78	11	89	100
Maize	284	21	79	100
Rice	119	8	92	100
All crops	1944	25	75	100

Table 7. Percentage distribution of major crop fields by seedbed type

Crops	No. of fields	No-till	Till or Ridge	Mound	Total
Cassava	632	37	49	15	100
Yam	119	10	13	76	100
Sweet potato	70	0	43	57	100
Plantain*	-	-	-	-	-
Cooking banana*	-	-	-	-	-
Maize	235	29	69	2	100
Rice	101	52	46	2	100
Overall	1157	24	56	20	100

Note: *not applicable.

Tree crops were also grown and livestock kept. The most widely grown tree crops were oil palm observed in about 20% of the representative villages, coffee observed in 17%, and cocoa observed in 16% of the representative villages. Sheep/goats observed in nearly 90% and cattle observed in about 60% of the representative villages were the most widely kept livestock apart from chicken which was observed in almost all representative villages.

Cassava as a commercial crop

Cassava is assessed as a commercial crop in terms of sale of output, cash income earning, and use of purchased inputs in cassava production in relation to other staple crops in the cassava growing areas.

Cassava sale. An average of about 40% of cassava per field was planted purposely for sale. Other studies (Spiro 1980, Fresco 1982, and Tollens 1992) suggest that more of cassava would be sold than of other crops. The proportion of cassava planted for market per field ranged from zero to 100%; no cassava was planted for sale in about 5% of the fields.

The proportion was negatively related to ease of access to market centers because of limited diversification in the number of crops produced in remote areas. Where cassava marketing middlemen (traders and processors) were available, the proportion was high in the good market access areas because the participation of the middlemen in cassava marketing discouraged crop diversification away from cassava as market-access improved. Access to cassava production credit resulted in an increase in the proportion; some of the credits were provided with the condition that the product was sold to the creditor. Access to improved postharvest handling facilities also led to a substantial increase in proportion. As cassava roots are bulky and perishable and therefore expensive to transport in the fresh form, farmers are likely to sell more processed than fresh cassava.

The proportion was lower in areas of high demographic pressure than in areas where pressure was low. However, where cassava was the main crop in the cropping system, the proportion was significantly higher in areas of high population densities than in areas of low density.

Cash income generation. In the cassava producing areas, production of food crops was the major source of cash income for the smallholder households. The food crops contributed about 40% of the household cash income. The industrial crops and nonfarm activities contributed 25% each while livestock contributed 10%. Rice and cassava accounted for the largest proportion of the cash incomes generated for the producing households from food crops. But the rice-producing households were fewer, by far, than the cassava-producing households. Consequently, in the cassava-growing areas where the most important source of cash income was food crop production, cassava was the most important food crop generating cash income. Cassava was, therefore, not a subsistence crop or just a food security crop, it was the main source of cash income for the producing households.

Cassava production was more egalitarian, in terms of distribution of cash income, than most of the other food crops. There were significant disparities in the distributions of the cash income from the various commodities; the disparity in the case of cassava was one of the lowest. In addition, more households earned cash income from cassava than from any other commodity. Cassava is able to perform this role because the crop, relative to most of the other food crops, has a wide ecological adaptation; it is less expensive to produce as it tolerates poor soil, adverse weather, and pest/disease. Carbohydrate yield from the cassava per unit of resource is higher than

that from most of the other major food crops. In addition, cassava is widely accepted as food for humans in various forms in many parts of Africa even outside its major producing areas, hence it has a wide market. Disparity in the distribution of cash income from cassava was significantly reduced where improved postharvest handling technology was available. Access to such technology motivated more farmers to produce cassava and to market convenient cassava food products.

The cash income from cassava was higher in villages where farmers engaged in nonfarm cash-generating activities or where tree crops such as oil palm, cocoa, or coffee were grown. Availability of these alternative cash earning opportunities did not discourage the production of cassava for sale. The cash income from cassava was also higher in villages where sheep/goats were kept but lower where cattle was kept. There was competition between cattle-keeping and cassava production; cassava was grown more frequently in distant fields where cattle grazed and fencing cassava fields against cattle would be an unprofitable investment. Cassava has low value per unit weight and cattle need study fences to keep them off. On the contrary, there was complementary between sheep and goat-keeping and cassava production; cassava was produced mostly in distant fields and processed more frequently in areas of residence where sheep and goats fed often on the bi-products of cassava processing.

In West Africa, the cash income from cassava was higher in areas of high than low population density; in East Africa, the reverse was the case. Access to market, credit, and postharvest handling facilities was not as good in East Africa. Population pressure alone is not a sufficient guarantee that farmers will earn a cash income from cassava production. If there are no market opportunities in a densly populated area, farmers will produce for home consumption.

Planting high-yielding varieties of cassava made a significant difference in the cash income only where the production system was positively linked to the market. Differences in market factors produced the greatest difference in the cash income from cassava. Cash income was significantly higher in villages with easy access to market centers, production credit, marketing middlemen, or improved postharvest handling facilities.

Use of purchased inputs. In the production of the major food crops, purchased inputs would include rented farmland, hired labor, chemical fertilizers, and farm mechanization, especially of land clearing, seedbed preparation, and field-to-home transportation. The use of other farm chemicals was rare. Information on improved planting materials was collected for cassava alone. Farmers did not often purchase planting materials of local landraces of food crops but produced their own.

Hired labor was the most frequently used purchased input; it was generated locally and widely available to the farmers. Rented farmland was also generated locally but traditional land tenure practices were often a constraint on its use. Inorganic fertilizer and mechanized farmland clearing had the lowest frequency of use. Inorganic fertilizer was imported in virtually all the countries and was not always available locally. Mechanized farmland clearing and seedbed preparation were often provided by governments as services to the smallholders at subsidized rates. Adoption of the purchased inputs except mechanized seedbed preparation was higher in West Africa than in East or Central Africa. The adoption of the mechanized seedbed preparation was highest in Uganda. The adoption of all of the purchased inputs was very low in Zaire, Central Africa.

Rented farmland, hired labor, and mechanized land clearing and transportation were used at least as frequently in cassava production as average for other food crops, but inorganic fertilizer and mechanized seedbed preparation were used less often. Cassava was grown more frequently

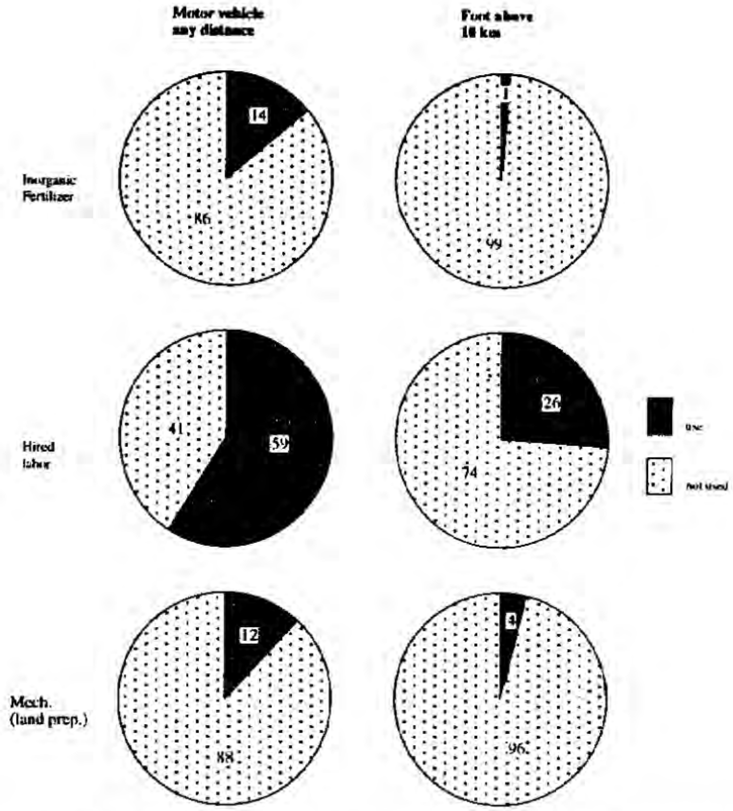

Fig. 8. Percentage distribution of arable crop fields by use of purchased inputs by access means to market.

than average on no-till seedbeds for which mechanized seedbed preparation was not relevant. Cassava root yield response to the application of fertilizers was conditioned on edaphic conditions and fertilizer type. That these two purchased inputs were not used in cassava production as often as in the production most other staple crops did not make cassava a less commercial crop. It only meant that inorganic fertilizer was often unsuitable while mechanized seedbed preparation was often irrelevant to cassava production.

Rented farmland, hired labor, and mechanized transportation were used more frequently in villages which processed cassava into *gari* or *attieke* (cassava granules) than in villages which processed into chips or which did not process at all. Compared with fresh roots or even chips, cassava granules is a convenient food which is attractive to urban consumers. It therefore has a wider market.

The adoption of each of the purchased inputs was more frequent in good market access areas than in poor market access areas (fig. 8). Access to market determined not only market availability for the farm products but also the farmers' access to the purchased inputs.

Conclusion. Cassava was produced with the relevant purchased inputs as often as, and in some cases, more often than other staples. A large proportion of cassava, which was likely to be larger than most other staples, was planted purposely for sale. In the cassava-producing areas, cassava generated cash income for the largest number of households in comparison with other staples. Therefore, cassava was important not just as a subsistence or food security crop, but even more as a major source of cash income for producing households. Easy access to market, above all, enhanced the use of purchased inputs, cassava planting for sale, and cash earning in cassava production.

Cassava production constraints

Plant pests/diseases. It was originally considered that cassava was not attacked by many pests or diseases in Africa, but increasingly, these are being recognized as problems of economic importance. Two arthropod pests, cassava mealybug (CMB) and cassava green mite (CGM); and two diseases, African cassava mosaic disease (ACMD) and cassava bacterial blight (CBB), are of economic significance.

ACMD was the most widespread of the four problems and symptom severity scores of 2.0 (on a scale of 1–4; 1 is lowest and 4 is highest) and above were observed on more landraces than for any other problem. The disease has been known since 1894 and has been studied since the 1930s (Hahn and Keyser 1985, Thresh et al. 1994). Hahn et al. (1981) reported that ACMD was the most widespread disease of cassava in tropical Africa and India; it was regarded as the most important vector-borne disease of any African food crop in a recent economic assessment (Geddes 1990). CMB, CGM, and CBB have very different histories as they are recent introductions and were first reported in Africa only about 20 years ago (Nyiira 1972; Hahn et al. 1981; Yaninek 1994).

CMB was the least widespread of the three (table 8); symptom severity scores of 2.0 and above were observed in relatively few villages compared with CGM and CBB. This can be explained by the fact that before the survey, IITA, in collaboration with other international research agencies and African national programs, had brought CMB under control by releasing, beginning in 1981, an insect parasitoid *Epidinocarsis lopezi* (Herren et al. 1987; Neuenschwander 1994). Although CBB was more widespread than CMB, symptom severity scores above 2.0 were recorded in fewer villages than for CMB.

Table 8. Incidences of four major cassava plant pests/diseases in the villages and landraces assessed in each of ten countries, 1989–91

Country	No. assessed		% villages (landraces) affected			
	Villages	Landraces	CMB	CGM	ACMD	CBB
Côte d'Ivoire	40	271	5 (2)	7 (3)	95 (42)	24 (5)
Ghana	30	175	7 (3)	7 (2)	100 (43)	10 (5)
Nigeria	65	361	57 (16)	31 (9)	89 (33)	86 (28)
Zaire	71	385	24 (10)	59 (38)	68 (44)	45 (27)
Tanzania	39	308	33 (11)	92 (51)	72 (27)	23 (7)
Uganda	40	280	5 (2)	100 (49)	64 (30)	72 (27)
Burundi	39	179	5 (1)	49 (31)	8 (3)	0 (0)
Malawi	67	423	34 (18)	49 (22)	40 (11)	6 (1)
Kenya	34	184	6 (1)	59 (24)	65 (25)	6 (1)
Zambia	34	235	15 (4)	57 (40)	68 (32)	13 (4)
All 10 countries	463	2801	23 (8)	53 (28)	66 (29)	32 (12)

The incidence of CMB was relatively high in Nigeria, Zaire, Malawi, and Tanzania and low in Côte d'Ivoire, Uganda, Burundi, Kenya, and Ghana. Symptom severity scores were highest in Ghana and Zaire and lowest in Uganda and Burundi (table 9). CGM was more widespread in Zaire and the countries of eastern and southern Africa than in those of West Africa. However, mean symptom severity scores for the landraces that were infested exceeded 2.0 only in Zambia and Zaire. ACMD was observed in almost all the villages assessed in West Africa. The disease was less common in villages of Central, East, and Southern Africa, with the exception of Uganda. The incidence was particularly low in Burundi, although the mean symptom severity score for the

landraces infected exceeded 2.0 there and also in Ghana, Uganda, and Zaire. CBB was widespread in Nigeria, Zaire, and Uganda, but was found in relatively few or in no villages in Burundi, Malawi, Kenya, Ghana, and Zambia.

CMB damage was not observed in any landrace assessed in the highland humid zone and was higher in the subhumid zone than elsewhere (table 10). CMB symptom severity scores were similar in each of the three climatic zones where the disease was recorded. The incidence of CGM was higher in the highland humid zone than in each of the other zones. The differences between the other zones were not significant. By contrast, the symptom severity score was significantly less in the subhumid zone than elsewhere and was highest in the nonhumid zone. The incidence of ACMD was lowest in the highland humid zone. The symptom severity scores were significantly higher in the two humid zones than elsewhere. The incidence of CBB was lower outside the humid zone than within. The symptom severity score was lowest in the subhumid zone. The differences were highly significant between the humid and nonhumid zones.

The symptom severity scores for CGM, ACMD, and CBB were similar in both the highland and lowland humid zones. The symptom severity scores of ACMD and CBB were highest in the humid zone, while that of the CGM was highest in the nonhumid zone. However, the symptom severity score for CGM was not statistically higher in the nonhumid than in the humid zones. Therefore, the problems of CGM, ACMD, and CBB were not higher in any other zone than in the humid one. The symptom severity score for CGM was lowest in the subhumid zone, whereas scores for CBB were similar in the subhumid and nonhumid zones. Hence, these problems were not less severe in any other climatic zone than in the subhumid one.

CBB is more widespread and severe in the savanna and forest transition ecological zones of Africa than in the rainforest. Severe incidences of the disease have, however, been reported from the rainforest zones of Nigeria (Terry 1981). In the forest zone, CBB and CMB are not generally a major problem. In the savanna zone, where rainfall is less than 1200 mm and the dry season sometimes lasts more than five months, CBB is not a major problem whereas CMB is. CBB is widespread in savanna areas where rainfall exceeds 1500 mm (Mabanza 1981).

Table 9. Mean symptom severity scores (1–4) for four major cassava plant pest/diseases by country

Country	CMB		CGM		ACMD		CBB	
	N	Score	N	Score	N	Score	N	Score
Côte d'Ivoire	5	1.2	7	1.1	114	2.0	14	1.7
Ghana	5	2.4	3	2.0	76	2.2	8	1.0
Nigeria	57	1.5	37	1.1	118	1.4	100	1.2
Zaire	38	2.3	148	2.1	170	2.4	104	1.8
Tanzania	35	1.8	157	1.3	88	1.3	22	1.1
Uganda	5	1.0	136	1.7	83	2.7	79	1.6
Burundi	2	1.0	56	1.2	5	2.2	0	-
Malawi	2	1.5	44	1.5	46	1.7	2	1.5
Kenya	74	1.8	94	1.8	47	1.7	3	1.3
Zambia	10	1.5	95	2.2	76	1.6	9	1.4
All 10 countries	233	1.8	772	1.7	823	1.9	341	1.5

Note: N = number of land score affected.

Cassava is propagated vegetatively and the use of planting material derived from pest infested or disease infected plants is a common way of spreading many of the pest/diseases of the crop

(Boher and Verdier 1994, Rossel et al. 1994, Thresh et al. 1994). **Hence, the selection and use of planting material derived solely from healthy plants can reduce the incidence and severity of some of the important pest/diseases. The farmers' sources of planting materials were mainly their own production fields or neighbors and sometimes cassava marketing middlemen.**

Table 10. Incidences and symptom severity scores (1–4) for four major cassava plant pests/ diseases by climatic zone in 10 countries

Pest/disease/ climatic zone	No. of landraces total	affected (and %)		Mean symptom severity score	Probability levels of significance differences 1 by 2	1 by 3	1 by 4	2 by 3	2 by 4	3 by 4
CMB										
1. HL humid	205	0	(0)	-	*	*	*	*	*	*
2. LL humid	863	57	(7)	1.75	*	*	*	*	*	*
3. Subhumid	789	105	(13)	1.77	*	*	*	*	*	*
4. Nonhumid	812	66	(8)	1.74	*	*	*	*	*	*
CGM										
1. HL humid	205	74	(36)	1.73	*	**	*	*	*	*
2. LL humid	863	201	(23)	1.74	*	*	*	***	*	*
3. Subhumid	789	207	(26)	1.52	*	**	*	***	*	***
4. Nonhumid	812	234	(29)	1.81	*	*	*	*	*	***
ACMD										
1. HL humid	205	36	(18)	2.28	*	***	***	*	*	*
2. LL humid	863	331	(38)	2.23	*	*	*	***	***	*
3. Subhumid	789	206	(26)	1.68	*	***	*	***	*	*
4. Nonhumid	812	204	(25)	1.54	*	*	***	*	***	*
CBB										
1. HL humid	205	36	(18)	1.78	*	***	**	*	*	*
2. LL humid	863	164	(19)	1.54	*	*	*	***	*	*
3. Subhumid	789	90	(11)	1.30	*	***	*	***	*	*
4. Nonhumid	812	47	(6)	1.40	*	*	**	*	*	*

Notes:
HL = highland, LL = lowland
*** $P \leq 0.01$, ** $0.05 \geq P > 0.01$, * $0.10 \geq P > 0.05$

The farmers selected cuttings for cleanliness to only a limited degree. When they had alternative sources, they would derive cuttings from plants not older than twelve months and they would use freshly cut material. They would not use stems which carried lesions or cankers but did not always discard stems affected by pests/diseases. However, they did select cultivars for resistance against pests/diseases and would abandon cultivars that were very susceptible to any of these. Otim-Nape et al. (1992) reported that the variety Bukalasa II that was released by the Uganda Department of Agriculture in the 1950s because of its resistance to ACMV and because its roots cooked well had largely been abandoned by farmers in most districts of the country, mainly because of its high susceptibility to CGM.

