Root Crops in Developing Countries - An Economic Appraisal

Authors: D. Horton, J. Lynam, and H. Knipscheer, Economists with CIP, CIAT, and Small Ruminant CRSP Indonesia (formerly with IITA).

ABSTRACT

Recent developing country patterns and trends in production and use of cassava, potato, sweet potato, yam, and taro are documented and analyzed. Production costs for these crops are estimated and related to their marketing and uses. The roles of these crops in different ecological zones and farming systems are discussed. Research and development programs are reviewed. Some tentative projections of root and tuber crops production and use are made to the year 2000.

Introduction

Historically, tropical root crops have received little attention from scientists and policymakers (Coursey and Haynes, 1970). In recent years several national and international organizations have undertaken research and development programs involving these crops. Actual and potential contributions of these crops to the world's food supply remain poorly understood. Several recent publications, including the proceedings of the five symposia sponsored by the International Society for Tropical Root Crops, contribute to an understanding of the origin and spread of root crops, their biology, and technological advance. But few serious studies of the socioeconomic aspects of their production and use have been conducted. Those available generally draw on a restricted information base, such as case studies or surveys of only one or a few crops in a single country, or draw comparisons among crops or countries in a rather haphazard fashion.

This paper seeks to contribute to the understanding of tropical root crops from an economic point of view. Wherever possible, data are presented on, and comparisons are drawn among, the major root crops and their production and use in different world regions. Time series of production in developing countries are charted and factors likely to influence future developments are discussed.

Discussed here are five major root crops: potato (*Solanum tuberosum*), sweet potato (*Ipomoea batatas*), cassava (*Manihot esculenta*), yams (*Discorea* spp.), and cocoyams: taro (*Colocasia esculenta*) and tannia (*Xanthosoma* spp.). An attempt was made to present each crop in balanced perspective, however, more space is allocated to cassava and potato, the crops for which the authors had most information at hand. The focus is on developing countries and the role root crops may have in development.

Production Patterns and Trends

a. Source of Data

The origins and historical spread of tropical root crops are traced in several publications (León, 1977; Coursey and Booth, 1977; Coursey and Haynes, 1970; Salaman, 1949; Burton, 1966; Yen, 1982), but nowhere are their present distribution patterns and recent trends in production and yield well documented. In this section an attempt to fill this void is made presenting information compiled from published and unpublished data from the Food and Agriculture Organization of the United Nations (FAO).

The authors are aware that FAO data have many limitations. For example, national averages conceal important regional differences within countries. And since root crops are generally grown and consumed on small, isolated farms, underreporting of production and use is likely. Nevertheless, no better data set is available for comparative analysis of crop production and use. Hopefully, this analysis will stimulate much-needed improvement in country-level estimates, and comparative analysis based on micro-level (rather than country-level) information.

b. World Distribution of Root Crops

Global Patterns

According to FAO estimates for 1980, every country in the world produces one or more root crops. These crops occupy approximately 50 million hectares and have a total worldwide production of 560 million tons. Developing market economies account for about a third of world production, followed by the Asian centrally planned economies (mainly China) with just under 30%. Potatoes are produced in more countries than any other root crop (Table 1). In fact, potatoes are grown in more countries than any other single crop, with the exception of maize. In developing countries, however, sweet potatoes and cassava are grown in an equal or larger number of countries. Potato is the only root crop produced in significant amounts in developed countries. Because cassava, yams, and cocoyams can only be grown under tropical conditions, they are produced exclusively in Asia, Africa and Latin America. Sweet potatoes are also grown primarily in developing countries.

The world's five leading producers of root crops, in descending order of importance, are China, Russia, Poland, Nigeria, and Brazil. China produces large volumes of both sweet potatoes and potatoes; Russia and Poland produce potatoes; Nigeria produces mainly yams and cassava; Brazil produces mainly cassava. Total world potato production is roughly 260 million tons, sweet potato production 150 million, cassava production 120 million, yam production 20 million, and cocoyam production only around 6 million tons.

Developing Country Patterns

Within the developing market economies, cassava stands out as the leading root crop, with 115 million tons of annual production. Potato totals 30 million tons, followed by yam (20 million), sweet potato (15 million), and cocoyam (5 million tons).

Cassava is produced in large volumes in Africa, the Far East, and Africa. Twenty-two developing countries produce over 500,000 tons of cassava annually, but more than 60% of total world production is concentrated in five: Brazil (with 25 million tons), Thailand, Indonesia, Zaire, and Nigeria (Table 2).

Table 1. Number of countries producing root crops and root crop production 1981.

	Potato	Sweet potato	Cassava	Yam	Cocoyam
No. producing countries					
World	130	106	95	43	29
Market economies					
Developed	28	6	0	2	1
Developing	91	96	92	41	27
Centrally planned economies					
European	7	0	0	0	0
Asian	4	4	3	0	1
Production (10^6t)					
World	258(298)	146(139)	127(128)	22	6
Market economies					
Developed	72	2	0	0	0
Developing	33	15	120	22	5
Centrally planned economies					
European	135	0	0	0	0
Asian	18(58)	129(122)	7(7)	0	1

Sources: All estimates are from FAO Production Yearbooks and unpublished data supplied by FAO Basic Data Unit, except figures in brackets ( ) which are based on estimates of China production supplied by B. Stone, personal communication.

Potatoes are grown in all developing regions but in much smaller volumes than cassava. Twelve developing countries produce more than 500,000 tons of potatoes. India, the largest producer (with 10 million tons) is followed by Turkey, Argentina, Colombia, and Brazil. These five countries account for over 50% of total potato production in the developing market economies but only 7% of world production.

Sweet potatoes are grown in more developing countries than any other root crop, but generally in small volumes. Only nine countries produce over 500,000 tons; Indonesia, the largest, produces only 2.2 million tons.

Yams and cocoyams are grown primarily in West Africa. With an annual yam production of 15 million tons, Nigeria accounts for 70% of total world production of this crop. Nigeria is also the world's largest producer of cocoyam. With 2.0 and 1.4 million tons, respectively, Nigeria and Ghana produce three-fifths of the world's cocoyams.

Several developing countries are highly dependent upon root crops in their diet (Table 3). In Zaire, for example, more than 50% of the total caloric intake is provided by cassava. In Tonga, the Solomon Islands and Burundi sweet potatoes provide 20% or more of all calories consumed. In the Ivory Coast yams and cocoyams provide over 20% of all calories.

c. Recent Trends in Root Crop Production

According to FAO statistics, world potato production has fallen slightly over the last two decades and sweet potato production has increased by 25%. These world trends are strongly influenced by estimates for China, which are subject to considerable debate. The FAO estimates that Chinese potato production has increased by about 50% since the early 1960's and that sweet potato production has increased by 30% over the same period. Based on a detailed examination of Chinese statistics, Bruce Stone, of the International Food Policy Research Institute, has concluded that Chinese potato production has increased by 180% and sweet potato production has increased by 45%. Assuming that Stone's estimates for Chinese root crop production are reasonably accurate, world production of both potatoes and sweet potatoes has increased by approximately 10% and 35%, respectively, over the last two decades, while production of cassava, yams, and cocoyams has increased by 65%, 35%, and 80%, respectively (Table 4).

In developed market economies, the area seeded to potatoes-- the only root crop of economic significance --has fallen by approximately 40% since 1960, yields have increased by 30% and total production has fallen by 20%.

In developing market economies, the area under potatoes has increased over the same period by 40%, yields have increased by 45% and total production has doubled. Sweet potato production, area, and yields are about the same now as they were in the early 1960's. Production of cassava, yams, and cocoyams has increased by roughly 50%, 30%, and 60%, respectively, due mainly to increases in their seeded area. Average yields of cassava and yams have increased by only about 10% and 20%, respectively, over the last two decades; cocoyam yields have reportedly fallen by 20%.

In recent years potato production has increased most rapidly in Asia and Africa (where per capita production levels are low) and least rapidly in Latin America (where the potato is a staple food item in the diet). Since the early 1960's sweet potato production has increased slightly in Africa and the Near East and has fallen in the Far East and in Latin America. Over the same period, cassava production has doubled in the Far East, due primarily to rapid growth in Thailand. African cassava production has increased moderately; Latin American production rose in the 1960's but fell in the 1970's. Production of yams has increased from a very small base in Latin America, and decreased (again from a small base) in Asia. In Africa, yam production has increased moderately over the same period. Production of cocoyam has increased substantially in Africa but has fallen in all other regions (Table 5).

d. Value of Root Crop Production

While total value of root crop production in developing countries falls far behind that of cereals, three of the 10 food crops with highest production value are root crops: cassava, potato, and yam.

