

**CASSAVA IN ASIA: RESEARCH AND DEVELOPMENT TO INCREASE ITS
POTENTIAL USE IN FOOD, FEED AND INDUSTRY
- A THAI EXAMPLE¹**

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ABSTRACT

This paper reviews cassava in Asia with emphasis on Thailand, culminating in a definition of the research areas that will contribute effectively to development goals in the region. The first section outlines regional trends in production, trade and utilization, drawing comparisons to global trends. A basic tenet of the paper is that the competitive marketplace – at local, regional and international levels – is rapidly changing cassava's roles in development. Hence, in the second section the discussion is placed in the context of the external social, economic and political environments that impact the cassava sector. The third section then indicates specific constraints and opportunities in the cassava system. Finally, we outline the role of key research areas for the cassava systems of Asia.

Introduction

Cassava (*Manihot esculenta* Crantz) has its origin in Latin America, where it has been grown as a staple food by the native Indian population for at least 4000 years. After the discovery of the Americas, the crop was introduced by European traders into Africa as a potentially useful food crop; later it was also taken to Asia to be grown as a food security crop and for the extraction of starch. Thus, in the 19th Century cassava became an important food and industrial crop in southern India, Malaysia, Indonesia and the Philippines. After the second World War it also became an important industrial crop in Thailand, while in southern China and Vietnam it was initially used as a food crop but has become more recently an important crop for animal (mainly pig) feeding and for processing into various industrial products such as native starch, modified starch, MSG, sweeteners and alcohol.

1. Cassava Production Trends

Figure 1 shows the cassava production areas in the world, while **Figures 2** and **3** show in more detail the distribution of cassava in Asia and in Thailand respectively. **Figure 1** and **Table 1** indicate that in 1998 about 56% of cassava was produced in Africa, 27% in Asia, and only 17% in Latin America. During the past decade cassava production in Asia grew at an average annual rate of 1.35%, while in Asia and Latin America it decreased at a rate of 0.82 and 0.64%, respectively.

Figure 2 and **Table 2** show that within Asia most cassava is produced in Thailand, followed by Indonesia, India, China, Vietnam and the Philippines. Yields are by far the highest in India, with an average yield of 24.0 t/ha, compared with 16.3 t/ha in Thailand and 14.4 t/ha for Asia as a whole.

¹ This paper is a modified version of the paper by C.H. Hershey and R.H. Howeler (2001), which in turn is based on Hershey *et al.* (2000).

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Figure 2. Cassava production zones in Asia in 1999. Each dot represents 10,000 ha of cassava.

To a large degree, Thailand has defined the variations in total annual output for Asia over the past 30 years. Other countries have made relatively modest contributions to the fluctuations in aggregate production (**Figures 4 and 5**). In Thailand, cassava area and production increased markedly during the 1970s and early 80s, reaching a peak in 1989, after which both declined (**Figure 6**). The reduction in area is not being offset fully by yield increases, as the crop has been pushed towards more marginal land in the Northeast. It appears that this trend may have reversed over the past few years with widespread adoption of new varieties and improved production practices.

Table 1. Cassava production in the world, in the continents and in various countries in Asia in 1998.

	Cassava production (‘000 t)	Annual rate of growth 1990-98 (%)
World	162,327	+0.34
<i>-Africa</i>	<i>90,109</i>	<i>+1.35</i>
<i>-Latin America and Caribbean</i>	<i>27,619</i>	<i>-0.82</i>
<i>-Asia</i>	<i>44,416</i>	<i>-0.64</i>
-China	3,651	+0.69
-India	6,000	+1.03
-Indonesia	14,728	-0.39
-Malaysia	400	-0.13
-Philippines	1,787	-0.20
-Thailand	15,591	-1.54
-Vietnam	1,783	-1.32

Table 2. Area, yield and production of cassava in Asia, 2000.

Country	Area (ha)	Yield (t/ha)	Production (tonnes)
ASIA	3,351,119	14.4	48,163,007
Brunei	135	11.9	1,600
Cambodia	7,000	9.6	67,500
China	235,045	16.0	3,750,658
India	250,000	24.0	6,000,000
Indonesia	1,205,330	12.8	15,421,885
Laos	5,200	13.7	71,000
Malaysia ^a	39,000	10.3	400,000
Maldives	9	4.7	42
Myanmar	7,736	11.4	88,144
Philippines	210,000	8.5	1,786,710
Sri Lanka	29,470	8.8	260,000
Thailand	1,135,394	16.3	18,508,568
Vietnam	226,800	8.0	1,806,900

^aAccording to Dr Tan Swee Lian, MARDI, FAO data for Malaysia are highly inaccurate. National figures show that current area is on the order of 7000 ha, with average yields of about 20 t/ha.

Source: FAOSTAT, 2001.

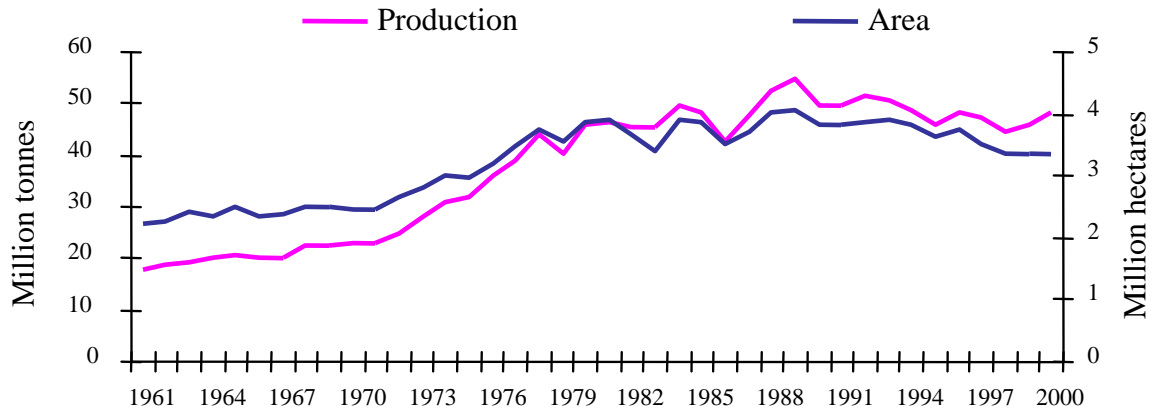


Figure 4. Aggregate area and production of cassava in Asia, 1961-2000
 Source: FAOSTAT, 2001.

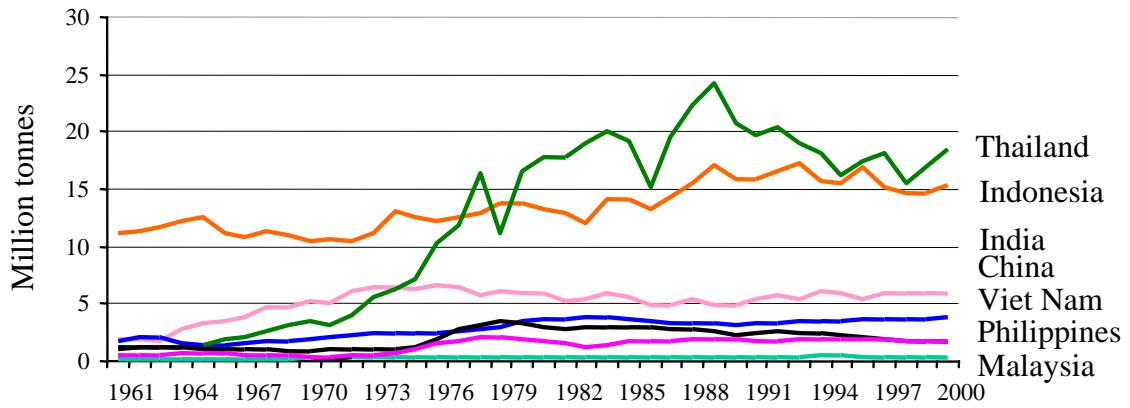


Figure 5. Cassava production trends in Asia's principal producing countries.
 Source: FAOSTAT, 2001.

