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GLOBAL MARKETS FOR ROOTS AND TUBERS IN THE 21st CENTURY

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Abstract

Commercial outlets for roots and tubers will continue to expand and diversify around the world in the decades ahead. This trend is a function of, and in response to, a complex set of factors both on and off the farm. Cassava, potatoes, and sweet potatoes have all increased in output and productivity since 1960. Utilization patterns have undergone even more dynamic changes. Many of these trends, however, have varied considerably across commodities and regions and over time in the last 30 years. Because these tendencies show every indication of continuing in the decades ahead, this paper examines them closely to clarify important differences and similarities. The paper also outlines global trends driving these developments, makes projections regarding root-based products that will become increasingly important in the future, and describes illustrative cases where commercial changes are already occurring. The paper then explores the potential contribution that market-driven product development for root and tuber crops can make to the quest for evermore productive, yet environmentally sound, food systems in the developing world.

Introduction

As the global community approaches the year 2000, agriculture its source of sustenance for millennia has entered a definitive phase of evolution. The subsistence nature of much of the crop and livestock production around the world is rapidly changing. Farming in Asia, Africa, and Latin America is becoming more and more market oriented.

Only in the last few decades have tropical and subtropical countries begun to witness the massive impact of yield-increasing technology capable of generating startling increases in the volume of surpluses available for sale in a single production cycle.

In the midst of this agrarian transformation, the prospect of continued growth in output and productivity raises crucial questions regarding the commercial outlook for those crops long considered as basically subsistence commodities, with all that implies for both production

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and utilization patterns. These concerns are particularly pronounced for the future of root and tuber crops. In short, if more cassava, potatoes, or sweet potatoes are harvested, where and in what form will they be marketed?

Perhaps more compelling are the following queries: Can roots and tubers compete with other commodities in global markets in the 21st century? What is required to improve the competitiveness of these crops on which at least one-fifth of the world's population currently depends as a source of food and income?

This paper addresses these questions in five parts. Part I reviews production and utilization statistics of recent decades for the two major root crops (cassava and sweet potatoes) and for the potato tuber. Part II focuses on five major emerging patterns in root crop utilization most likely to continue and expand in the 21st century. Part III analyzes related off-farm, socio-economic trends. Particular attention is given to their probable effects on root and tuber crops, and the people who produce them. Part IV presents three case studies of actual and/or potential market diversification for cassava, potatoes, and sweet potatoes. Part V discusses product development for roots and tubers, and its implications for the environment. The paper then makes some conclusions.

Production and Use of Roots and Tubers, 1960-1990

The output of potatoes, sweet potatoes, and cassava increased markedly in the last three decades (Tables 1, 2, and 3). Increases were particularly impressive for cassava and potatoes in both Asia and Africa. In contrast, root crop production in Latin America, the center of origin for all three crops, increased by much less (e.g., by only 30% for cassava), and sweet potato production actually declined by roughly 20%. In Africa, however, sweet potato production nearly doubled during the last 30 years as area planted rose by slightly more than 100%. In fact, root crop production increases have been a result more of area expansion than of increasing yields (e.g., in China between 1961-1963 and 1988-1990, cassava area increased by 129%, yields by just 28%). Only in the case of sweet potatoes in China where total area of the crop actually declined over the 30-y period while yields increased by 118%—do we see a different picture.

Since the 1960s, utilization patterns for the three crops have changed substantially. Establishment and growth of a cassava drying and pelleting industry for export in South-East Asia during the 1970s exploited the feed industry's pioneering use of dried (stable) root products, albeit after export to Europe (Calpe 1992). Similarly, cassava starch production has expanded from traditional small-scale processing to modern, industrial processing for both export and national markets in South-East Asia and Brazil. In Africa, a huge range of traditional processed food products have been developed from cassava (NRI 1992). These have undergone mechanization and large-scale expansion in some areas, especially in Nigeria (Nweke 1992). In several Latin American countries, small-scale processing operations for local feed production were established during the 1980s (Ospina and Wheatley 1992). Readers should be aware that this major shift in utilization patterns for cassava has yet to be registered in the FAO Food Balance Sheets, which indicate that less than 15% of the crop is processed (Scott and Suárez 1992).

For sweet potatoes, a significant shift in utilization has also occurred, from fresh food to feed use, in the major producing country, China, since the 1970s. In the 1960s, more than 50% of sweet potato production was for human food. By 1990, in Sichuan Province, major use was as animal feed (Table 4). In addition, the use of sweet potato starch for noodle production has expanded, and waste from starch processing has become an important pig feed in its own right. Nevertheless, sweet potatoes have not yet seen widespread use of dried products for feed production or of starch for multiple end-uses.

Whereas fresh cassava and sweet potato roots are often not preferred fresh foods as is the case in Asia and Latin America and have frequently been replaced by cereals in urban diets for that reason, the potato is a high-status, preferred product (Scott and Suárez 1992). High prices commanded on the market for fresh tubers are not, at first sight, conducive to the development of processing; but, in fact, storage to capture high off-season prices is highly lucrative in many countries (Dahiya and Sharma 1994; Scott 1988a). The FAO (1994) Food Balance Sheets suggest that utilization patterns have not changed much over the years, remaining at about 4% of developing country production. The rapid spread of fast foods into many developing countries is, however, resulting in increases in the production of potato-based snack foods and French fries (Scott 1994).

Current Patterns and Future Trends in Root and Tuber Utilization and Trade

Trade in potatoes fresh tubers, seed, and processed products is expanding extremely rapidly (Scott 1994). Current estimates suggest that trade in potatoes represents roughly 4% of global production, up from about 1% just 30 years ago (Figure 1). Moreover, these estimates are only for fresh tubers and seed. Available data indicate a substantially lucrative and growing trade in processed potato products (Scott 1994). Egypt, Cyprus, and Morocco among others have long exported potatoes to Europe in the winter months (Abbott 1987). Recent growth in seed exports to North Africa and in processed potato products to South-East Asia has been particularly impressive. Many developing countries (e.g., Colombia and India) are interested in and increasingly capable of expanding their potato exports in one form or another. These developments suggest continued growth in foreign potato trade in the decades ahead.

International trade in cassava feed pellets is stagnant, but trade in starch is increasing. With the negotiation of the new General Agreement on Tariffs and Trade (GATT) accord in 1993, the quotas permitted by the European Union (EU) for importing cassava pellets can be expected to decline and the price paid for pellets to decrease.

As both Thailand and Indonesia operate a policy of distributing export quotas based on exports to non-EU markets, the effect will be to increase the non-EU price for pellets. Trade in pellets has been stagnant for some time, and cassava production in Thailand is constant at 20-24 million tons per year. Thai policy is now to decrease the area planted to cassava while maintaining production through yield improvements. As subsidies are withdrawn, cassava can be expected to play a more important role in national feed industries. Thailand and Indonesia are switching from chips and pellets for feed use to starch for export and national food industries.

Starch production in Thailand has been increasing at a rate of 8% per year, and considerable research by the public and private sectors has been devoted to the development of modified starches for a variety of industrial uses (Cenpukdee et al. 1992). The trend to add value to cassava and other root starches will continue.

Dried chips or pellets are also used by some national feed industries (e.g., Colombia, Ecuador, Brazil, and Indonesia) to produce balanced feed rations. Because dried-root products contain less protein than other energy sources, their incorporation into rations is economic at a price discount to maize or sorghum (15%-25% discounts are common). Chip production can therefore be a successful household or village enterprise industry, adding value and generating employment. In addition, by-products from starch or other processes constitute other low-cost, energy- and fibre-containing feed products, which are widely used in some countries (e.g., cassava in Indonesia and sweet potatoes in China). With the removal of market distortions in the future, the use of root products by national feed industries will increase.