Shortage of planting materials. There is a high turnover in cassava landraces as African farmers are continually introducing new landraces with desired attributes into their cropping systems. Such landraces are not necessarily improved varieties, but are often local and vary with villages, regions, and countries. As new landraces are introduced, the farmers often abandon existing ones

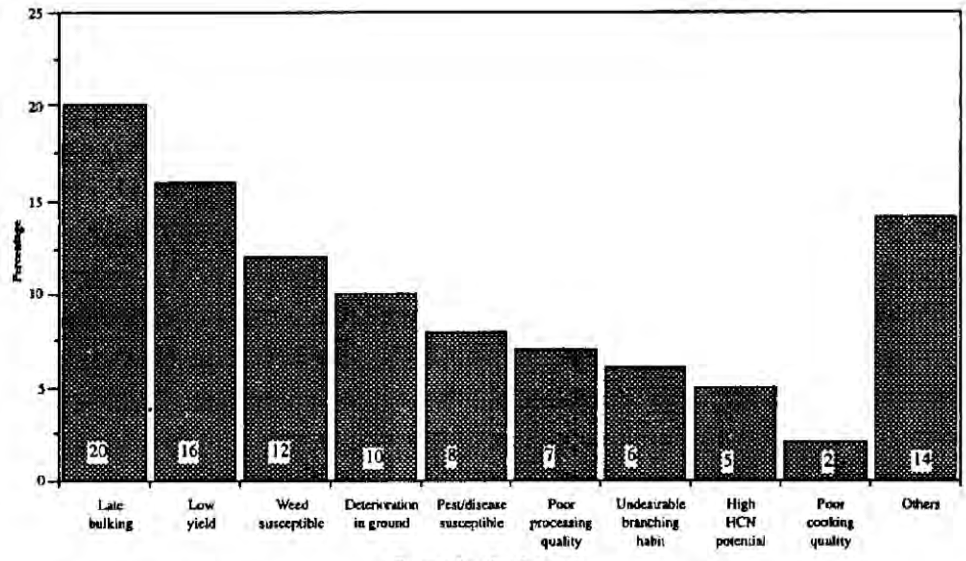

Fig. 9. Percentage distribution of abandoned cassava landraces by reasons.

that may not possess the desired attributes. The main sources of cassava planting material for a village were neighboring villages and towns. Some material was also reported to have been introduced from other countries. Such material was brought by traders, migrant farmers or development agencies, and church or other nongovernmental organizations. Less than 5% were reported to be from government sources.

It was reported during the COSCA survey that farmers had abandoned the cultivation of about 400 landraces since 1900. Approximate years of abandonment were traced by the farmers in the Phase I group meetings. Similarly, approximate years of introduction were also traced for 30% of the 2808 landraces recorded. The information may be imprecise because the numbers of landraces introduced or abandoned cluster around decade ends. This suggests that there must be some memory lapses, which is understandable as the information was not based on written records. The collective memory, however, spans different generations of people since the age composition of the village groups was very diverse.

The relative frequency of reasons given for abandoning landraces shows that the farmers were selecting for early bulking, high root yield, weed suppression, good in-ground storability, disease and pest tolerance, good processing qualities, desirable branching habit, good in-ground storability, low HCN potential, good cooking qualities, and others including good yield of planting material, in descending order of frequency (fig. 9).

The low frequency of good yield of planting materials did not mean that it was not an important desired attribute. Shortage of planting materials is a constraint to cassava production particularly in dry areas such as in the nonhumid zone where biomass production is usually low in comparison with moist areas; and when new materials such as improved varieties are being introduced for the first time. Shortage of planting materials is a major constraint to cassava production under both situations because the multiplication rate is very low in comparison with crops, such as grains, propagated by seed. The materials are bulky and highly perishable as they dry up within a few days after harvest. Hence, multiplication and distribution are very expensive. In both Kenya and Malawi, good yield of planting materials ranked high as a desired attribute. It is shown below that heavy public investment in multiplication and distribution of the planting materials was a major factor which contributed to widespread adoption of improved cassava varieties in Nigeria.

Declining fallow periods. The farmer group interviewed in each village was asked to describe the three most common fallow systems including crops grown, number of crop cycles before fallow if any, duration of each crop cycle, duration of the fallow, etc. A crop cycle was described as the cultivation of the same set of crops for a crop season or more without a change in the crop combination.

Greenland (1974) classified fallow systems into three: shifting cultivation (long fallow), recurrent cultivation (short fallow), and continuous cultivation (no fallow). For COSCA purposes, long fallow is considered to be less than 10 years of continuous cultivation followed by 10 or more years of fallow. For short fallow, the limits are less than 10 years of continuous cultivation combined with less than 10 years of fallow between crops. Continuous cultivation involves at least 10 years of continuous cropping with less than one year of fallow between crops. Most of the farmer groups interviewed considered that most fields would recover their fertility after 10 years of fallow. Okigbo (1984) stated that in areas of low population density where long periods of fallow were adopted, there was no guarantee that the farmer would return to the original farmed area in a definite period of time. Where population pressure was high, fallow periods were drastically reduced and farmers returned to the same piece of land after less than 10 years of fallow, leading to what was sometimes designated land rotation.

An average of 1.8 systems, excluding those involving perennials such as cocoa, coffee, oil palm, and rubber, or semi-perennials such as bananas, plantains, and pineapples, were described per village. Approximately 20% were continuous cultivation, 75% short, and only 5% long fallow systems. Intra-village variations were due to differences among sites, within the village, in incidences of plant pests and diseases, soil fertility, and in crops grown, among others.

The incidences of CMB, ACMD, and CBB were highest and the incidence of CGM was lowest under short fallow systems (table 11). The symptom severity scores for CMB ranged from 1.67 to 1.90 and did not differ statistically between the various fallow systems. The severity of CGM was higher in short fallow than in the other fallow systems. The difference in symptom severity score was not, however, significant between short and long fallow systems. ACMD and CBB decreased significantly from long through short fallow to continuous cultivation systems.

The reasons for these correlations are not clear. One possibility is that farmers may be able to cultivate continuously where pest and disease pressures are low, but need to alternate cropping and fallow periods to break the pest/disease cycles where the pressures are high.

The proportions of cassava fields under the different systems were similar to the overall average proportions (table 12). In contrast, yam was seldom grown under continuous cultivation and it was grown more than any other crop under short and long fallow systems. Maize, rice, and sweet potato were commonly grown under continuous cultivation and maize and sweet potato did not appear to be adaptable to long fallow systems. The proportions of fields of beans/peas were more evenly distributed under different fallow systems than cassava fields, but the beans/peas comprised a wide range of different legume crops. Hence, as a single crop, cassava seems to be the most adaptable to different fallow management practices.

Although cassava is well adapted to growing under continuous cultivation, it was not as frequently grown under that system as other major staples except yam. This is probably due to the long growth cycle of cassava relative to other crops. Several authors (Martin 1956, Lagemann 1977, and Fresco 1986) argue that as fallow periods decline, cassava, which has a high carbohydrate yield per unit of input, will be increasingly replacing crops which demand high soil fertility and production labor. However, farmers do not seem to be able to respond to declining soil fertility resulting from shortening fallow periods by substituting cassava for other crops. Its

long growth cycle relative to other arable crops puts cassava at a comparative disadvantage under conditions of declining fallow periods. Although cassava can be harvested as from six months from planting, most available varieties do not attain maximum yield before 22–24 months (Nweke et al. 1994). Under continuous cultivation where the fallow period is under one year, such varieties can only be grown at a disadvantage because they will have to be harvested before they attain maximum yield.

Table 11. Incidences and symptom severity scores (1–4) of four major cassava plant pest/diseases by fallow systems in 10 countries assessed

Pest/disease fallow system	No. of landraces assessed	% landraces affected	Mean severity score	Probability levels of significance of difference		
				C. and R.	C and S.	R and S.
CMB						
Continuous cultivation(C)	148	8	1.67	*	*	0
Short fallow(R)	70	10	1.90	*	*	*
Long fallow (S)	14	8	1.85	*	*	*
CGM						
Continuous (C)	554	29	1.62	***	*	*
Short fallow (R)	173	24	1.94	***	*	*
Long fallow (S)	45	27	1.82	*	*	*
ACMD						
Continuous (C)	474	25	1.86	**	***	*
Short fallow (R)	294	41	2.02	**	*	***
Long fallow(S)	54	(32)	2.41	*	***	***
CBB						
Continuous cultivation (C)	145	(8)	1.45	*	***	*
Short fallow (R)	174	(24)	1.48	*	*	***
Long fallow(S)	21	(13)	2.00	*	***	***

Notes:

*** $P \leq 0.01$, ** $0.05 \geq P > 0.01$, * $0.10 \geq P > 0.05$

Table 12. Percentage distribution of village fallow systems by major crops*

Crops	No. of systems	Percentage			
		Long fallow	Short Fallow	Continuous cultivation	Total
Cassava	218	4	79	17	100
Yam	65	14	82	4	100
Sweet potato	16	0	62	38	10
Maize	59	0	78	22	100
Rice	58	2	69	29	100
Beans/peas	33	10	66	24	100
All six crops	449	5	75	20	100

Note:

*based on Côte d'Ivoire, Ghana, Nigeria, Tanzania, Uganda, and Zaire

Inter-village variations in the fallow systems were due to demographic and market pressures, among other factors. The proportions of the fallow systems were less than 5% long fallow, about

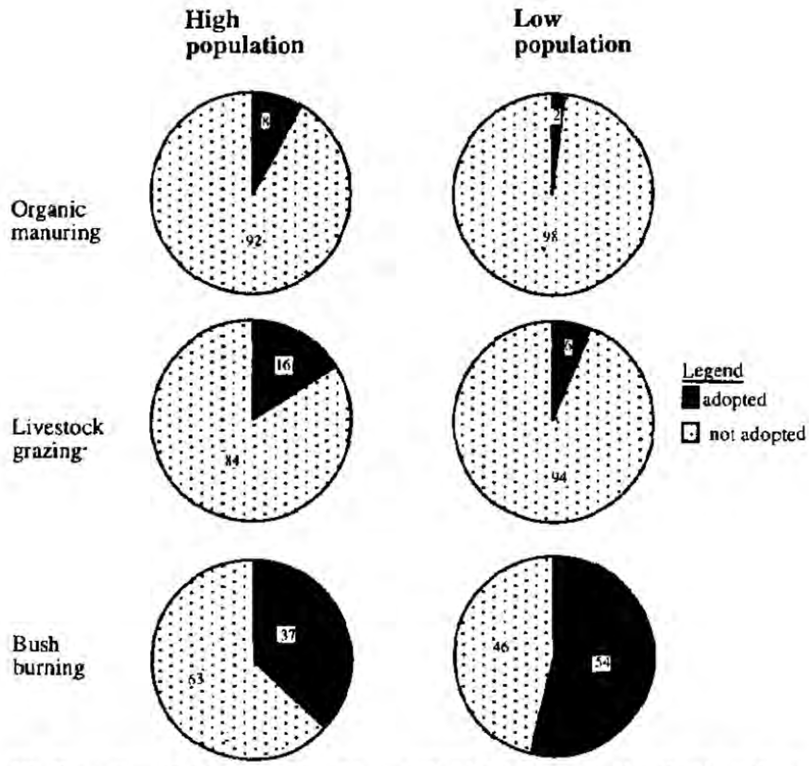

Fig. 10. Percentage distribution of arable crop fields by adoption of cultural practices by demographic pressure zone.

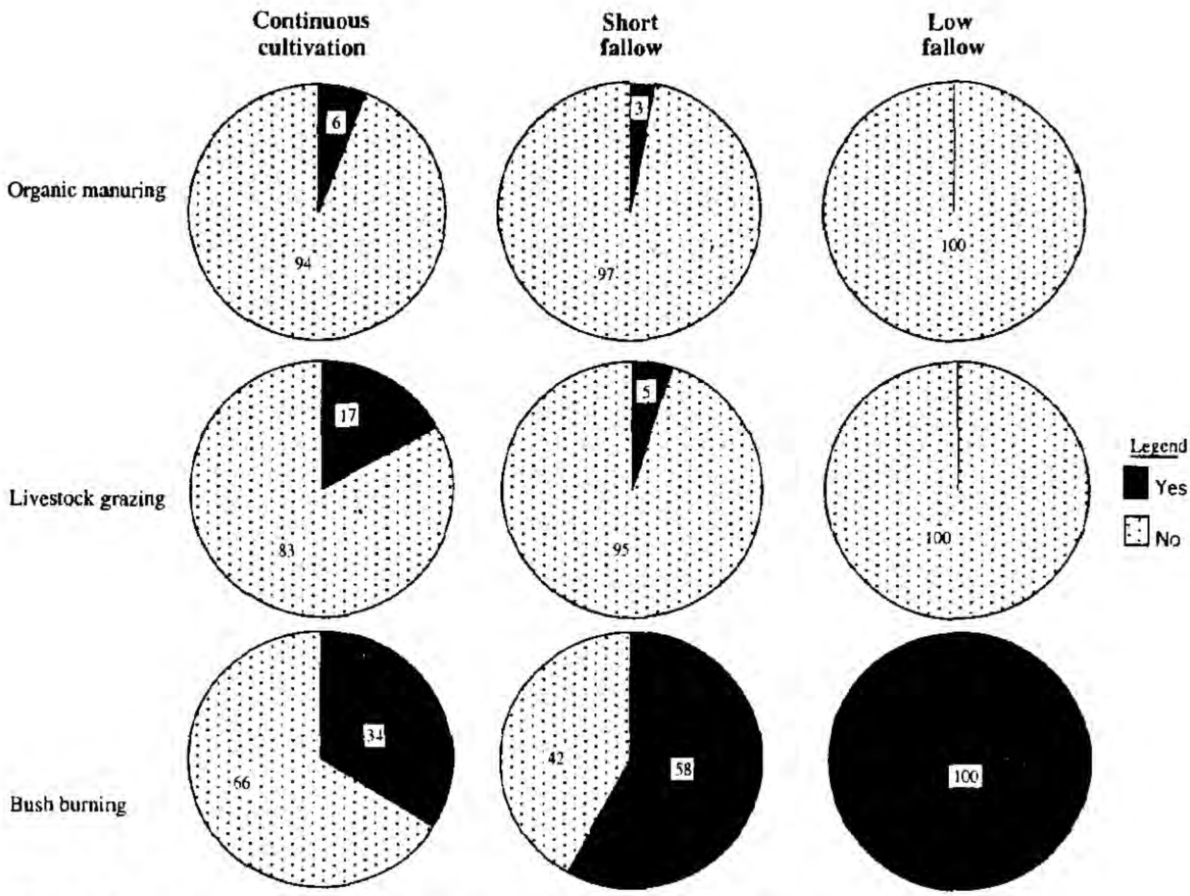

Fig. 11. Percentage distribution of arable crop fields by adoption of cultural practices by fallow systems.