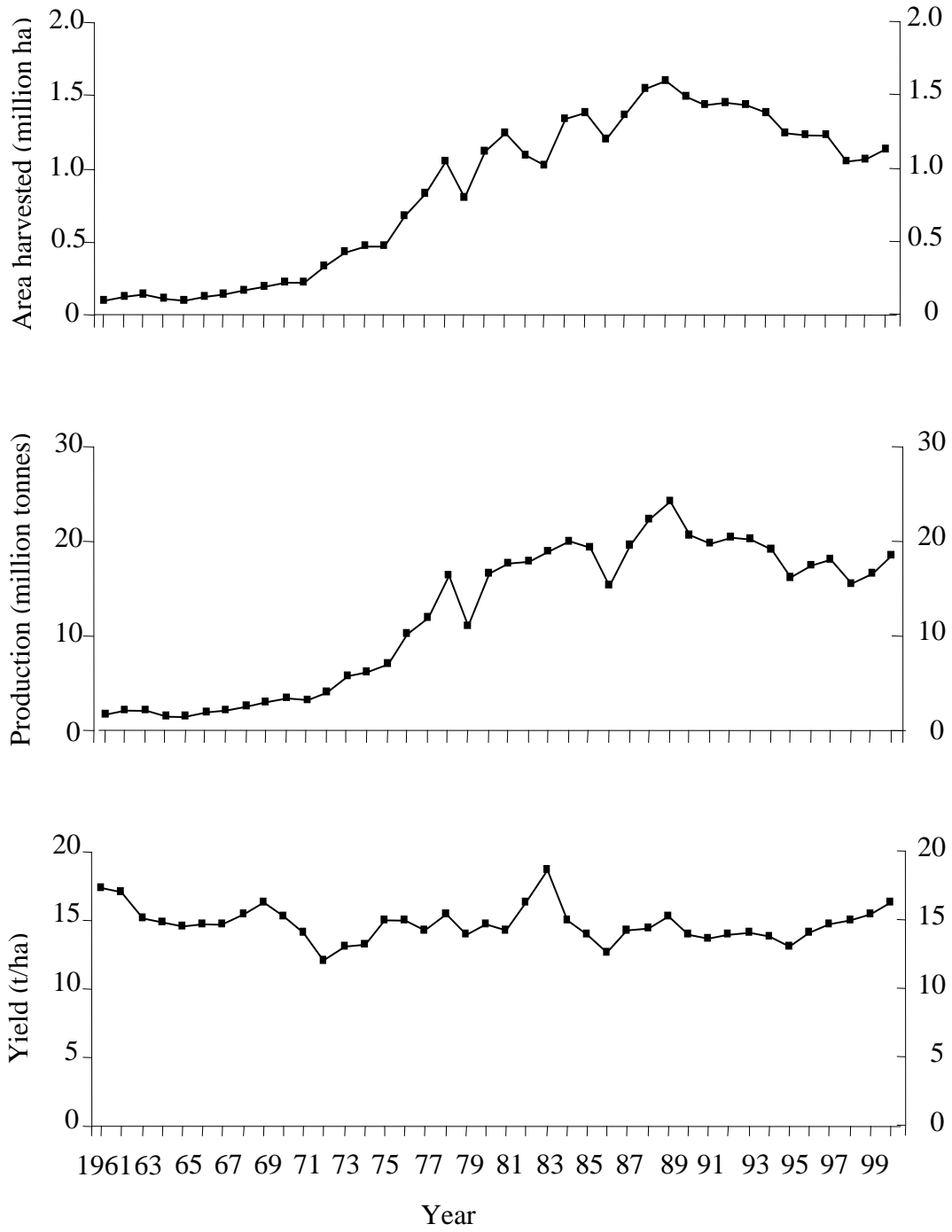


Figure 6. Cassava harvested area, production and yield in Thailand from 1961 to 2000.
 Source: FAOSTAT, 2001.

2. Production Systems

Most crops occupy the micro-environments where they are best adapted within a region. Cassava, though, rarely does. In rainfall-limited areas such as eastern Java, northeast Thailand, or non-irrigated southern India, few crops can match the stability of production of cassava. Cassava normally occupies the hillsides and drought-prone areas, and acid soil regions where other crops can be successfully grown only with high input levels.

Production practices vary widely across the region (**Table 3**). The vast majority of farms in Asia are small, usually in the range of 0.5-5 ha. In the more land-rich areas, cassava competes principally with tree crops: coconuts in the Philippines; coconuts and rubber in Kerala, India; oil palm and rubber in Malaysia and the outer islands of Indonesia; cashew in southern Vietnam and rubber in eastern Thailand.

Cassava is mainly monocropped, but intercropping is common on parts of Java where there are not severe soil and water constraints. Main intercrops here are upland rice, maize and various grain legumes. In Tamil Nadu of India, intercropping with vegetables has become relatively common. In China and Vietnam, maize, peanuts, black beans and various minor species, such as watermelon or pumpkin, may be intercropped, usually at a low density. Cassava is commonly used as an intercrop during the establishment of young tree crops like rubber and cashew, especially in China and South Vietnam.

In contrast to both Latin America and Africa, genetic diversity is extremely limited in commercial plantings in Asia, with the exception of Indonesia. In most countries only a few varieties account for most of the production. The narrow genetic base has apparently not led to any major production disasters. It did, however, limit the possibilities to extend the range of adaptation, or to make adequate improvement in some characters. By good fortune, few of the pests and diseases of the New World found their way to Asia, so a broad genetic base was less critical for supplying resistance genes, as compared with Africa or Latin America.

Production practices may be fully manual, or with mechanized/animal-powered land preparation. The broadly rising incomes and labor costs in Asia are motivating increased mechanization, especially in Thailand and Malaysia, and in the plantation systems of other countries. Most other operations are manual. The largest production cost for cassava in Asia is consistently labor, especially for land preparation, weed control, and harvest. But many of the labor inputs for cassava are technically difficult to substitute with mechanization on small holdings with irregular terrain.

Production costs vary significantly across the region (**Table 4**). Production costs per ha for advanced farmers in Thailand are higher than in Indonesia and the Philippines, but lower than in Vietnam, China and India. When calculated per tonne of fresh roots produced, production costs in Thailand are slightly higher than in Indonesia and the Philippines, but much lower than in India and China. **Table 5** shows, however, that for the average Thai farmer the cost of production per ha is lower, but the cost of production per tonne is considerably higher due to the lower yields obtained. It is clear that cassava products from Thailand can remain competitive on the world market only if farmers increase their yields through the use of improved varieties and better production practices.

Table 3. Characteristics of cassava production and utilization in Asian countries.

	China	India	Indonesia	Malaysia	Philippines	Thailand	Vietnam
Cassava production ('000 t) 1997	3,501	5,979	16,102	22	1,900	18,084	1,983
Cassava harvested area ('000 ha)	230	244	1,300	2.1	215	1,230	239
Cassava yield (t/ha)	15.2	24.5	12.4	10.3	8.8	14.7	8.3
Utilization -main	Starch	Human	Human	Starch	Human	Animal feed (50%)	On-farm
-secondary	-domestic On-farm pig feed	consumption Starch -domestic	consumption Starch -dom./export	-domestic	consumption Starch -domestic	-exp. (90)/dom. (10) Starch (50%) -exp. (60)/dom. (40)	pig feed Starch -export/dom.
Farm size (ha/farm)	0.5-1.0	0.4-0.6	0.4-1.0	2-3	3-4	4-5	0.6-0.8
Cassava area (ha/farm)	0.2-0.4	0.3-0.4	0.3-0.5	-4	-	2-3	0.25-0.30
Crop. system (%) -monocrop	40	70	40	99	60	95	65
-intercrop	60	30	60	1	40	5	35
Time of planting	March	Apr/Sept	Oct/Nov	year round	May-Aug	Apr-May Oct-Nov	Feb-May
Land preparation	manual/oxen	manual/oxen	oxen/manual	tractor	oxen	tractor	oxen/manual
Planting position	horizontal	vertical	vertical	horizontal	horizontal	vertical	horizontal
Weed control	manual/ herbicides	manual/gorru	manual/ herbicides	herbicides/ manual	manual/ oxen	manual/mech./ herbicides	manual
Fertilization -organic	some	some	some	none	some	some	some
-chemical	low	rel. high ¹⁾	rel. low (N only)	high	low	Low-medium	low
Labor cost (US\$/day)	1-2	2-3	1-2	4-5	2-3	3-4	1-2
Production costs (US\$/ha)	300-500	500-1,000	300-500	390-520	300-700	300-400	200-700

¹⁾in irrigated areas

Source: Adapted from Howeler, 2000.

Table 4. Cassava production costs (US \$ /ha) and profitability in various countries in Asia in 1998-2000.

	China ¹⁾	India ²⁾	Indonesia ³⁾	Philippines ⁴⁾	Thailand ⁵⁾	Vietnam ⁶⁾
Labor Costs (\$/ha)	167.40	421.70	185.37	218.80	167.18	213.60
Labor costs (\$/manday)	1.86	1.29	1.11	2.00	3.24	1.78
-land preparation (mandays/ha)	7.5	1.5	45	8.1	2.4	5
-preparation planting material	-	1.9	5	-	-	5
-planting	15.0	14.8	15	9.4	9.1	10
-application fert. and manures	5.0	10.7	12	2.5	6.4	5
-application other chemicals	-	0.3	-	-	-	-
-irrigation	-	51.9	-	-	-	-
-weeding and hilling up	40.0	208.6	40	26.9	8.0	40
-harvesting (includes loading)	22.5	37.2	50	37.5	25.7	55
-transport and handling	-	-	-	25.0	-	-
Total (mandays/ha)	90.0	326.9	167	109.4	51.6	120
Other Costs (\$/ha)	260.22	242.15	80.55	163.25	198.73	171.07
-Fertilizers and manures	130.11	159.39	79.44	53.75	61.97	80.36
-Planting material	-	26.83	1.11	25.00	-	-
-Other materials (herbicides, sacks)	37.17	2.23	-	20.00	25.84	-
-Transport of roots	-	-	-	-	70.38	-
-Land preparation by tractor	92.94	53.70	-	64.50	40.54	90.71
Total Variable Costs (\$/ha)	427.62	663.85	265.92	382.05	365.91	384.67
-Land rent and/or taxes	94.94	236.50	46.67	-	48.89	60.00
Total Production Costs (\$/ha)	520.56	900.35	312.59	382.05	414.80	444.67
Yield (t/ha)	20	40	20	25	23.40	25
Root price (\$/t fresh roots)	29.74	38.00	17.78	25.00	21.62	21.42
Gross income (\$/ha)	294.80	1,520.00	355.60	625.00	505.91	535.50
Net income (\$/ha)	74.24	619.65	43.01	242.95	91.11	90.83
Production costs (\$/t fresh roots)	26.03	22.51	15.63	15.28	17.73	17.79

Sources: ¹⁾Tian Yinong for Guangxi, China

²⁾Srinivas, 2001; for irrigated cassava in Tamil Nadu, India

³⁾J. Wargiono for monoculture cassava in Lampung, Indonesia

⁴⁾Bacusmo, 2001; for monoculture cassava in the Philippines

⁵⁾Adapted from TTDI, 2000; average of 527 advanced farmers in Thailand

⁶⁾Farmers estimate for monoculture cassava in Dongnai province of Vietnam

Table 5. Cassava production costs (US \$/ha) in Thailand in 1999/2000.

	Average all farmers ¹⁾	Average advanced farmers ²⁾
I. Labor costs (\$/ha)	168.48	167.18
-Labor costs (\$ /manday)	3.24	3.24
-land preparation (mandays/ha)	1.6	2.4
-planting	9.1	9.1
-fertilizer application	6.1	6.4
-weeding	14.0	8.0
-harvesting	19.4	25.7
-loading	1.8	-
Total (mandays/ha)	52.0	51.6
Other costs (\$/ha)	125.68	198.73
-Fertilizers and manures	20.23	61.97
-Planting materials	26.66	-
-Herbicides and pesticide	8.57	25.84
-Fuel and lubricants	2.15	-
-Inplements and others	3.64	-
-Land preparation by tractor	40.50	40.54
-Transport of harvest	-	70.38
-Interest and opportunity costs	23.93	-
Total Variable Costs (\$/ha)	294.16	365.91
Land rent and taxes	44.15	48.89
Depreciation of machinery	3.39	-
Total Production Costs (\$/ha)	341.70	414.80
Yield (t/ha)	16.52	23.40
Root price (\$/t fresh roots)	21.62	21.62
Gross income (\$/ha)	357.16	505.91
Net income (\$/ha)	15.46	91.11
Production costs (\$/t fresh roots)	20.68	17.73

1US \$ = 37 baht in 1999/2000.; cost of labor 120 baht/day

Sources: ¹⁾ Office of Agric. Economics (OAE), 2001.