Several countries have been experimenting with the production and use of root flours for food use mainly as wheat flour substitutes. In Indonesia, one company has been using cassava flour in the commercial production of a range of cakes and cookies for several years (Damardjati et al. 1996). In Colombia, food industry trials identified promising functional advantages of cassava flour over wheat flour for several product categories, including processed meats and cookies. A pilot project, involving small-farmer, cooperative-based, flour production, is operating (Wheatley and Best 1991). In Vietnam, cassava flour is commercially used for substituting wheat flour in bread production. Nigeria has made similar uses of flour during times of wheat import bans.

These experiences provide considerable information on both technical and business-related aspects of widespread use of root flours by food industries. Similar work involving sweet potatoes has been under way in Peru, Burundi (Berrios and Beavogui 1992), and Cameroon (Odaga and Wanzie 1992) for several years now and shows considerable promise. China has had success with potato flour (Gitomer 1996); but, given the high price of fresh tubers, this appears to be the exception that proves the rule (Scott et al. 1993b).

Starch extraction from root crops by large-scale processing enterprises expanded rapidly in many countries during the 1980s. Plants with a capacity to process more than 200 t of roots per day are common in Thailand, Brazil, and Indonesia. In many cases, however, these exist alongside small- and medium-scale, traditional, processing operations.

Although large plants employ more efficient technologies with higher extraction rates than small plants, they suffer from several disadvantages in obtaining supplies of raw material. As the size of processing plants increases and distances from production centers grow, complex networks of intermediaries are needed to guarantee regular supplies so that seasonal shortages do not reduce capacity use. For the highly perishable cassava, where fresh root deliveries must be made daily, starch quality can suffer significantly if deteriorated roots are used.

In contrast, small plants have lower transport costs, access to local supply networks for raw material, and low capital investment. Seasonal operations are therefore economical. Although large plants continue to expand root processing, the viability of small-scale enterprises will remain attractive in many areas especially if investment is made in equipment to improve efficiency and product quality with all the local welfare benefits this entails.

Global Socio-Economic Trends

Commercial opportunities for root and tuber crops will be strongly influenced by several important socio-economic trends. These include demography, economic growth, diet diversification, food and feed industry developments, and trade expansion. Each merits closer consideration.

Demography. Although larger developing countries including China, India, Indonesia, and Brazil are expected to achieve annual population growth rates of less than 2% during the 1990s, most others will exceed this figure, especially in sub-Saharan Africa (Scott and Suárez 1992).

In Latin America, urbanization rates are already very high (70%-85% in most countries). As population growth slows, some countries will experience absolute declines in rural populations in some regions. In Africa and Asia, urbanization rates are currently much lower (20%-30%); however, they are expanding at two or three times the rate of population growth, fuelled by the extremely small size of the average farm (e.g., less than 0.5 ha/family in Java).

Incomes. In Asia, incomes will most probably continue to grow strongly in the 21st century. Income growth will also occur in Latin America and, hopefully, in Africa. However, income growth will be greater in urban than in rural areas, and even more so than in the marginal areas where cassava and sweet potatoes tend to be produced by the poorest and least dynamic.

This represents a challenge, but also an opportunity. Low-cost production of processed, root-based products designed to appeal to urban consumers offers the possibility of linking poor small farmers of root crops to growth markets with potentially high profit margins. The same is true for meat production via the efficient use of root crops as a feed. As incomes increase in most countries, meat production also increases rapidly.

Diet diversification. In increasingly urban societies, often with both a growing middle class and large low-income groups, several growth markets for root and tuber crops will develop. Features of urban life are high rates of female participation in the work force limiting time available for food preparation and exposure to mass advertising, thereby facilitating diet diversification. The main consequence of this will be the growing demand for convenience foods. For example, instant noodles have been developed in response to massive consumer demand in South-East Asia. This trend has already emerged in Africa as well: in Nigeria, for example, the private sector has developed an instant pounded-yam product to complement the traditional time- and labour-intensive, but highly preferred pounded yam (Bogunjoko 1992).

Convenience foods require processing to increase shelf life and reduce preparation time. Primary processed root and tuber products (flour and starch) are potential raw materials for such secondary processing. Potato products such as French fries and chips (crisps) are convenience foods aimed at the fast-food market. The production of prepared (peeled and cut) potatoes for supplying fast-food outlets has become a growth sector in many developing countries in recent years (see below).

Food and feed industry developments. The food and feed industries are developing rapidly in many countries in response to the trends in consumer demand outlined above. These enterprises are eager to obtain raw materials that are cost competitive, of good and uniform quality, and available on a regular basis. Currently, many imported foodstuffs and feeds fulfil these needs, because their countries of origin have subsidy systems, well-developed supply networks, and established quality standards. Subsidies have been reduced in recent years, and this trend will accelerate with new GATT agreements. Root crops therefore offer an increasingly interesting raw material for food and feed industries. However, supply (seasonality and competition between markets) and quality (from myriad small processors) problems must be overcome before massive use can be made of this raw material.

Expansion in international trade. Reductions in market distortions will occur because of (1) decreases in subsidies for the export of wheat, maize, and other cereals; (2) reductions in tariffs; and (3) general liberalizing of international trade as negotiated under GATT and to be implemented by the new World Trade Organization. Given this scenario, trade in cassava pellets for feed will probably not expand, but trade for starch and starch derivatives will. International trade in fresh potatoes will grow from the current 4% of world production. Trade in processed potato products will also increase, especially in those tropical countries that need to import such commodities to supply the expanding fast-food industries (see below).

Implications of These Trends for Root Crops

Primary products of roots and tubers (flour and starch) could become highly cost competitive with imported, temperate-climate cereals if there were fair market competition. However, current subsidies and the political and economic interests they fostered appear destined to remain a brake on the diversification of end-products for roots and tubers in the foreseeable future. Nevertheless, much scope exists for identifying priority food products and markets, as well as root-production regions to supply the necessary raw materials, that would focus development efforts in coming years.

Increased use of primary processed root and tuber products will continue to be constrained by seasonality of supply (thus limiting raw material availability to industry) and by poor, variable quality (especially where production is by many small-scale operations). R&D efforts aimed at overcoming these limitations will allow the potential cost advantages of root crops to be fully exploited.

Where root or tuber starch is the cheapest source of starch, development of a wide range of modified products for the food industry, as well as derived starch products such as glucose, can be expected.

In Africa, root and tuber crops are vitally important food staples. The products of the major root crop cassava are processed foods: either dried and stable (e.g., *gari* flour) or moist and more perishable (*chikwangue* and *fufu*). In contrast to Latin America, where urbanization has resulted in decreased cassava consumption (because of perishability and quality problems with fresh roots), in Africa, traditionally processed products are suitable for inclusion in urban diets. The Collaborative Study of Cassava in Africa (COSCA) found that cassava production is increasing most rapidly in peri-urban areas (Nweke 1992).

The future of cassava in Africa looks good, given high rates of urbanization (if from a low base) and no adverse preference problems. As a modern food-processing industry develops to supply urban markets, cassava flour and starch will be natural raw materials unless wheat subsidies continue to distort raw material use well into the future. Cassava flour, produced under rustic conditions, is already an important food in countries such as Tanzania and Mozambique. As food industries develop and flour quality (e.g., colour and hygiene) improves, market diversification will accelerate.

In Latin America, many rural consumers used to be locked into subsisting on cassava or sweet potatoes, partly because these were well adapted to local agricultural systems.

However, as these consumers moved to urban environments, they dropped the two roots from their diets. Two interrelated factors accounted for this shift in eating habits: one was the availability of a wider range of food products at reasonable prices. The second was that fresh roots had (and still do) often proven unsuitable for urban food purchase, storage, and preparation practices. This was especially true for the highly perishable fresh cassava roots, where urban consumers were often offered only poor-quality, expensive roots. As a result, consumers shifted *en masse* to rice or potato consumption, especially in the 1960s and 1970s (Janssen and Wheatley 1985).