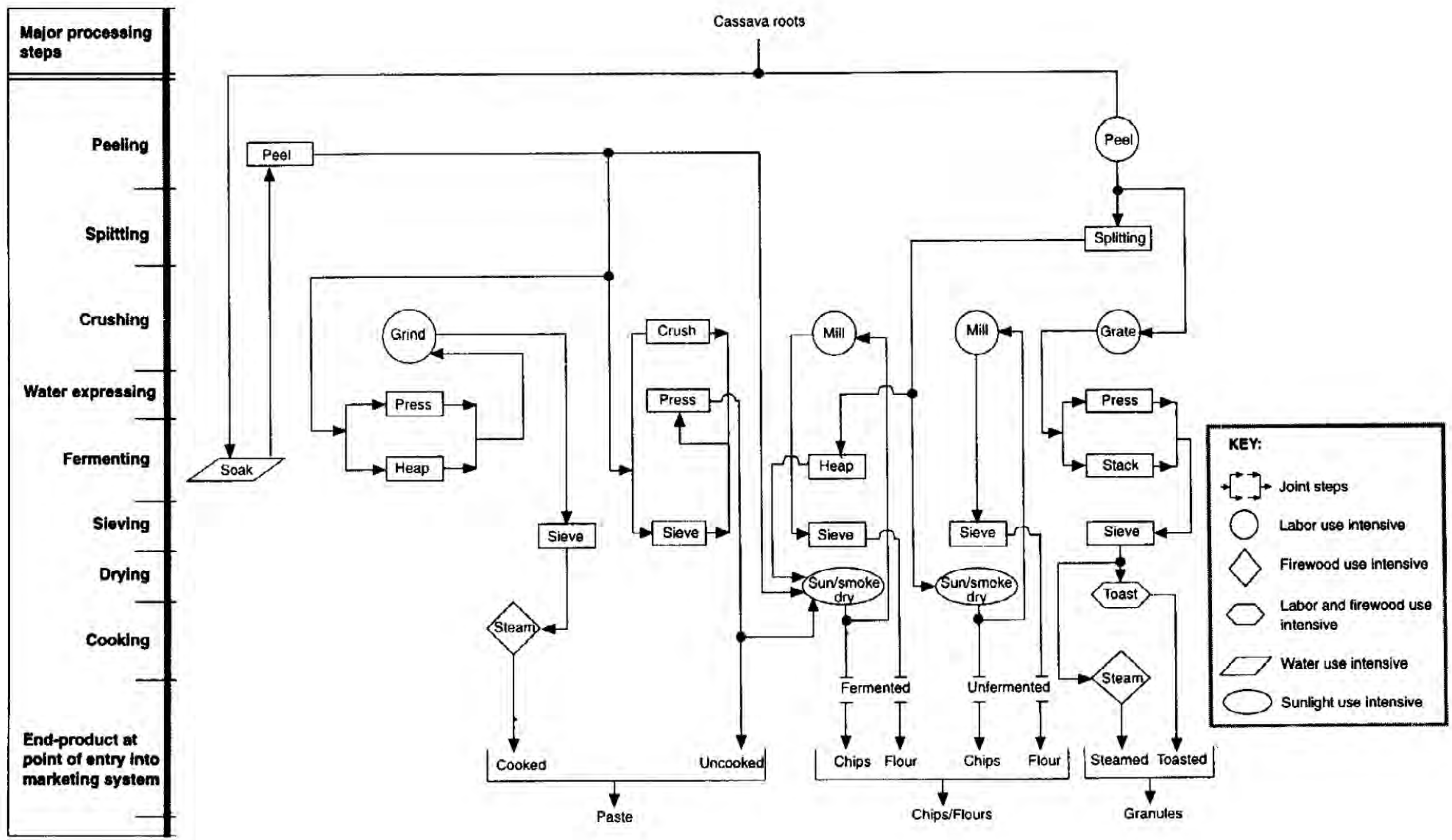

Fig. 12. Processing steps for various products from cassava roots.

70% short fallow, and above 25% continuous cultivation among high demographic pressure villages compared with above 5% long fallow, about 80% short fallow, and just above 10% continuous cultivation among low demographic pressure villages. The trend from low to high market pressure zones is similar.

The farmers ability to respond to declining fallow periods due to demographic, market, pests/disease, and other pressures by replacing more susceptible crops with cassava is constrained by the long duration of the cassava crop. The farmers however respond to declining soil fertility by adopting intensified land use cultural practices such as organic manuring and livestock grazing. Both practices were more frequent in high than in low population density areas (fig. 10) and as fallow period declined (fig. 11).

Traditional processing technology. Traditionally, cassava roots are processed into many different products by a variety of methods (fig. 12), depending on locally available processing resources, local customs, and preferences. The processing of cassava roots serves to improve the

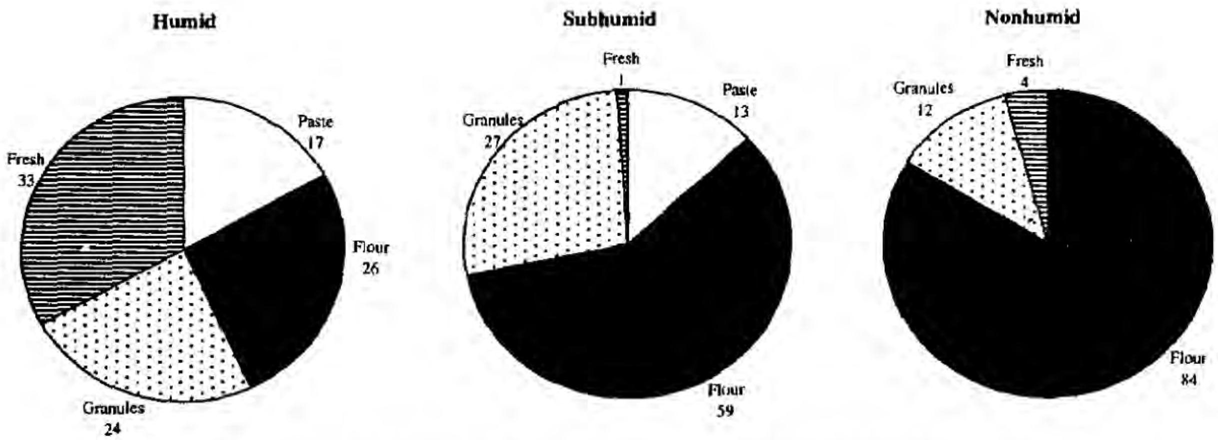

Fig. 13. Percentage distribution of villages by major cassava products used by climate zone

quality of the product which in turn leads to an expanded market by attracting higher income urban consumers. While the market for certain cassava products is largely limited to low income groups, other forms of cassava have a significant market among medium to high income groups. The extent to which the potential market for cassava may be expanded would therefore depend largely on the degree to which the quality of the various processed products can be improved to make them attractive to consumers in the higher income brackets, without significant increases in processing costs, which are already high.

Available processing resources or market demand for cassava products determines, to a large extent, the type of cassava product processed in a village. Traditional cassava processing techniques are flexible in terms of resource requirements. While the procedures for making cassava pastes are mostly water-use intensive, the techniques used for making cassava granules are mainly fuelwood-use intensive. Distribution of the main cassava products processed has definite climatic trends; processors in each climatic zone concentrate on making products which reflect the resource endowments of that zone. The relative frequency of pastes as a principal cassava product made with water-use intensive techniques declines from the humid zone to the nonhumid zone, where rainfall is limited. On the other hand, the relative frequency of chips/flour,

which requires ample sunshine for drying, decreases from the nonhumid zone, where sunshine is most abundant, to the humid zone where sunshine is the most limiting factor (fig. 13). High labor requirement is a constraint which no traditional processing technique has been able to circumvent.

Nevertheless, the main cassava processed products can be classified into two groups. In one group are those products which depend on the ready availability of resources, and in the other are those which are processed even if the resources have to be purchased. The first group includes chips/flour which is processed where sunlight is abundant, and wet paste which is the main processed product if water supply is readily available. The second group includes steamed pastes, and steamed and toasted granules, which are the main products, even if the necessary processing resources have to be purchased. Products in the second group are made using relatively advanced techniques and they enter the market system in ready-to-serve form, or require minimal preparation. These products are especially attractive to urban households because of their convenience. On the other hand, the products in the first group require additional processing in the home, such as cooking and pounding, as in the case of wet paste, or milling/pounding as in the case of chips.

The attractiveness of chips/flour and wet paste depends on the quality of water used in soaking and the conditions of the drying environment. Toasted and steamed granules do not pass through soaking or drying stages and therefore, are not exposed to the vagaries of the environment, as are products in the first group. Steamed paste also passes through the soaking stage, but by the time it reaches the consumer it is neatly wrapped up. Consequently, the products in the second group are usually more attractive to urban consumers, and are more competitive with food grains in the market place, than chips/flour and wet paste. Products in the first group are made more by the household for home consumption, and those in the second group are more frequently made for sale. However, wet paste in southern Nigeria and chips in Zaire are assuming an increasing commercial importance.

Water and fuelwood scarcity are not constraints to the quantity of cassava processed; the amount processed is determined by market demand, type of cassava cultivated, bitter or sweet, and by the availability of labor. Access to water and fuelwood can influence the type of product into which cassava is converted. However, this constraint is generally limited to chips/flour and wet paste which are mainly processed for home consumption. Market demand determines whether or not cassava is transformed into steamed or toasted granules, which is produced more for sale than for home use.

Cost-saving advantages of yield increasing technology may not fully translate into expanded production if there is no matching cost-saving technology at the processing stage. This is because cost, especially labor constraint, is merely shifted to the processing stage. Improvement in the processing technology would have as much effect on cassava production expansion as improvement in yield.

Inadequate market access infrastructure. Farmers' access to market is defined to include ease of access to market, availability of cassava marketing middlemen, and credit which would link the farmers to sources of demand for farm products and supply of farm inputs.

The market access information as based on road maps was collected at different times and varies widely in veracity. It was therefore considered essential to collect information during the survey that would permit a more objective definition of market access infrastructure. Accordingly, the farmers interviewed in Phase I were asked to indicate the main market used to sell their cassava products, the proximity of the market in kilometers, and the means of access. This was

by motor vehicle, foot, or other means, including use of bicycles, animals, or boats. Proximity to market is grouped into categories above or below 10 km, based on a subjective estimate of the distance a farmer can walk in a day with a head load of cassava products. Farmers in more than 50% of the villages attended markets on foot over distances of up to 10 km. Since the 10 km cut-off point is more or less arbitrary, it is uncertain how many of these villages have good or poor market access infrastructure. About 10% of the villages fall into the "others" category and it is not easy to determine whether or not this group of villages has good or poor market access infrastructure. Respondents in only 25% of the villages stated that they went to markets by motor vehicle, indicating good access. In 15% of the villages access to markets was by foot over distances exceeding 10 km, indicating poor access.

Ease of farmers' access to market places is not a sufficient index of the farmers' market accessibility. There are situations where the farmers and the consumers or the middlemen have different market access conditions to the same markets. Where marketing middlemen (traders and processors) are available, they sometimes take the market to the farm gate. Availability of middlemen would facilitate the marketing process for the farmers, especially to distant markets. Thus, farmers would be able to spend more time on production activities and less on marketing. About 35% of the representative villages sold cassava to traders, 20% to processors, and 45% sold directly to consumers as their most frequent buyers. Berry (1993) observes that people who plant cassava as a commercial investment often sell the crop in the ground to buyers who assume the risks and cost of managing the farm until harvesttime, as well as of harvesting and marketing of the tubers. The middlemen were most commonly available in West Africa and least in East Africa.

Among traditional credit institutions: moneylenders, cooperative societies, and traders who provide production credit to farmers, the cooperative societies were the most widespread, being available in 70% of the villages surveyed. They were widespread in all countries surveyed except in Zaire. Cooperative societies were more common in areas where farmers had than in areas where they did not have easy access to market places. Access to production credit from traders was available in only 20% of the villages. It was most common in Nigeria and was not observed in Uganda. Access to moneylenders was the least common; it was available in only 15% of the representative villages. It was most common in Nigeria and Ghana and least in Tanzania and Uganda.

III. Prospects for Cassava Land Area expansion

Trends in cassava land area are discussed in relative terms, the concept is based on qualitative information derived from farmer group responses to the questions: what have been the trends (increasing, no change, or decreasing) in cassava production in the last 20 years? Why? What is being replaced by cassava or what is replacing cassava? The last question assumes that the increase in cassava production, if any, is due to increasing land area under cassava.

Cassava land area can be expanded through land-use extensification, when land that was not previously included in the rotation is brought into cultivation (Fresco 1993). Cassava production can also be expanded through land-use intensification, if fields already in the rotation are cultivated more frequently by either an increase in the number of consecutive cropping years, by shortening of fallow, or by including cassava into intercrops previously not so intercropped. Furthermore, cassava land area can be expanded by reallocating to cassava land under ecologically alternative crops while maintaining total land area under cultivation, number of consecutive cropping years, as well as present fallow periods.

Direction of trends in cassava land area

Cassava land area was reported, by the farmer groups, to have increased, in the 20 years prior to the COSCA survey, in about 65% of the representative villages. Famine and hunger, market demand, and population growth were most frequently cited as reasons for the increasing trend (fig. 14). The percentage distribution of what cassava was replacing is presented in figure 15. About 30% of the representative villages reported that cassava land area had declined; the most common reasons cited were plant pests/disease problems (fig. 16). Cassava had been replaced by pasture, maize, millet, and sorghum (fig. 17). A time series analysis shows that, on average annual basis, cassava land area was 36% higher in 1984–86 than in 1961–65 in Africa (de Bruijn and Fresco 1989).

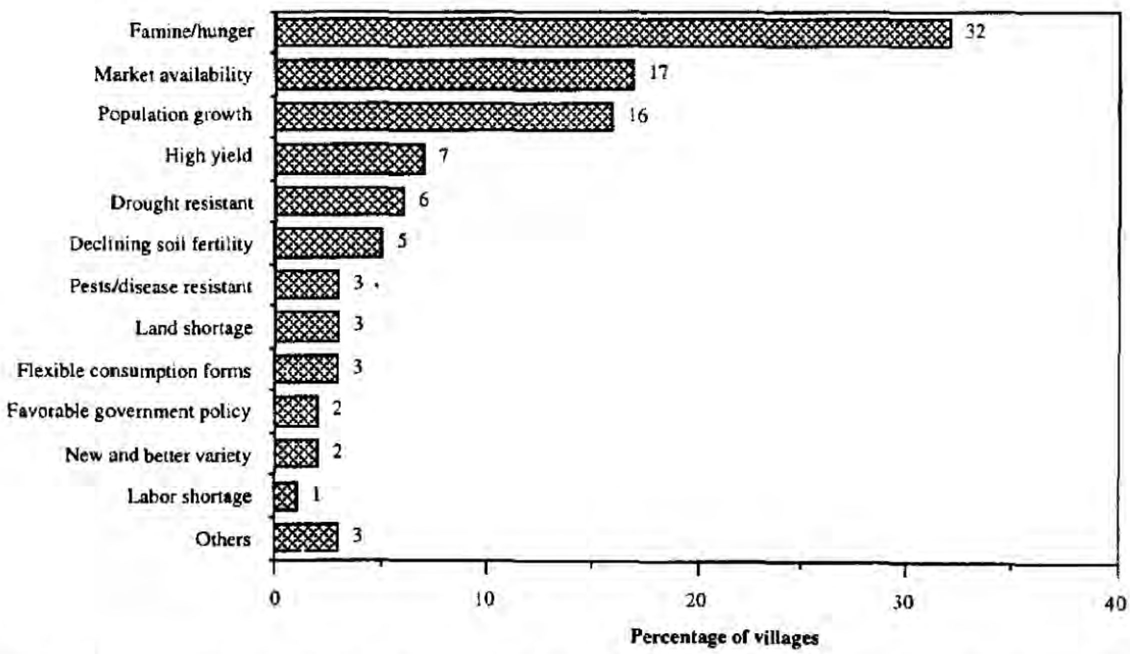

Fig. 14. Percentage distribution of representative villages which reported increasing trend in cassava land area by reason for the increase.

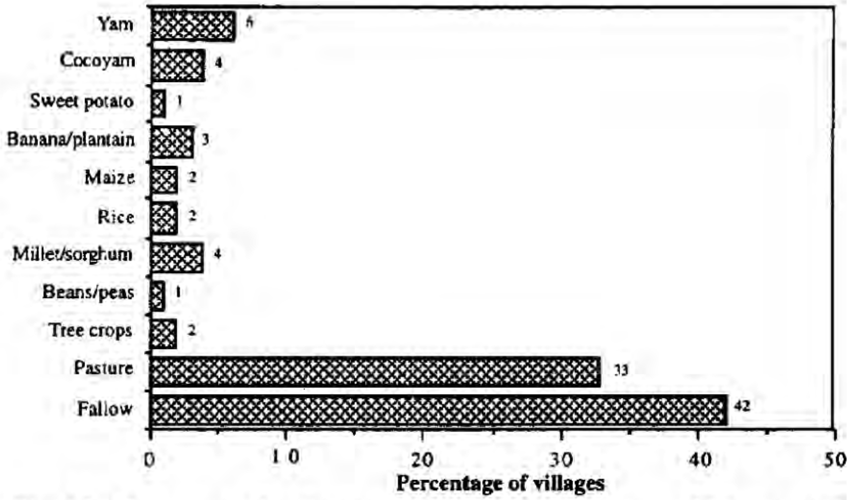

Fig. 15. Percentage distribution of representative villages which reported increasing trend in cassava land area by what cassava was replacing.

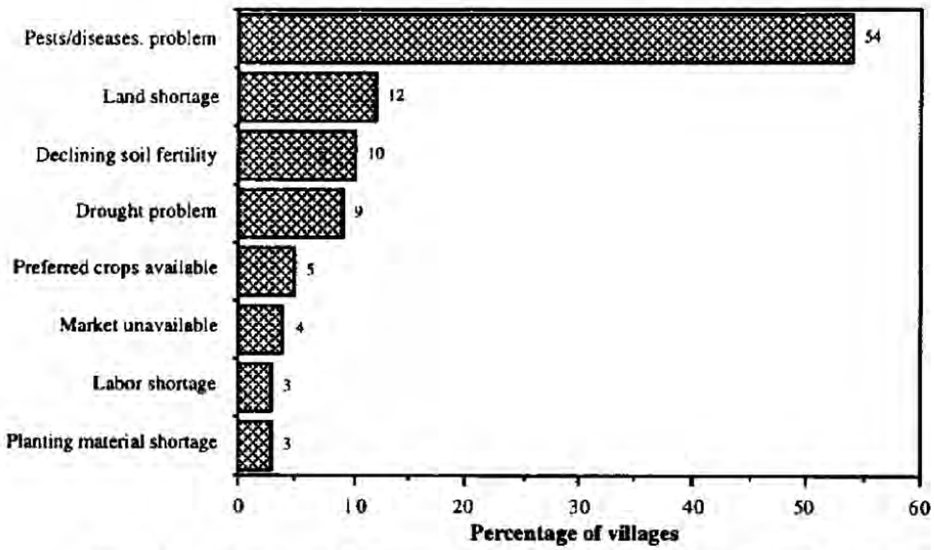

Fig. 16. Percentage distribution of representative villages which reported decreasing trend in cassava land area by reasons for the decrease.