²⁾ Adapted from TTDI, 2000.

In general, however, Asian countries are comparatively efficient producers, by use of some inputs, good management, and low pest and disease pressures. **Table 6** illustrates production costs for Thailand, Brazil and Colombia, and the competitive advantage that Thailand has had in world markets in part because of lower costs, both in production and processing.

Table 6. Cassava production costs, farmgate prices, and product prices in three major producing countries (average for 1990-1994, US\$/tonne).

	Cassava production costs	Farmgate price of cassava		Domestic chip price	Cassava starch price
		For industrial use	For fresh consumption		
Thailand	\$20.34	\$28.67	-	\$85.70	\$233.34
Brazil	\$27.80	\$31.63	\$128.18	-	\$357.17
Colombia	\$34.85	\$42.20	\$85.30	\$177.77	\$522.95

Source: Henry and Gottret, 1996.

3. Products and Markets

Diversity is the defining characteristic of cassava products and markets in Asia, both within and across countries. About 40% of cassava in the region is destined for human consumption (in Indonesia, the level is about two-thirds) (FAOSTAT, 1997). Most of the remainder is processed for industrial purposes, principally pellets for animal feed, and starch. Fresh roots are not traded on any significant scale. The initial processing defines to some degree the market sector to which roots can be destined. This is unlike the grains such as maize which are traded as whole, unprocessed grain, to be converted into any number of products in the importing country.

a. Fresh for human consumption

Outside of Kerala, India and some poorer districts of China and Vietnam, nearly all cassava for food is first processed; direct consumption of baked or boiled fresh roots is minor. This form of consumption is largely a rural practice, and often by households having cassava in their own backyard garden. Fresh consumption has limited growth potential, and in fact will probably decline with increasing urbanization and changes in dietary preferences.

b. Flour

Cassava flours come in many forms. The most common is *gaplek* in Indonesia. Roots are peeled, chipped or sliced, and dried. The dried chunks are ground or milled to a meal, which is then used in a wide array of food preparations. It is consumed especially in times of rice scarcity, and partially substitutes for rice in rural daily diets. Cassava flour may also partially substitute for wheat flour in bakery and other products. This is still minor in Asia, but is reported unofficially from several countries (Henry and Gottret, 1996).

c. Chips and pellets for animal feed

The commercial cassava pellet industry has its origin in Thailand, which has a long history of an agricultural economy driven by exports. With a surplus land base, rice exports became the foundation of Thai trade up to World War II. Development of the upland sector in the North and Northeast brought diversification to agriculture, adding maize, cassava, pineapple and sugarcane.

Exports of dried cassava products climbed steadily up to 1990, but declined afterwards as Europe began to withdraw its favorable import conditions. Thailand has aggressively sought alternative markets, with some success, but not nearly at levels absorbed by Europe in the 1980s (**Figure 7, Table 7**). While the potential for development of internal markets remains promising, the generally low commodity prices of the past several years have made this difficult.

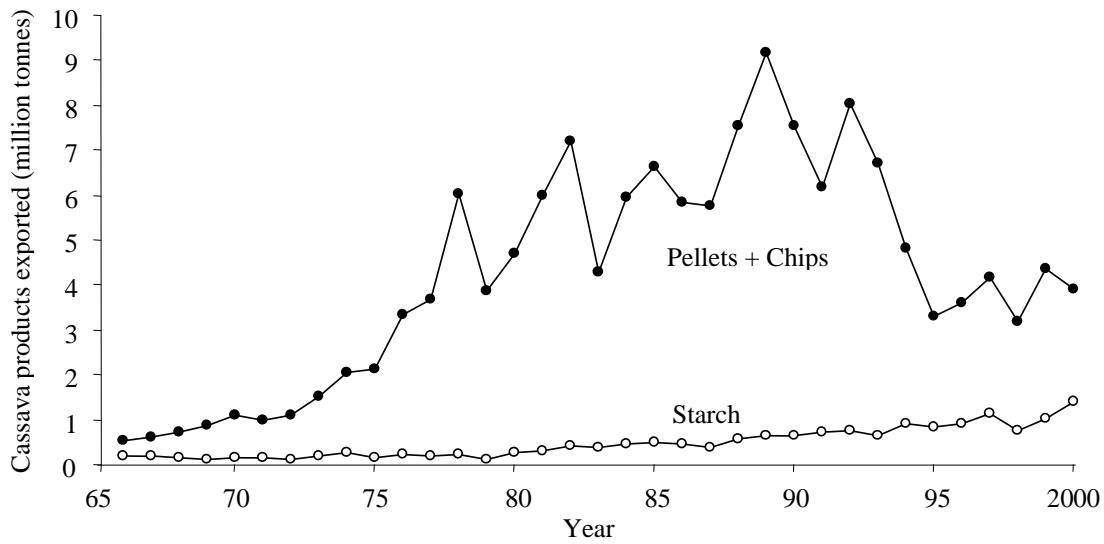


Figure 7. Quantities of cassava products exported from Thailand from 1966 to 2000.
Source: Adapted from TTTA, 2000.

Table 7. World trade of cassava products (chips, pellets and starch: million tonnes).

	1994-1995	1996-1997	1998-1999
	avg.	avg.	avg.
World exports	6.30	6.39	5.47
Thailand	5.00	5.16	4.62
Indonesia	0.60	0.43	0.23
China & Taiwan	0.40	0.39	0.20
Others	0.25	0.42	0.43
World imports	6.30	6.39	5.47
European Union	4.20	3.72	3.58
China & Taiwan	0.65	0.61	0.62
Japan	0.35	0.38	0.32
Korea, Rep.	0.35	0.46	0.35
Others	0.70	1.23	0.61

Source: FAO Commodity Market Review 1999-00.

d. Starch for food and industry

Starch for industry is classified as *native* or *modified*. The technology for modifying starches with physical, chemical and biological processes is highly advanced and evolving rapidly. These modified starches are absorbing an increasing market share. At the same time, there is pressure in some industries, especially foods, to move away from modification based on chemicals.

Starch-derived products include sweeteners (high fructose syrup, glucose syrup), dextrans, monosodium glutamate, pharmaceuticals and various chemicals. Starch is used in large quantities in the manufacture of paper, plywood, textiles, and as a filler/stabilizer in processed foods. New products from starch are continually entering the marketplace. Biodegradable plastics appear to be especially promising. Throughout the region, the industry is moving toward larger, more technologically advanced plants, and small, less efficient factories are closing.

Thailand is leading the Asian *starch boom*, surpassing Indonesia in recent years (**Figure 8**). Both export sales and domestic use have increased significantly. Although the starch export industry of Thailand has been active since the 1940s, it was rejuvenated in the 1980s when Europe began to set limits on imports of cassava chips and pellets. This was also a time of rapid economic growth in Thailand, and the starch industry attracted the attention of entrepreneurs. At present, about 45% of cassava root production in Thailand is used for production of starch, 55% of which is utilized locally for production of various products, while 45% is exported (**Figure 9**). The focus for exports has been on modified starches, to get around some of the import barriers imposed against native starch. Nonetheless, the increase in starch exports has not nearly kept pace with the decline in pellet exports. Private and public sectors are cooperating to identify and exploit internal growth markets for starch as a complementary strategy to export-orientation.

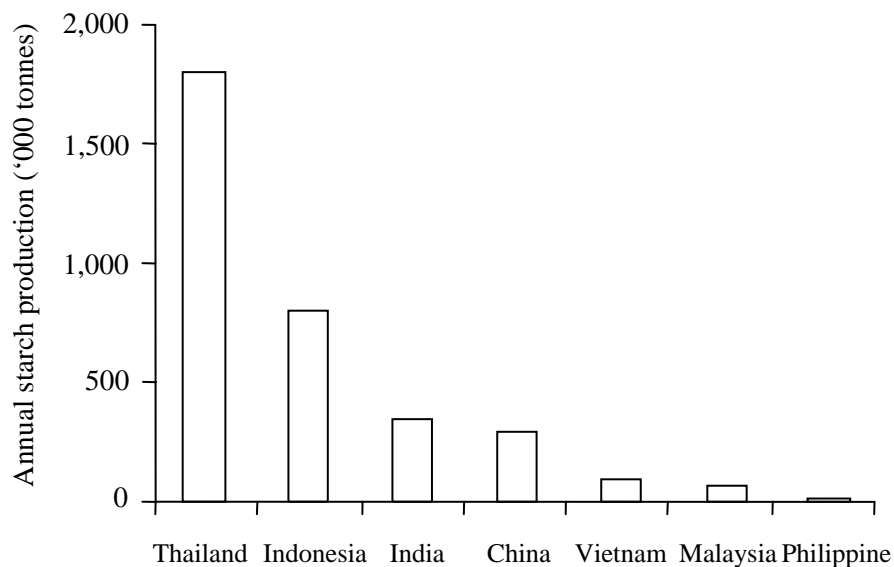


Figure 8. Cassava starch production in various countries in Asia (in 1992).

Source: Ostertag, 1996.