Average prices for potatoes and yams tend to be high (US$140-$160/t) relative to prices for cassava and sweet potatoes ($70-$90/t). Cocoyam prices are intermediate ($120/t). A higher proportion of sweet potatoes, cocoyams and potatoes are consumed directly by humans than is the case with cassava and yams. (Losses and waste are higher for the latter two crops, a substantial proportion of cassava is exported to Europe for livestock feed, and the reproductive rate of yam is low). For these reasons, while the ranking of root crops in terms of the value produced and value destined for human consumption is the same as their ranking in terms of total production, the differences between the crops become smaller (Table 6). For example, the volume of cassava produced is nearly 300% greater than that of potatoes, but the value produced is only 80% greater and the value destined for human consumption only 40% greater.

Table 2. Ten largest producers of root crops in developing market economies and production 1979/81.

Potatoes		Sweet Potatoes		Cassava		Yam		Cocoyam	
Country	10^6T	Country	10^6T	Country	10^6T	Country	10^6T	Country	10^6T
India	9.3	Indonesia	2.2	Brazil	24.5	Nigeria	15.3	Nigeria	2.0
Turkey	2.9	India	1.5	Thailand	14.5	Ivory Coast	2.0	Ghana	1.4
Brazil	2.0	Korea Rep.	1.2	Indonesia	13.7	Ghana	0.7	Ivory Coast	0.3
Colombia	1.9	Philippines	1.1	Zaire	12.4	Benin	0.7	Pap. N.Guinea	0.2
Argentina	1.8	Burundi	0.9	Nigeria	10.8	Togo	0.4	Philippines	0.1
Peru	1.6	Rwanda	0.9	India	5.9	Cameroon	0.4	Egypt	0.1
Egypt	1.1	Brazil	0.8	Tanzania	4.6	Ethiopia	0.3	Madagascar	0.1
Bangladesh	0.9	Bangladesh	0.8	Mozambique	2.8	Cent.Af.Rep.	0.2	Centr.Af.Rep.	0.1
Chile	0.9	Uganda	0.7	Philippines	2.3	Zaire	0.2	Gabon	0.1
Mexico	0.8	Pap. N.Guinea	0.4	Colombia	2.1	Pap.N.Guinea	0.2	Zaire	---

Source: FAO (1982), and unpublished data supplied by FAO Basic Data Unit.

Table 3. Ten developing market economies with highest percent of calorie intake derived from root crops.

Potatoes		Sweet potatoes		Cassava		Yam		Cocoyam		All roots	
Country	%	Country	%	Country	%	Country	%	Country	%	Country	%
Bolivia	9.3	Tonga	39.4	Zaire	55.7	Ivory Cst.	18.1	Samoa	15.9	Zaire	57.9
Peru	6.7	Solomon Is.	30.2	Congo	50.6	Togo	15.5	Ghana	11.4	Congo	54.2
Ecuador	5.6	Burundi	20.3	Cnt.Afr.Rep.	38.6	Nigeria	15.5	Solomon Isl.	6.8	C.Afr.Rep.	49.4
Colombia	3.8	P.New Guinea	15.6	Mozambique	36.1	Benin	12.0	P.New Guinea	4.5	Tongo	45.7
Chile	3.3	Rwanda	15.5	Angola	31.9	C.Afr.Rep.	8.5	Fiji	3.7	Solomon Is.	44.2
Turkey	3.2	Martinique	5.0	Comoros	25.2	Solomon Is.	7.2	Gabon	3.1	Burundi	38.2
Argentina	3.0	Comoros	4.6	Tanzania	24.1	Gabon	5.4	Ivory Coast	2.3	Mozambique	37.1
Burundi	2.7	Uganda	4.5	Liberia	21.0	Jamaica	5.3	Cnt.Afr.Rep.	2.3	Ghana	35.5
Rwanda	2.4	Guadaloupe	3.1	Benin	20.4	Ghana	5.3	Nigeria	2.2	P.N.Guinea	35.2
N.Caledon.	2.3	Madagascar	3.0	Togo	19.8	P.N.Guinea	5.0	Togo	1.0	Angola	35.2

Source: FAO (1980).

Table 4. Percent change in production, area, and yield of root crops 1961/65.

	Potato	Sweet potato	Cassava	Yam	Cocoyam
Production					
World	- 3(8)	23(33)	65(66)	34	81
Market Economies					
Developed	-20	-70	NA	171	-16
Developing	101	0	49	33	58
Centrally Planned Economies					
European	- 8	NA	NA	NA	NA
Asian	-62(178)	33(47)	119(126)	NA	NA
Area					
World	-18(-5)	11	55	12	99
Market Economies					
Developed	-39	-66	NA	190	-22
Developing	38	0	32	12	92
Centrally Planned Economies					
European	-21	NA	NA	NA	NA
Asian	21(107)	13	167	NA	NA
Yield					
World	20	44	13	18	- 9
Market Economies					
Developed	30	-10	NA	10	9
Developing	45	0	13	18	-18
Centrally Planned Economies					
European	18	NA	NA	NA	NA
Asian	20	58	7	NA	NA

Sources: All estimates are from FAO Production Yearbooks and unpublished data supplied by the FAO Basic Data Unit, except figures in brackets ( ) which are based on estimates of China production supplied by B. Stone (IFPRI), personal communication.

NA = not applicable or not available.

Technology, Productivity, and Costs

a. Production Zones and Farming Systems

Few detailed studies of root crop farming in the tropics have been published. Village-level anthropological studies are available for specific locations, but few comparative studies have been made. For these reasons, the present section is exploratory, rather than definitive. By bringing together information from a number of sources and venturing some generalizations, we hope to encourage debate, the exchange of information, and more serious comparative research on root crop farming systems. A brief overview of production zones and farming systems is presented for each of the major root crops, followed by a brief comparative analysis.

Table 5. Root crop production in developing market economies 1979/81 and percent change in production 1961/65 - 1979/81.

	Potato	Sweet Potato	Cassava	Yam	Cocoyam
Production (10^6t)					
Africa	3	5	46	21	4
Latin America	10	2	30	0	0
Near East	6	0	0	0	0
Far East	11	7	36	0	0
% change in production					
Africa	135	24	43	33	58
Latin America	40	-27	16	128	-16
Near East	138	21	-90	-33	-12
Far East	114	- 9	109	-33	-22

Source: FAO Production Yearbooks and unpublished data supplied by FAO Basic Data Unit.

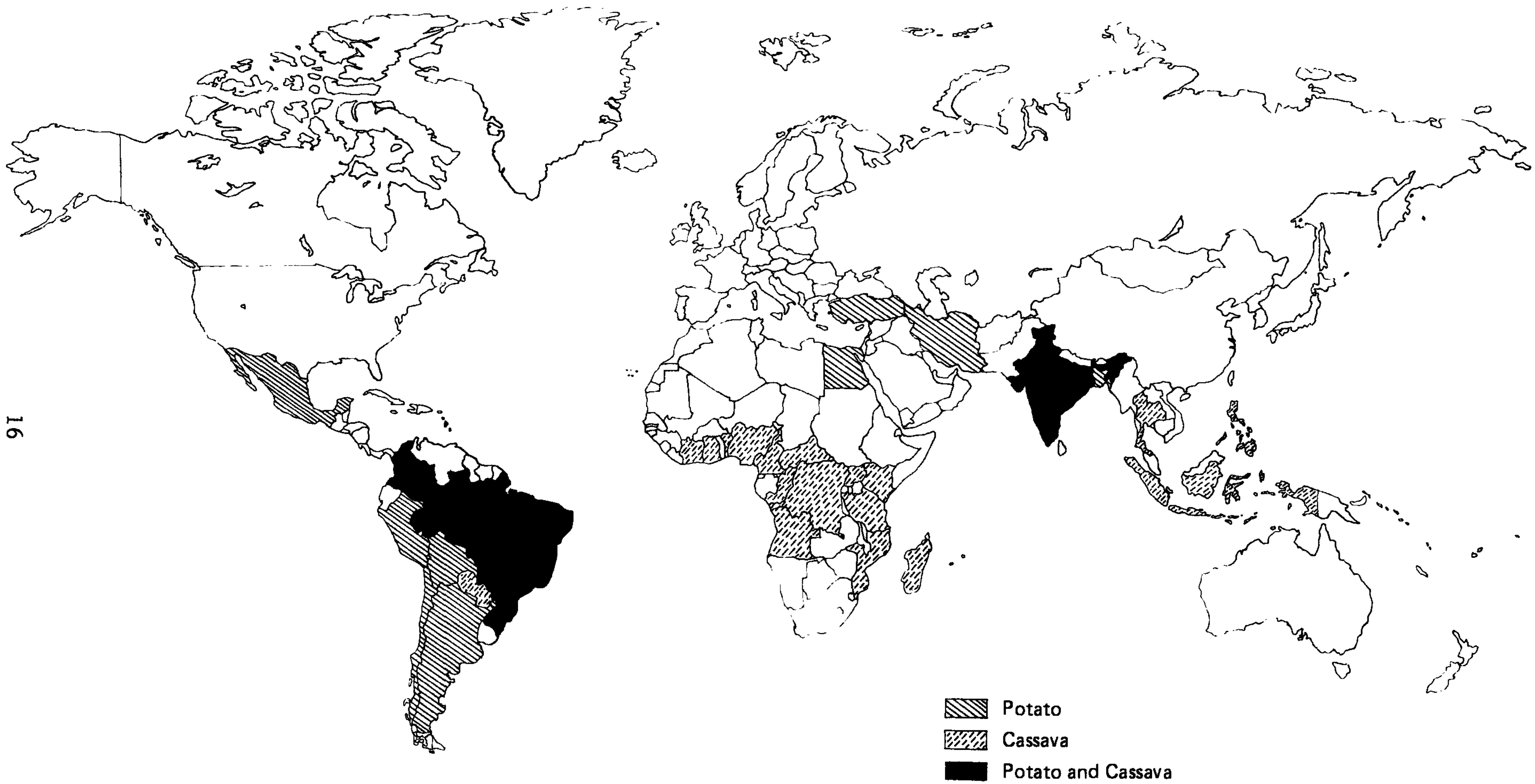
Table 6. Value of root crop production in developing market economies.