In Brazil, however, where cassava is processed into a dry, stable, and easy-to-prepare product (*farinha*), it has remained an urban staple, although with reduced consumption as diets have generally diversified.

Market Diversification for Cassava: The Case of Indonesia

Annual cassava production in Indonesia increased from 12 to 16 million tons during the 1980s. At the beginning of the last decade, the bulk of cassava production was used in traditional, small-scale, starch-extraction enterprises. The starch was mainly employed in the production of *krupuk*, a traditional cracker or snack, and also of *gaplek*, dried chips, for both export and food in some regions. By 1990, the picture had changed radically with the rapid emergence of a modern food and feed industrial sector in the country. This development catalysed major shifts in cassava use and, consequently, a growing diversification in the market for the crop.

Cassava starch production expanded with the establishment of many large-scale extraction enterprises that used modern technologies to achieve high starch-recovery rates. The starch from this primary processing industry, which was price competitive with other starches and even flours, began to be used as a raw material for a wide range of food and other products. At the same time, the medium- and large-scale feed industry came to rely on *gaplek* as the dominant energy source for feed rations, both balanced compound feeds and feed concentrates. Cassava starch also found its way into numerous, non-food industrial products (paper, plywood, textiles) as a low-cost, high-quality, raw material for specific uses.

Estimates of cassava use as a raw material by the primary and secondary, large- and medium-scale processing enterprises in Indonesia can be gleaned from the findings of a recent industrial survey (MIN 1991). In primary processing, nearly one million tons of cassava roots are processed into 250,000 t of starch and 120,000 t of *gaplek* (Table 5). This is in addition to the (presumably) much larger volumes being processed in traditional, small-scale, and farm-level enterprises throughout the country. This same industrial sector also processes 1.7 million tons of imported wheat in only two wheat mills (both in Java). At the same time, the large- and medium-scale primary sectors process smaller volumes of rice and maize than cassava.

Considering secondary processing of these primary processed products, the food industry uses mostly wheat flour, but cassava starch is the second most important raw material, ahead of rice flour and maize starch. *Gaplek* is the major feed energy source, with double the volume of maize. In the other industrial sectors, use of cassava starch is double that of wheat flour, the only other carbohydrate source used with any frequency. Considering raw material use by all three industrial sectors (food, feed, and others), cassava chips dominate because of the huge volumes used in local feed industries, followed by maize, wheat flour, then cassava starch. Total industrial use of more than 120,000 t of cassava starch in 1990 represented 1 million tons of fresh roots or about 7% of the domestic annual cassava production.

Although more than 250,000 t of cassava starch are produced by large- and medium-scale primary processing enterprises, only 96,000 t are used by the same scale food industry (Table 5). A further 30,000 t is used by other industries, implying that more than 100,000 t of starch is used by small-scale enterprises, probably in the manufacture of *krupuk*, or exported. *Krupuk* is the major food product category that uses cassava, closely followed by noodles. More than 40,000 t of starch are used every year in noodle manufacture, representing only 10% of the total starch or flour used by the noodle industry, with rice being the major raw material (Table 6).

Other categories in which significant volumes of cassava are used are liquid glucose, some types of candy, and bakery goods (Table 6). Although the first two use only small volumes of cassava, this represents a substantial share of all purchases of cassava starch and flour. Cassava has therefore already established itself as the dominant raw material in the market. Consequently, increases in demand for cassava in these industries will occur only as demand for the end-products expands. There is no scope for cassava to increase its market share.

However, the situation is different in the bakery sector. The 4,000 t of cassava starch and flour used constitute only 3.5% of the total flour and starch used by bakeries. Further work is needed to identify the types of bakery products in which cassava is being incorporated and the quality specifications required. This information should also serve to develop strategies for increasing the market share of cassava in this sector. The 4000 t used in bakery products in 1990 consisted entirely of starch. Since then, a commercially successful cassava flour industry has been established, and flour is being used in some cake and other products, substituting for wheat flour (Damardjati et al. 1996).

The market share of cassava in Indonesia is likely to expand during the coming years as flour, as a product, becomes established and as quality control and supply are improved. The sheer size of this sector (more than 100,000 t of imported wheat flour used in 1990) represents a promising market for cassava.

Cassava chips already have a dominant role as an energy source for animal feed products (both balanced feeds and concentrates) in Indonesia. The growth in demand for animal feeds will continue to increase the demand for chips. Relative prices in national and export markets will determine if this is filled more by increased *gaplek* production or reductions in export volumes over time.

In non-food industries, relatively low volumes of flours and starches are used; nevertheless, interesting market opportunities exist. Cassava starch already dominates these non-food industries as a source of carbohydrates, providing nearly 100% of total needs in the paper, textile, and cardboard box sectors. The opportunity exists, however, to expand demand in one sector: the production of plywood. Here, only 3000 t of cassava starch was used in 1990, less than 2% of total needs (Table 6). The bulk of flour requirements were met with the purchase of 145,000 t of imported 'industrial' flour, which may be substandard wheat flour. Market development here could entail production of an intermediate-quality cassava flour, in which such aspects as colour and purity were carefully controlled, but others such as microbial counts could be less rigorously enforced.

Data on the growth of cassava use in these and other industrial sectors in Indonesia from 1973-1990, as well as on employment generation and value, added as a function of input costs, provide some provocative indicators (Table 7). For example, while all industrial sectors expanded (number of enterprises) by at least 300% from 1973-1990, the plywood industry has been especially dynamic. This sector increased from 5 to 135 enterprises during the last 2 decades. It also established itself as the second largest employer (after textiles) of all the industries in which cassava starch is used. Finally, the bakery sector clearly adds most value to raw material inputs (value added/input costs) with a value of more than 5.

Given this situation, future expansion of demand for cassava products through increased market penetration looks most promising in the bakery and plywood industries. Noodle production is also worth investigating. Demand in other sectors will increase in line with overall market expansion.

In Indonesia, cassava has clearly made the transition to an industrial raw material with multiple end-products, while still being produced and to a large extent primary processed by small farmers and enterprises, thereby providing significant social benefits.

Markets for Processed Potatoes in Asia and Latin America

FAO statistics estimate relatively minor quantities of potatoes are currently processed in developing countries (roughly 4 million tons), with little change in utilization patterns over the last 3 decades (Scott and Suárez 1992). These estimates are very misleading for two reasons: first, country-level utilization statistics in a variety of cases (see below) clearly indicate processing to be at least two to three times more important in absolute and percentage (of total production) terms than the FAO figures would suggest. Moreover, all indications are that the trend is definitely upward. Second, many countries import processed potato products that are not included in calculations concerning domestic potato output, but greatly increase the economic importance of processing for the countries in question.

The following case studies illustrate these observations:

Greater China. The People's Republic of China is not only home to the world's largest McDonald's restaurant, but also, with the break-up of the former Soviet Union, it has emerged as the largest potato producer in the world. Historically, farmers and processors have processed from 20% to 40% of China's potato production either into starch for making noodles or into animal feed (Gitomer 1996). With the economic reforms in the countryside and the rapid economic development in urban areas in the last 10 years, processing has shifted sharply towards making such products as potato chips (crisps) and flour noodles for domestic markets and for export.

Hong Kong, Singapore, and, to a lesser extent, **Taiwan** are major users of processed potato products. By the late 1980s, McDonald's alone operated 24 outlets in Hong Kong and 19 in Singapore (Scott 1988b). These locations have witnessed a steady increase in imports of processed potato products from the USA during the late 1980s (Scott 1994).

Colombia. FAO statistics suggest only 4% to 5% of output goes to processing. But a recent survey of the processing sector showed roughly 15% of annual production (i.e., more than 300,000 t and increasing) goes to processing in the form of chips (crisps), French fries, and precooked potatoes (Rodríguez and Rodríguez 1992).