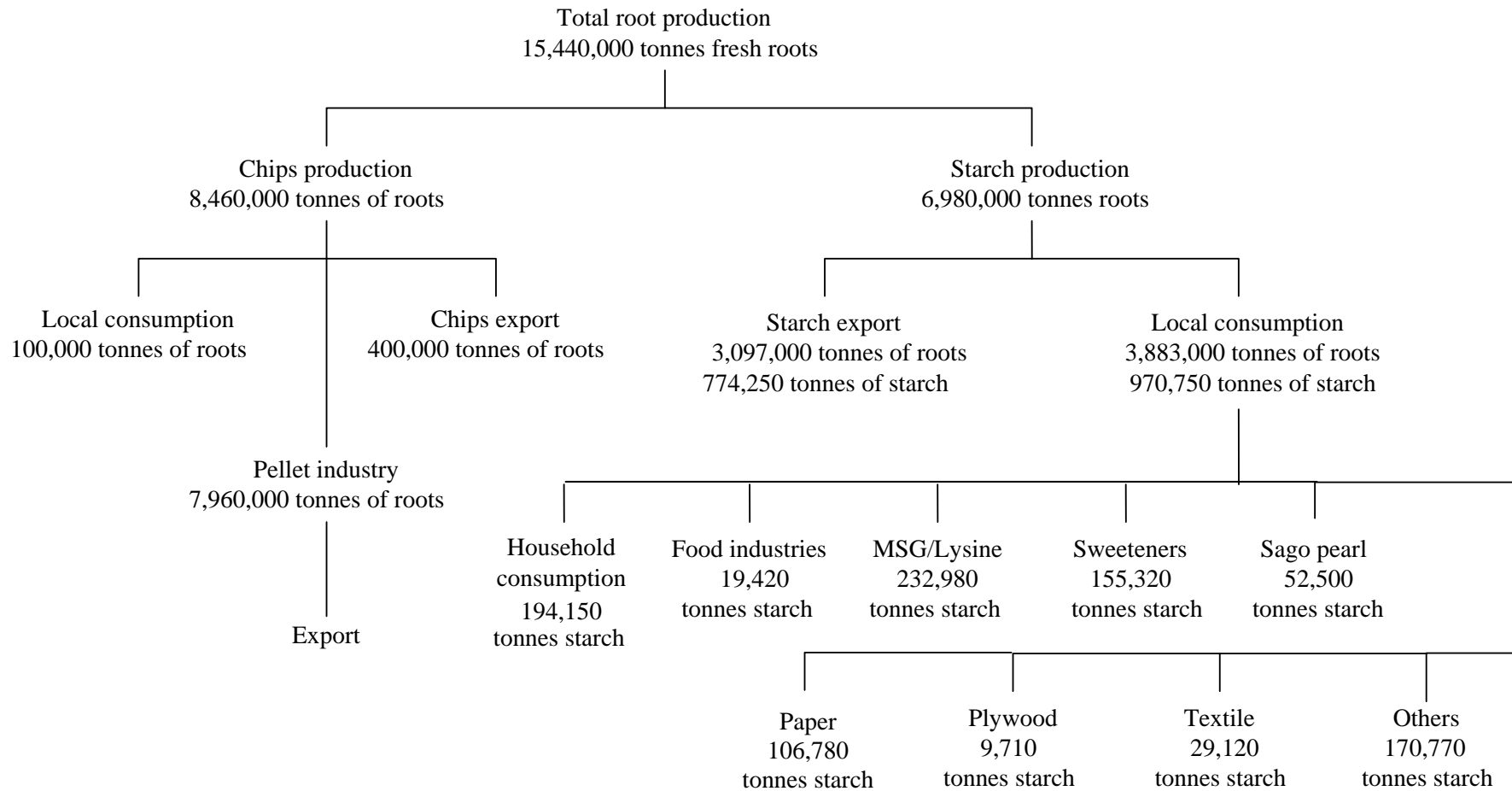


Figure 9. Distribution of cassava roots for industrial processing in Thailand in 1998.

Note: Modified starches are partially distributed over export, food, and the paper, textile and plywood industries.

Source: Modified from TTTA, 1999.

Internal markets absorb most of Indonesia's starch. Nearly two-thirds goes into cassava crackers (*krupuk*). Because of the specific starch characteristic required for this product, maize starch is not a competitor. This gives some insulation from the fluctuations of world starch prices. Both China and Vietnam have significantly expanded and modernized their starch industries. Monosodium glutamate and glucose (starch derivatives) are rapidly growing markets in both countries. In Thailand, Indonesia and Vietnam, cassava is virtually the only raw material for starch production. Any growth in starch demand should benefit the cassava sector. In China, India and the Philippines, there are other starch sources (especially sweetpotato and maize in China), but these are often used in industries such as noodle-making where cassava starch does not compete. Hence, even in these countries the market potential for cassava starch is strong.

e. Ethanol

In some countries cassava is used for the production of ethanol. In the late 1970s several alcohol distilling factories were set up in Brazil using fresh cassava roots as raw material. The alcohol was used as automotive fuel, either mixed with gasoline (up to 20% alcohol) for which no motor modification is required, or as pure anhydrous ethanol, in which case the carburetor and some other parts need to be modified (de Souza Lima, 1980). Both result in less atmospheric pollution than the use of gasoline. By the late 1980s, however, nearly all cassava-based distilleries were converted over to using sugarcane as the raw material, since the sugarcane bagasse could be used as fuel, thus saving on energy costs.

In China, several factories in Guangxi, are now using the solid waste (pulp) of the cassava starch industry for the production of ethanol (Gu Bi and Ye Guozhen, 2000), and in the Philippines the San Miguel Corporation is setting up a cassava-based alcohol factory in Negros Oriental for use in the liquor industry (Bacusmo, 2001).

4. Projections

Thailand's continuing efforts to reduce its dependency on the European animal feed market will dominate directions of the Asian cassava sector for the next decade. This will take several forms: introducing production technology to keep prices competitive with alternative energy sources; aggressively seeking new markets outside Europe; development of internal feed markets; and further diversification into starch and flour, with strong support for research on new processes and products. Other countries of the region, once with aspirations to penetrate export markets for pellets, are now recognizing that opportunities will depend very much on increasing production and processing efficiencies (**Table 8**).

Prospects for starch vary widely depending on the specific market. There are two extremes: purely commodity starches with generic application, and highly specialized starches reliant on functionality. The latter are often derived from modified starches. However, in the middle, there are starches that are comparatively specialized, though sharing functionality with other starches. In this group, functionality is the initial criteria of suitability, followed by price and supply. For generic starch, the different sources (maize, cassava, sweetpotato, white potato) compete with one another on the basis of price. The

markets for specialized starch are rather uncertain. On the one hand there is increasing demand, but on the other, there is a continually evolving technology for modifying starches to meet specific product properties. While technology for modification is moving rapidly, at

Table 8. Present constraints in cassava production, processing and marketing, and potential future cassava products.

Country	Constraints	Future potential
China	Crop competition	Starch
	Small farms	MSG
	Soil erosion	Modified starch
	Low soil fertility	Animal feed
India	Crop competition	Starch
	Mosaic disease	Modified starch
	Small farms	Converted starch
	Markets	Sweeteners Snack foods
Indonesia	Small farms	Starch
	Price fluctuations	Modified starch
	Soil erosion	Animal feed
	Low soil fertility	Flour MSG
Malaysia	Crop competition	Starch
	High labor cost	Modified starch
		Animal feed
		Snack foods
Philippines	Financial resources	Starch
	Markets	Animal feed
	Low soil fertility	Alcohol
Thailand	Price fluctuations	Modified starch
	Labor shortages	Domestic animal feed
	Low soil fertility	MSG
	Soil erosion	Lysine
Vietnam: North	Small farms	Animal feed
	Financial resources	
	Low soil fertility	
Vietnam: South	Small farms	Starch
	Financial resources	MSG
	Low soil fertility	Animal feed
	Crop competition	

Source: Compiled by R. Howeler from interviews, personal observations and national program data.

the same time there is a strong trend away from modified starches in some products and in some key markets like the US and EU. For example, baby foods use virtually no modified starches, and the amounts used in soups is much reduced compared to just five years ago. Ostertag (1996) suggests that most developing countries will use their resources most effectively to first concentrate on developing internal starch markets, to reduce the risks inherent in the export sector.

Whether or not the use of alcohol as automotive fuel is economically viable depends mainly on the world price of oil. During the past two decades oil prices have been relatively low and alcohol substitution would be more expensive; however, this can change in the future as oil supplies become exhausted or when for political reasons production does not keep pace with demand.

In a recent study of the major tropical root crops, Scott *et al.* (2000a) project cassava production and utilization in the year 2020, based on a model that takes into account virtually all the world's food production and consumption (International Model for Policy Analysis of Commodities and Trade (IMPACT)). Moderate demand growth for cassava products in Asia through 2020 will sustain viable cassava-based development. The growth sectors vary within the region. In China, growth in feed demand will be among the strongest anywhere, at 2.1% per year, accompanied by a continuing trend for lower direct use as food. Southeast Asia should see healthy growth in all sectors: 1.4% in food, 0.13% for feed, and a total of 1.25% (including industrial use) (**Table 9**). The import demand in the non-cassava producing countries of East Asia will rise at 1.0% per year, providing some additional market possibilities.

Table 9. Projected production and utilization of cassava in 2020.

	Growth rate for utilization 1993-2020 (percent per year)			Utilization in 2020 (million tonnes)	Production in 2020 (million tonnes)
	Food	Feed	Total		
Southeast Asia	1.4	0.13	1.25	27.0	51.1
China	-1.27	2.08	1.19	3.9	4.2
Other East Asia	-0.95	1.09	0.63	3.5	0.0
India	1.00	0.00	1.00	7.6	7.8
Other South Asia	1.00	0.00	0.83	0.6	0.6
Latin America	0.26	1.26	0.78	39.3	40.5
Sub-Saharan Africa	2.51	0.29	2.47	166.0	166.0
Developing	2.01	1.18	1.88	248.8	271.1
Developed	0.03	0.01	0.02	22.7	0.4
World	2.01	0.59	1.68	271.6	271.6

Source: Adapted from Rosegrant and Gerpacio, 1997; and Scott *et al.*, 2000b.

B. THE EXTERNAL ENVIRONMENT: INFLUENCES ON THE FUTURE OF THE CASSAVA SECTOR

Agricultural research has a key role in development. But for maximum impact it must be attuned to the broader social and economic environments of the target area. Progress towards improvement of production, processing and market development systems that will broadly benefit society is intimately related to broader trends and influences.