	Total Production			Human consumption	
	Volume (10^6t)	Price (US$/t)	Value (10^9US$)	% Prod.	Value (10^9US$)
Cassava	113	70	7.9	56	4.4
Potato	30	142	4.3	71	3.1
Yam	22	163	3.5	58	2.1
Sweet Potato	15	89	1.3	82	1.1
Cocoyam	5	123	0.5	77	0.4

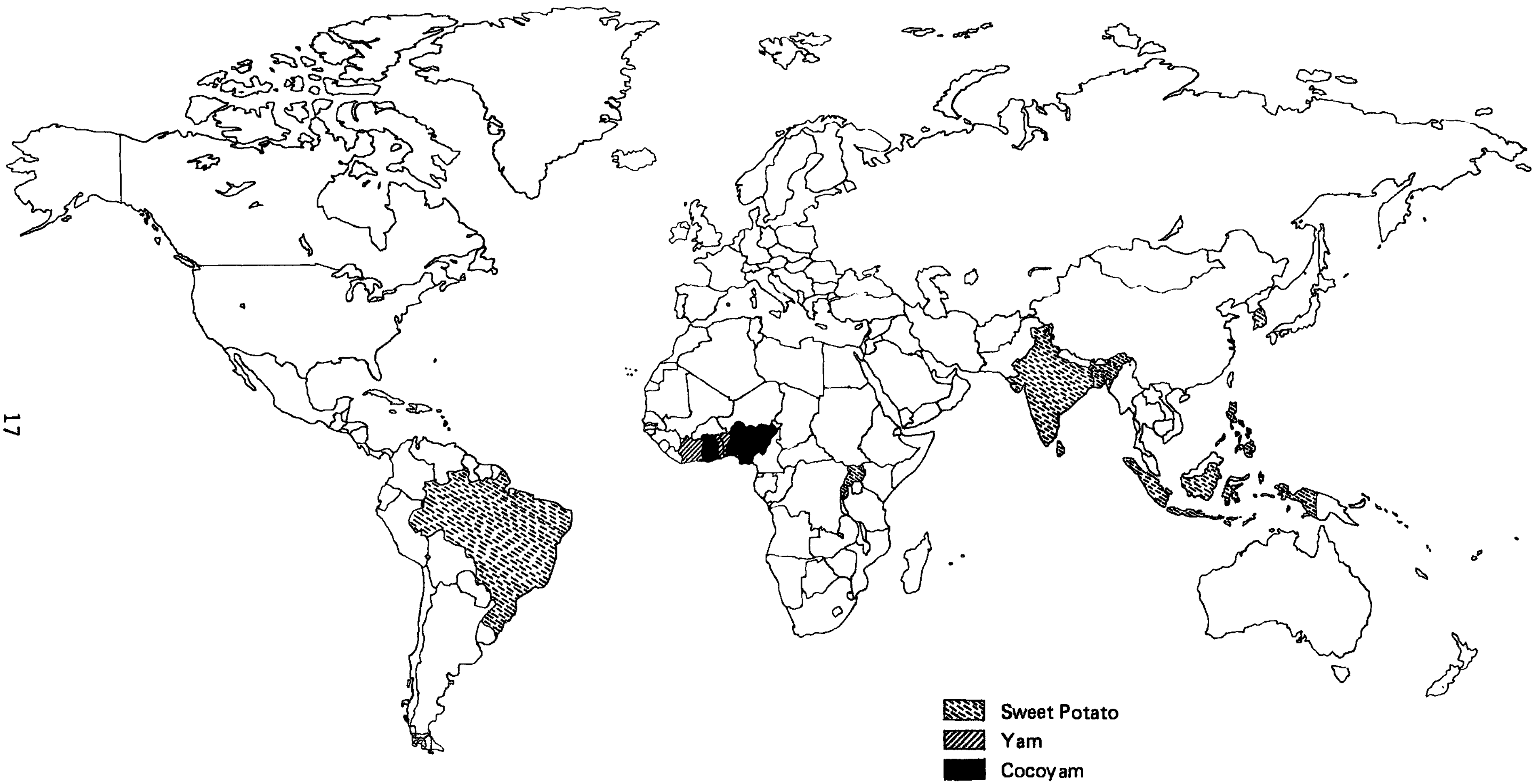
Sources: Volume: 1980 estimate for all developing market economies, from FAO (1982). Price: 1977 estimated weighted average farm-gate price for all developing market economies, provided by FAO Basic Data Unit (unpublished). Percent production destined to human consumption: average estimate corresponding to period 1975/77, derived from FAO (1980). Value of total production: total production volume multiplied by price. Value of human consumption: value of total production multiplied by percent human consumption and divided by 100.

Cassava

Cassava is unknown in a wild state and its evolution as a species is directly linked to selection by man under cultivation. Cassava's center of origin is tropical America but exact time and location of domestication and the direct ancestor are not known. During its evolution, cassava was probably selected for enlarged roots, ability to germinate from stem cuttings, and erect plant type (Jennings, 1976).



Map 1. Developing market economies producing over 500,000 tons of cassava and potato, 1980.



Map 2. Developing market economies producing over 500,000 tons of sweet potato, yam, and cocoyam, 1980.

Certainly by the beginning of the 19th century cassava had been effectively distributed worldwide throughout the tropics. Expansion of cassava production in the 19th century was hastened by import of gari processing technology into West Africa, by the promotion of cassava as a famine reserve by colonial governments such as the Dutch in Java and the British in West Africa and Southern India, and by establishment of a cassava processing and export industry in Malaya in the 1850's. By the 1880's the tapioca trade was well established in Malaya and by the turn of the 20th century production and trade in cassava products, particularly starch, had been started by the Dutch on Java and by the French in Madagascar, with Brazil also exporting modest amounts.

Because of cassava's long growth season, cultivation is limited to the tropics and subtropics. Cassava is nevertheless the most widely grown root crop in the tropics and is grown across a wide range of agro-climatic conditions (Flach, 1982). It is grown from sea-level to almost 2,000 meters in the American tropics and in areas with as little as 70 mm of rainfall to conditions representing tropical rainforest. However, cassava's defining characteristic is its ability to produce economic yields under relatively marginal soil and rainfall conditions. Cassava is efficient in water use and is able to withstand dry periods of up to 4 to 5 months. Also, it is particularly adapted to tropical soils, being tolerant to low pH and high aluminum content. Cassava forms an effective mycorrhiza association and is efficient in phosphorous uptake and utilization. Economic rather than physical factors are the principal determinants of where cassava is grown.

Cassava has several salient characteristics which define its economic competitiveness with other carbohydrate staples and its role within farming systems:

(a) High carbohydrate yields per unit of land and labor.
(b) Adaptation to poor soils and water stress with little use of purchased input.
(c) Compatibility with a variety of crops in association.
(d) An indeterminate harvest period.
(e) Relatively high costs and completely mechanizing cassava production.
(f) Bulkiness, 60% to 70% water content, and extreme perishability after harvest.