Guatemala, Costa Rica, and Panama. These countries have a rapidly expanding fast-food industry with both national and multinational firms competing aggressively for an expanded market share. In Guatemala, one locally owned fast-food chain with 27 domestic outlets (and three in the neighbouring countries of Honduras and El Salvador) uses more than 100 t of fresh potatoes per week for French fries and hash browns. In Panama, one local agribusiness processes about 150 t of potatoes per month into precooked and frozen products. In Costa Rica, currently more than 10% of yearly production (55,000 t) goes to processing for use by the fast-food industry, with some outlets being forced to purchase potatoes retail to meet opening-day supply requirements (Scott et al. 1992).

Thailand. From 20% to 25% of domestic potato production goes to processing (Konjing et al. 1989). About 10 years ago, Thailand had only two McDonald's outlets; now, more than 20 operate in the country (McDonald's Corporation 1993).

Indonesia. The FAO Food Balance Sheets suggest that the amount of processing of domestically produced potatoes is insignificant (Bottema et al. 1989). Siregar (1989) estimates that 6% of potato production in Java (i.e., 12,000 t/y) goes to the processing industry. But, at the same time, imports of processed potato products have risen from 38 t with a value of US$85,000 in 1981 to more than 1700 t with a value of US$1.4 million in 1989 (Bottema et al. 1991). These imports go to supply the local snack and fast-food industry, as well as supermarket chains.

India. India currently processes only about 50,000 t of potatoes (Verma 1991). However, recent changes in economic policy have led to multinational investments by the processing industry (e.g., Pepsi, McDonald's), with others certain to follow. The size of the Indian market currently more than 850 million consumers and the growing presence of a young, educated, and more affluent middle class suggest strong growth prospects (Dahiya and Sharma 1994).

These cases all share certain common explanatory factors:

(1) Mushrooming urban populations with, even if minimally, a growing middle class of higher income consumers.

(2) A desire by local consumers to diversify their diets away from strictly cereal staples for reasons of gastronomic appeal, status, and variety.

(3) Growing female participation in the urban work force, thus, less time is available for preparing food at home; hence, the appeal of precooked, processed potatoes.

(4) A shift in working hours to a more westernized lunch hour schedule; hence, fast foods are imperative if thousands of consumers are to be served within a short period of time.

(5) Demonstration effect through motion pictures, television, and travel or education abroad by developing country nationals who subsequently acquire a taste for potatoes.

(6) Tourism bringing millions of foreigners (who bring their eating habits) to developing countries every year.

Potential Markets: Sweet Potatoes in Sichuan Province, China

Sichuan is the largest sweet potato-producing province in China, producing more than 20 million tons in 1993. Like the rest of China, Sichuan is undergoing extremely rapid industrial development, with consequent changes in incomes and income distribution, the balance in economic growth in the countryside versus in the cities, and in food habits. Sweet potatoes have traditionally been a famine reserve crop in China, but increasing rice production has reduced direct human consumption of sweet potatoes to less than 20% of total production

(Table 4). Currently, the roots are mostly used as the main feed component for raising pigs on small farms. In fact, more than 85% of pigs are, at present, produced in tiny, almost backyard, systems (Scott et al. 1993a).

The last 20 years have seen the nation but particularly Sichuan Province shift the use of sweet potato roots from fresh food to pig feed, with some starch extraction to diversify use (Scott and Suárez 1992). In Sichuan Province, sweet potatoes form the basic energy source for pig feed during 5-7 months of the year, coinciding with peak production times before the spring festival. Also at this time, 15%-25% of sweet potato production is used for starch extraction, with wet starch used directly to produce noodles (Timmins et al. 1992). Waste from starch processing is a useful pig feed. Starch extraction is currently carried out by households or village enterprises (Wiersema 1992).

What can be expected for the future? Income growth in China is fuelling a rapid increase in demand for meats, but for chicken and fish (Simpson et al. 1994). Pig production is expected to increase only modestly (less than 10%), to about 385 million head in 2010, according to the World Bank specialists. This apparent stagnation in the pig sector hides a projected, dramatic shift in pig production systems. By 2025, World Bank specialists believe that only 25% of all pigs will be raised in small-scale systems. According to this scenario, the remainder will be produced by large commercial enterprises, using commercially produced compound feeds. Compound feeds in Sichuan do not, at present, contain sweet potatoes as an energy source. This suggests a rapid decline in demand for sweet potatoes for animal feed may occur, as compound feeds replace on-farm feed production.

Field-level data on prices, pig performance, and other input costs gathered in Sichuan in March 1994 demonstrate clearly, however, that sweet potatoes have an important role to play in swine production until well into the future. Moreover, when these figures were used to model the efficiency and profitability of different feeding systems, they showed that the more effective use of sweet potato roots can actually assist in developing the on-farm pig production sector so it can compete with the large-scale, compound-feed users (Table 8).

Current sweet potato-based systems suffer from a lack of protein, vitamins, and minerals in the diet, resulting in poor performance of pigs and, consequently, slow growth, low profitability, and few pigs per year on each farm. The use of compound feeds greatly increases efficiency turnover of pigs on the farm. Overall, however, profitability does not increase much because of the high costs of compound feeds in Sichuan, which, itself, produces insufficient maize (used to supply feed energy in commercial rations) and protein sources.

If protein, mineral, and vitamin supplements to sweet potato-based feeds are used, then efficiency and profitability increase dramatically (Table 8). Thus, with correctly formulated dietary supplements, sweet potatoes can help small-scale pig farmers to remain competitive for the future and offer the potential for significant value-added income from crop production. Product innovation would come, not so much from processing roots, but from developing appropriate supplements to add to the fresh roots (or from starch-processing waste).

The Sichuan climate is too cold to permit cassava production, and maize production is consistently inadequate for food and feed needs. Sweet potato starch is therefore highly cost competitive with other starch sources in the region. Table 9 gives starch and flour prices in Suining, a major sweet potato-producing area of Sichuan, and for Chengdu, the provincial capital. Sweet potato starch is cheaper than maize starch in Suining, but more expensive in Chengdu. However, information from the latter market in 1992 suggests that, at times, sweet potato starch prices in Chengdu are lower than those for maize starch.

The potential therefore exists for sweet potato starch to occupy the diversified range of uses that cassava starch has developed in Indonesia, especially if industries are established close to rural production areas. Indeed, starch is currently being used by industries other than that for noodles, although detailed information similar to the statistics for Indonesia are simply not yet available (Li *et al.* 1992; Wiersema 1992).

Sweet potato noodles are a traditional product of Sichuan, with high consumption during the spring festival. They are manufactured by numerous household enterprises and marketed locally, as well as in the major urban centres of the province. Traditional technology is entirely manual. It involves pounding the dough through a saucepan with holes to obtain the noodles, which are then passed quickly through boiling and cold water to partially gelatinize the starch.

This labour-intensive process is being replaced by a simple, extruder-based technology, developed through collaborative research between the Sichuan Academy of Agricultural Sciences (SAAS) and the Centro Internacional de la Papa (CIP). A single-screw extruder, with a water jacket to maintain temperatures close to 100 ^{o}C, is used to force dough through a die plate to give noodles of various cross-sectional widths. After initial teething troubles, these extruders are now commercially successful, with several companies producing and selling them locally. Some are even shipped for sale to other provinces in China. One enterprise sold more than 100 machines between January and October 1993 at a cost of about US$500 each.

The use of an extruder reduces variable costs and labour. But it also generates some quality changes in the final product, because the starch is gelatinized to a greater extent than if the manual method were used. How these quality alterations relate to consumer acceptability is the focus of current research. Continued research to improve technologies and develop new markets is essential if the full potential of this versatile crop is to be realized.