1. Trade and Economic Policy

The policy arena, possibly more than any other influence, sets the stage for cassava's role in a given country. Agricultural policy, as well as broader economic and trade policies, impact the cassava sector in several ways. Liberalized trade became the economic mantra of the 1990s. The watershed Uruguay round of multilateral trade negotiations, under the General Agreement on Tariffs and Trade (GATT), was a fundamental influence on the direction of the global economy. While more recent attempts at broad trade agreements under the World Trade Organization, successor to GATT, have been less successful, there is little likelihood of reversing the broad trend toward freer trade. Trade liberalization will bring complex and sometimes unpredictable adjustments to agriculture. The implementation of regional trade agreements is well-advanced in Asia. The Asia Pacific Economic Co-operation forum (APEC) has 18 members, which in total comprise half the world economy. Most of the major cassava-producing countries of the region (except India) are members. APEC aims to achieve free and open trade and investment by 2010 for its industrialized members and by 2020 for the others.

Previously-protected sectors of the economy are in flux as they are subjected to the open market. Countries that expect to export their products are under strong pressure to open their markets to imports as well. Agriculture has been one of the sectors most broadly affected by this trend, since it is of nearly universal relevance to countries' economies, and touches fundamentally on the lives of nearly all people. On the whole, liberalized trade agreements should drive broad-based growth through specialization, efficiency gains, and increased trade in agricultural products. In a free trade environment, commodity prices typically fluctuate more (based on supply and demand) than in a regulated environment. Producers are more likely to switch in and out of crops to take best advantage of these fluctuations. The dilemma that cassava-producers often face, however, is the fact that they have little flexibility in choice of crops. First, on the more marginal soils, cassava may be the only choice without resorting to costly inputs. Secondly, the nature of cassava's propagation does not allow quickly gearing up for production if a supply of planting material has not been assured by the previous year's crop. Stabilizing demand in an environment of freer trade will depend on the ability of the industry to respond quickly to shifts in product demand.

A second trend important to trade is the tendency to add value at the site of origin, and to trade in processed products. By 2020, there will be far less trade of the traditional raw agricultural products (e.g., grains); most will be products with value added either by processing or through genetically engineered specialty traits incorporated for specific end-uses. Often, trade policies affecting processed products are different from those imposed on raw products.

2. Demographics, Income and Food Demand

Population increase remains a major driving force that will shape development progress, at least for a few more decades to come. Poorer countries absorb most of the impact. While on a global level it seems that food production can keep pace with population increase, poverty and hunger persist in many countries, especially in the tropical belt. The consequences of these dual scourges of poverty and hunger then reverberate throughout all areas of human and environmental well-being.

The United Nations projects that global population will continue to rise to about the year 2040, when it will have doubled from today's level, to 8-11 billion. Growth rate should decline from about 1.4% to 1.0% by 2020. This mean rate hides the highly disproportionate differences between developed and developing countries – a 3.4% population increase in the former, compared to 35.8% in the latter, in the period from 1998 to 2020. By far the greatest burden of this continued population growth will be felt in urban areas. Latin America is already at a level of almost three-quarters of its population living in cities. Like much of the rest of the world, Asia has been moving toward greater urbanization for at least several decades (**Figure 10**). Both Africa and Asia appear set to continue a nearly linear trend toward greater urbanization, with about equal numbers of rural and urban residents in both regions by 2020 (FAOSTAT). This is largely the dynamic that drives commercial agriculture -- urban dwellers need to purchase nearly all their food.

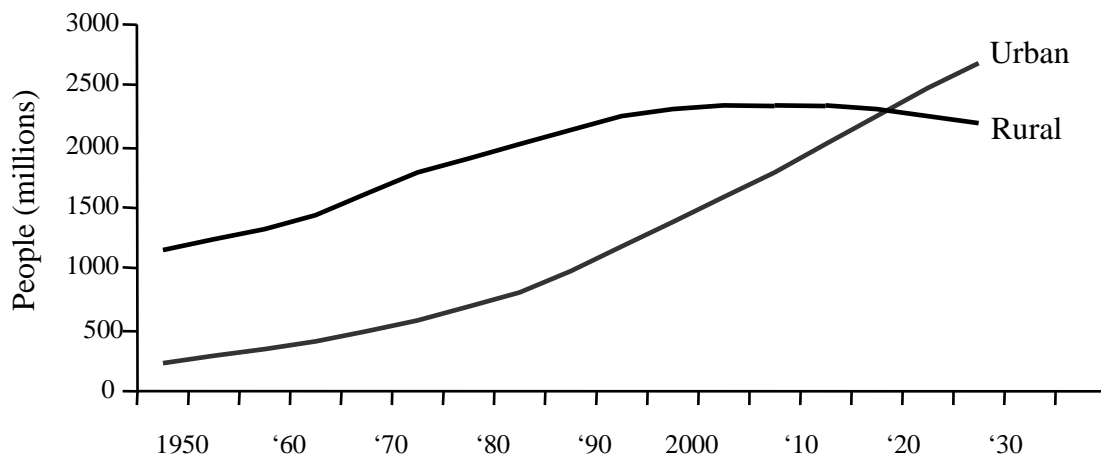


Figure 10. Historical and projected population growth in Asia.
Source: FAOSTAT, 2001.

Population dynamics affect cassava production and marketing in various ways. In the simplest of cases, population increase imposes a proportional increase on food demand. With most of the productive land already cultivated, this places pressure on marginal environments where cassava has strong adaptive advantages. On the other side, urbanization typically reduces demand for cassava and its products for direct food use. Huang and Bouis (1996) note several reasons for shifts in food demand that follow urbanization:

- A wider choice of foods is available in urban markets

- People are exposed to new dietary patterns from different regional traditions
- Urban lifestyles place a premium on foods that require less time to prepare
- Transaction costs are lower
- Urban occupations generally require fewer calories than more physically demanding rural ones

Except in Indonesia and southern India, cassava has never been broadly popular as a dietary staple in Asia. In several countries there remains a considerable stigma against cassava as a food -- a reflection of past difficult economic times. Rising incomes will further erode cassava's direct role in Asian diets. The overwhelming preference for rice as the starchy staple, and the increasing demand for meat (**Figure 11**), will keep per capita consumption levels low throughout Asia. The growth in meat consumption, however, is the basis for projecting strong potential to use cassava for on-farm feeding, or in balanced rations, especially for pigs and chickens.

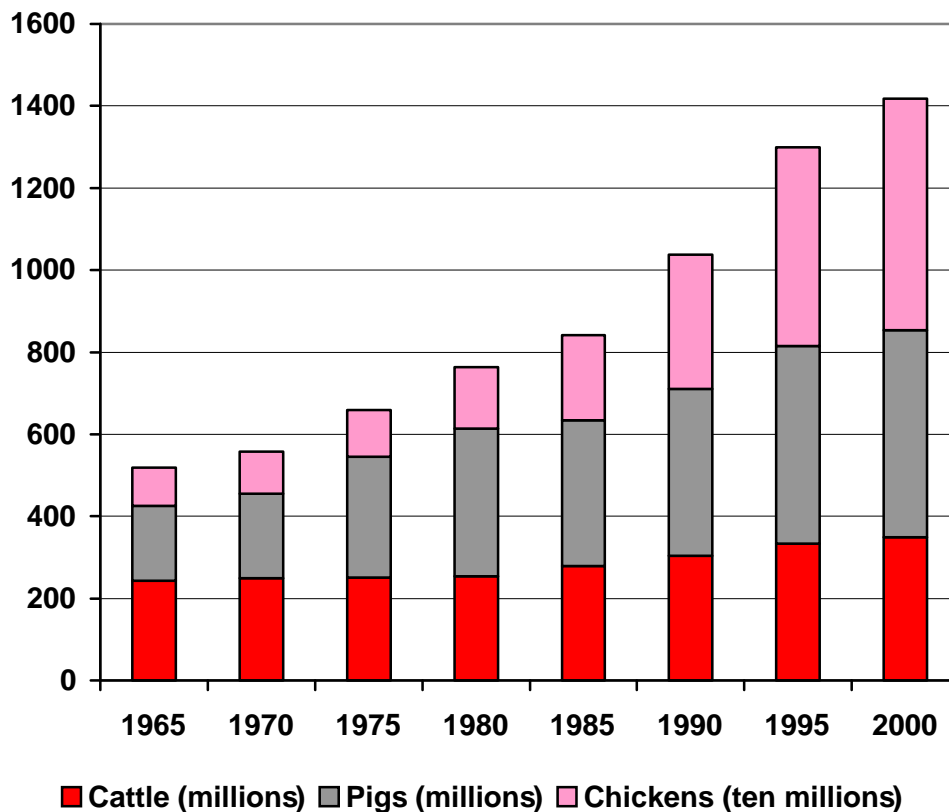


Figure 11. Animal stocks in seven major cassava producing countries of Asia.

While not all countries have benefited equally, Asian economies on the whole have seen healthy growth in the past two decades. Industrial development, the service sector,

and labor demand, have all had an impact that affects all sectors of society. Rising household incomes open the way for purchase of consumer goods, education and health care. Improved tax bases contribute to public infrastructure in the form of roads, schools and public services. In this scenario, cassava tends to move toward industrial uses, such as animal feed and starch-based products.

3. Trends in Competing Commodities

Cassava's competitive position in national and international markets is closely linked to internal and world supplies and market prices of alternative commodities or products. Because of cassava's versatility, it may compete with a range of products in different markets. In the market for balanced feed rations, cassava in dried chip or pellet form competes mainly with sorghum or maize, and sometimes barley. On a global level, maize is the principal source of starch.

In the cassava-producing countries of Asia, rice, maize and cassava production all increased three to five-fold in the past twenty-five years (**Figure 12**). Even this dramatic success, however, was not adequate for supplying growing and somewhat more affluent populations. Grain imports, dominated by wheat, maize, rice and soybeans, rose from just over ten million tons in 1960 to 47 million tonnes in 1995, with some decline again in the latter part of the decade during the Asian economic slowdown (**Figure 13**).