Because of these characteristics cassava is particularly adapted to small farm production systems. Commercialization is either costly or requires a processing component.

Cassava is essentially a small farm crop. In the Americas, where there is such a disparity in farm size, 75% of cassava farmers operate farms of 20 hectares or less --small farms by American standards, particularly for the more marginal, lowland areas where cassava is principally produced. In Asia cassava is cultivated in populous areas such as on Java in Indonesia and in Kerala in India. Almost by definition cassava is cultivated in these areas on small farms, rarely exceeding 2 ha in size. Cassava is exclusively an upland crop in these areas and is usually cultivated in poorer soil areas and where rainfall is limiting. In Thailand 73% of cassava farmers have farms less than 6.4 ha in size. As most cassava is cultivated in the northeast, it is usually on relatively marginal land with few other cropping alternatives. In Africa the role of cassava is defined not so much by farm size as by population pressure and the length of the following period in shifting cultivation systems. Here again, cassava has become a principal crop where fallow systems are particularly short and soil fertility conditions are poor.

Cassava has been widely characterized as a subsistence crop. This has arisen partly from colonial experience where cassava either was a plantation crop or was cultivated as a famine reserve crop. The locus of cassava production principally on small farms has also tended to support this view. However, a closer scrutiny of existing data suggests that cassava is very much a commercial crop. In the Americas an estimated 70% of production is marketed (Lynam and Pachico, 1982). This is as well the case in Asia, even in countries such as India and Indonesia where cassava is used principally as a food source (Unnevehr, 1982). In Africa, where the population is still essentially rural-based and where cassava is almost solely used as a food, it is more closely identified as a subsistence crop. Nevertheless, an extensive trade in gari exists in Nigeria (Coursey, 1978) and kokonte (dried cassava) in Ghana (Southworth et al, 1979). Thus, part of the reason cassava is so widely produced is not because it is the subsistence crop <u>par excellence</u> but because it is a cash crop with an existing market. Future development of cassava will depend on reinforcing the commercialization of the crop.

Cassava is produced not only under relatively marginal agricultural conditions but also under low input conditions, in the sense of purchased inputs. First, as cassava is vegetatively propagated through stem cuttings, seed costs are nil. Second, rarely are fungicides, insecticides or herbicides used in cassava production systems. This is not to imply that cassava is not susceptible to diseases and pests but apparently the varieties that farmers plant are either resistant to the dominant diseases and pests or can yield well under attack. In the latter case traditional varieties appear to be excessively leafy, a tolerance mechanism for the major portion of the insect-disease complex which attacks the leaves (Cock, 1978). Moreover fertilizer is not used to any great extent in cassava production systems. For example, in Brazil only 9% of the cassava area is fertilized. Even on Java in Indonesia, where land use is intensive and fertilizer prices are heavily subsidized, only an average of 8.1 kg of fertilizer per hectare is used for cassava, compared to 178.9 kg/ha averaged over all crops (Roche, 1982).

Outside of Asia a defining characteristic of cassava production is a fallowing system. In most of Latin America this fallowing system occurs within a permanent farm system while in Africa fallowing is more often associated with shifting cultivation systems. In eastern Nigeria cassava yields have been linked to population density and average fallowing period, which varied from 0 to 7 years (Lagemann, 1977). Moreover, in Colombia preliminary evidence suggests that fertilizer cannot perfectly substitute for fallowing in maintaining yield levels (CIAT, 1982).

<u>Potato</u>

The potato is of highland origin. Domesticated in the Andes of South America, it has achieved major importance as a food crop near its origin and in similar mountainous areas elsewhere (the Himalayas and cool highland areas of Central and Eastern Africa). After being taken to Europe in the early 16th century, the potato remained as a botanical curiosity for two centuries because of the plant's maladaptation to Europe's long-day, short-season growing conditions (Salaman, 1949). However, once varieties were selected which produced well under European conditions, the potato became an important food of rural peasants and low income urban wage earners across Europe, and in North America. Most research on the potato has been done in Europe and North America, and most varieties now grown in the tropics (outside the Andes) are of northern latitude origin.

In highland farming systems the potato is generally grown by small farmers cultivating no more than 1 to 2 hectares in a number of distinct parcels of land. The crop is typically rainfed and subject to a number of hazards, including droughts, excessive rain, frost, hail, or typhoons, depending upon the location. Highland farmers generally retain a substantial part of their harvest to use as seed the next season. In areas where potatoes are a relatively inexpensive food (the Andes, Central Africa and the Himalayas) farmers also store large amounts for home consumption. Where potatoes are relatively expensive (Central America and South East Asia) farmers usually consume less of their own potatoes, sell the harvest and purchase other cheaper foods with the proceeds of their sales.

In recent years potato production has spread gradually out of its traditional mountainous environment into hotter, generally drier, areas. Typical of such non-traditional cultivation areas are Peru's coastal valleys, the plains of India, Bangladesh and Pakistan, and the irrigated oases of north Africa.

In many irrigated, arid areas potatoes are becoming an increasing attractive winter crop, grown on relatively large, commercially oriented farms. Since harvesting is done at the beginning of summer, storage and marketing present major problems for this perishable crop in these areas. Refrigerated storage is generally required both for seed and table potatoes in these areas.

Recently, potato production has begun to expand in relatively warm, humid zones which harbor a number of pests and diseases of the potato. In such areas, farmers often apply high levels of chemical pesticides and prefer varieties which are resistant or tolerant to pests and diseases. Production is generally on a small scale, as part of complex multiple cropping systems. Traditional slash-and-burn systems prevail where land is relatively abundant and potatoes are cheap; intensive horticulture systems prevail where land is scarce and potatoes are dear (Harmsworth and Albert, 1982; Rhoades, 1982).

In temperate zones, under arid, irrigated conditions, and in cool highland areas, potatoes are generally produced as a sole crop. At lower elevations, particularly in humid zones, relay cropping and intercropping are common.

In most areas where they are grown, potatoes generate returns which are high on average but highly variable. For this reason, the few farmers who specialize in potato production tend to be large, financially well-off producers. The majority of developing country farmers are highly diversified and plant a small proportion of their land to potatoes with a dual purpose: home consumption and limited market sale.

Sweet Potatoes

Sweet potatoes are grown in more developing countries than any other root crop, yet little is known about the crop's production zones and practices. Lack of attention given to this crop by agriculturists reflects that while sweet potatoes are grown in many places they are usually of secondary importance in relation to other crops. Sweet potatoes are important in many poor isolated areas where few agricultural studies have been conducted.

The sweet potato is a relatively short maturity crop tolerant to a wide range of growing conditions. It is grown in the tropics, sub-tropics, and in warmer temperate zones (such as southern USA). It is relatively cold-tolerant, and hence is grown in many tropical highland zones (East Africa and highland New Guinea).

Sweet potatoes can be grown on relatively infertile soil with few inputs, and can withstand periods of irregular rainfall and drought. Tubers can be left in the ground after maturity, but once harvested they generally have a short storage life. For these reasons, in developing countries sweet potatoes are generally grown by small farmers on marginal land as a subsistence crop for immediate consumption. Culls are often fed to livestock. In times of war or famine, populations in several countries (Taiwan, the Philippines, South Korea, and Rwanda) have survived on the sweet potato. It is believed these unpleasant circumstances may have led to a degree of consumer prejudice against the sweet potato as a food (Tsou and Villareal, 1982). In recent years per capita consumption of sweet potatoes has fallen sharply in many areas.

Yams

Yams are grown in tropical regions scattered throughout the world, but the main production center is the savanna region of West Africa. White yam (*Discorea rotundata*) is believed to be indigenous to the area stretching from Ivory Coast to Cameroon (Okuli, 1981) and is generally considered to be the best edible yam in that region (Irvine, 1976). Yam is a prestigious component of the West Africa diet, and its taste is regarded to be superior to that of all other root crops.

Yam, as with nearly all African food crops, is generally intercropped. Intercropping advantages include minimizing risks associated with diseases, pests, and price fluctuations, evening the distribution of food and income supply over the whole year, and intensifying land use (Norman, 1975). Because yams are generally intercropped, yield figures can be misleading unless presented with the yield of the intercrops (which is seldom the case).

African production of yams, as well as cassava, cocoyams, and sweet potatoes, is concentrated in areas within 15 degrees of the equator, labeled the African Root Crops Belt (Nweke, 1981). In this region about 40% of the daily energy intake is derived from root crops (22% from cassava, 10% from yam, 4% from cocoyam and 2% from sweet potatoes). The principle producing (and consuming) country for most root crops in the Belt is Nigeria, which also accounts for more than 50% of the area's population.