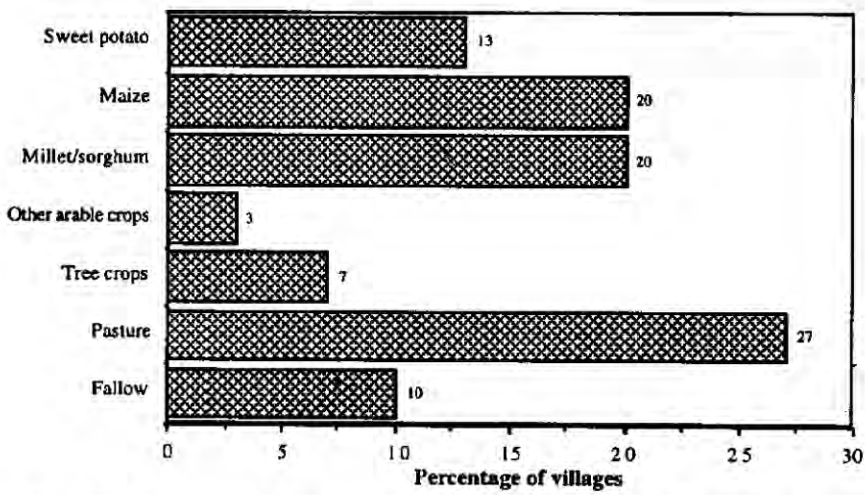

Fig. 17. Percentage distribution of representative villages which reported decreasing trend in cassava land area by what was replacing cassava.

Determinants of cassava land area expansion

Attempt is made here to verify the reasons cited by the farmers as factors driving the trend in the cassava land area.

Analytical model

As the dependent variable is a qualitative information, increasing or not increasing, the Probit (the standard cumulative distribution function) and the Logit (the logistic distribution) models (Polson and Spencer 1991) are suitable frameworks for the analysis. Following Polson and Spencer (1991) and Adesina and Zinnah (1993) the Probit model is:

$$T_i = F(W_i) = \int_{-\infty}^{w_i} \frac{1}{\sqrt{2\pi}} \exp\left(-S^2/2\right) ds \qquad \text{..... Eqn. III-1}$$

$$\text{For } -\infty < w_i < \infty; \quad w_i = X'_i \beta$$

where T_i is the probability that cassava land area was increasing in the *ith* village, zero otherwise, X is the n × k matrix of the explanatory variables, and ß is the k × 1 vector of parameters to be estimated.

The logistic distribution function is closely associated with the standard normal cumulative function of the Probit model. For eqn. III-1, the change in the probability that cassava land area was increasing in a village given change in any one of the explanatory variables, can be computed as:

$$\frac{\partial T_i}{\partial x_i} = \left(\frac{\partial F}{\partial w_i}\right)\left(\frac{\partial w_i}{\partial x_i}\right) = F(w_i)\ \beta \qquad \text{......Eqn. III–2}$$

where $F(w_i)$ is the standard normal density (logistic density) function for the Probit (Logit) model.

Polson and Spencer (1991) concluded that either the Probit or the Logit model was valid because neither dominated the other on purely statistical grounds.

Empirical model

Explanatory variables are climate and altitude which have been shown to influence cassava production (Nweke 1995) and incidence of cassava plant pest/disease, village famine experience, and population and market pressures which were cited by the farmers as reasons for the trends in cassava land area. Other farm activities such as crops grown and livestock kept in the village are specified since cassava was reported to have replaced or to have been replaced by other crops or pasture.

Indices of demographic pressure are village population density and fallow systems. Indices of market pressure are ease of access to market centers, cassava marketing middlemen, and improved processing technologies which link the farmer to sources of market demand for cassava products and sources of supply of production inputs. The relative importance of cassava to the farmers in the food crop system can help explain why cassava is replacing or is being replaced by other staple crops. The variables are defined in table 13.

Seven variations of the model are estimated: variations of the climatic zone and the cassava plant pests/disease with variations of the three market access indices; all the other variables are included in each variation (table 14), the seventh variation is a combination of all the variables.

Table 13. Definition of variables specified in the cassava land area trend regression function

Variables	Type	Explanation
Dependent variable		
CASTREND	Binary	1, if cassava land area was increasing; else, 0
Explanatory variables		
LLHUMID	Binary	1, if climatic zone was lowland humid; else, 0
HLHUMID	Binary	1, if climatic zone was highland humid; else, 0
SUBHUMID	Binary	1, if climatic zone was subhumid; else, 0
NONHUMID	Binary	1, if climatic zone was nonhumid; else, 0
CMB	Binary	1, if cassava mealybug was observed; else, 0
CGM	Binary	1, if cassava green mite was observed; else, 0
ACMD	Binary	1, if cassava mosaic disease was observed; else, 0
CBB	Binary	1, if cassava bacteria blight was observed; else, 0
FAMINE	Binary	1, if famine was experienced in the village; else, 0
MAINCROP	Binary	1, if cassava was the primary crop in the village; else, 0
COCOA	Binary	1, if cocoa was grown in the village; else, 0
COFFEE	Binary	1, if coffee was grown in the village; else, 0
OILPALM	Binary	1, if oil palm was grown in the village; else, 0
CATTLE	Binary	1, if cattle was kept in the village; else, 0
GOAT	Binary	1, if sheep/goat was kept in the village; else, 0
MKTACC	Binary	1, if means to market was motor vehicle; else, 0
MKTCHANN	Binary	1, if cassava was sold through middlemen; else, 0
POPDENS	Binary	1, if population density was high; else, 0
CONTCULT	Binary	1, if fallow system was continuous cultivation; else, 0
SHORTFAL	Binary	1, if fallow system was short fallow; else, 0
LONGFAL	Binary	1, if fallow system was long fallow; else, 0
GMACHINE	Binary	1, if cassava grating machine was available; else, 0

Empirical results

The specified variables explained about 15% of the variations in the probability that cassava land area was expanding in a village. This is true across all six variations of the regression function (table 14). The estimates suggest that the probability of an increasing trend was highest in the lowland humid zone; but the differences were not statistically significant. The probability of an increasing trend was inversely related to the incidences of CMB and CGM; the relationship was significant for CMB but not for CGM. The probability was directly related to the incidences of ACMD and CBB; the relationship was highly significant for CBB but not significant for ACMD.

There was an inverse relationship between famine occurrence and the probability. The relationship was significant at high probability levels in most of the specifications. The probability seemed higher where cassava was the main crop in the cropping system than where another crop was the main crop, but the difference was not significant.

The estimates suggest that the probability was higher where a tree crop was grown than where no tree crop was grown. The difference was, however, significant only in case of oil palm. The probability was higher where sheep/goats were kept than where they were not kept; it was lower where cattle was kept than where not kept, the differences were significant in both cases.

Table 14. Parameter estimates (based on Probit model) of the determinants of probability of expansion in cassava land area

Explanatory variables	Population Density			Fallow System			δ dep./1/ δ exp. var.
	Access means to market	Marketing channel	Processing technology	Access means to market	Marketing channel	Processing technology	
INTERCEPT	0.0735	0.0069	0.1036	-0.0417	-0.1454	-0.0440	-
	(0.188)	(0.020)	(-0.305)	(-0.105)	(-0.416)	(-0.127)	
HLHUMID	-0.1463	-0.1108	-0.0457	-0.1388	-0.0876	-0.0170	-0.044
	(-0.498)	(-0.406)	(-0.168)	(-0.489)	(-0.331)	(-0.085)	(-0.438)
SUBHUMID	-0.2661	-0.0145	0.0015	-0.2867	-0.0170	-0.0103	-0.090
	(-1.66)	(-0.072)	(0.007)	(-1.258)	(-0.085)	(-0.050)	(-1.125)
NONHUMID	0.1817	0.0663	0.0569	-0.2022	0.0894	0.0782	-0.040
	(0.807)	(0.332)	(0.283)	(-0.900)	(0.448)	(0.390)	(-512)
CMB	-0.3287	-0.3846	-0.3273	-0.3353	-0.3709	-0.3112	-0.130
	(-1.614)*	(-2.136)**	(-1.814)*	(-1.641)*	(-2.050)**	(-1.718)*	(-1.840)
CGM	-0.1034	-0.1492	-0.1810	-0.0736	-0.1013	-0.1260	-0.005
	(-0.598)	(-0.951)	(-1.150)	(-0.420)	(-0.635)	(-0.785)	(-0.086)
ACMV	0.1419	0.2265	0.223	0.1795	0.2302	0.2271	0.045
	(0.781)	(1.364)	(1.343)	(1.005)	(1.394)	(1.381)	(0.728)
CBB	0.6966	0.5888	0.5504	0.6431	0.5107	0.4563	0.193
	(3.616)***	(3.364)***	(3.110)***	(3.238)***	(2.828)***	(2.481)***	(2.754)***
FAMINE	-0.1372	-0.3636	-0.3205	-0.1606	-0.3816	-0.3395	-0.050
	(-0.803)	(-2.358)**	(-2.062)**	(-0.948)	(-2.486)**	(-2.203)**	(-0.850)
MAINCROP	0.0277	0.1294	0.1245	-0.0022	0.0819	0.0764	0.002
	(0.153)	(0.805)	(0.770)	(-0.012)	(0.506)	(0.468)	(0.032)
COCOA	0.3116	0.3617	0.4862	0.3234	0.3755	0.5015	0.092
	(0.936)	(1.167)	(1.520)	(0.970)	(1.207)	(1.506)	(0.783)
COFFEE	0.0252	0.0877	0.0196	0.0658	0.2026	0.1395	0.046
	(0.085)	(0.328)	(0.073)	(0.217)	(0.750)	(0.501)	(0.439)
OILPALM	0.6557	0.5892	0.4533	0.6546	0.5653	0.4275	0.513
	(2.376)**	(2.329)**	(1.722)*	(2.314)**	(2.238)**	(1.622)*	(1.532)
CATTLE	-0.2960	-0.2918	-0.2943	-0.2869	-0.2843	-0.2865	-0.076
	(-1.828)*	(-1.954)**	(-1.966)**	(-1.766)*	(1.899)*	(-1.911)**	(-1.358)
GOAT	0.5007	0.4093	0.3735	0.5092	0.4111	0.3707	0.167
	(1.944)**	(1.838)*	(1.678)*	(1.966)**	(1.834)*	(1.656)*	(1.891)*
POPDENS	-0.1203	-0.0730	-0.0872	-	-	-	-0.055
	(-0.747)	(-0.501)	(-0.596)				(-0.965)
SHORTFAL	-	-	-	0.1010	0.2527	0.2825	0.032
				(0.507)	(1.383)	(1.517)	(0.470)
LONGFAL	-	-	-	0.1790	0.2544	0.2104	0.072
				(0.796)	(1.256)	(1.048)	(0.918)
MKTACC	0.3530	-	-	0.3582	-	-	0.096
	(1.691)*			(1.703)			(1.312)
MKTCHANN	-	0.4018	-	-	0.4185	-	0.147
		(2.454)***			(2.554)***		(2.407)**
GMACHINE	-	-	1.0357	-	-	1.0440	0.317
			(2.163)**			(2.141)**	(1.887)*
Statistics:							
No. of obs.	368	439	439	369	440	440	368
Chi sq.	71.04	88.59	88.77	70.86	91.28	90.93	82.09
P> Chi sq.	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Pseudo Rsq.	0.1506	0.1538	0.1541	0.1500	0.1582	0.1576	0.1740
Log likelihood	-200.3028	-243.6658	-243.5764	-200.8036	-242.7726	-242.9471	-194.7788
Obs. P	-	-	-	-	-	-	0.6603
Pred. P	-	-	-	-	-	-	0.7218

Notes:
*** $P \leq 0.01$, ** $0.01 < P \leq 0.05$, $0.05 < P \leq 0.10$
1/ change in independent variable with respect to change in explanatory variable

There was no significant relationship between the probability and either of the demographic pressure indicators. There were, however, significant and positive relationships between the probability and each of the market and cassava processing technology indicators.

The above relationships did not change significantly when the demographic, market, and processing technology variables were specified in one function. The estimates under this combined specification suggest that change in processing technology, incidence of some plant pests/diseases, production of certain livestock and certain tree crops, and in-market access factors will have significant effects on the probability of an increasing trend in cassava land area. These possibilities are discussed as follows:

Discussion

(a) Climate and cassava plant pests/disease

Land area under cassava was expanding in all the climatic zones but was fastest in the lowland humid zone (table 15).

The incidences of CMB and CGM discouraged cassava land area expansion in some places. Although IITA and other agencies had carried out a biological control of CMB, by the time of the survey, the control measures had not taken full effect in some parts of sub-Saharan Africa. Hence, some farmer groups interviewed cited the cassava plant pest problem as a reason for declining trend in cassava land area in their respective villages.

Table 15. Percentage distribution of representative villages by trends in cassava land area expansion by climatic zones, and by incidence of cassava plant pests/disease

Climatic zone and cassava plant pests/disease		No. of villages	Percentage		
			Increasing	Not increasing	Total
Climatic zone:					
	highland humid	38	53	47	100
	lowland humid	138	75	25	100
	subhumid	128	64	36	100
	nonhumid	136	54	46	100
Pests/disease:					
	CMB - observed	115	58	42	100
	not observed	355	64	36	100
	CGM - observed	255	58	42	100
	not observed	215	68	32	100
	ACMD - observed	313	69	31	100
	not observed	157	50	50	100
	CBB - observed	154	72	28	100
	not observed	316	57	43	100

Cassava land area appeared to be expanding more rapidly in areas where the problems of ACMD and CBB existed. It was not certain that these were cause and effect relationships. Those two problems were more serious within than outside the humid zones. However, in Central Africa where cassava leaf is an important food item, leaves which showed ACMD symptoms were cherished for their taste. In addition, the improved cassava varieties bred at IITA which were

already widely cultivated in Nigeria and were spreading in other countries had been shown to be highly tolerant of the four pests/diseases, but particularly of CBB and ACMD problems (Nweke 1994b).

(b) Tree crop production

Cassava land area was increasing in more villages where each of the tree crops was produced than where they were not produced (table 16). In some areas, farmers have increased the production of cassava relative to other food crops, which are more labor intensive, to release labor (especially male) for tree crop production. The growth of oil palm production in the Ngwa area of southeast Nigeria absorbed male labor, leaving food crop production increasingly to women who switched to cassava to maintain output. The growth of towns and rural incomes throughout the region however created a greater demand for staple foodstuffs. This, in turn, attracted young men into cassava processing, enabling them to capture part of the profits from the growing demand for food (Martin 1984).

Table 16. Percentage distribution of representative villages by trends in cassava land area expansion by tree crop proportion and by livestock keeping

Tree crop/livestock		No. of villages	Percentage		
			Increasing	Not increasing	Total
Tree crop:					
	Cocoa - produced	76	87	13	100
	not produced	394	58	42	100
	Coffee - produced	81	75	25	100
	not produced	389	60	40	100
	Oil palm - produced	92	90	10	100
	not produced	378	56	44	100
Livestock:					
	Cattle - kept	270	54	46	100
	not kept	200	74	26	100
	Sheep/goats - kept	407	65	35	100
	not kept	63	49	51	100

(c) Livestock production

The relative number of villages which reported an increasing trend in cassava land area was higher among those which kept sheep and goats than in villages which did not keep the small ruminants. There is complementarily between sheep and goat rearing and cassava production. In compounds where cassava processing is carried out, sheep and goats often feed on cassava processing residues. In addition, where cassava is grown in compound gardens, it is often possible to fence out sheep and goats. But the cause and effect relationship between sheep/goat keeping and the trend in cassava land area is not straightforward. Introduction of sheep/goats into a village could lead to an increase in cassava processing activities; the farmers may wish to utilize the cassava bi-products in sheep and goat feeding. Alternatively, an increase in cassava processing would mean an increase in the sheep/goat population; the increase in the cassava processing would mean an increase in the cassava processing bi-products as feed for the small ruminants.

There was a negative relationship between cattle keeping and the trend in cassava land area. Cassava is grown more frequently on distant fields, as opposed to near fields (table 6); cattle also graze more frequently in distant fields. There is, therefore, competition between cassava and pasture in the distant fields; where cattle are free grazed they often cause damage to cassava fields. Fencing to keep off cattle from cassava fields is unlikely to be a profitable investment because cassava has relatively low value per unit weight while a sturdy fence would be needed to keep off cattle. Hence cattle rearing would, under certain conditions, constitute a disincentive to cassava production.

(d) Occurrence of famine

The relative number of villages which reported expanding cassava land area was higher among the villages which did not experience than among others which experienced famine (table 17).