Potential Markets for Root Flours

For many tropical countries, the use of root flours to substitute for imported wheat flour has a long history of research effort, with significant investment into laboratory-scale production of composite breads and other bakery products. Some countries even established laws ordering the use of cassava flour in bread (Brazil and Paraguay), although without success. Root crops could not compete with imported, often subsidized, wheat, nor with the national wheat-flour lobbies. The supply of other flours was erratic and quality, dubious. All schemes foundered, especially those focusing on large-scale flour production near major urban markets. Recently, different approaches have been tried in several countries. These include small-scale cassava flour production for food uses and the use of raw, grated sweet potatoes, as well as sweet potato flour in baked goods.

In Colombia, Indonesia, Peru, and Vietnam, for example, cassava projects are in different stages of execution with mixed, but promising results. One overall conclusion is that, under current conditions, root flours can compete successfully with wheat flour in local markets close to production regions.

A prime example of this is Peru, where a highly successful project has established a cassava flour plant in Pucallpa, in the Amazon Basin. Cassava is produced locally, but imported wheat has to be trucked over the Andes from coastal ports. Previous internal subsidies, which resulted in a standard national wheat price, meant that the true cost of the wheat flour was not reflected in market prices in isolated places like Pucallpa. With recent economic reform and the reduction of internal subsidies, economic logic now favours the use of cassava flour in this region (Salas Domínguez *et al.* 1996).

Similar situations may occur in North-East Brazil, many Indonesian and Philippine islands, inland parts of South-East China, and some land-locked countries of sub-Saharan Africa. As subsidies are reduced and international market prices allowed to operate with fewer distortions, cassava products such as flour and starch should find expanding markets.

A similar scenario should apply to sweet potatoes. The geographic location of the emerging market niches will depend on the intensity of local sweet potato production and the relative price of flours in those areas. The following caveat, however, will apply: sweet potatoes have only recently been the focus of concerted, international efforts to improve yields and thereby reduce unit production costs. Hence, the prospects of dramatic improvements in competitiveness in the years ahead may well be greater for this root crop than for those others that have already experienced the impact of yield-increasing technology resulting from decades of breeding and adaptation research.

Product Diversification for Root Crops and the Environment

Developing countries are placing increasing emphasis on sustainable crop production, within the context of mushrooming demographic pressures on the environment, land degradation, and climatic changes. Both sweet potatoes and cassava are low-input crops that can yield well under marginal agro-climatic conditions. Sweet potatoes, potatoes, and cassava have specific characteristics that can enhance soil conservation, erosion control, and use of marginal land. For example, sweet potatoes are often planted in parts of Asia, East Africa (Ewell and Kirkby 1991), and Latin America as a cheap, nutritious means of rapid ground cover. In West Africa, sweet potatoes are frequently grown before rice to avoid exhausting soil nutrients (Gura 1991). Cassava has the ability to produce well in semi-arid conditions that are marginal for most other crops.

Potatoes, however, currently require relatively high levels of inputs (although these may also benefit succeeding crops), including pesticides. These costs are compensated for by the high value of the output. However, a focus on biological control of potato pests and diseases is an important element of current potato research and development in many developing countries (CIP 1992).

Development of new markets for root and tuber crops will act to strengthen demand for them. This could have the following implications for environmental and sustainable agriculture:

(1) Improved demand for the crop, reflected in better and/or more stable prices, means fewer risks for farmers when cultivating that crop. Such farmers become more interested in investing in new technologies to sustain crop production. That is, they have an incentive to practice better husbandry of natural resources, which now become seen as a source of long-term income. Research in Colombia confirmed that farmers are more interested in adopting new technologies when access to new markets is developed (Henry 1992).

(2) Market development stimulates the use of crop waste and by-products from processing (e.g., starch waste for feed), thus reducing environmental pollution while constituting new income sources for small-scale farmers and processors. Post-harvest losses of fresh roots are also reduced.

(3) Development of efficient, small-scale, rural processing enterprises, capable of being managed and operated by households or cooperative-based units, offers greatly enhanced potential for income generation from activities that do not increase pressure on land resources. That is, a smaller share of rural income will be derived from primary crop production, and a larger share from processing and marketing of products with added value. Increasing incomes of smallholders from crops without increasing production is a big step toward achieving sustainable land use.

    Long-distance transport of perishable root crops is often uneconomical. Consequently, large-scale processing plants may be at a disadvantage, compared with smaller enterprises who use local supplies of raw materials. Here, economic rational and environmental benefits coincide. Small-scale community-level processing for local markets, with positive environmental spin-offs is an exciting opportunity for community development. The lower efficiency of small-scale operations can be offset by lower raw material costs and higher quality (freshness), as well as lower marketing costs. The differences between small- and large-scale processing operations are summarized in Table 10.

(4) Diversification of end-products will probably require raw material with different quality attributes. Ensuring stability of raw material supply across seasons will require either storage (which may be costly) or varieties with different maturity dates and/or optimal climatic tolerances. The combination of these two factors will work towards increasing farmer interest in new varieties and in conserving and using existing germ plasm. Conservation of biodiversity will thereby be enhanced. Alternatively, it may be increasingly difficult to maintain farmer interest in conserving varieties for crops that are declining in importance even in centres of genetic diversity.

In summary, for many reasons and in a variety of ways, root and tuber crops offer a means by which economic development that is sensitive to the environment can be achieved in certain tropical and subtropical regions.

Conclusions

Root and tuber crops will play an increasingly important role in global markets in the 21st century. These include both national and international markets for a variety of finished products and inputs for industry. As the use of roots and tubers expands and diversifies for food, feed, and manufacture in response to these commercial opportunities, rural welfare and environmental benefits will result. For roots and tubers to realize their full potential, however, a number of specific points based on the foregoing analysis of emerging market developments should be considered. These observations should provide useful food for thought in deliberations on the direction and emphasis of future commodity research.

(1) Continuity of supply, consistent good quality, and price competitiveness are needed if root and tuber crops and their primary processed products are to become more important raw materials for food and feed industries.

(2) Small- and medium-scale enterprises do have some advantages over large-scale enterprises in terms of raw material supply and quality, local marketing links, and their potential to generate significant income for rural populations. Research to improve efficiency and quality of small-scale processing is highly relevant if these enterprises are to capitalize on their existing advantages.

(3) Root products such as flour and starch will be most competitive close to their loci of

major production, especially where marketing costs for imported (cereal-based) flours and starches make them expensive and/or scarce. Such locations are ideal for the pilot production of new processed products, focusing first on local markets. Examples are cassava flour in the Pucallpa region of Peru and sweet potato starch in Sichuan Province, China.

(4) Efficient and profitable use of farm-produced fresh roots and tubers as feed by small-scale livestock producers (e.g., sweet potatoes in China) can be developed by applying appropriate nutrient supplements.

(5) Development of small-scale processing enterprises for roots and tubers is compatible with and even enhances the rural environment. Added value through small-scale processing reduces the pressure for income generation from crop production and provides incentive for farmers to conserve natural resources.

This paper has provided a necessarily concise review of many trends and current root and tuber projects and enterprises with the hope of identifying some priorities for R&D activities in the coming years. The enormous potential of these crops is closer to being realized now than at any time in the past.

References

To save space, the following acronym is used:

CIP — Centro Internacional de la Papa
(*International Potato Center*)

Abbott JC. 1987. Agricultural marketing enterprises for the developing world. Cambridge University Press, Cambridge, UK.

Berrios D; Beavogui M. 1992. Trials for the introduction of sweet potato in bread making in Burundi. In: Scott G; Ferguson PI; Herrera JE, eds. Product development for root and tuber crops, vol. III, Africa. Proc. Workshop on Processing, Marketing and Utilisation of Root and Tuber Crops in Africa; 26 Oct-2 Nov 1991 at the International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria. CIP, Lima, Peru. p 373-376.