Cocoyams

The two main genera of cocoyams are *Colocasia* (taro) and *Xanthosoma* (tannia). Colocasia originated in Southeast Asia and spread across Africa to the Americas. In Nigeria it is called "old" cocoyam to distinguish it from the "new" cocoyam, or tannia, which originated in South or Central America and reached West Africa later. It is believed that tannia is rapidly replacing taro in West Africa (Doku, 1981). In Nigeria, the largest producer of this crop, cocoyam is appreciated for its easy digestibility. Farmers distinguish "soft" and "hard" varieties. The soft ones are often used for pounding a yam-cocoyam mixture.

In Nigeria cocoyam is typically a secondary crop ranking far behind yam and cassava (gari) in production and consumption. However, in parts of Ghana, Cameroon, and Gabon, cocoyam is a staple food. Here, the usefulness of cocoyam as an intercrop between tree crops is one reason for its popularity.

Cocoyam is adapted to hydromorphic soils but is generally grown on well-drained, relatively fertile upland soils. Its cultivation has been associated with that of tree crops, especially cocoa (hence, the name "cocoa-yam").

Although most farmers use a rotation, cocoyam is sometimes grown without interruption up to 6 years in succession. It is often planted in clusters between scattered trees. Spacings within clusters differ from those between clusters. Hence, in comparing yields it is important to know if the sample is based on a small area containing one or part of one cluster, or a large area containing several clusters. In the latter case, yield estimates will be substantially lower than in the former. A recent survey in Cameroon (Atayi and Knipscheer, 1980) found average yield to be as low as 1,172 kg/ha for cocoyam (compared with 1,267 kg/ha for cassava in the same, extensively cultivated area). In contrast, Nigerian sources (Phillips, 1976; Olayida and Olowude, 1972; Onwueme, 1978; Federal Office of Statistics, 1979) generally indicate an average yield of about 6 t/ha.

For cocoyam production, as for most food crops in tropical Africa, labor is the main input. Although good quality land and cash are scarce, farmers consider the availability of labor to be their main production constraint. A recent survey (Knipscheer and Wilson, 1981) indicated, rather surprisingly, that cocoyam requires less labor than does cassava. The same survey also showed that cocoyam was generally planted by women, and that hired labor was seldom employed.

Farmers use corms, cormels and headsets as planting material. Little is known about the reproduction factor for cocoyam but it is believed to be much higher than that for yam. Planting material is stored in shady places and is usually covered with (palm) leaves. Presprouted headsets and cormels are then selected for planting on low mounds, ridges or on the flat.

Comparisons

Given the wide range of conditions under which many of the root crops are grown, and the sketchy nature and uneven quality of information on their production zones and systems, any general statements about them may be subject to considerable error and numerous exceptions. With this in mind, the following paragraphs are offered as a starting point for much-needed future comparative analysis.

From the comparative Table 7, derived from Kay (1973), some summarized data on root crops relates to their production zones and farming systems. From this Table it can be seen that potatoes have a shorter vegetative period than most other root crops, and do best under cooler temperatures. Potatoes can, in fact, be grown in areas with high daytime temperatures, but do not tuberize well if night temperatures are above 20 degrees C. For economic yields potatoes require relatively high inputs of fertilizer and organic matter. They do poorly in water-logged soils. For potato production, optimal rainfall is less than for the other root crops, but potatoes require relatively regular watering and are highly susceptible to drought. Potato tubers can be stored in the ground for short periods, and harvested tubers can be stored for long periods if they are pest and disease free and if adequate conditions of temperature (low) and humidity (high) are maintained.

Table 7. Comparative data on root crop characteristics.

	Potato	Sweet potato	Cassava	Yam	Taro	Tannia
Growth period (months)	3-7	3-8	9-24	8-11	6-18	9-12
Plant annual or perennial	Annual	Perennial	Perennial	Annual	Perennial	Perennial
Optimal rainfall (cm)	50-75	75-100	100-150	115	250	140-200
Optimal temp. (°C)	15-18	> 24	25-29	30	21-27	13-29
Drought resistance	No	Yes	Yes	Yes	No	No
Optimal Ph	5.5-6.0	5.6-6.6	5-9	NA	5.5-6.5	5.5-6.5
Fertility requirement	High	Low	Low	High	High	High
Organic matter requirement	High	Low	Low	High	High	High
Can be grown on swampy, waterlogged soil?	No	No	No	No	Yes	No
Planting material	Tubers	Vine cuttings	Stem cuttings	Tubers	Corms/ Cormels	Corms/ Cormels
Period crop can be stored in ground	Short	Long	Long	Long	Moderate	Long
Post-harvest storage life	Long	Short	Short	Long	Variable	Long

Source: Derived from Kay (1973).

NA = Not available.

Other root crops have longer and more variable growing periods; cassava, the extreme case, with 9 to 24 months. Other root crops also do better under higher temperatures; yam, the extreme, with an optimal 30-degree (C). While sweet potatoes and cassava are responsive to fertilization, they can produce economic yields on poor, unfertilized soils with little organic matter. Their tubers cannot be stored more than a few days after harvest, but they can be left unharvested for long periods. Both these crops are highly drought resistant.

In contrast to cassava and sweet potatoes, yams and cocoyams require good soils and adequate moisture. While tannia and yams do not do well in swampy areas, taro can be grown on waterlogged soils. Both yams and cocoyams can be left on the plant after maturity and harvested as needed. If care is taken in harvesting and handling so not to damage tubers, they can also be stored well after harvest.

b. Input Use and Costs

Few cost-of-cultivation studies have been published for root crops in developing countries, and those available often have the following methodological weaknesses.

First, many inputs used in the production process are of household origin, not purchased. Several possible ways of estimating opportunity costs for these inputs are available but authors seldom specify their methods clearly. Hence, comparisons based on different sources may be misleading.

Second, where root crops are intercropped, many field inputs contribute to the productivity of two or more crops. Again, few authors detail the procedures they use for costing out these inputs. The yam studies by Diehl (1982) and Bachman (forthcoming) are valuable exceptions.

Third, published cost estimates are often based on conventional wisdom, guestimates, experimental trials, or recommended technological packages, rather than on detailed recording of actual farming practices. Hence, the representativity of the figures is often questionable.

Fourth, published cost estimates are generally presented in local currencies and conversion into a common currency base (dollars or pounds sterling) is sometimes problematic, due to artificial currency rates and lack of precise dates for costs in countries with high rates of inflation.

Realizing these difficulties, we have tabulated and analyzed available cost estimates for root crops to arrive at broad, tentative generalizations concerning input structure and level of costs associated with different root crops (Tables 8, 9, and 10).

The figures support three general statements:

First, production costs per hectare are lowest for cassava and highest for potatoes. The general range of variable costs is \$100 to \$200/ha for cassava and \$1,300 to \$1,800/ha for potatoes. Available sweet potato cost estimates are in the range of \$300 to \$600/ha. And yam and taro estimates are \$600 to \$800/ha. While these cost estimates are imprecise and based on very little information, their relative magnitudes are consistent with the observation that in most developing areas potatoes and yams are costly crops to produce, whereas sweet potatoes and cassava are cheap. They are also consistent with the observation that potato and yam crops are given special attention by farmers. They tend to be grown on the best land and in the first year of rotation cycles, whereas sweet potatoes and cassava are typically grown on marginal lands and/or at the end of rotations, before fallow.

Table 8. Cassava: Variable costs of production and labor input/ha in selected locations.

	Indonesia[1] Gurung Kidul	India[2] Salem	Brazil[3] Maranhao	Thailand[4] Cholburi	Thailand[4] Nakornrajsima
Variable cost					
Structure					
Labor	97	55	100	44	64
Land prepar.	--	8	--	34	34
Seed	3	--	--	10	2
Fertilizer	--	36	--	10	--
Pesticides	--	--	--	2	--
Total	100	100	100	100	100
Total (US$)	97	164	145	171	99
Labor Input (days)	346	138	84	75	67

Sources: [1]Roche (1982). [2]Subramanian and Uthamalingam (1980). [3]Ministerio da Agricultura, Brazil (1977). [4]Tinprapha (1979).

Table 9. Potatoes: Variable costs of production and labor input/ha in selected locations.