Table 17. Percentage distribution of representative villages by trends in cassava land area expansion by famine experience and main crop in cropping system

Famine experience/main crop	No. of villages	Percentage		
		Increasing	Not increasing	Total
Famine:				
Experienced	321	62	38	100
not experienced	142	67	33	100
Main crop in the cropping system:				
Cassava	152	68	32	100
Yam	38	95	5	100
Sweet potato	0	-	-	-
Plantain	5	100	0	100
Cooking banana	3	100	0	100
Rice	13	92	8	100
Millet/sorghum	29	57	43	100
Maize	136	46	54	100

Famine was not commonly reported in the traditional cassava areas as in grain areas (fig. 18) and therefore was not an important driving factor for the cassava land area expansion. Cassava plays a famine prevention role because it provides a stable base to the food production system (Romanoff and Lynam 1992).

(e) Demographic pressure

There is hardly any difference in the relative numbers of villages which reported expanding cassava land area between zones of high and low population densities (table 18). This can be explained by the roles of the different crops in the food system. Cassava land area was increasing virtually everywhere yam, plantain, cooking banana, and rice were traditionally the main crops, although number of villages sampled in each case was low (table 17). In contrast, where the grains, essentially maize, sorghum, and millet were traditionally the main crops, cassava land area was not increasing in as many villages as where cassava itself was traditionally the main crop. Where cassava was the traditional main crop, both market and demographic pressures are driving the cassava land area expansion (fig. 19). In the traditional grain areas, however, market was a

more important driving factor for the cassava land area expansion (fig. 20). Most of the grain areas are within the dry zone where cassava consumption may not be an important part of the food culture (Romanoff and Lyman 1992).

Table 18. Percentage distribution of representative villages by trends in cassava land area expansion by demographic pressure indicators

Demographic pressure indicators		No. of villages	Percentage		
			Increasing	Not increasing	Total
Population density:					
	high	229	62	38	100
	low	214	65	35	100
Fallow system:					
	continuous cultivation	272	58	42	100
	short fallow	129	78	32	100
	long fallow	71	51	49	100

(f) Declining fallow

The relative number of villages which reported expanding land area was highest in the short fallow zone (table 18). The short fallow zone is mostly the zone of both high demographic and market pressures. The number of villages which reported the expanding land area was higher in areas of continuous cultivation than areas of long fallow but the difference was not statistically significant. Though both the demographic and the market pressures are high and though cassava is a crop that can be frequently grown under continuous cultivation, production expansion is restricted by its long growth cycle.

(g) Access to market

Ease of access to market centers and to cassava marketing middlemen influenced the cassava land area positively to very significant degrees (table 19). This was partly due to the use of certain purchased inputs in cassava production. In a separate analysis Nweke (1995) had shown that the relative number of villages which reported increasing land area was higher in villages where rented farmland, hired labor, or mechanized field-to-home transportation was used than where not used. Availability of farmland for renting or availability of labor for hire enabled farmers who did not have adequate supply of such input from own sources to expand cassava production. Mechanized transportation saved labor which could be channelled into expanding production.

The positive correlation between the cassava land area expansion and the various market factors was also due to increased market demand for cassava associated with improved market access. A market link road expanded market demand because farmers could reach more consumers. In the Bandudu region of Zaire, where the completion of a new tarmac road to the capital city of Kinshasha facilitated the transportation of processed cassava products, the onset of several cases of *Konzo* (a paralytic disease) was linked to the consumption of "insufficiently processed cassava roots" (Tylleskar et al. 1991). The resulting expanded demand through improved market access caused the farmers who made chips/flour to reduce the soaking period from three or four days to one or two days.

Table 19. Percentage distribution of representative villages by trends in cassava land area expansion by market access indicators

Market access indicators		No. of villages	Percentage		
			Increasing	Not increasing	Total
Market access means:					
	good	77	79	21	100
	poor	308	63	37	100
Cassava marketing channel:					
	through middlemen	141	79	21	100
	direct to consumers	329	56	44	100

(h) Improved processing technology

Almost all the villages which had access to mechanized cassava grating technology or which processed cassava into *gari* reported expanding cassava land area (table 20). The use of the improved postharvest handling facilities also expanded market demand because it improved product quality. Quality processed cassava products are more convenient to urban consumers and are more competitive with food grains in the market place.

Table 20. Percentage distribution of representative villages by trends in cassava land area expansion by processing technology indicators

Cassava processing technology indicators		No. of villages	Percentage		
			Increasing	Not increasing	Total
Cassava grating machine:					
	available	43	98	2	100
	not available	420	60	40	100
Form cassava product used:					
	granules	55	93	7	100
	chips	192	63	37	100
	fresh root	57	77	23	100
	others	76	53	47	100

Easy access to market centers did not make as much impact on the cassava land area expansion as the improved postharvest handling facility which produced the greatest positive impact on the cassava land area expansion. Farmers could expand cassava land area under conditions of difficult access to market centers provided improved processing technologies were available. This was because the improved processing technologies improved product quality, reduced bulk, extended shelf life, and made it possible for quality cassava products to be transported at reduced costs over poor roads to distant urban market centers. This observation was quite significant because it implied that although the agricultural research agencies could not build market link roads, such agencies could still contribute, in a positive way, to the reduction of cost of transportation of cassava products, and hence to expansion of market for cassava by developing improved cassava processing technologies.

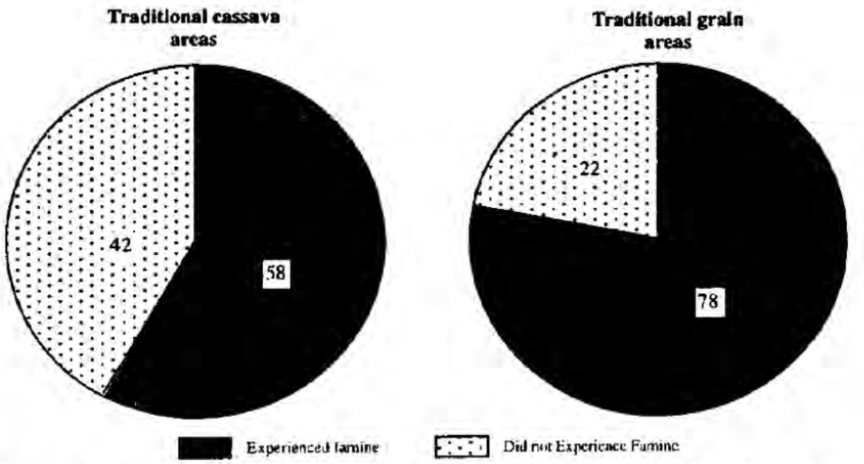

Fig. 18. Percentage distribution of representative villages by tradition cassava and traditional grain areas by famine experience.

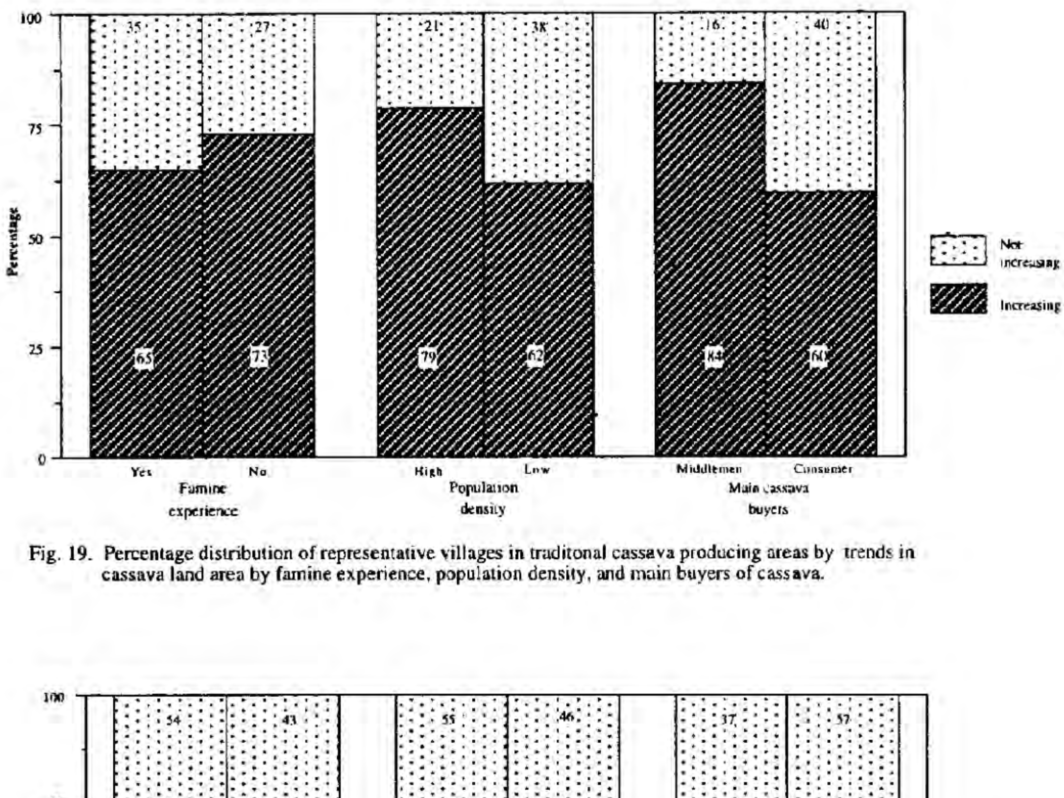

Fig. 19. Percentage distribution of representative villages in traditonal cassava producing areas by trends in cassava land area by famine experience, population density, and main buyers of cassava.

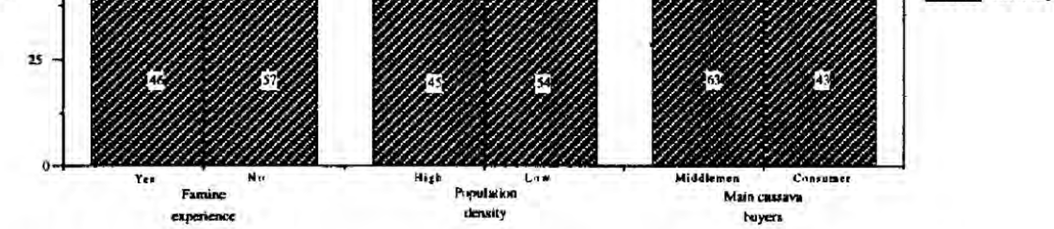

Fig. 20. Percentage distribution of representative villages in traditional grain producing areas by trends in cassava land area expansion by famine experience, population density, and main buyers of cassava .

Improved postharvest handling facilities made a greater impact on the cassava land area expansion than easy access to market places also because the improved processing technologies were labor saving. Processing of cassava into certain products was very labor intensive; Nweke (1994a) had shown that planting of high-yielding cassava varieties was not likely to lead to increased cassava production if it was not linked to an improved processing technology because labor constraint was at the processing stage. Some cassava farmers in Nigeria who were cultivating the high-yielding varieties bred at IITA sometimes cut back on new plantings because they were unable to process what they had already cultivated.

IV. Prospects for Increase in Yield[1]

Lagemann (1977) observed that cassava root yield declined as population density increased in southeast Nigeria. Nweke (1995) demonstrated that cassava root yield responded positively to application of relevant purchased inputs such as hired labor and planting materials of improved cassava varieties. The objective of this section is to assess the relationship between cassava root yield and demographic and market pressures. The assumption is that the trend in cassava root yield will be influenced by trends in demographic and market pressures.

The indicators of demographic pressure namely population density and agricultural land-use intensification, market access indicator, namely market access infrastructure and production technology have all moved, more or less, in a positive direction in the past 20 years. It is assumed that they will continue to move in the same direction over the next 20 years. Evidence that human population in sub-Saharan Africa will decline in absolute terms in the next 20 years is not available; the rate of growth may, perhaps, slow down, but even that is not certain. Trends in agricultural land-use intensification, at least in reduced fallow periods, are positively related to population trends. Although market access infrastructure has in recent years deteriorated in many parts of sub-Saharan Africa (Berry 1993), road networks, especially in West Africa, are better today than they were 20 years ago. Even in countries such as Zaire, where extensive deterioration in the road system has occurred, wide-scale distribution of cassava and other food crops has continued because of expanding urbanization (Tollens 1992). The potential for growth in yield provided by existing improved cassava varieties has not been fully exploited; the new varieties are still mainly grown by farmers in Nigeria. The farmers in most of the other sub-Saharan African countries have not adopted these improved varieties on any scale to make an impact on production growth. In addition, more varieties based on polyploids are being further developed (Hahn et al. 1990).

There are, however, negative variables which affect root yield; among these are drought and the outbreak of pests and diseases which are not easily predicted. In the past, drought occurred from time to time, but it did not necessarily lead to long-term yield decline. Pests and diseases could reduce total yield on a long-term basis, but recent positive experience with the biological control of the cassava mealybug in sub-Saharan Africa (Neuenschwander et al. 1990) show that technology has the potential to control the pests and diseases of food crops. Discouraging government policy is a predictable negative factor as it has hardly improved in any of the countries.

Level of the root yield

The overall mean of fresh root yield/ha was estimated as 11.9 tonnes (Table 21); the distribution was skewed to the lower side with a mode of 8 tonnes; the range was from less than 1 tonne to about 60 tonnes. Nweke et al. (1991) found mean root yields to be 10.7 t/ha for villages around Onitsha, 9.2 t/ha for villages in the Abakaliki area, and 36.9 t/ha for villages around Zaki-biam, all in different ecological zones of southeast Nigeria. Bangwe (1990) observed a mean yield of 10.4 t/ha for cassava harvested at 30 months or less after planting, 11.3 t/ha for others harvested at 31 to 36 months, and 16.8 t/ha for those harvested 37 months or above after planting in villages of northwest Zambia.

1 Based mainly on Enete et al. 1995 and Nweke and Spencer 1995

FAO information indicates that the average annual yield for the period 1986–1988 for the COSCA countries was 8.5 t/ha. This figure was obtained by weighting the annual average with the number of COSCA villages in each country. The unweighted mean was only 7.1 t/ha. The information for the period closer to 1991, when COSCA information was collected, was not readily available. FAO derives its yield data from land area and production reports prepared by the various countries (FAO 1989).

Table 21. Overall average root yield components for cassava in Africa

Yield component	Mean	Minimum	Maximum	Standard deviation	No. of fields
Fresh root (t/ha)	11.90	0.40	67.10	8.39	501
Plant density (std/ha)	7774	500	41250	5280	500
Number of roots per plant	6	0	36	4.33	500
Average root wt. (kg/root)	0.40	0.05	5.18	0.32	500
Harvest index	0.50	0.03	0.89	0.13	497

Berry, commenting on official government data for cassava, observed that it was difficult to document trends in output or yield. Yields of cassava are difficult to measure accurately, given the farmers' practice of harvesting little by little, and published data rarely state the method of measurement used. Given these problems, it is not surprising that previous production data are inconsistent and unreliable (Berry 1993).

Determinants of cassava root yield

Analytical procedure

The effects of market and demographic pressures, intensified agricultural land use and technology on cassava root yield, are estimated in an ordinary least square (OLS) regression framework in which the cassava root yield in kg/ha was the dependant variable. The demographic pressure and intensified land-use variables, namely village-level population density and fallow system, and cultural practice of organic manuring in the field; market pressure variable, namely village market access infrastructure condition; and technology variable, namely use of improved cassava variety at the field level were specified as independent variables. Also specified as independent variables were the agronomic practices of the cassava plant density and cassava age in months after planting which have been shown to seriously influence cassava root yield. The cassava plant density was also specified in a polynomial form because there was an optimum plant density beyond which root yield declined (Nweke et al. 1994). The unit of analysis was the individual cassava field. The variables are defined in table 22.

Six variations of the function are estimated; they are the three demographic pressure and intensified land-use variables by two market pressure and technology variables (table 23).

Empirical results

The specified independent variables explained just above 10% of the variation in the cassava root yield; to explain significantly more will require specification of environmental factors which can explain the cassava root formation biologically. The use of the improved cassava varieties was very dominant in explaining the yield; where it was specified, it reduced the level of significance of all other variables except cassava plant density. The agronomic factors were positive and significant determinants of the cassava root yield.