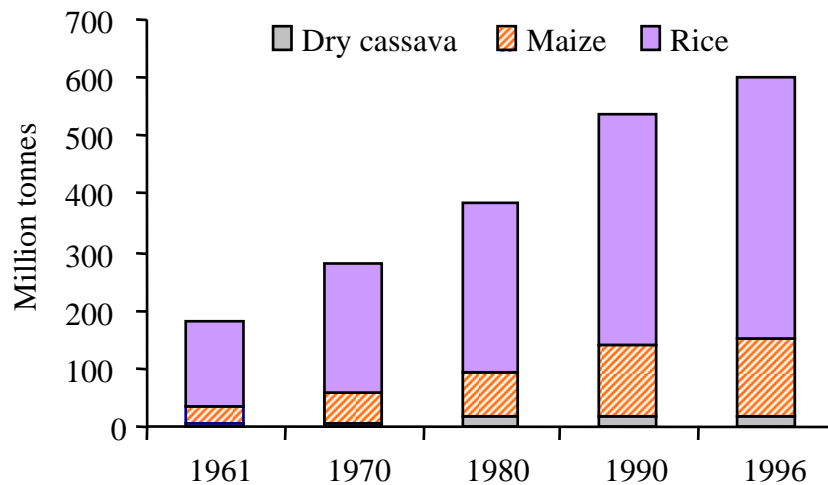


Figure 12. Crop production trends in seven major cassava-producing countries of Asia.

Source: FAOSTAT.

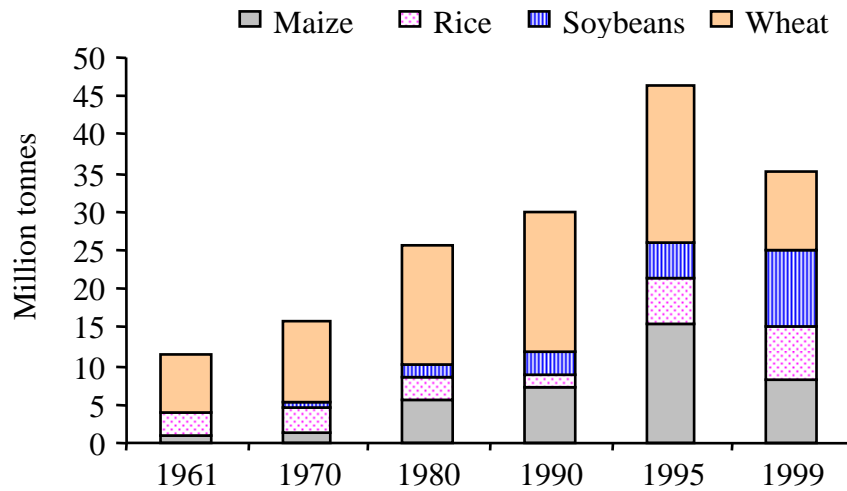


Figure 13. Grain imports to seven major cassava-producing countries of Asia.
Source: FAOSTAT.

However, on a global basis, grain supplies have increased steadily and prices have been declining in inflation-corrected terms. Decline during the last five years has been particularly steep. Prices in 1999 were virtually identical to those in 1985 (uncorrected for inflation) (Figure 14). Projections by IFPRI and FAO indicate that if governments pursue appropriate economic policy and invest in agricultural research, cereal prices will continue their downward trend (Pinstrup-Anderson and Garrett, 1996). The cassava market will, for the most part, parallel these declining commodity prices. Rosegrant and Gerpacio (1997) project a price decline for cassava on world markets of 3.4% by the year 2020. While this is a lesser decline than projected for other roots and tubers, it represents a substantial challenge to growers.

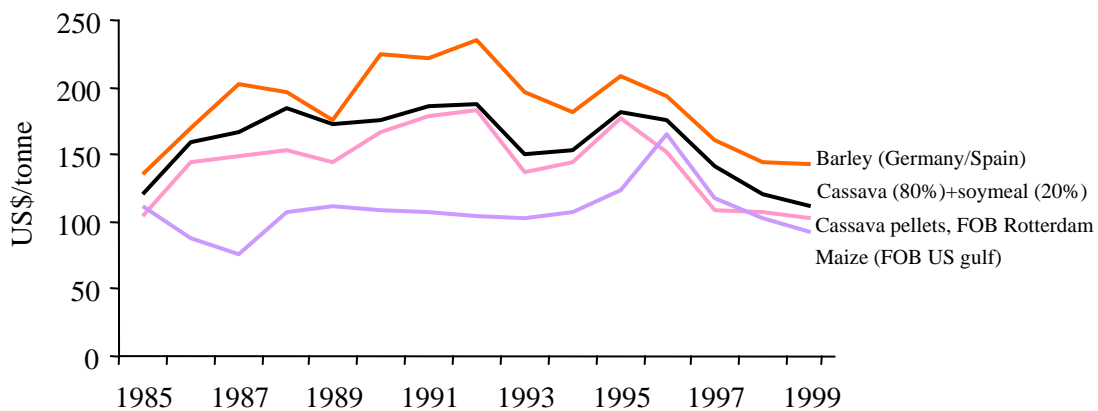


Figure 14. World prices of cassava and competing grains (unadjusted for inflation).
Source: FAOSTAT.

Prices of both cassava starch and hard pellets exported from Thailand have seen an almost continuous decline since their peaks in mid 1995 (**Figure 15**). At the end of 2000, the world price of both products was less than 50% of what it was five years earlier. This and the closing of tariff advantages in the EU has led to a steady decline in the price of fresh roots in Thailand (**Figure 16**). Except for a sudden rise in root prices in early 1998 (due to a shortage of roots at a time when world starch prices temporarily increased dramatically), the fresh roots price declined steadily from a peak of about 2000 baht/tonne in early 1996 to about 850 baht/tonne in Feb 2001. During the past year the price has remained low until late 2001 when it increased to about 1,200 baht/tonne (TTTA newsletter of Dec 15, 2001). At these very low prices, farmers' gross income barely covers the cost of production (**Table 5**), and they will soon look for alternative crops or other sources of income. Only with the use of better production practices can farmers survive the current low prices for cassava roots (see "advanced farmers" in **Table 5**).

4. Science and Agricultural Research

Scientific advances underpin development. Four elemental shifts underway will define the agricultural landscape in the next few decades in developing countries: (1) the privatization of knowledge and technology; (2) the biotechnology and information revolutions; (3) the increasing policy focus on low-cost food supplies for urban centers as compared to income-generation and food security concerns for producers; and (4) increasing sector specialization in world markets; the trend toward specialized value-added traits for most commodities.

These shifts have fundamental implications for the gap between science in developing and developed countries. Without sweeping agreements on equitable interchange of information, genetic resources and technology between North and South, there will be a continual further eroding of competitiveness in developing countries. The recognition that, in the long term, this gap is detrimental to everyone, should drive new interest in mechanisms to improve investment in research in developing countries. During the next decade the large multi-national agricultural research firms will begin to see the developing countries as a major growth market for biotechnology-derived, IPR-protected technology. However, a turn-around in narrowing the science and technology gap that exists between developed and developing country capacity in science is not yet on the horizon.

5. Infrastructure

Subsistence farming requires virtually no infrastructure -- no need for purchased inputs, and no need for highways for reaching markets. Commercial agriculture, on the other hand, depends heavily on infrastructure. Rapid economic expansion and urbanization have outstripped the capacity of existing infrastructure, and created serious impediments to further investments and growth. Insufficient electricity generation capacity, outdated and inadequate telecommunications facilities, poor roads and inefficient ports are the most crucial infrastructure problems.

Purchased inputs for agriculture are for the most part available, but may not be used on cassava because of other constraints. There is little likelihood of major investment in infrastructure aimed solely at supporting cassava development, but the general development of the region will bring collateral benefits to growers, processors and consumers. The Thai cassava industry maintains a competitive edge over its neighbors because of earlier investments in processing facilities, roads and harbor infrastructure.

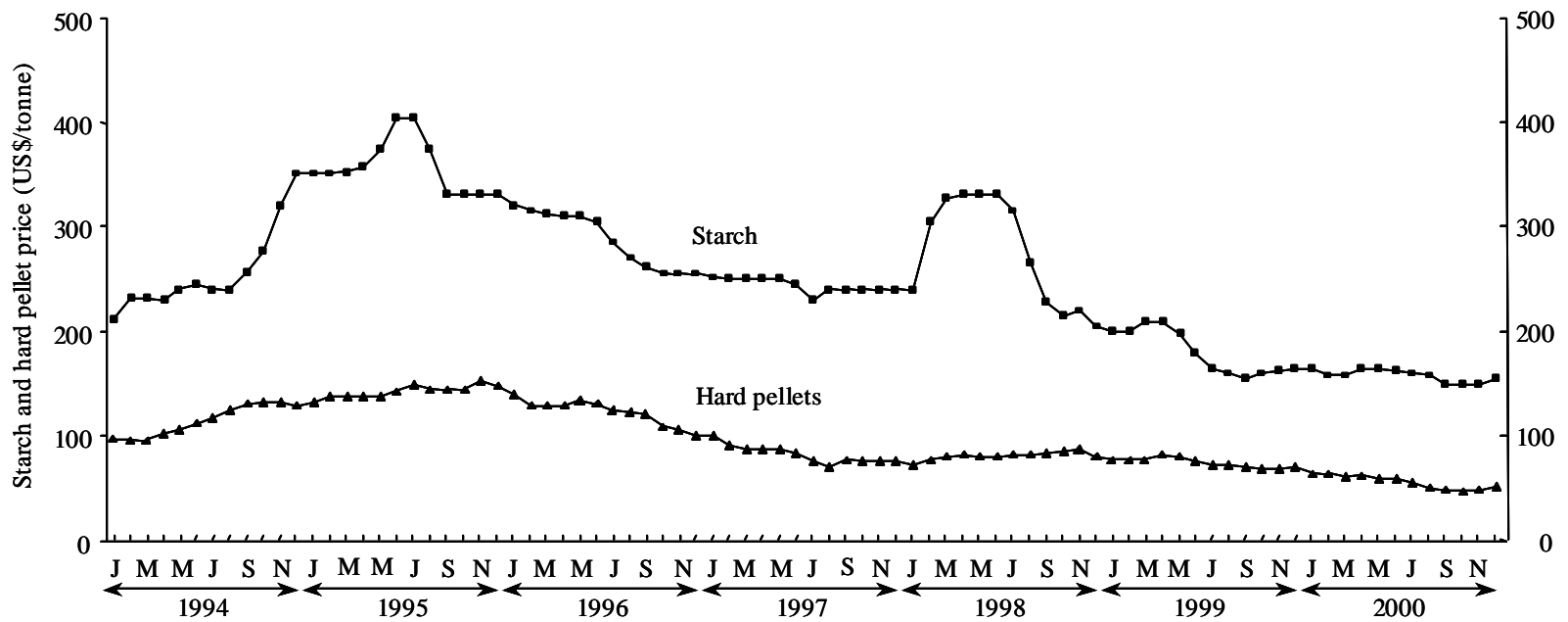


Figure 15. Monthly trend in the price (FOB Bangkok) of cassava starch and hard pellets from 1994 to 2000.