	Peru[1] Coast	Ecuador[2] Machachi	Chile[3] Central	Pakistan[4] Punjab	Philippines[5] Bagui	Rwanda[6] Ruhengeri
Variable Cost						
Structure						
Labor	17	37	24	18	16	62
Land Prepar.	11	7	25	6	2	--
Seed	38	27	37	53	55	38
Fertilizers	20	19	12	20	17	--
Pesticides	14	10	2	3	10	--
Total	100	100	100	100	100	100
Total (US$)	1,653	1,496	1,444	1,352	1,893	306
Labor Input (days)	73	213	63	125	211	230

Sources: [1]CIP estimates (unpublished). [2]Soliz (1978). [3]Fu(1979). [4]Wustman and Mahfooz (1980). [5]PCARR(1979). [6]Dürr(1982).

Table 10. Sweet potatoes, yams, and taro: variable costs of production and labor input/ha in selected locations.

	Sweet Potato Peru[1]	Sweet Potato Bangladesh[2]	Taiwan[3]	Yam Nigeria[4]	Taro Western Samoa[5]
Variable Cost Structure					
Labor	45	59	39	66	52
Land prepar.	42	11	28	1	-
Seed	8	23	10	26	48
Fertilizers	3	7	22	6	-
Pesticides	2	-	1	2	-
Total	100	100	100	100	100
Total (US$)	300	408	586	612	787
Labor Input (days)		353	400	344	203

Sources: [1]CIP estimates. [2]Elias et al (1980). [3]AVRDC (1977). [4]Diehl (1982). [5]Tupuola (1982).

A second generalization is that total variable cost figures are strongly associated with costs of planting material rather than such factors as the labor intensity of the crop. In cassava production, planting material generally represents only a few dollars/ha; in sweet potato production planting material is more costly, but well under $100/ha. In contrast, in taro production "seed" may cost $400/ha; in yam and potato production seed generally costs over $500 and sometimes more than $1,000/ha. Hence root crops with highest seed costs have highest production costs per hectare.

A third generalization is that fertilizers and pesticides are seldom applied to root crops, with the important exception of potatoes.

c. Measures of Productivity

Among numerous measures of crop productivity, yield/hectare -- the most common -- is not necessarily the most useful. Because of the high water content of root crops, total yield figures often have little relation to production of dry matter, energy, and protein per hectare.

Total yields of root crops generally exceed those of cereals and pulses by a wide margin and are on par with vegetable yields. Among root crops, potato has the highest average yield in the developing market economies (11 t/ha) and cocoyam the lowest (4 t/ha).

In terms of gross returns per hectare, potatoes also rank highest among root crops, followed closely by yams (Table 11). Sweet potatoes, cassava, and cocoyams generate only about 30% to 40% of the per hectare returns of these two top-ranking crops (due both to their relatively low prices and yields). Data for four important cereal crops illustrate the superiority of root crops over the cereals in gross return per unit of land.

Table 11. Average root crop and cereal grain yields, prices, and gross returns/ha in developing market economies.

	Yield (t/ha)	Price (US$/t)	Gross Return (US$/ha)
Potato	10.9	142	1,500
Yam	9.0	163	1,469
Sweet Potato	7.1	89	629
Cassava	8.8	70	613
Cocoyam	4.2	123	514
Rice	2.2	170	366
Wheat	1.5	148	217
Maize	1.5	119	177
Sorghum	1.0	123	117

Sources: Yield: average estimate for 1979/81 from FAO (1982). Price: weighted average farm-gate price corresponding to 1977, provided by FAO Basic Data Unit (unpublished). Gross return: yield multiplied by price.

It is well known that root crops and vegetables have high moisture content. Nevertheless, in terms of dry matter production per hectare, cassava, yams, potatoes, and sweet potatoes rank highest on the list of major food crops (Table 12). Potatoes and yams also rank first and second in of edible energy production per hectare per day; sweet potatoes rank sixth and cassava ninth. Among major food crops, only potato remains on the list of the most productive crops in terms of edible protein production per hectare per day.

Table 12. Top ranking foodcrops in terms of dry matter production/ha and edible energy and protein production/ha/day in developing market economies.

	Dry Matter Production		Energy Production		Protein Production	
Rank	Crop	T/Ha	Crop	MJ/Ha/Day	Crop	Kg/Ha/Day
1	Cassava	3.0	Potatoes	216	Cabbages	2.0
2	Yams	2.4	Yams	182	Dry broad beans	1.6
3	Potatoes	2.2	Carrots	162	Potatoes	1.4
4	Sweet potatoes	2.1	Maize	159	Dry peas	1.4
5	Rice	1.9	Cabbages	156	Eggplants	1.4
6	Carrots	1.7	Sweet potatoes	152	Wheat	1.3
7	Cabbages	1.6	Rice	151	Lentils	1.3
8	Bananas	1.5	Wheat	135	Tomatoes	1.2
9	Wheat	1.3	Cassava	121	Chickpeas	1.1
10	Maize	1.3	Eggplants	120	Carrots	1.0

Sources: Yield: FAO (1982) and FAO (unpublished). Vegetative period: FAO (1981) and Goering (1979). Edible portion, dry matter, and food composition: USDA (1975) and INCAP (1961).

Labor utilization and yields of individual root crops vary widely, making it difficult to state valid generalizations about labor productivity. Survey results from areas of Nigeria where labor is the principal input in production of yams, cocoyams, and cassava, indicate that on a per-hectare basis yams require more labor than cocoyams and cassava, and that the labor productivities of these three crops are approximately 30, 40, and 60 kg/man-day, respectively (Knipscheer and Wilson, 1981).

Chandra et al (1974, 1976) analyzed the efficiency of two production systems in Fiji, one based on root crops and the other on cereals. The conclusion was that the root crop system had a much higher total energy return per unit of cropped area, per total energy input, and per man-hour expended than that of the system based on cereal crops (Evanson and De Boer, 1978).

Based on production cost estimates and established energy conversion factors, energy budgets have been estimated for root crops in selected sites (Table 13). Given the small number of observations available and the numerous assumptions underlying the calculations, these estimates should be considered as rough approximations of true values.

Three broad generalizations can be made on the basis of these energy budgets.

First, for a given crop, budgets can differ radically between production systems. In the USA (Washington state), for example, the total energy input for one hectare of potatoes is six times that used in Rwanda. Moreover, in the USA over 95% of the energy input is from non-renewable sources, whereas in Rwanda practically all energy used is in the form of labor and seed.

Second, assuming that production conditions on Peru's coast are similar to those elsewhere in developing countries, potato production generally requires more energy than production of other root crops, and particularly more energy from non-renewable sources.

Third, the crops and systems which require the highest energy inputs also generate the highest _net energy output_, but they tend to have lower _energy conversion ratios_ (energy output:energy input) than the more traditional systems based on hand labor and low total energy inputs.

Marketing and Utilization

Reasonably complete, and presumably accurate, sets of country-level statistics on crop production and foreign trade are published in FAO _Production Yearbooks_ and _Trade Yearbooks_, but no similar statistical base exists on domestic commodity utilization.

Periodically FAO publishes estimates of volumes used for seed, feed, fresh food, and processing in its _Food Balance Sheets_, but the estimates for root crops are highly inaccurate. Estimates of volumes processed are included, for example, only where processed commodities enter into foreign trade.

Even though accurate country-level statistics are not available, the general patterns and trends in root crop utilization can be summarized briefly for each main root crop.

a. Cassava

Cassava's extreme perishability after harvest, the resultant inability to store cassava, its bulkiness, and the large assembly costs due to many small-scale producers, all make marketing of fresh cassava expensive. Hence, advantages of cassava on the production side are lost by the disadvantages of marketing the crop, unless cassava is processed or consumed in the production zone. Processing, besides relieving these marketing restrictions, opens cassava to many end uses, some having higher growth prospects than others. However, only in a few cases has cassava been integrated into these growth markets, with cassava in Thailand produced for the EEC animal feed market being the most prominent example.

Apart from Thailand and Malaysia, cassava is principally used as a food source. In Africa it is used almost exclusively as food; in the Americas a significant percentage is also used as an on-farm feed source; and in Asia a sizeable portion goes into industrial uses or is processed and exported. Only in Asia where cassava production has been growing most rapidly, has there been a transition in traditional use patterns. In Africa and especially in Latin America use patterns have not changed markedly and during the past decade production has been virtually stagnant.

Prices for fresh cassava roots in representative countries of Latin America and Asia suggest high marketing margins. In general about 60% of the retail price goes to moving cassava from farm gate to the consumer. The result is high prices in urban areas for cassava on a calorie basis as compared to grains. High levels of fresh cassava consumption are thus found exclusively in rural production zones. Estimates of annual consumption per capita as high as 115 kg have been reported in Kerala, India; 250 kg in rural Nigeria; and 180 kg in rural Paraguay. However, because of marketing costs and high relative prices, per capita consumption of fresh roots is low outside production zones, particularly in urban areas.