The quadratic form of the plant density was negatively and significantly related to the root yield. The market pressure, the demographic pressure, and the intensified land-use variables, excluding fallow system, were positively and significantly related to the cassava root yield. These correlations are explained as follows:

Table 22. Definition of variables specified in the cassava root yield regression function

Variables	Type	Level of information	Explanation
Dependent variable			
YIELDHA	Continuous	Field	cassava root yield in kg/ha
Explanatory variables			
PLDENS	Continuous	Field	cassava plant density in number of stands/ha
PLDENSQ	Continuous	Field	cassava plant density in number of stands/ha squared
AGEMAP	Continuous	Field	age of cassava field in months after planting (MAP)
POPDENS	Binary	Village	1, if population density was high; else, 0
CONTCULT	Binary	Village	1, if fallow system was continuous cultivation; else, 0
SHORTFAL	Binary	Village	1, if fallow system was short fallow; else, 0
LONGFAL	Binary	Village	1, if fallow system was long fallow; else, 0
MANURE	Binary	Field	1, if organic manure was applied; else 0
MKTACC	Binary	Village	1, if means to market was motor vehicle; else, 0
IMPROVED	Binary	Field	1, if improved cassava variety was planted; else, 0

Table 23. Parameter estimates for cassava root yield per unit of land area (kg/ha) regression function

Variables	Population density		Fallow system		Organic manuring	
	Market access	Improved variety	Market access	Improved variety	Market access	Improved variety
INTERCEPT	2980.135 (2.050)**	5505.841 (3.223)***	4858.628 (3.614)***	6751.739 (4.098)***	3947.775 (2.882)***	6140.439 (3.829)***
PLDENS	0.520 (3.037)***	0.196 (3.198)***	0.529 (3.051)***	0.6746 (3.581)***	0.608 (3.581)***	0.734 (4.031)***
PLDENSQ	-0.12E-4 (-1.891)*	-0.157E-4 (-2.218)***	-0.123E-4 (-1.910)**	-0.171E-4 (-2.482)***	-0.139E-4 (-2.182)**	-0.186 (-2.735)***
AGEMAP	288.952 (4.205)***	122.474 (1.617)*	237.992 (3.563)***	93.465 (1.335)	250.105 (3.765)***	80.231 (1.150)
POPDENS	2018.671 (2.593)***	1629.812 (1.853)*	-	-	-	-
SHORTFAL	-	-	424.046 (0.528)	-370.045 (-0.442)	-	-
LONGFAL	-	-	-1547.743 (-1.227)	-1799.988 (-1.649)*	-	-
MANURE	-	-	-	-	3301.902 (2.274)**	-763.043 (-0.334)
MKTACC	3264.135 (3.675)***	-	3440.944 (3.923)***	-	3637.465 (4.155)***	-
MPROVED	-	5837.051 (4.060)***	-	6355.412 (4.630)***	-	6592.396 (4.816)***
Statistics						
No. of obs.	437	361	451	398	451	398
F	12.25	10.48	9.44	9.36	11.98	10.66
$P > F$	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
R-sq	0.12	0.13	0.10	0.11	0.12	0.11

Note:
*** $P \leq 0.01$, ** $0.01 < P \leq 0.05$, * $< P \leq 0.10$

Discussion

(a) Cassava plant density

Cassava root yield increased with cassava plant density up to a point beyond which the yield declined with further increase in the plant density. Mean plant density was approximately 8,000 stands/ha and the range was 500 to 40,000 stands/ha. The cassava plant density was greater in areas of high than low population density, in peri-urban centers, and where market access was easy. In these areas the plant density exceeded the level necessary for maximum root yield (Nweke et al. 1994).

(b) Cassava plant age

Similarly, the cassava root yield increased with the age of the cassava plant. Jones (1959) observed that some early bulking varieties of manioc form edible roots within six to eight months after planting and may be harvested then. However, most varieties were left in the ground for a longer period during which they continue to bulk. Early harvesting was associated with high market and demographic pressures.

A percentage distribution of the area of standing mature cassava fields by age shows that from 12 months after planting, the area declined rapidly; the rate of decline was however higher in zones of good than poor market access infrastructure (fig. 21). Cassava fields located in high demographic pressure areas were also harvested significantly earlier than others in low demographic pressure areas (fig. 22). Among fields which were replanted annually, cassava land area declined to zero at 13 months after planting (fig. 23). Jones (1959) further observed that where there was competition for land or where crops were planted in the field annually, manioc was generally harvested within 12 months.

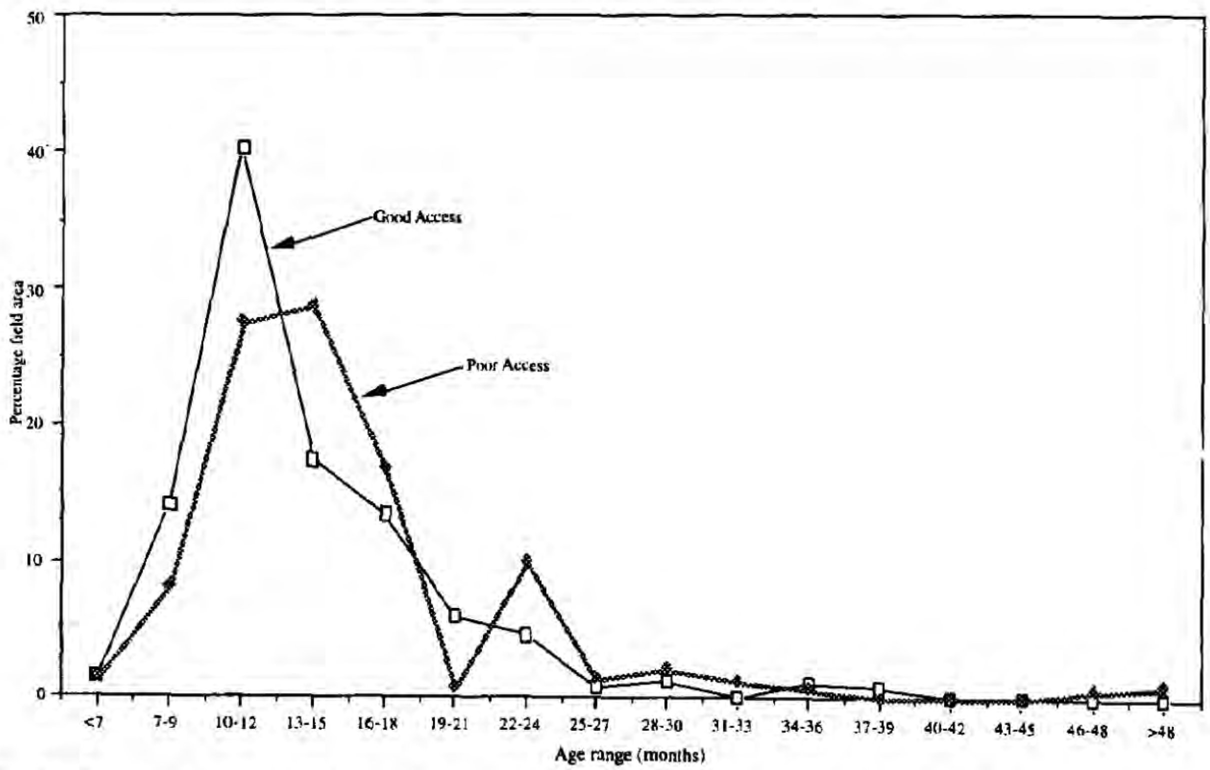

Fig. 21. Percentage distribution of mature cassava field area by age by market access infrastruture zones.

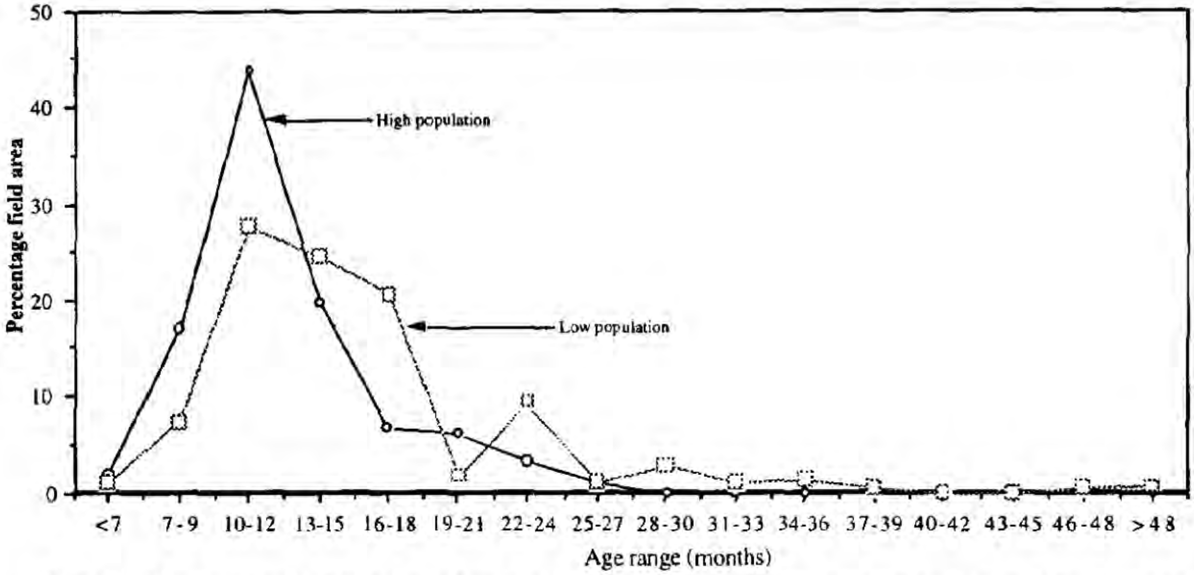

Fig. 22. Percentage distribution of mature cassava field area by age by population density zones.

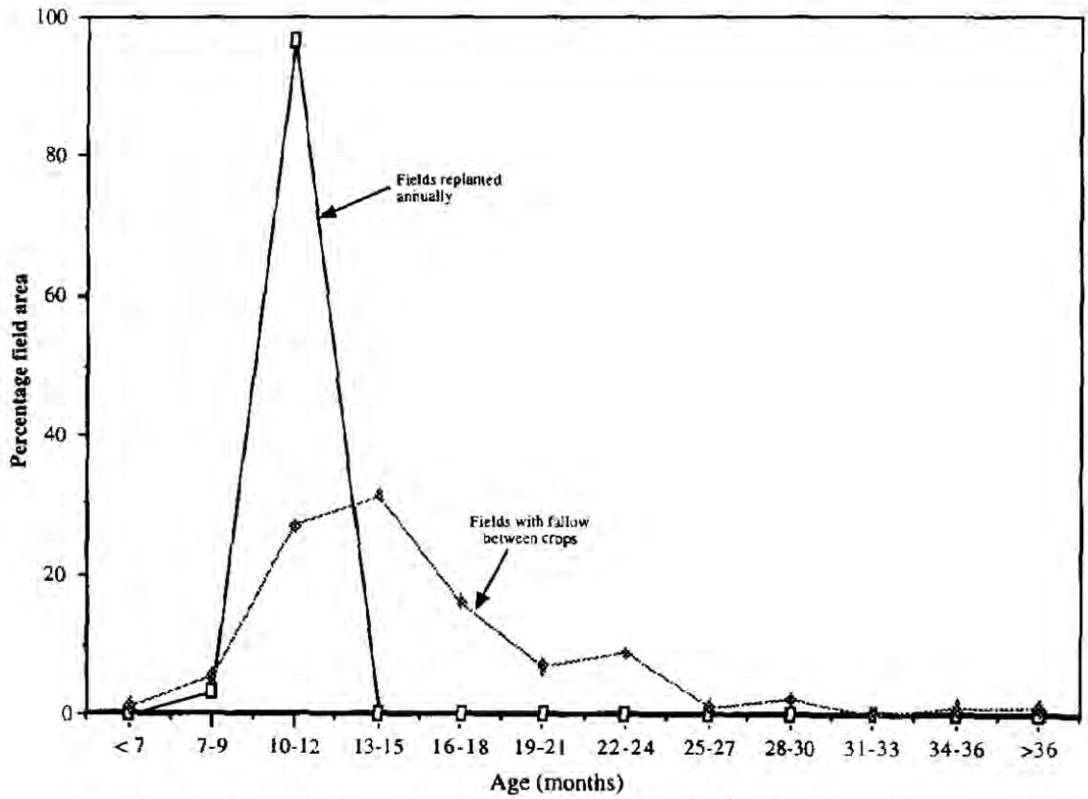

Fig. 23. Percentage distribution of mature cassava field area by age by fields replanted annually and fields with fallow between crops.

(c) Market pressure

The cassava root yield was higher in areas of good than poor market access (table 24) with a margin of nearly 40%. This could be due to use of purchased inputs, especially chemical fertilizer and hired labor. The frequencies of adoption of these purchased inputs were directly related with level of development of market access infrastructure (fig. 8). The cassava yield was significantly higher in fields in which those inputs were applied than where they were not applied.

Table 24. Cassava root yield per unit of land area (t/ha) by condition of market access and use of purchased inputs

Market access/purchased inputs	Mean	Minimum	Maximum	Standard deviation	No. of fields
Access to market					
good	15.55	1.30	67.30	10.53	110
poor	11.28	0.40	43.63	7.00	342
Purchased inputs					
chemical fertilizer – used	15.35	3.90	67.30	12.00	45
not used	11.58	0.40	43.63	7.31	493
hired labor – used	14.24	1.30	67.63	9.06	196
not used	10.55	0.40	43.63	6.74	342

The cause and effect relationship between cassava yield and the application of chemical fertilizer is however not definite. The fields in which fertilizers were applied were a subset of the fields in which hired labor was used. Cassava root yield response to chemical fertilizer use depends on the type of fertilizer and on soil nutrient status.

Some other production intensification practices associated with increased commercialization have negative effects on cassava root yield. The early harvesting of cassava in the more commercial areas, which has already been discussed, is one of such practices. Since cassava root yield is directly and statistically significantly related with the age of cassava at harvest, early harvesting means reduced yield, unless the variety cultivated is an early bulking type. Adoption of cassava plant density which is higher than necessary for maximum root yield is yet another production intensification practice which has a negative effect on cassava root yield in the more commercial areas. The negative effects of these seem to be outweighed by the positive response of cassava to the applications of various purchased inputs.

(d) Demographic pressure

The cassava root yield was higher in areas of high than areas of low demographic pressure (table 25) although by a small margin. This was due to adoption of intensified land-use cultural practices such as organic manuring and livestock grazing. The cassava yield was significantly higher in fields in which organic manure had been applied than where not applied. Frequencies of adoption of these practices, although low in general, were higher in high than in low population density areas (fig. 10).

Although the difference in the root yield between areas of high and low demographic pressure was statistically significant, the margin, about 15%, is low in comparison with the difference made by improved market access. The cultural practice with respect to land-use intensification, such as livestock grazing and the application of organic manure, are not enough to sufficiently raise the cassava root yield in high population villages because of low frequencies of the land-use intensification practices, the early harvesting of cassava, which is more frequent in high than in low population density areas, and the adoption, in some high population density areas, of cassava plant density at levels which are higher than necessary for maximum root yield.

Table 25. Cassava root yield per unit of land area (t/ha) by population density and cultural practices

Market access/cultural practices		Mean	Minimum	Maximum	Standard deviation	No. of fields
Population density						
	high	12.85	0.40	67.30	8.81	270
	low	11.01	0.78	35.00	6.68	227
Cultural practices:						
	organic manuring – practiced	13.00	0.78	43.63	10.01	37
	not practiced	11.82	0.40	67.30	7.69	501
	livestock grazing – practiced	13.16	0.40	52.20	11.68	50
	not practiced	11.76	1.13	67.30	7.36	488
	bush burning – practiced	12.08	1.23	67.30	7.70	319
	not practiced	11.63	0.40	43.63	8.10	219

(e) Declining fallow

The cassava root yield was lowest under long fallow system (table 26); the practice of organic manuring and livestock grazing were minimal under this system (fig. 11). Even though the intensified land-use cultural practices were more frequently adopted under continuous cultivation than under the short fallow system, cassava yield was significantly higher under the short fallow system. This was a consequence of early harvesting and excessively high plant density practiced more frequently under continuous cultivation. When the yield was standardized to per unit of time, there was no difference in the root yield between the two systems.

Table 26. Cassava root yield per unit of land area (t/ha) and per unit of time (t/ha/year) by fallow system zone

Fallow system		Mean	Minimum	Maximum	Standard deviation	No. of fields
Yield (t/ha)						
	continuous cultivation	11.54	0.40	36.00	7.16	246
	short fallow	13.01	0.78	67.30	8.84	218
	long fallow	9.77	1.28	30.95	6.44	74
Yield (t/ha/year)						
	continuous cultivation	10.64	0.58	36.00	7.06	246
	short fallow	10.74	0.78	53.84	7.51	218
	long fallow	7.68	1.25	30.95	6.25	74

(f) Use of improved varieties

The cassava root yield from fields planted with improved varieties, 19.2 t/ha, was higher by more than 65% than yield from fields planted with local varieties, 11.6 t/ha (table 27). The improved varieties are more tolerant than the local varieties to common diseases such as ACMD and CBB, and to pests such as CGM and CMB (Nweke 1994b). IITA obtained averages of 21.0 t/ha in 1983, 23.5 t/ha in 1984, and 16.0 t/ha in 1985 in researcher-managed on-farm trials with the improved varieties in three locations within the humid zone of Nigeria (IITA 1986). The narrow gap between experimental and farm-level yields of the improved cassava varieties arises from the

breeding philosophy behind the improved varieties. According to Chief S.K. Hahn[1] (personal communication), those varieties were bred for low-input production. This made it possible for them to attain their full yield potentials at the farm level.

Table 27. Cassava root yield (t/ha) by improved and local varieties

Statistics	Improved	Local
Mean	19.21	11.63
Minimum	4.25	1.23
Maximum	36.00	67.30
Standard deviation	8.04	7.56
No. of fields	33	366

Spread of improved cassava varieties

In the Phase I COSCA survey, the farmer groups were asked to indicate the relative number (none, few, many, or most) of farmers in the village who were cultivating improved cassava varieties. The concept of improved varieties differed from country to country. In countries where bred varieties had been released the concept was usually clear, but in others where such varieties had not been released, improved varieties had been taken to mean selections from local genotypes which had desired attributes.

Based on the rapid rural appraisal survey, the improved varieties were available in nearly 90% of the 65 villages representing the cassava growing areas in Nigeria, while many or most of the farmers grew the improved varieties in nearly 60% of the 65 villages. In the detailed field-level survey, it was observed that in the humid zone of Nigeria, about 60% of the cassava land area carried improved varieties, in the subhumid about 35%, and in the nonhumid areas sampled, 40% of cassava land area carried the improved varieties. In the 1960s, some improved cassava varieties were released by Nigerian national research systems, but mostly by IITA, Ibadan. The varieties released in the 1960s are no longer easily distinguished from a wide range of local genotypes. Improved varieties in Nigeria are defined as bred varieties which were released since the 1970s.