Source: Thai Tapioca Trade Assoc. (TTA), 2000.

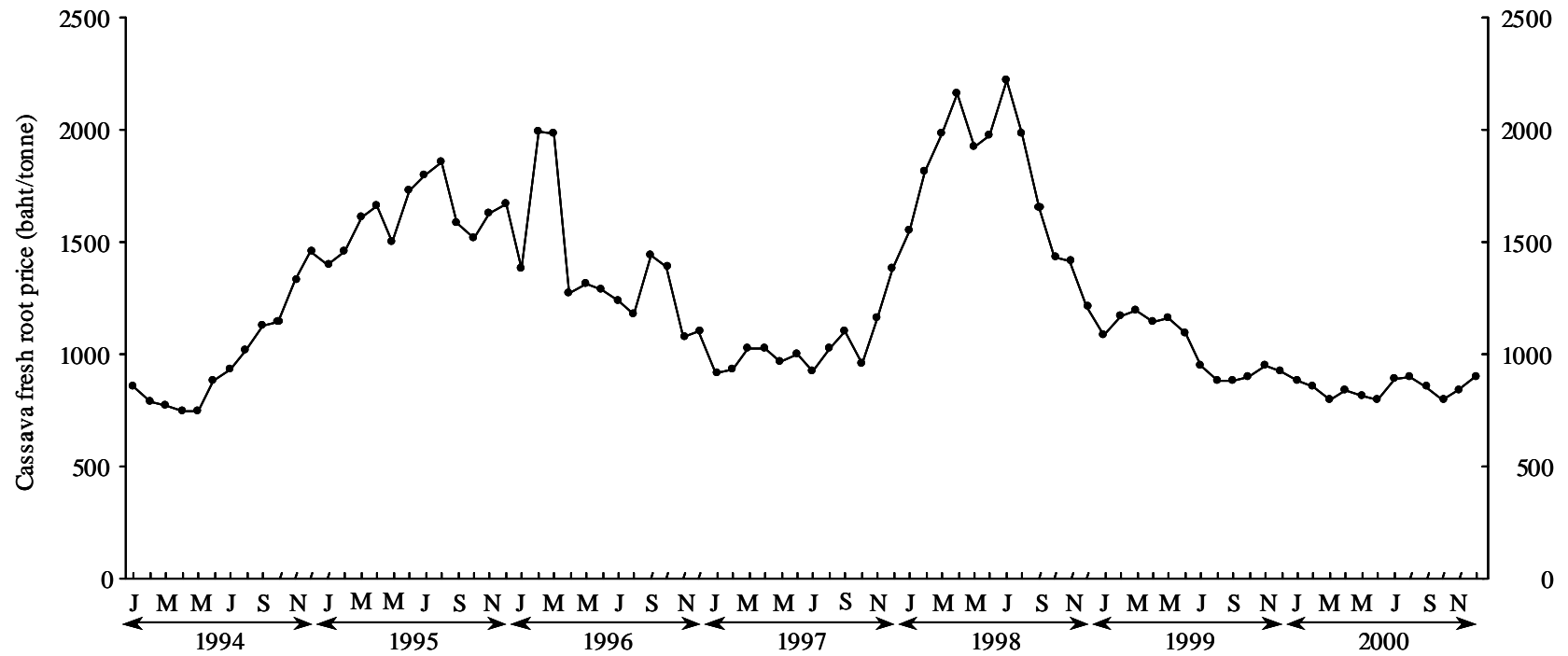


Figure 16. Monthly trend in the price of fresh cassava root (at 30% starch content) in Nakorn Ratchasima province of Thailand from 1994 to 2000.

C. CONSTRAINTS AND OPPORTUNITIES FOR SYSTEM IMPROVEMENT

1. The Resource Base and Production Technology

There are several fundamental issues surrounding development strategies that exploit marginal lands, both from the economic and environmental vantage points. Although less-favored areas make up only about 24% of the total land area in developing countries, they contain more than 36% of all the rural poor. The largest share of these people, 263 million, live in Asia. In the past, governments and donors adopted a strategy of investment in high-potential areas, since by definition, these generate more agricultural output and higher economic growth at lower cost. Even with these strategies, however, population growth and pressure on the environment have continued to worsen in less favored areas. A consensus is now evolving that critical investment in these areas is socially necessary, economically viable, and imperative for reversing serious land degradation.

Cassava can be a key component within this strategy. The comparative advantage that the crop has here is quite strong, but there are trends that could change this. First, other crops may begin to offer broader alternatives to cassava farmers. Breeders of several species, especially maize and sorghum, have paid more attention to stress tolerance in the past twenty years. There are certainly practical limits to which breeders can take a given species in adapting it to new environments, but there is also apparently considerable margin for improvement for most crops in stressed environments. This progress could displace cassava from some areas, and perhaps continue to push the crop toward the very poorest soils. The need for effective and economical soil fertility maintenance and erosion control will increase with this trend.

Secondly, farmers' increased purchasing power, and technology for soil stabilization, will allow improvement in some areas, from marginal to moderately productive conditions. This would also tend to displace cassava with higher value, more demanding crops. In either scenario, cassava will probably be pushed further toward the very poorest soils, exacerbating the risk of environmental degradation. Clearly, if there are crops that provide better income to growers than cassava, and/or are less of a threat to the environment, these should be encouraged.

Most national cassava programs have given research priority to resolving production constraints, especially through varietal improvement, and crop and soil management. This approach evolved from the era of explosive growth in cassava markets, and the need to meet market demand with increased production. As the challenges of marketing cassava products become more acute, and environmental concerns more apparent, programs are shifting the balance of research investment to include both demand and supply factors.

In an exercise to quantify constraints on global production, processing and marketing, CIAT surveyed a broad range of scientists and others knowledgeable about the cassava system, for their experience and perspectives (Henry and Gottret, 1996). A follow-up study (Van Norel, 1997) obtained further information from national programs, intending especially to upgrade information on post-harvest constraints. **Table 10** summarizes key information for Asia, with comparison to global estimates. In spite of the rather hypothetical nature of some of these estimates, the relative values across categories of

constraints, and across continents, give a tangible basis for prioritizing research. The following sections review the constraints that could be targeted to achieve the greatest economic impact.

Table 10. Cassava constraints analysis for Asia, with comparison to global.

Constraints	Yield gain from alleviating constraint		Asia's contribution to global yield gain (%) ¹⁾
	(%)	('000 tonnes)	
Production			
Soil management	35	17,067	36
Crop management	21	10,291	22
Intrinsic yield potential	24	11,384	31
Climate	11	5,153	25
Diseases	2	929	3
Pests	3	1,478	7
Total	96	46,301	2396
Post-harvest			
Quality	13	6,390	31
Processing	4	1,806	30
Product marketing	4	1,727	47
Total	21	9923	32
Total Cassava Sector	116	56,224	24

¹⁾Yield gain in Asia as percent of expected global yield gain from alleviating a given constraint.

Source: Adapted from Henry and Gottret, 1996.

a. Yield potential

Intrinsic yield potential of varieties may be the single most important factor limiting yields in Asia (**Table 10**). The definition of yield potential for cassava needs to be considered within the context of the crop's predominant role in Asia as an upland crop, in poor soils and with irregular rainfall. The CIAT survey specified a moderate level of management inputs, within the reach of most farmers of the region.

For the medium-term future (10-15 years), this would rarely include irrigation, with the exception of existing irrigated areas. The definition specifies nutrient use at low to moderate levels, but with most other agronomic practices at optimum levels -- land preparation, planting systems (time of planting, stake position, spacing), and weed control. Within these parameters, the analysis suggested a possible 26% yield gain across 89% of the Asian cassava-growing area, or a 24% potential increase over all Asia.

Until 15-20 years ago, the germplasm base in Asia was very narrow, with most countries relying on only a handful of varieties. This was undoubtedly one of the principal constraints to improving yield potential. Thailand was the extreme case, where all but a small percentage of area was planted to Rayong 1. Indonesia has reasonably broad diversity, but still narrow in comparison to Latin America. With the establishment of the CIAT Regional Office in Bangkok in 1983, one of the main thrusts has been to increase genetic diversity in the region. Typically, breeders introduce ten to thirty thousand seeds, each genetically distinct, every year from nurseries in Colombia. Even though only a small fraction of this diversity ever reaches farmers' fields, there is little doubt that far more genetic diversity was introduced into Asia in the past twenty-five years than in the previous two hundred.

The Thai breeding program has been particularly successful in broadening the genetic base by the introduction of sexual seed from Latin American. Through selection and an intensive crossing program, a large number of new varieties have been developed and released, replacing now almost entirely the traditional variety Rayong 1 (**Table 11**).

Table 11. Spread of new cassava varieties in Thailand from 1989/90 to 1999/00.