Generalized consumption of cassava thus depends on trade in its products and this depends on processing. Countries with high per capita cassava consumption levels in general, consume it in a processed form, such as farinha da mandioca in Brazil, gari in Nigeria, casabe in Haiti, and gaplek in Indonesia. Cassava consumed in these forms is often the cheapest available calorie source. However, traditional staples based on processed cassava are notoriously difficult to introduce into other non-consuming countries, since their consumption is usually tied to locally prepared dishes. Moreover, consumption of these traditional cassava staples is difficult to increase in consuming countries.

Income elasticities for processed forms of cassava tend to be low or negative. Income elasticities for gaplek in Indonesia have been estimated to be -0.62 (Dixon, 1982) and for farinha da mandioca in Brazil at -0.34 (Lynam and Pachico, 1982). Rapid replacement of gari by imported rice and wheat in Nigeria during the last decade would suggest a similar situation in Africa. In general, the market potential for traditional processed forms of cassava is limited. However, while consumption of processed cassava is high among the poor, income elasticities are still positive and quite high among the poorest income strata -- 0.85 in Indonesia (Dixon, 1982). Lowering relative costs of these staples would thus tend to raise consumption in this group without the higher income strata competing for supplies and putting pressure on prices (Timmer and Alderman, 1979). Thus, reduced prices of these products can play a key role in nutrition policies in developing countries.

Table 13. Illustrative energy budgets for root crops (gigajoules per ha).

	Potatoes			Cassava	Yam	Taro	
	USA	Peru Coast	Rwanda	Thailand	Cameroon	Western Samoa	
Labor	0.14	0.43	1.35	0.39	2.30	1.19	
Oxen	-	1.44	-	0.30	-	-	
Seed	1.13	9.75	3.97	0.81	13.70	7.68	
(1) Sub-total	1.26	11.62	5.32	1.50	16.00	8.87	
Tractor and equipment	12.43	-	0.11	-	-	-	
Fertilizers	16.59	15.0	-	-	-	-	
Pesticides	1.70	0.31	-	-	-	-	
(2) Sub-Total	30.73	15.31	0.11	-	-	-	
(3) Total Energy Input	31.99	26.93	5.43	1.50	16.00	8.87	
(4) Gross Energy Output	82.48	53.74	19.08	40.32	38.03	47.15	(28.29)
Net Energy Output (4)-(3)	50.48	26.81	13.65	38.82	22.03	38.29	(19.42)
Gross energy output per unit of non-renewable energy (4)/(2)	2.68	3.51	173.45	∞	∞	∞	(∞)
Gross energy output per unit of total energy input (4)/(3)	2.58	2.00	3.51	26.88	2.38	5.32	(3.19)
Crop yield (t)	25.6	16.9	6.0	7.3	9.0	11.5	(6.9)

Sources: Input structure and yield: same sources as Tables 12-14. Energy conversion factors: Pimentel (1974)

Note: Numbers in brackets () under Taro refer to yields on previously cropped land (assumed yield = 6.9 t/ha); other figures for taro refer to yields on land after fallow (assumed yield = 11.5 t/ha).

Demand growth for cassava in traditional markets is limited. As economies urbanize and sources of demand shift to urban areas, fresh cassava as a food source in the economy will lose the comparative advantage it has in rural production zones. For traditional processed staples, consumption will decline with increasing income. In Africa countries, such as Zaire and Ghana, where population remains mainly rural, population growth is high, and growth in per capita income is nil, demand for cassava will continue to be strong. However, where economies are rapidly changing, per capita incomes are growing, and there is rapid urbanization, as in Latin America, demand for cassava in its traditional consumption forms will be stagnant or declining. However, such structural changes could induce rapid growth in other markets for cassava. Particularly prominent markets are those for starch, animal feed concentrates, and composite flour.

Market development for cassava is most clear in Latin America. Rapid growth in the poultry industry has resulted in a rapid increase in feed-grain demand, which has outstripped domestic production. Development of a dried cassava industry in this area would not only achieve a reduction in foreign exchange but also increase small farmer incomes and make more productive use of marginal agricultural areas. In Asia market development is more varied. Indonesia is developing a large domestic market for cassava starch and India is doing the same thing to a more limited extent. The Philippines, Malaysia, and possibly China are likely to focus on the animal feed market. Most of Africa outside Nigeria, on the other hand, will probably continue to focus on the human consumption market.

Current trends in export markets for cassava products indicate that development of these alternative markets must rely on expansion of domestic uses. Only about 4% of world starch production moves in trade, most of which is cassava starch. Through technical change, the developed countries, which make up the principal importers, are replacing imports with domestically manufactured starch. Traditional starch exporters, such as Malaysia, Togo, Madagascar and Brazil, have either substantially reduced their exports or ceased trading entirely. Thailand remains as the only exporter of any importance.

Over the past decade there has been a rapidly increasing trade in cassava pellets for animal feed. This market was created by a gap in the EEC tariff structure, by which grains came under the variable levy and cassava under a 6% *ad valorem* duy. World market prices for cassava were determined by high internal grain prices in the EEC. Exports of cassava pellets from Thailand reached a level of over 6 million tons in 1981, and because cassava was displacing domestically produced grains, the EEC in 1982 imposed a "voluntary" quota on cassava imports. Hence cassava exporters must search for alternative markets. It is not clear if cassava can compete against coarse grains in the broader world market, but certainly for most cassava producing countries higher returns will be achieved by developing domestic markets.

b. Potatoes

About 45% of the world potato crop is used for human consumption (fresh and processed), 30% is fed to livestock and 15% is kept for seed. Only about 2% is used for starch production; the remainder (just under 10%) is waste (van der Zaag and Horton, 1983). Production of fodder potatoes is practically limited to Europe. Some western European countries previously grew fodder potatoes on a large scale, but this practice is disappearing. At present only eastern European countries grow potatoes for stock feed in large quantities. In Russia and Poland nearly one-half and two-thirds of the potato crop is used for fodder, respectively. Potato production for starch and alcohol is of limited importance in the world. Only in the Netherlands, where more than one-third of the total crop is grown for starch, is production of potatoes for starch really important. Other countries where potato production for starch is of some importance are Poland, the USSR, and Japan. Since the World War II processing of potatoes for human consumption has been a growth industry, particularly in the USA where more than half the potatoes are consumed in processed forms --primarily frozen french fries, dehydrated instant potatoes, snack foods including potato chips (USDA, 1979).

In developing countries practically no potatoes are grown for livestock feed or for production of starch or alcohol, although culls are sometimes used for these purposes (primarily fodder). Nearly all potatoes are grown for human consumption in fresh form. In the Andes, the Himalayas, and elsewhere some potatoes are processed for human consumption, often using age-old methods (Werge, 1977; Rhoades, 1983). Accurate estimates of the amounts involved are unavailable, but they are believed to be small relative to total production. Industrial processing of potatoes for consumption in fast-food restaurants and as snack foods (potato chips) or convenience foods (dehydrated instant mashed potatoes) is expanding in several countries, but account for a small fraction of total production. Consumers of these products are limited to relatively high income earners in urban areas.

In Europe and Latin America, potato consumption appears to have stabilized. In many parts of Africa and Asia per capita consumption is increasing at a rapid rate.

Farm-level and retail prices for potatoes, wheat, and rice in major world regions have been analyzed by van der Zaag and Horton (1983). Their analysis indicates that, on average, potatoes are more expensive in developing than in developed countries. In contrast, wheat and rice are cheaper in developing than in developed countries. It is often argued that the high retail price of potatoes in developing countries is due to high marketing costs and profits of middlemen. However, evidence presented by the same authors indicates that marketing margins are higher in developed than in developing countries. The principal reason for high potato prices in developing areas is high production cost rather than excessive marketing margins. Still, marketing margins for root crops are higher than those for grains, and will remain a considerable factor in price.