In Côte d'Ivoire and Ghana, the leaders of the national cassava research program did not identify bred varieties in any village in the Phase I survey. However, in the detailed survey, the cassava research leaders identified fields of "improved" varieties in some of the villages earlier visited.

Based on the Phase I survey, Tanzania cassava research leaders reported that in 50% of the representative villages "few" farmers grew improved varieties. This finding could not, however, be corroborated during the detailed field-level survey where no such improved varieties were found. Ugandan researchers, on the other hand, gathered from the Phase I survey, that improved varieties were grown in 15% of the representative villages. They however reported presence of a wide range of locally selected high-yielding landraces as improved varieties in several of the fields surveyed in the detailed field study.

The improved cassava variety is broadly defined, for the purpose of this analysis, to include the bred varieties released in Nigeria since the 1970s, and the improved varieties as reported in Côte d'Ivoire and Ghana.

1. Chief S. K. Hahn was responsible for the breeding of the improved cassava varieties released by IITA in the 1970s

Circumstances of spread of improved varieties in Nigeria

The spread of the improved varieties in Nigeria was due to a combination of factors.

(a) Superior attributes of the improved varieties

The improved varieties performed well in terms of most of the farmers' desired attributes presented in fig. 9.

High yield and early bulking. The improved varieties outyielded the locals by a wide margin (table 27). The farmers' need for early-bulking cassava varieties arises from demographic pressure and the commercialization of cassava production. Commercialization of production would affect desired age at harvest for two reasons. One is that a commercial producer is interested in rapid turnover; the shorter the bulking period, the higher the rate of turnover. The second is that middlemen, traders, or processors are particular about the quality of the product they purchase for resale or for processing. They would not buy old cassava (poor quality product); thus farmers who sell through the middlemen would be concerned with the bulking age of cassava varieties they cultivate.

The improved varieties seem to attain the peak yield at or before 15 months after planting (fig. 24). Additional yield between 12 and 24 months after planting is 2 t/ha, an increase of about 10 percent. In contrast, the yield of the local varieties increases more slowly and does not peak until at least 22–24 months after planting. The result is that the additional yield between 12 and 24 months is about 7 t/ha, an increase of more than 60%. Hence, the improved varieties bulk significantly earlier than the local varieties. Making a similar comparison, Nweke et al. (1988) showed that the older the cassava is harvested, the less the difference in yield between the improved and the local varieties. They observed that the difference in yield declined from 77% at nine months to 75%, 56%, and 32% for cassava harvested at 12, 16, and 18 months, respectively.

The above observations suggest that the main yield advantage of the improved over local varieties is in earliness of bulking, rather than the level of yield per se. Given time, the local varieties close the yield gap with the improved varieties.

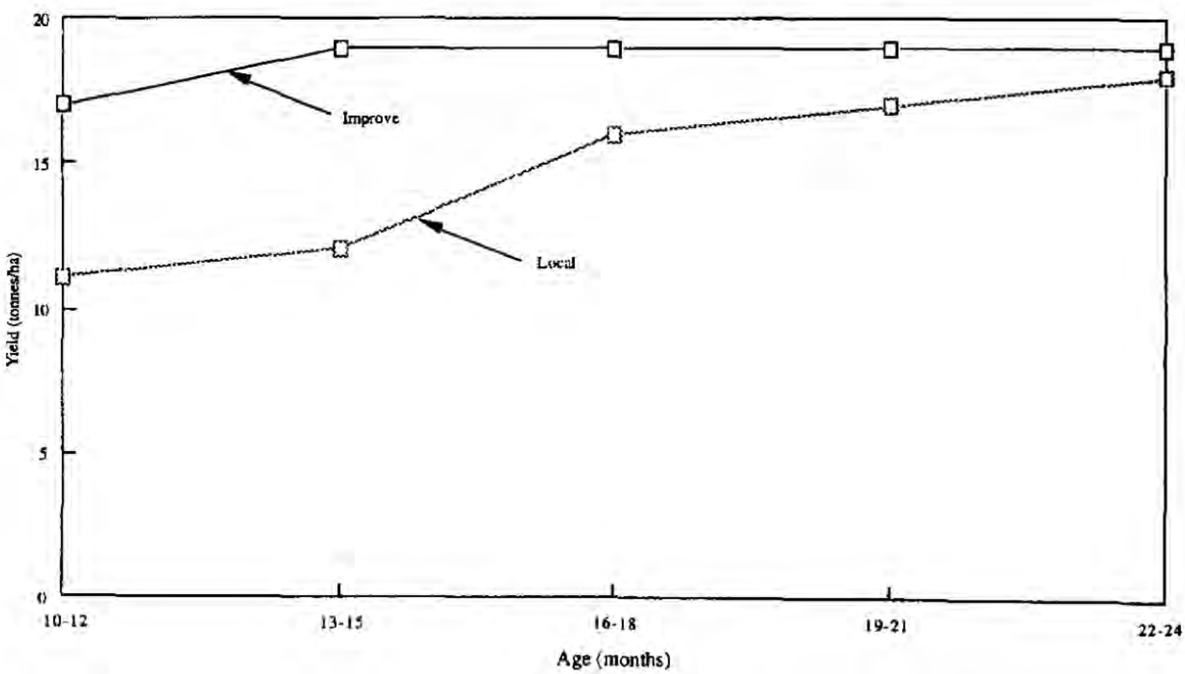

Fig. 24. Cassava root yield by age of cassava plant and by local and improved varieties in Nigeria.

Low HCN potential. The issue of level of toxicity of the breakdown products of cyanogen in cassava has been very controversial. In Nigeria, several cases of food poisoning, some of which have led to deaths, have been attributed (not based on scientific observation) to cassava consumption, linking it to HCN in the cassava. Cassava does not contain HCN at all but rather cyanogenic glucosides that, upon an enzymatic breakdown catalyzed by linamarase, release HCN (Maduagwu et al. 1981; Bokanga 1992). Hence, what is relevant is not the level of HCN but the potential to release HCN, which is a reflection of the amount of cyanogenic glucosides. The HCN or the linamarine is eliminated when cassava is properly processed (Maduagwu et al. 1981; Hahn 1982).

The fresh roots of the local varieties are higher in HCN potential (an average of 2.35 on a one-to-three scale), than the fresh roots of the improved varieties (an average of 2.20). The estimation of HCN potential of the root was, however, based on the picric acid test method (Almazan 1987). This method is semi-quantitative; it was adopted because an alternative qualitative method suitable for quick assessment in the field was not available. In spite of this methodological problem, it does not appear that the improved cassava varieties are higher in HCN potential than the local cassava varieties, on an average basis.

Farmers appear to be the best source of information regarding the relative levels of HCN potential in cassava. They distinguish between two sets of cassava varieties: (1) sweet varieties: those with roots they can eat raw without prior transformation; and (2) bitter varieties: those that if eaten raw, or even boiled or roasted without prior processing, are presumed to be harmful to humans and animals. This convention is adopted in referring to these two sets of cassava varieties in this report.

The farmers identified both the bitter and the sweet cassava among the improved as well as among the local varieties. They classified 80% of the improved varieties as bitter and 20% as sweet; they also classified about 50% of the local varieties as bitter and about 50% as sweet. Sweet cassava occupies roughly 30% and bitter cassava about 70% of improved cassava land area. The proportions are similar in the case of local varieties. In other words, farmers' judgments support the above conclusion that the improved varieties, on the average, do not appear to contain higher HCN potentials than the local varieties.

Resistance to pests/disease. The incidences of the two arthropod pests (CMB and CGM) were higher among the local landraces than among the improved varieties, whereas the incidences of the two diseases (ACMD and CBB) were somewhat less (table 28). However, the symptom severity scores for all four problems were significantly lower for the improved varieties than for the local landraces, indicating substantial differences in tolerance.

Hahn et al. (1981) stated that the development of resistant cultivars provides the most appropriate and realistic approach to control of cassava pests and diseases. They reported that ACMD-resistant breeding materials from IITA have been tested in many countries in West, Central, and East Africa, and in India and have consistently shown disease resistance. This absence of regional variation in resistance to ACMD and the polygenic nature of the resistance suggest that it is durable and widely applicable, which is consistent with the allotetraploid and genetically heterozygous nature of cassava. The CBB-resistant materials from IITA showed resistance when tested in Kenya and Zaire, suggesting that this resistance is also generally effective. Resistance of cassava to CBB is polygenic, durable, and effective in several localities. Some cultivars at IITA seem resistant to CGM and the progenies raised from several parents produced at IITA showed resistance to CGM in Tanzania (Hahn et al. 1981).

Table 28. Incidences and mean symptoms severity scores for four major cassava pests/diseases by improved and local cassava genotypes in Nigeria

Variety	N	CMB	CGM	ACMD	CBB
Incidence (% infested/infected)					
Improved	49	20	4	73	71
Local	93	50	26	62	63
Severity (1 to 4 scale) [1/]					
Improved	-	1.20	1.00	1.47	1.34
Local	-	1.96	1.54	1.86	1.90
T ratio [2/]	-	3.15 ($P = 0.003$)	3.86 ($P = 0.001$)	2.45 ($P = 0.002$)	4.20 ($P = 0.001$)

Notes:
N = Number of landraces accessed
[1/] based on number of landraces infested/infected
[2/] t-test on severity scores

(b) Conducive macroeconomic conditions

Nigeria enjoyed relative peace and political stability for more than 20 consecutive years since the Civil War (1967–1970). Yakar (1992) observed that one of the critical constraints which impinge on sustainable food production in sub-Saharan Africa is the prevalence of political conflict in the region. Although Côte d'Ivoire, Ghana, and Tanzania have all enjoyed peace and stability for relatively long periods of time, those countries have faced deteriorating terms of trade since 1975, following declining world market prices of cocoa, coffee, cotton, and sisal; their major export items. Nigeria, however, was enjoying a windfall in the form of revenue from high prices and increased sales of petroleum. So, at a time when those countries were being confronted with drastic reductions in their foreign exchange base and hence were unable to service their external debts adequately, Nigeria was able to build interstate highways and expand higher education and research institutions, etc., all of which constitute relevant infrastructure for agricultural development.

Availability of petroleum has also probably aided the widespread availability of improved cassava processing technology in Nigeria. Nweke (1994a) has shown that higher root yields did not have cost-saving advantages at the processing level because traditional techniques were on a small scale with limited capital investment; processing costs per unit weight were constant, irrespective of quantity processed. Consequently, as yield per unit area increased, processing costs as a percentage of total costs per unit area also increased because constant processing costs per unit weight were added on to declining field costs per unit area. Tshiunza et al. (1996) have shown that while cassava fresh root yield per unit area was significantly higher for the improved than for the local varieties, there was no significant difference in field production labor per unit area between the improved and the local varieties. As a result, there was a significant difference in favor of the improved varieties in fresh root yield per unit of labor. But when processing labor was introduced, there was no longer a significant difference between the improved and the local varieties in *gari* yield per unit of labor. This was because processing cassava into *gari* is highly labor-intensive. Processing labor-saving technology will enhance the yield advantage of the improved varieties.

Mechanization of the grating step in the making of *gari* has been adopted in more than 50% of the Nigerian villages and in about 15% of the Ghanaian villages surveyed. Mechanized grating techniques involve the use of various types of mechanical cassava graters which are driven by electric, petrol, or diesel engines. Perhaps they are widely available in Nigeria because of the availability of petroleum products at relatively low prices.

With available oil revenue, the Federal Government of Nigeria was able to experiment with alternative large-scale agricultural extension programs, such as the National Accelerated Food Production Program (NAFPP) and agricultural development projects (ADPs) (Oyaide 1982). NAFPP commenced in 1972 with the objective of designing, testing, and extending technological packages for five crops: rice, maize, sorghum, millet, and wheat. Cassava was added in 1974. The packages were designed, based on available component technologies of improved crop varieties, fertilizers, and herbicides. The program was a cooperative effort among research institutes, and state and federal government extension services.

The cassava program of the National Seed Service (NSS) was established in 1986 by the Federal Government to contribute to efforts to distribute improved cassava planting materials. By the end of 1990, the program had made available to the ADPs enough improved cassava planting materials to plant 9,130 ha at the rate of 10,000 sets per hectare and had provided support to the various ADPs in conducting 283,420 small adoption demonstration plots of the improved cassava varieties in the farmers' fields throughout cassava-growing areas of Nigeria.

A case study of southeast Nigeria

In 1973, Lagemann (1977) observed large differences in cassava root yield among three villages with different levels of population pressures in southeastern Nigeria and argued that his findings supported Ruthenberg's (1976) thesis that intensification of traditional farming systems postpones, but does not avert involution and eventual impoverishment due to population growth. In 1993, the Nigerian national team of the COSCA study revisited the three villages to assess the trends in the cassava root yield 20 years after Lagemann's study. Southeast Nigeria, especially the Ibo speaking area, has been recognized as one of the most densely populated areas of Africa (Morgan 1955).

Sites of the study. The three villages studied by Lagemann in 1973 are Owerre-Ebeiri in Orlu area, Umuokele in Abor-Mbaise area, and Okwe in Umuahia area, all within the Ibo-speaking area of southeastern Nigeria. Orlu is located at longitude 7.03'E and latitude 5.77'N, Abor-Mbaire at longitude 7.21'E and latitude 5.48'N, and Umuahia at longitude 7.48'E and 5.52'N.

Differences in population density were Lagemann's dominant criterion for selection. He made use of the 1963 census information which showed the estimated densities for the three villages as: 100–200 persons/km^2 for Okwe, 350–500 persons/km^2 for Umuokele, and 750–1000 persons/km^2 for Owerre-Ebeiri. Hence the low population pressure village was Okwe, the medium was Umuokele, and the high population pressure village was Owerre-Ebeiri. Since 1963, Nigeria has conducted two population censuses, one in 1973 and the other in 1991, but neither was accepted by the Nigeria Governments as accurate.

There are fairly homogenous climatic conditions in all the three villages. According to Lagemann (1977), the mean annual rainfall in the three areas was estimated to be in the order of 2200 mm, with peaks in July and September and the so-called 'August break' in between. Mean daily maximum temperatures would be highest in January-February (33°C) and lowest in July (28°C), and mean daily minimum temperatures would be lowest in January–February ((20°C) and highest in March–April (22°C).

Soils in the areas are Ferrallitic soils which are completely weathered soils. The soils around Owerri, a major urban center situated between Orlu and Abor-Mbaise, where the medium and the high population density villages are located, however, belong to a subclass of deep porous red soils derived from sandy deposits. The natural fertility of these soils is low as the minerals consist almost exclusively of quartz, iron oxides, and kaolinite. The soils around Umuahia where the low population density village is located belong to another subclass of red and brown soils derived from sandstones and shales. Sandy soils are generally poor, but the nutrient retaining capacity of soils derived from shales is fairly high.

The low population village is situated some 15 km south of Umuahia, a major urban center and about 7 km from the National Root Crops Research Institute, Umudike. The road from Umuahia via Umudike to this village is a tarmac road which is now highly deteriorated. The village has a market held every eight days, and there are two other markets in the neighboring villages that the people of the village attend. One of them is Ndoro market about 2 km from the village while the other, Ariam market, is about 7 km away. The most common means of transporting goods to Ndoro market is foot/head while the most common means of transporting goods to Ariam market is by motor vehicle.

The medium density village is situated some 18 km from Owerri, and 2 km from Enyiogugu. The road from Owerri to this village is a deteriorated tarmac road, while the road from Enyiogugu to the village is an easily motorable dirt road. There is no market situated in the village. The major market used by the people is held every eight days in the neighboring Enyiogugu. The major means of transporting goods to the market is motor vehicle.

The high population village is located some 28 km from Owerri and 2 km from Orlu, a major urban center. The road from Owerri to this village is a tarmac road with a greater proportion of it closer to Owerri easily motorable. The shorter portion of the road, closer to the village, is in poor condition, hardly motorable. There are four markets, each of which is held on a different day in the traditional 4-day week, situated in the village. In other words, there is no day without a functioning market within the village. The tempo of commercial activities in the village is therefore relatively high.

Fallow periods. Land fallow but no crop rotation was practiced in all the three villages. The lengths of the fallow periods declined with increasing population pressure. While farmers in the low density village leave their land for as long as six years to fallow , those in the medium density village leave theirs for four years. There is no fallow at all in the high density village. In 1973, Lagemann observed 5–6 year fallow periods for the low, 3–4 year fallow periods for the medium, and 1–2 year fallow periods for the high density villages. This indicates that while there has not been any change in fallow periods in the low and the medium density villages, fallowing virtually disappeared in the high density village between 1973 and 1993.

Cassava root yield in 1993. The mean cassava fresh root yield for the three villages was 6.06 t/ha and the range was 0.50–19.25 t/ha (table 29), the mode was 6–7 t/ha. These do not compare favorably with similar estimates for Nigeria as a whole. The COSCA study estimated, for Nigeria as a whole, the mean of 14.74 t/ha and a range of 1.25 to 67.30 t/ha (table 30).