Bogunjoko JST. 1992. Research and development into commercial yam processing in Nigeria: Cadbury's Poundo yam. In: Scott G; Ferguson PI; Herrera JE, eds. Product development for root and tuber crops, vol. III, Africa. Proc. Workshop on Processing, Marketing and Utilisation of Root and Tuber Crops in Africa; 26 Oct-2 Nov 1991 at the International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria. CIP, Lima, Peru. p 471-473.

Bottema JW; Siregar H; Pasaibu SM; Gijsberg G; Basuki RS, eds. 1989. Potato in Indonesia: prospects for medium-altitude production. Coarse Grains, Pulses, Root and Tuber Crops Centre (CGPRT), Bogor, Indonesia.

Bottema T; Hadi PU; Ferrai MF. 1991. Potato in Indonesia: recent developments. In: Proc. Symposium on Developments in Potato Processing and Storage in Asia; June 17-18, Bandung, Indonesia. Asian Potato Association, Bandung, Indonesia.

Calpe CA. 1992. Roots, tubers and plantains; recent trends in production trade, and use. In: Machin D; Nyvold S, eds. Roots, tubers, plantains and bananas in animal feeding. Proc. FAO Expert Consultation; 21-25 Jan at CIAT, Cali, Colombia. CIAT, Cali, Colombia. p 11-25.

Cenpukdee U; Thiraporn C; Sinthuprama S. 1992. Cassava processing and utilisation in Thailand. In: Scott G; Wiersema S; Ferguson PI, eds. Product development for root and tuber crops, vol. I, Asia. Proc. International Workshop on Processing, Marketing and Utilisation of Root and Tuber Crops in Asia; 22 Apr-1 May 1991 at Visayas State College of Agriculture (ViSCA), Baybay, Leyte, Philippines. CIP, Lima, Peru. p 51-60.

CIP. 1992. Annual Report. Lima, Peru.

Dahiya PS; Sharma HC. 1994. Potato marketing in India: status, issues and outlook. Working Paper No. 1994-2. Social Science Department, CIP, Lima, Peru.

Damardjati DS; Widowati S; Bottema T; Henry G. 1996. Cassava flour processing and marketing in Indonesia. In: Dufour D; O'Brien GM; Best R, eds. Cassava flour and starch: progress in research and development. Proc. International Meeting on Cassava Flour and Starch; 11-15 Jan 1994 at CIAT, Cali, Colombia. p 89-104.

Ewell P; Kirkby R. 1991. Roots, tubers and beans in the food system of Eastern and South-Eastern Africa. In: Veelbehr E, ed. Dialogue and training for the promotion of roots, tubers and legumes in Africa. German Foundation for International Development (DSE), Feldafing, Germany.

FAO (Food and Agriculture Organization). 1994. Food Balance Sheets. Rome Italy.

Gitomer C. 1996. Potato and sweet potato production in China: systems, constraints, and potential. CIP, Lima, Peru.

Gura S. 1991. Sweet potato — no longer to be neglected. Entwicklung + Ländlicher Raum 1:20-23.

Henry G. 1992. Adoption, modification and impact of cassava drying technology: the case of the Colombian North Coast. In: Scott G; Ferguson PI; Herrera JE, eds. Product development for root and tuber crops, vol. III, Africa. Proc. Workshop on Processing, Marketing and Utilisation of Root and Tuber Crops in Africa; 26 Oct-2 Nov 1991 at the International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria. CIP, Lima, Peru. p 481-492.

Janssen WG; Wheatley CC. 1985. Urban cassava markets: the impact of fresh root storage. Food Policy 10:265-257.

Konjing C; Konjing K; Chaowakul M; Thongjiem M; Wiersema S. 1989. A study of marketing, consumption, and demand for potatoes and potato production. Department of Agriculture, Kasetsart University, and CIP, Bangkok, Thailand.

Li WG; Xiuquin W; Huiyi C; Rong D. 1992. Sweetpotato in China. In: Scott G; Wiersema S; Ferguson PI, eds.

Product development for root and tuber crops, vol. I, Asia. Proc. International Workshop on Processing, Marketing and Utilisation of Root and Tuber Crops in Asia; 22 Apr-1 May 1991 at Visayas State College of Agriculture (ViSCA), Baybay, Leyte, Philippines. CIP, Lima, Peru. p 41-50.

McDonald's Corporation. 1993. 1992 Annual Report. Oak Brook, IL.

MIN (Ministry of Industry). 1991. Annual survey of medium- and large-scale industry in Indonesia, 1990. Jakarta, Indonesia.

NRI (Natural Resources Institute). 1992. COSCA Phase I processing component. In: Scott G; Ferguson PI; Herrera JE, eds. Product development for root and tuber crops, vol. III, Africa. Proc. Workshop on Processing, Marketing and Utilisation of Root and Tuber Crops in Africa; 26 Oct-2 Nov 1991 at the International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria. CIP, Lima, Peru. p 165-192.

Nweke F. 1992. Traditional cassava processing in sub-Saharan Africa and research implications. In: Scott G; Ferguson PI; Herrera JE, eds. Product development for root and tuber crops, vol. III, Africa. Proc. Workshop on Processing, Marketing and Utilisation of Root and Tuber Crops in Africa; 26 Oct-2 Nov 1991 at the International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria. CIP, Lima, Peru. p 147-164.

Odaga A; Wanzie R. 1992. The use of sweet potato in bakery products in Cameroon. In: Scott G; Ferguson PI; Herrera JE, eds. Product development for root and tuber crops, vol. III, Africa. Proc. Workshop on Processing, Marketing and Utilisation of Root and Tuber Crops in Africa; 26 Oct-2 Nov 1991 at the International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria. CIP, Lima, Peru. p 377-384.

Ospina B; Wheatley CC. 1992. Processing of cassava tuber meals and chips. In: Machin D; Nyvold S, eds. Roots, tubers, plantains and bananas in animal feeding. Proc. FAO Expert Consultation; 21-25 Jan at CIAT, Cali, Colombia. CIAT, Cali, Colombia. p 41-65.

Rodríguez P; Rodríguez A. 1992. Algunos aspectos de la industrialización de la papa en Colombia. Rev Papa 5:4-7.

Salas Domínguez S; Guzmán Y; Aquino S. 1996. Producing cassava flour in Peru and Its Prospects for Development. In: Dufour D; O'Brien GM; Best R, eds. Cassava flour and starch: progress in research and development. Département des systèmes agroalimentaires et ruraux of the Centre de coopération internationale en recherche agronomique pour le développement (CIRAD-SAR) and CIAT, Cali, Colombia. p 25-29.

Scott G. 1988a. Marketing Bangladesh's potatoes: present patterns and future prospects. CIP and Australian Development Assistance Bureau (ADAB), Dhaka, Bangladesh.

Scott G. 1988b. Marketing Thailand's potatoes: present patterns and future prospects. CIP, Lima, Peru.

Scott G. 1994. The emerging world markets for potatoes and potato products with particular reference to developing countries. Econ Gestion Agro-Aliment 30:19-27.

Scott G; Suárez V. 1992. Transforming traditional food crops: product development for root and tuber crops. In: Scott G; Ferguson PI; Herrera JE, eds. Product development for root and tuber crops, vol. III, Africa. Proc. Workshop on Processing, Marketing and Utilisation of Root and Tuber Crops in Africa; 26 Oct-2 Nov 1991 at the International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria. CIP, Lima, Peru. p 3-23.

Scott G; Herrera JE; Espinola N; Daza M; Fonseca C; Fano H; Benavides M, eds. 1992. Desarrollo de productos de raíces y tubérculos, vol. II, América latina. Proc. International Workshop; 8-12 Apr 1991 at the Instituto de Ciencia y Tecnología Agrícolas (ICTA), Villa Nueva, Guatemala. CIP, Lima, Peru.