It is generally assumed that potato consumption is insensitive to changes in prices and income levels. This assumption is based primarily on results of household surveys in Europe and the USA. To study the relation between incomes, potato prices, and potato consumption van der Zaag and Horton (1983) calculated income and price elasticities using data from 51 countries. The estimated coefficients were 0.965 and -2.209, respectively. The postulated consumption function explained 75% of the variation in per capita potato consumption. These results, which indicate that potato consumption is much more responsive to price and income changes than previously assumed, are consistent with the observed rapid growth rates of potato consumption in many developing areas.

c. <u>Sweet Potatoes, Yams, and Cocoyams</u>

Sweet potatoes are used primarily as human food (Kay, 1973). In some developed countries, such as the USA, a significant proportion of the harvest is processed (canned, frozen, dehydrated) for consumption in the form of such products as pie fillings and purees, but in the developing countries the major proportion of the crop is cooked and eaten directly after harvest. In a few areas, where production costs are especially low, large amounts of sweet potatoes are fed to livestock (Taiwan and South Korea) or converted into low-grade starch (Japan). In parts of Asia and Africa tops of vines and leaves are eaten as a vegetable. In most areas sweet potato consumption is declining.

Yams have been since ancient times one of the basic staple foods in West Africa. Prior to the introduction of American foodcrops, such as maize, cassava, and tannia, and Asian rice and taro they were of more central importance than they are today. But still they are one of the most popular and prestigious foods of the region (Coursey and Booth, 1977). Yams are also important staple foods in parts of Melanesia, Polynesia and the Caribbean.

Neither taro nor tannia is indigenous to Africa, but have become important foods in many areas, particularly in forest zones. In Ghana, for example, cocoyam production is second only to that of plantain among the staple crops (Coursey and Booth, 1977).

Yams and cocoyams are produced almost exclusively for human consumption. While an active domestic trade in these root crops exists in many areas, only insignificant volumes are traded internationally as a high-cost tropical specialty food (Lambert, 1982; Tupula, 1982). Being relatively expensive, yams and cocoyams are not used for production of starch or alcohol. Only the overly mature tubers, unfit for human consumption, are fed to hogs. Both taro and tannia contain an irritant that causes scratchiness in the mouth if eaten raw or poorly cooked. As a general rule tannia contains less irritant and requires less cooking than does taro (Knipscheer and Wilson, 1981).

Future Prospects

If present trends continue, cassava and potato production will continue to increase through the end of this century. The projected rate of potato production is higher than that for cassava, but cassava will continue to be the major root crop in the developing market economies. In contrast, yam production will increase only slightly and sweet potato production is likely to decline. In this final section we review factors which may influence future trends in production and use of root crops.

a. Cassava

The future of cassava in developing countries depends principally on ability of production and marketing systems to respond to changing economic conditions. Increasing rural population densities and population expansion into more marginal areas will continue to be the principal impetus for cassava expansion in most of Africa. Gari and kokonte will become important as cheap calorie sources for low income populations in the growing urban areas. In Latin American, on the other hand, growth in production will depend on cassava becoming competitive in domestic markets for carbohydrate supplies for mixed animal feeds. Balance of payments constraints and lack of a tropical wheat technology may as well provide stimulus for the development of a composite flour industry. Moreover, given proper planning, improved cassava technology and new markets can be used as one of the few means of increasing small-farmer incomes in the more marginal agricultural areas of the American lowland tropics.

The future of cassava in world trade will essentially depend on technical change in Thailand and policy toward cassava on the part of the EEC. It is probable that the Common Agricultural Policy cannot afford to allow unrestricted cassava imports and that access to that market will become increasingly restricted. This will force Thailand to look to other markets. The structure of the world starch market and trade restrictions in principal importing countries --apart from the USA-- would argue for continued stagnation in world trade in cassava starch. Thailand in the longer term must thus attempt to realign prices with world grain prices and compete in these markets. The recent movement of Thai exports to hard pellets will help in this but Thailand's success in achieving this realignment will depend on longer term trends in the world feedgrain market and on a substantial increase in farm level productivity.

For the rest of Asia the prospects for cassava are mixed. In Indonesia and southern India cassava is likely to continue to be a principal component of food and nutrition strategies. In Indonesia cassava is likely to continue to expand, especially in the older transmigration schemes and will principally serve an expanding domestic starch market with some potential for the production of high fructuose sweeteners to replace the sugar imports. In Malaysia the cassava industry will probably continue to stagnate as it must compete for the same land with higher value tree crops. The future of cassava in the Philippines is in the animal feed market and this will depend on developing low cost drying technologies.

Cassava's multiple uses, its adaptation to many soil and climatic stresses typical of the lowland tropics, and its carbohydrate production potential should provide a niche for the crop in the agricultural development plans of many developing countries. As the above highlights, development of cassava is not undimensional but will depend on land use patterns and land potential, the stage of urban and industrial development and economic policy objectives. Certainly cassava deserves a close look in agricultural development plans in tropical countries.

b. Potatoes

Trends in future production and use of potatoes in the tropics and subtropics will depend in large part on their price to consumers, which, in turn, depends largely on production cost per unit of output.

As many authorities have noted, many developing countries have little additional land to bring under cultivation. Hence, as population expands and man/land ratios increase, productivity of land now under cultivation must be increased. Crops that produce large amounts of energy and protein per unit of time and land area, such as the potato, will become increasingly attractive. Although we emphasize the importance of reducing production costs we should not forget that this should not be at the expense of the potato's productivity per hectare and per unit of time.

As discussed by van der Zaag and Horton (1983), possibilities of reducing the total cost of potato production per hectare are rather limited. Breeding varieties which are resistant to major diseases, improving tuber seed programs, and in specific regions use of true potato seed may allow perhaps a 25% reduction in total production cost per hectare. On the other hand, increasing prices and rates of application of chemical fertilizer and pesticides may be expected offset these cost reductions.

Possibilities of reducing production cost per unit of output seem to be much greater. In some cases yields could be increased substantially with only a modest increase in production cost per hectare. This would allow potato prices to decline while grower's profits increased.

Given the present high level of tuber seed costs, research and development programs should emphasize better production and distribution of healthy and cheap seed. More attention should also be paid to making it easier for farmers to produce potatoes under difficult growing conditions. Needed are varieties which are tolerant to drought, heat, and frost. Such varieties would help growers increase yields with only moderate increases in production costs per hectare. Better technologies are also needed for storage of both consumption and seed potatoes over long, hot periods. Attention should be paid to development and introduction of simple storage systems and means of transforming fresh potatoes into more easily stored, high value products. Breeding for keeping quality should receive more attention than it has in the past.

If research and development programs are successful, in the future potatoes may be produced and made available to consumers year-round at considerably lower prices than at present (discounting for inflation). This, in turn, would stimulate an increase in potato consumption.

Taking all factors into account, it seems likely that in many areas where the potato is now a luxury vegetable it will become a staple vegetable, and in some places where it is now a staple vegetable it may become a basic staple food. However, in many parts of the tropics and sub-tropics where the potential yield of the potato crop is low it is unlikely that in the near future potatoes can become competitive in price with alternative food crops which are better adapted to local growing conditions.

As a final point, it should be noted that limited potato production in low-potential areas does not necessarily lead to low consumption in these areas. Many lowland areas can be supplied by nearby high-potential areas. In particular, as transportation systems improve, the high-potential areas can be expected to supply growing urban markets more cheaply.

c. Sweet Potatoes, Yams, and Cassava

In relation to the situation with potatoes and cassava, little research has been conducted on factors influencing trends in production and use of sweet potatoes, yams, and cocoyams.

As noted above, in recent years sweet potato production has been relatively stable in Africa and the Far East and has declined in Latin America and the Near East. Consequently, average per capita production has fallen significantly in the developing market economies as a whole.

In Taiwan, where production has declined to about one-third of its peak 1964 level, two major factors have been identified as bringing about this decline (Chen, 1982). First, as the standard of living has risen in Taiwan, people have tended to eat more rice at the expense of sweet potato. Second, hogfeed based on corn rather than on sweet potato has been adopted by the large-scale hog-raising industry that has developed in recent years. Shrinking market demands have made sweet potato production unprofitable relative to other crops. The cited study concluded that future expansion of sweet potato production would require creation of a new market image for sweet potatoes for human consumption and development of appropriate technology for utilizing sweet potatoes in ready-mixed hogfeeds.

A major constraint in the development of the feed concentrate market is the trypsin inhibitor in sweet potatoes, which can only be deactivated at high temperatures. Whether inhibitor-free varieties can be bred remains to be determined. Specialized varieties are needed for food and feed uses, and new market channels and handling techniques need to be developed for sweet potatoes destined for human consumption.

Yams and cocoyams do not face consumer resistance, as is the case with sweet potatoes. On the contrary, they are preferred foods in many tropical areas. But, as with potatoes, they are often expensive relative to other foodstuffs, such as cassava and rice. Several authors conclude that major barriers to expanding yam production are its high labor requirement and the high cost of planting material. Extremely little research has been conducted on these crops' production constraints, marketing, and demand, and with the present state of knowledge little can be said about the future prospects for their production and use.

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