Table 29. Cassava root yield components in three study villages, southeast Nigeria

Yield component	Mean	Minimum	Maximum	Standard deviation	No. of fields
Fresh roots (t/ha)	6.06	0.50	19.25	4.30	62
Plant density (stds/ha)	11218	4000	25500	4329	62
Number of roots/plant	3.99	0.61	9.48	2.13	62
Average root weight	0.15	0.01	0.36	0.07	62
Harvest index	0.45	0.06	0.75	0.15	61
Age at harvest (mths)	9.15	6.00	21.00	4.03	196

Soil conditions may be a major factor in these yield differences between the three villages and the rest of Nigeria. The soil types in these villages as described by Lagemann (1977) differ from the major soil types found in the forest and the moist savanna where 75% of cassava in West Africa is grown as described by Lawson et al. (1981). Additional factors would be differences in the cassava plant density and cassava age at harvest. According to the COSCA data, the mean cassava plant density for Nigeria was lower than the mean for the three villages. It appears that the densities in the three villages were, in most cases, higher than necessary for maximum root yield. In addition, the mean age of the cassava was substantially higher for Nigeria as a whole than for the three villages. It appears again that the cassava in the three villages is, in most cases, harvested earlier than necessary for maximum root yield.

Table 30. Cassava root yield components in Nigeria

Parameter	Fresh roots (t/ha)	Plant density (stds/ha)	Age at harvest (mths)
Mean	14.74	10214	14.05
Minimum	1.25	1250	6.00
Maximum	67.30	41250	28.00
Standard deviation	9.11	5002	4.94
No. of fields	165	173	174

The mean fresh root yield was lower in fields in which inorganic fertilizer or organic manure was applied than in the fields in which neither of those inputs was applied (table 31). The yield from the fields where improved variety was used was almost double that of the local landraces; this difference was statistically significant. The effect of improved variety on cassava root yield was therefore overwhelming.

The mean cassava root yields were 4.04 t/ha for the high, 4.77 t/ha for the medium, and 9.27 t/ha for the low population villages in 1993 (table 32). This cross-sectional trend in yield is consistent with Lagemann's observation in 1973 that the yield was substantially higher in the low population village than in the high or medium population village. The differences in the soils of the three villages are contributory factors to the large differences in the yields. In addition, there are differences in the fallow periods, in the cassava plant densities, and in the ages of the fields at harvest.

Table 31. Cassava fresh root yield (t/ha) under alternative input applications in three villages, southeast Nigeria

Input		Mean	Min.	Max.	Std. Dev.	No. of fields	T-ratio	LSD
Inorganic fertilizer:								
	used	4.41	0.50	8.80	2.52	18	2.00*	2.35
	not used	6.74	0.90	19.25	4.70	44		
Organic manure:								
	used	3.91	1.20	16.35	3.58	16	2.00**	2.40
	not used	6.81	0.50	19.25	4.31	46		
Improved cassava variety:								
	used	9.33	3.80	16.35	6.10	5	2.00*	3.94
	not used	5.77	0.50	19.25	4.05	57		

Notes:
* significant at 10%, ** significant at 5%

Table 32. Cassava root yield components by demographic pressure in three villages, southeast Nigeria

Demographic pressure		Fresh root (t/ha)	Plant density (stds/ha)	Age at harvest (mths)
High				
	Mean	4.04	11288	7.8
	Minimum	0.90	4000	6.0
	Maximum	15.40	25500	20.0
	Standard deviation	3.23	5711	3.8
	No. of fields	20	20	73
Medium				
	Mean	4.77	11988	10.0
	Minimum	0.50	7500	6.00
	Maximum	16.50	21500	20.0
	Standard deviation	3.54	3687	4.0
	No. of fields	21	21	63
Low				
	Mean	9.27	10381	10.0
	Minimum	4.30	5500	6.00
	Maximum	19.25	18750	21.0
	Standard deviation	4.15	3348	4.0
	No. of fields	21	21	60

The plant densities were higher in the high and medium density villages than in the low density village. It appears that the plant densities were higher than necessary for maximum root yields in proportionately more fields in the high or medium density villages than in the low density village. Figure 25 shows the distribution of the cassava fields by age in months after planting (MAP) in the three villages. The most recently planted fields were one month old in the medium density village, two months old in the high density village, and three months in the low population density village. This means that, based on environmental conditions such as rainfall distribution, the low density village planted earlier than other village. The modal age of the cassava fields was six MAP in the high density and eight MAP in the medium and low density villages. The peak at the eighth month was much higher for the medium than for the low density villages. This means

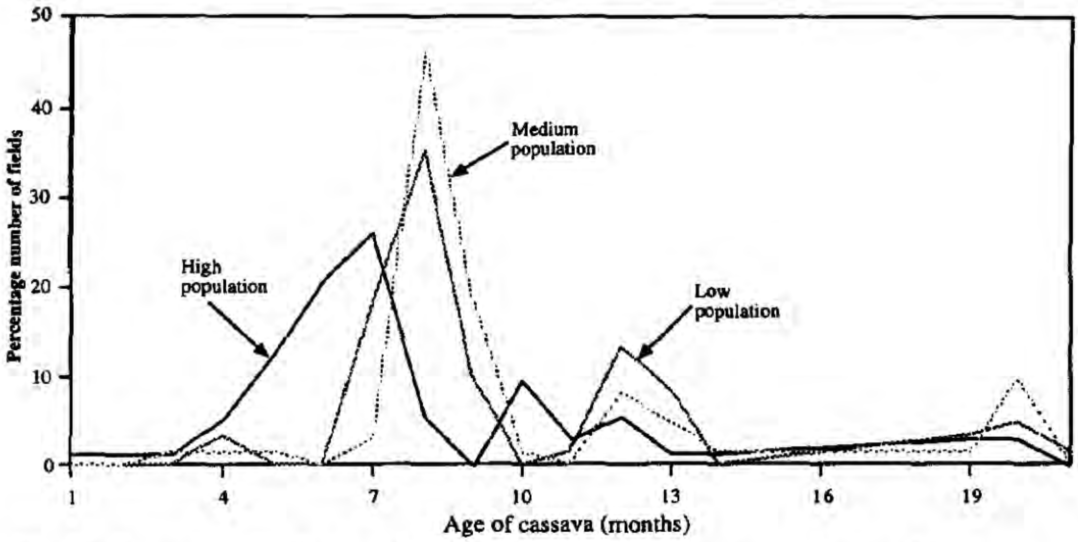

Fig. 25. Percentage distribution of mature cassava field area by age by demographic pressure zone

that cassava was harvested significantly earlier in the high density village than in the medium and low density villages. It was harvested earlier in the medium than in the low density villages.

Cassava root yield trend, 1973–1979. In 1973, Lagemann found the mean cassava root yields for the three villages to be 2.0 t/ha for the high, 3.8 t/ha for the medium, and 10.8 t/ha for the low density villags. This means that between 1973 and 1993, cassava root yield doubled in the high density village, increased by about 25% in the medium, but declined by 15% in the low density village (fig. 26). The yield trend for each village is the 1993 mean yield expressed as a percentage of 1973 mean yield. Lageman's data were no longer available for use for this analysis.

These trends fail to confirm Lagemann's (1977) conclusion that yield seems to be lower

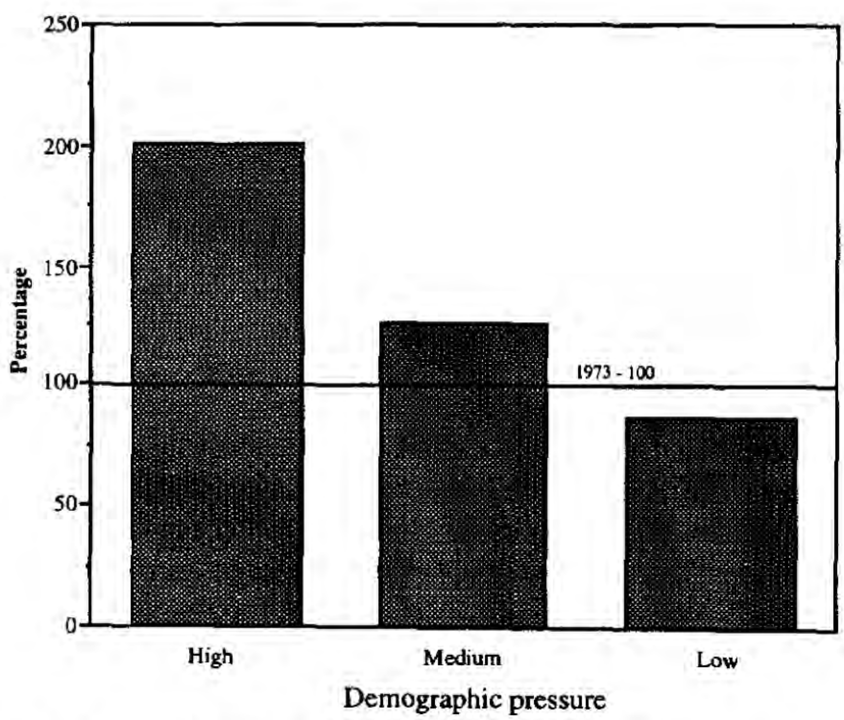

Fig. 26. Cassava root yield trends (1973–93) by demographic pressure.

where the population pressure on land is highest. This assertion is because between 1973 and 1993, the population of the three villages must have increased, but yield increased rather than declined in the high and medium population density villages. The yield gaps observed among the three villages are due to other reasons than the population density differences.

The frequency of use of inorganic fertilizer in the fields of the villages was generally low; 30% (high density village), 43% (medium density village), and 14% (low density village). Organic manure was used in 65% of the fields in the high density village, in 5% of the fields in the medium density village, and in 10% of the fields in the low density village. This shows that purchased inputs were most frequently used in the high density village. It was pointed out earlier that access to market was best in the high density village. The differences in the yield trends could not, however, have been due to these differences in the uses of fertilizer and manure since the cassava root yield did not seem to respond to their applications.

The differences in the yield trends may be explained by the differences in the frequency of use of improved cassava varieties among the three villages. The frequency of adoption of an improved cassava variety decreased with decreasing population pressure. The improved variety was used in 15% of the fields in the high density village and in 10% of the fields in the medium density village. No improved cassava variety was used in the low population village. The improved cassava variety observed in the villages did not exist in 1973.

V. Summary of Observations

Areas of cassava production and production constraints

The importance of cassava in comparison with other staples decreased from the humid through the subhumid to nonhumid zones. Cassava was by far the most widely grown of all the staples in the humid zone. In the zone, the relative importance of cassava was higher in the high than in the low population areas. Although cassava was more important in the humid than in the subhumid zone, it was still the most important staple in the subhumid zone. Within the nonhumid zone, even though sampling was biased in favor of cassava, its relative importance was fourth, following maize, millet/sorghum, and beans/peas. In this zone the relative importance of cassava was higher in areas around market centers than in areas which were remote from market centers. In general, sub-Saharan Africa can be broadly divided into two food zones: the moist zone where the starchy staples dominate, and the drier zones, where grains and grain legumes are the dominant staples; cassava dominates all other staples in the moist areas.

Shortage of planting materials is a constraint to cassava production, particularly in dry areas such as in the nonhumid zone where biomass production is usually low in comparison with moist areas; and when new materials such as improved varieties are being introduced for the first time. Shortage of planting materials is a major constraint to cassava production under both situations because the multiplication rate is very low in comparison with crops such as grains propagated by seed. The materials are bulky and highly perishable as they dry up within a few days after harvest. Hence, multiplication and distribution are very expensive.

It was originally considered that cassava was not attacked by many pests or diseases, but increasingly these are being recognized as problems of economic importance. Two pests: CMB and CGM, and two diseases: ACMD and CBB, are of great economic importance. The use of improved varieties which are resistant to the main pests/diseases seems to hold promise for the future control of these problems. Currently, the problems appear to be less in the relatively few places where purchased inputs are used in agricultural production. However, the majority of the cassava producers have relied mainly on crop rotation, fallow management, and cultivar selection from among available landraces for the control of the pests and diseases.

Fallow systems varied within a village, depending on incidence of the pests/diseases, soil fertility status, and crops grown in different parts of the village. The severity of CMB did not differ statistically between the various fallow systems. The severity of CGM was higher in short fallow than in the other fallow systems. The severities of ACMD and CBB decreased significantly from long through short fallow to continuous cultivation systems. The reasons for these correlations are not clear. One possibility is that farmers may be able to cultivate continuously where pest and disease pressures are low, but need to alternate cropping and fallow periods to break the pests/ disease cycles where the pressures are high.

Inter-village variations in the fallow systems were due to differences in market and demographic pressures, among other factors. There were direct relationships between the market and the demographic pressures and the trend from long fallow through short fallow to continuous cultivation. As a single crop, cassava is adapted to growing under all fallow systems; it was however not as frequently grown under continuous cultivation as most other staples because of its long growth cycle. Farmers respond to declining soil fertility by adopting purchased inputs such as chemical fertilizers and hired labor in high market pressure areas and intensified land-use cultural practices such organic manuring in high demographic pressure areas.

Prospects for land area expansion

Demographic and market pressures and improvement in postharvest handling technologies are among the most important determinants of cassava land area expansion. Though cassava is suitable for cultivation under continuous cultivation systems, expansion under that fallow system is restricted by the long growth cycle of the crop. Where cassava was the traditional main crop, both market and demographic pressures are driving the cassava land area expansion. In the traditional grain areas, however, market was a more important driving factor for the cassava land area expansion. Easy access to market influenced cassava land area expansion positively because it facilitates farmer access to purchased inputs and to market demand for the cassava products. Cassava was produced with the relevant purchased inputs as often as, and in some cases, more often than other staples. A large proportion of cassava, which was likely to be larger than most other staples, was planted purposely for sale. In the cassava-producing areas, cassava generated cash income for the largest number of households in comparison with other staples. Therefore, cassava was important not just as a subsistence or food security crop, but even more as a major source of cash income for producing households.

Easy access to market centers did not make as much impact on the cassava land area expansion as the cassava marketing middlemen and in particular the improved postharvest handling facility which produced the greatest positive impact on the cassava land area expansion. Farmers would be able to expand cassava land area under conditions of difficult access to market centers provided improved processing technologies were available. This was because the improved processing technologies improved product quality, reduced bulk and extended shelf life, and made it possible for quality cassava products to be transported at reduced costs over poor roads to distant urban market centers. This observation is quite significant because it implies that although agricultural research agencies could not build market-link roads, such agencies could still contribute, in a positive way, to the reduction of cost of transportation of cassava products and hence to expansion of markets for cassava by developing improved cassava processing technologies. Improved postharvest handling facility made greater impact on the cassava land area expansion also because they were labor saving. Processing of cassava into certain products was very labor intensive; planting of high-yielding cassava varieties was not likely to lead to increased cassava production if it was not linked with an improved processing technology because labor constraint was at the processing stage.

Prospects for yield increase

Cassava root yield responded positively to organic manuring, livestock grazing, inorganic fertilizer application, and use of hired labor. But that was only able to sustain yield at average levels under conditions of reduced fallow which accompanied increases in demographic pressure and improvement in market accessibility. One reason for this would be that the rates of adoption of the purchased inputs and the cultural practices appear to be lower than the rates of increases in demographic pressure and associated shortening of fallow. Another consideration is that as the demographic pressure increases and market accessibility improves, the age of cassava at harvest declines below that which is necessary for most of the presently available varieties to attain maximum root yield.

Experience with improved cassava varieties widely grown in Nigeria indicates that technologies can be relied upon to offset the effects of high demographic pressure and declining fallow periods to increase average root yield in the future. Improved varieties produce systematically

higher root yields than local varieties, even without organic manuring, livestock grazing, inorganic fertilizer application, or the use of hired labor. However, most of the circumstances which have permitted wide adoption of the improved cassava varieties in Nigeria do not yet exist in many other African countries. Such circumstances include the existence of peace and political stability which will enable farmers to settle down with confidence and make necessary investments in food production. Most African countries do not have a sufficient revenue base to develop the necessary infrastructure for the wide-scale multiplication and distribution of planting materials and extension of the improved cassava varieties. The infrastructure necessary for the processing and marketing of increased cassava production is not positively linked with the consumer. If these negative circumstances could be turned around, cassava root yield will increase in sub-Saharan African, rather than stagnate.

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This report attempts to identify the factors which drive cassava production in Africa. Easy access to market influenced cassava land area expansion positively because it meant access to production input and to product demand. However, its impact was not as much as that of improved processing technology which made the greatest impact on the cassava land area expansion. Improved processing technologies improved product quality, reduced bulk, extended shelf life, and made it possible for quality cassava products to be transported at reduced costs over poor roads to distant urban market centers. In addition, the improved processing technologies were labor saving.

Farmers were unable to respond to shortening fallow periods, resulting from increasing demographic pressure, by replacing more resource demanding crops with cassava because its long growth cycle was a constraint to its production under continuous cultivation system. In a few cases farmers responded to declining soil fertility by adopting some purchased inputs. Cassava root yield responded positively to those inputs but they were only able to sustain the yield at average levels under conditions of reduced fallow because their rates of adoption were lower than the rates of increases in demographic pressure. In addition, the increasing demographic pressure led to early cassava harvest before the roots attained maximum sizes. Improved varieties produce systematically higher root yields than local varieties. However, most of the circumstances which have permitted wide adoption in Nigeria do not yet exist in many other African countries. Such circumstances include political stability which enables farmers to confidently invest in food production. Most African countries do not have an adequate revenue base to develop the necessary infrastructure for the wide-scale multiplication and distribution of planting materials and extension of the improved cassava varieties. The infrastructure necessary for the processing and marketing of increased cassava production is not positively linked with the consumer.