Scott G; Bo Fu S; Wei L. 1993a. Feed energy sources: sweet potatoes in China. Paper presented at the Feed Industry Development Project Research and Development Workshop (organized by the World Bank and the Ministry of Agriculture); 6-8 Dec at Beijing, China.

Scott G; Wong D; Alvarez M. 1993b. Improving village-level processing in developing countries: the case of potatoes. Ecol Food Nutr 30:145-163.

Simpson JR; Cheng X; Akira M. 1994. China's livestock and related agriculture: projections to 2025. CAB International, Wallingford, UK.

Siregar H. 1989. Imports and exports. In: Bottema JW; Siregar H; Pasaibu SM; Gijsberg G; Basuki RS, eds. Potato in Indonesia: prospects for medium-altitude production. Coarse Grains, Pulses, Root and Tuber Crops (CGPRT), Bogor, Indonesia.

Timmins WH; Marter AD; Westby A; Rickard JE. 1992. Aspects of sweet potato processing in Sichuan Province, People's Republic of China. In: Scott G; Ferguson PI; Herrera JE, eds. Product development for root and tuber crops, vol. III, Africa. Proc. Workshop on Processing, Marketing and Utilisation of Root and Tuber Crops in Africa; 26 Oct-2 Nov 1991 at the International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria. CIP, Lima, Peru. p 217-228.

Verma SC. 1991. Indian potato varieties can meet the requirements of the processing industry. In: Proc. Symposium on Developments in Potato Processing and Storage in Asia; June 17-18, Bandung, Indonesia. Asian Potato Association, Bandung, Indonesia.

Wheatley CC; Best R. 1991. How can traditional forms of nutrition be maintained in urban centers; the case of cassava. Entwicklung + Ländlicher Raum 1:13-16.

Wiersema S. 1992. Sweet potato processing in the People's Republic of China with emphasis on starch and noodles. In: Scott G; Wiersema S; Ferguson PI, eds. Product development for root and tuber crops, vol. I, Asia. Proc. International Workshop on Processing, Marketing and Utilisation of Root and Tuber Crops in Asia; 22 Apr-1 May 1991 at Visayas State College of Agriculture (ViSCA), Baybay, Leyte, Philippines. CIP, Lima, Peru. p 211-216.

Table 1. Potato production, area, and yield in developing countries by regions, 1961-1990.

Region	1988-1990			Change (%)[a]								
	Production (000 t)	Area (000 ha)	Yield (t/ha)	Production			Area			Yield		
				1	2	3	1	2	3	1	2	3
Africa[b]	6,116	650	9.4	75.0	91.1	254.3	86.7	48.0	176.4	-6.3	29.1	21.0
Sub-Saharan Africa[c]	2,282	381	6.0	70.3	40.8	139.9	83.3	31.4	140.9	-7.1	7.2	-0.4
Asia[d]	60,073	4,695	12.8	89.7	58.3	200.4	39.9	46.0	104.3	35.6	8.4	47.0
China	31,597	2,801	11.3	99.9	22.5	144.8	41.9	37.6	95.3	40.8	-11.0	25.4
Latin America[e]	12,877	1,018	12.7	29.2	38.8	79.3	1.4	-1.7	-0.3	27.4	41.2	79.9
Total	79,066	6,363	12.4	73.8	56.8	172.5	31.9	35.7	79.0	31.7	15.6	52.3

a. 1 = 1973-1975 versus 1961-1963; 2 = 1988-1990 versus 1973-1975; 3 = 1988-1990 versus 1961-1963.
b. Not including South Africa.
c. Not including Morocco, Algeria, Tunisia, Egypt, Libya, or South Africa.
d. Not including Israel or Japan, but including Oceania, except for Australia and New Zealand, and China.
e. Not including Canada or USA. Latin America is the centre of origin for the crop.

SOURCE: FAO Basic Data Unit, unpublished statistics.

Table 2. Sweet potato production, area, and yield in developing countries by regions, 1961-1990.

Region	1988-1990			Change (%)[a]								
	Production(000 t)	Area (000 ha)	Yield (t/ha)	Production			Area			Yield		
				1	2	3	1	2	3	1	2	3
Africa[b]	6,492	1,315	4.9	44.5	29.7	87.4	73.0	18.3	104.6	-16.4	9.6	-8.4
Sub-Saharan Africa[c]	6.401	1,311	4.9	46.1	29.5	89.3	73.6	18.3	105.4	-15.8	9.5	-7.9
Asia[d]	113,380	7,453	15.2	53.7	-15.4	30.1	-8.9	-29.5	-35.7	68.6	20.0	102.4
China	104,824	6,304	16.6	58.0	-15.7	33.2	-10.5	-31.8	-39.0	76.5	23.7	118.3
Latin America[e]	2,185	295	7.4	14.5	-31.6	-21.6	12.5	-23.2	-13.6	1.8	-11.0	9.3
Total	122,057	9,063	13.5	52.2	-14.1	30.6	-4.1	-24.9	-28.0	58.7	14.3	81.4

a. 1 = 1973-1975 versus 1961-1963; 2 = 1988-1990 versus 1973-1975; 3 = 1988-1990 versus 1961-1963.
b. Not including South Africa.
c. Not including Morocco, Algeria, Tunisia, Egypt, Libya, or South Africa.
d. Not including Israel or Japan, and including Oceania, except for Australia and New Zealand, and China.
e. Not including Canada or USA. Latin America is the centre of origin for the crop.

SOURCE: FAO Basic Data Unit, unpublished statistics.

Table 3. Cassava production, area, and yield in developing countries by regions, 1961-1990.

Region	1988-1990			Change (%)[a]								
	Production (000 t)	Area (000 ha)	Yield (t/ha)	Production			Area			Yield		
				1	2	3	1	2	3	1	2	3
Africa[b]	63,344	8,440	7.7	35.5	49.6	102.3	25.3	18.4	48.3	7.9	26.4	36.4
Sub-Saharan Africa[c]	65,344	8,440	7.7	35.2	49.6	102.3	25.3	18.4	48.3	7.9	26.4	36.4
Asia[d]	52,836	4,013	13.2	61.4	74.7	181.8	27.0	36.5	73.4	27.1	27.9	62.6
China	3,271	230	14.2	99.1	38.5	175.9	93.4	18.2	128.5	3.0	17.3	20.7
Latin America[e]	31,013	2,621	11.8	33.4	-2.1	30.6	39.1	-3.7	33.9	-4.1	1.7	-2.5
Total	149,193	15,074	9.9	41.2	41.3	99.5	28.4	17.8	51.3	9.9	19.9	31.8

a. 1 = 1973-1975 versus 1961-1963; 2 = 1988-1990 versus 1973-1975; 3 = 1988-1990 versus 1961-1963.
b. Not including South Africa.
c. Not including Morocco, Algeria, Tunisia, Egypt, Libya, or South Africa.
d. Not including Israel or Japan, but including Oceania, except for Australia and New Zealand, and China.
e. Not including Canada or USA. Latin America is the centre of origin for the crop.

SOURCE: FAO Basic Data Unit, unpublished statistics.

Table 4. Sweet potato utilization (%) in China, 1990.

Use	China	Sichuan Province	Suining County, Sichuan
Fresh food	15	22	8
Animal feed	28	42	50
Processed products (starch, chips, etc.)[a]	45	17	15
Planting material	12	11	12
Waste	-[b]	8	15

a. The “processed” category for China covers starch and derivatives, and dried chips and meal; for Sichuan Province, starch (the climate is not suitable for natural drying); and for other provinces, dried chips for animal feed.
b. Not known.

SOURCES: Sichuan Academy of Agricultural Sciences and Suining County Government Statistics. Unpublished reports.

Table 5. Summarized survey information of raw material (t) used by large- and medium-scale industries, Indonesia, 1990.

Commodity and products	Primary processing raw material	Primary processed products	Food industry raw materials	Feed industry raw materials	Other industry raw materials	Total industrial use of raw materials
Cassava						
Fresh roots	968,055	0	6,559	0	0	6,559
Starch	1,599	252,178	96,310	2,251	30,977	129,538
Chips	146,199	122,383	0	761,995	0	761,995
Flour	0	4,621	6,154	2,037	0	8,291
Starch waste	20,094	31,959	0	57,400	0	57,400
Wheat						
Grain	1,714,339	0	0	0	0	0
Flour	0	1,285,756	218,579	23,824	19,892	262,295
Rice						
Grain	610,963	382,917	46,062	4,354	0	50,416
Flour	0	11,767	561	0	0	561
Maize						
Grain	150,219	130,834	7,870	404,756	0	412,626
Starch and/or flour	0	1,100	321	0	0	321
Potatoes						
Fresh	0	0	57	0	0	57
Starch and/or flour	0	0	84	615	0	699
Sweet potatoes (fresh)	0	0	2,282	0	0	2,282
Green beans	0	0	802	0	0	802
Sago flour	0	2,206	3,764	0	0	3,764

Industrial flour (unspecified)	0	0	0	0	147,139	147,139

SOURCE: MIN 1991.

Table 6. Use of cassava (as starch, chips, or flour) in different industrial categories in Indonesia, 1990.

Product	Cassava (all forms) (t)	Percentage of total starch, flour, and grain use	Competing raw material
Food			
Noodles	40,500	9.2	Rice
Bakery goods and bread	4,500	3.5	Wheat
Liquid glucose	1,000	100.0	
Candy	6,000	65.0	Wheat
***Krupuk* crackers**	41,000	95.0	
Animal feed	922,000	68.0	Maize
Industry			
Textiles and yarn	9,000	99.0	
Plywood	3,000	1.8	Industrial flour
Paper	16,500	100.0	
Cardboard boxes	1,200	98.0	

SOURCE: MIN 1991.

Table 7. Cassava as raw material in Indonesian industry, 1990.

Industrial category	Enterprises (no.)		People Employed 1990 (no.)	Value added/ Input cost 1990
	1973	1990		
Noodles	98	313	16,439	0.368
Bakery goods and bread	75	331	23,931	5.053
Liquid glucose and syrups	8	26	1,800	0.716/0.879
Candy	34	100	10,393	0.305
Krupuk	78	417	15,253	0.443
Animal feed	10	78	9,858	0.395/0.874
Textiles and yarn	328	1,073	305,549	0.212/0.734
Plywood	5	135	175,875	0.512
Paper	27	87	28,408	0.247/0.536
Cardboard boxes	10	59	7,781	0.257

SOURCE: MIN 1991.

Table 8. Annual farm and pig productivity under different feeding systems in Suining County, China, 1994[a].

Cost item	Feeding system			
	On-farm feeds only	**On-farm feeds + additives**	**On-farm feeds + concentrates**	**Compound feeds only**
Sweet potatoes (kg)	2000	2000	2000	0
Maize (kg)	200	200	200	0
Other on-farm feeds (kg)	1000	1000	1000	0
Additives (kg)	0	51.2	0	0
Concentrates (kg)	0	0	205.0	0
Compound feeds (kg)	0	0	0	436
Investment in feeds ˜()	0	230.30	409.60	409.60
Total liveweight produced (kg)	128	194	267	108
Number of pigs reared	1.60	2.43	3.94	1.35
Mean time to slaughter (days)	278	182	125	100
Income from pig production ˜()	576.00	874.13	1,202.18	487.41
Income from feed sales ˜()	0.00	0.00	0.00	490.00
Total income from feed crops and livestock ˜()	576.00	874.13	1,202.18	977.41
Total feed costs ˜()	490.00	720.30	899.60	899.60
Weaning costs ˜()	72.00	109.27	150.27	60.93
Total revenue over input costs ˜()	14.00	44.57	152.30	16.89
Profit per pig ˜()	8.75	18.35	45.61	12.47

a. Using prices and other data collected in Sichuan Province during March 1994. Exchange rate: ˜8.7 = US$1.00.

SOURCE: P. Thorne and C. C. Wheatley, 1994, unpublished data.

Table 9. Wholesale market prices ˜(/kg) of starch and flours available in Chengdu and Suining, Sichuan Province, China, December 1993 and March 1994.

Product	Chengdu (Dec 1993)	Suining (Mar 1994)
Sweet potato starch	2.3	1.7
Maize starch	1.8	2.1
Bean starch	-	2.2
Pea starch	3.6	-
Rice flour	-	2.5

Table 10. Synthesis of differences between small- and large-scale cassava-processing operations.

Processing component	Scale of processing	
	Small	Large
Raw material costs	Low	Low
Processing costs		
Investment	Low	High
Variable	Low	Moderate
Processing efficiency	Acceptable	High
Marketing costs		
Local	Low	High
Major urban	High	Low
Quality control	Difficult	Straightforward
Waste use and/or treatment	None	Expensive

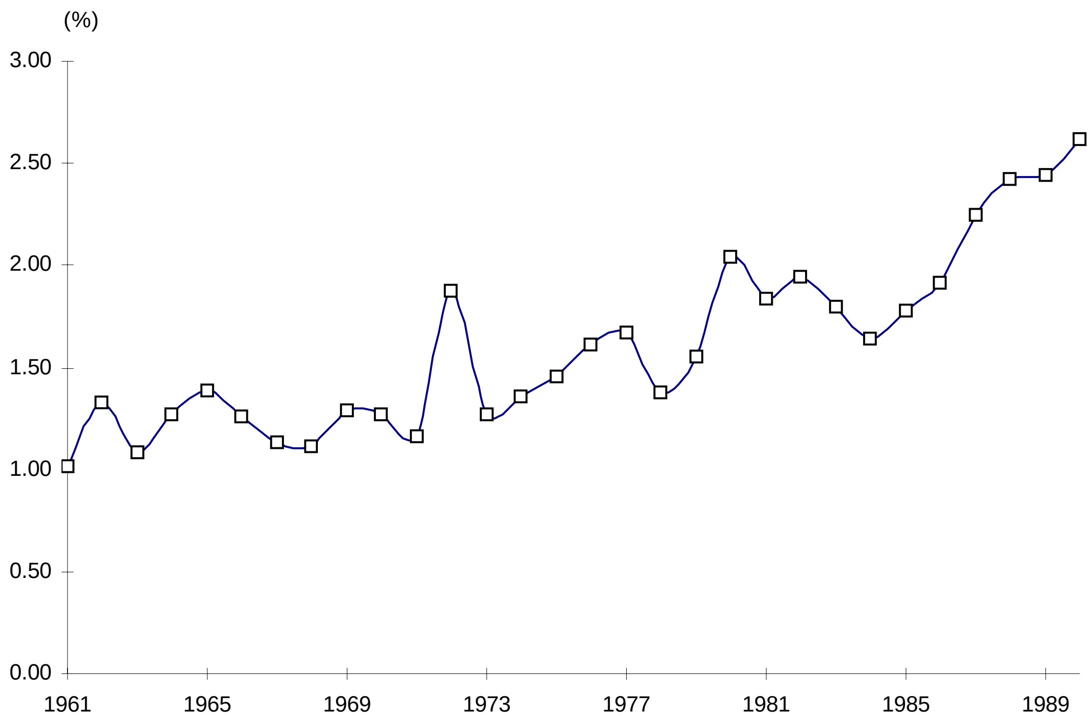

Figure 1. World potato exports as percentages of global production, 1961-1990 (taken from FAO Basic Data Unit, unpublished statistics).