Variety	Area (ha)						% in 1999/00
	1989/90	1991/92	1994/95	1995/96	1997/98	1999/00	
Local variety ¹⁾	1,470,382	1,400,256	949,204	840,253	416,113	146,297	12.7
Rayong 3	17,158	50,283	135,421	14,953	NA	27,004	2.3
Rayong 60	-	-	125,049	207,589	206,057	216,897	18.8
Rayong 90	-	-	35,461	81,049	143,055	220,926	19.2
Kasetsart 50	-	-	322	17,846	149,270	410,852	35.7
Sri Racha 1	-	-	NA	NA	NA	4,125	0.4
Rayong 5	-	-	NA	66,424	129,594	125,823	10.9
Total new varieties	17,158	50,283	296,253	387,861	627,976	1,005,627	87.3
Total cassava area	1,487,540	1,450,539	1,245,457	1,228,114	1,044,089	1,151,924	
% with new varieties	1.1	3.5	23.8	31.6	60.1	87.3	

¹⁾ >90% Rayong 1

Source: Sarakarn, 2001.

b. Soil management

Significant constraints from low soil fertility and erosion affect much of Asia's cassava. Nitrogen is frequently the limiting nutrient, in contrast to Latin America, where potassium and phosphorus tend to be more limiting (Howeler, 1995; 2002). Fertilizer recommendations have been established on the basis of extensive soil analyses and fertilizer trials. Fertility constraints are as much a function of education and credit availability as the lack of scientific information. In India, China, Vietnam and Thailand, many farmers use small amounts of fertilizer, usually not at economically optimum levels. In Indonesia, associated crops tend to be fertilized, with some residual benefit to cassava. Elsewhere, fertilizer use is very limited except for special situations, such as large

commercial plantations. It is estimated that economically optimum use of practices to improve soil fertility could add 22% to current yields across the region, or over ten million tonnes.

Limiting soil erosion is a challenge in virtually any system involving annual crops on sloping fields. Cassava has two features that increase this challenge somewhat: it is easy to plant on steep slopes, with minimal land preparation; and it has a relatively slow rate of canopy formation. On the positive side, the long growing season means that the soil is covered by vegetation and is undisturbed over a long period of time once the canopy is established (Howeler *et al.*, 2000). The survey estimated potential yield increases of 0-10% by adoption of erosion control practices. More importantly, erosion control is indispensable for sustaining longer term productivity.

c. Crop management

On a regional basis, Asia has higher average yields than either Latin America or Africa. Farmers tend to manage their crops intensively, because of high population density and the need to optimize productivity of land. Hence, only modest yield increases can be expected from improving crop management (excluding *soil management*) in the Asian situation. According to the CIAT survey, quality planting material (*stakes*) and better weed control could contribute 7-8% each to yield, while optimum land preparation and spacing would provide modest yield improvements of only 3-4% each.

Weed control consumes the second highest level of labor input among crop management operations in Asia, from a low of 8 mandays/ha in Thailand to a high of over 200 in Tamil Nadu, India (see **Table 4**). In general weed control is good; survey results indicate inadequate control in about 37% of area planted, for an overall potential yield increase of about 7%. Most weed control is manual, but herbicide use is increasing in all countries, and is most wide-spread in Thailand. As demand for herbicides grows, agro-industries will find it profitable to develop herbicides targeted more specifically to the cassava plant and cropping systems. Currently herbicides are adapted from other crop systems to cassava, and often have not been adequately researched to optimize their use.

A herbicide-resistant cassava could prove highly beneficial to growers. Herbicide resistance, especially to glyphosate, is already incorporated into several crops and is widely used in the United States and Argentina, especially in soybeans and maize. The last few years have seen some increase in consumer concern about food safety and environmental impact for these genetically engineered crops. So it is somewhat uncertain how quickly the technology will spread to other crops, even where there is high potential grower demand.

d. Climate constraints

Drought imposes severe constraints on cassava growth and yield in parts of Asia, particularly northeast Thailand, eastern Java, and southern India (especially Tamil Nadu). Survey results indicate a potential yield increase of 9%, through a combination of practical management, and breeding for varietal adaptation. Management can include improving the soil's water-retaining capacity through incorporating organic matter, surface mulching to reduce evaporation, or ridging to capture maximum rainfall. No increase is projected through expansion of area under irrigation.

e. Pests and diseases

Perhaps the single most striking contrast between cassava production in Asia and elsewhere is the severity of pest and disease constraints. With a few important exceptions, these constraints are very limited in Asia. The Indian cassava mosaic disease, with etiology and symptoms similar to the African strain, occurs exclusively in India. Control is mainly through resistant varieties. The survey estimated a potential medium-term yield increase of 6% within the affected area. This low figure reflects the fact that moderately resistant varieties are already widely used by farmers. Root rots and bacterial blight are endemic in the more humid environments, especially in the Philippines, and the sub-tropics. Root rots can be controlled mainly through management (rotation, land preparation) and bacterial blight through resistance breeding.

Among the arthropod pests, only the red spider mite is of broad importance. Its control through host plant resistance or biological control could contribute about 2% to overall yields in Asia. The pest and disease situation will require constant monitoring, since introduction of new pests or pathogens, or changes in cultural practices could set the stage for new yield-reducing outbreaks.

2. Production Potential

The sum of individual components defines a potential yield increase of 96% by moderate alleviation of constraints. Given the existence of technology components to address nearly all these constraints to some degree, it should be possible to test the reality of these figures. The Asia Cassava Research Network has carried out well-managed trials in Asia for almost two decades. While breeding trials are aimed mainly at identifying potential new varieties, the trials also include good soil preparation, optimum plant spacing and weed control, and moderate fertilizer use. Yields of the hybrids, under good management in representative cassava areas, have been two to five times greater than the national average. Most of this increase appears to be from management, since hybrids yielded about 30% more than local varieties, similar to the potential increase projected by the constraints analysis.

3. Post-harvest

In the context of the survey, post-harvest constraints do not quite fit into the same analytical scheme as production factors, for projecting yield gains from constraint alleviation. In order to be consistent with units for yield gain, the post-harvest elements are divided into three parts: quality improvements are based on expected price premiums; gains in processing on reduced costs per unit; and gains in marketing on reduction in marketing margins (mainly reducing consumer prices). These estimates have some highly subjective components, and are biased toward the very conservative side.

Improved root quality will have the highest overall positive impact on post-harvest constraints (**Table 10**). Two traits are especially relevant: starch and post-harvest deterioration. Starch content is key to nearly every use of cassava in Asia, and especially the industrial sectors of starch extraction and pellets for animal feed. Raising starch content by breeding is clearly feasible, and has been a major objective of genetic improvement in most programs. Much of the recent success of new varieties in Thailand derives from a higher starch content as compared to the traditional variety, Rayong 1 (CIAT, 1996).

Cassava roots normally begin to deteriorate within a few days after harvest. The processing industry has had to develop elaborate systems for coordinating supply of raw material with processing capacity. This has often worked best when roots are converted at the farm or village level to a more stable product, such as dried chips. When fresh roots are delivered to a central factory, many small producers must coordinate their harvests. Even under the best circumstances factories processing fresh roots cannot operate at full capacity throughout the year. Extending the shelf-life of fresh cassava roots could add valuable flexibility to cassava management systems.

Currently-known management techniques include refrigeration, paraffin-coating of roots, and treatment with microbial inhibitors, followed by storage in plastic bags. None of these are practical for managing large volumes of roots destined for processing. A genetic approach seems most appropriate, given the ease and low cost of implementation. Longer term, there is reason to believe biotechnology approaches could offer innovative solutions (Wenham, 1995).

D. CASSAVA AS A CATALYST FOR DEVELOPMENT: ROLES AND STRATEGIES FOR RESEARCH

Cassava thrives in Asia, and particularly in Thailand, because of the ability of growers, entrepreneurs, R&D institutions, and policy-makers to adapt to evolving physical, biological, economic and social environments. Optimizing the role of cassava as a catalyst for development in the coming years will build on these attributes and resources. Strategies revolve around the constraints and opportunities described in preceding sections.

There are three broad priority areas for intervention by R&D institutions: (1) stimulating higher demand through market development; (2) adding post-harvest value through process and product development; and (3) improved production systems through technology for increasing production efficiency and profitability. In addition, institutional support, including education of policy-makers, is an *umbrella* activity covering all these areas. Interventions in production, processing and marketing cannot be undertaken independently -- there is continual interaction and feedback among these system components.

1. Market Development: Stimulating Higher Demand for Cassava Products

Sometimes market demand drives product development, and sometimes new products create market opportunities. For either to succeed, products and markets need to develop in coordination.

Cassava markets are of two broad types: markets where cassava competes directly with other carbohydrate sources; and markets that make use of the specific traits of cassava. The non-specific markets include animal feed and most of the uses for starch. It is by far the largest current type of market for cassava in Asia. These markets will be driven by macro-economic forces such as growing demand for meat in developing countries, and the ever-widening range of uses for starch. The cassava sector, mainly processors, will need to drive product development for replacement of existing ingredients, including convincing the user that the alternative product is as good, if not better, than that already used.

There is a clear need to promote research on markets that exploit cassava's unique starch characteristics. In markets where starch-consuming industries are beginning to use

functional ingredients, tremendous market opportunity presents itself. Success depends on the ability of the starch industry to assist the processors in technical issues relevant to application development. This is a strategy with considerable risk, as noted by Ostertag (1996). The technology for starch conversion is well-advanced and evolving rapidly. New technologies will allow native starch from almost any source to be converted to specific market needs, and thus the differential between raw materials tends to disappear. There is, nonetheless, considerable concern about the engineering of microorganisms (for converting starch) that could have unknown consequences in the environment, or the health and environmental effects of chemical modification. With that caveat, there certainly is still some opportunity for developing markets that favor cassava starch, or expanding existing ones. Success will come mainly from partnerships between public R&D institutions and the private sector.

2. Process and Product Development: Adding Post-harvest Value

A subsistence crop has a very short pathway from production to utilization -- it is usually destined either for direct consumption by the producer, or fed to animals to obtain meat, eggs or milk. The global trend in commodity markets is to continually add value to products as consumers increase their economic position. Low-value raw products at the farm level pass a series of transformations, each of which produces income or other value to a particular consumer. In developed countries, even basic food products may be valued at hundreds of times the price received by the farmer for the raw product.

Without a tradition of consuming fresh cassava, Asia has been a leader in processing innovations to meet demands of new and changing markets. All of these began at the household and cottage-industry level. At the level of household processing, Indonesia is the leading example of diversity and innovation. Also at the household level, Thailand has fine-tuned chipping and drying to a highly efficient and cost-effective system that gets a high quality product to the market in a timely manner. In Vietnam and China, farmers feed cassava to pigs to obtain a value-added and more marketable product.

Animal feed and starch are the principal growth markets for the medium-range future. Both have a very broad range of levels of sophistication -- from rudimentary on-farm exploitation to high-tech industries. Across this range, there are interventions that have high potential to benefit the rural poor. The principal need for processing innovations lies in the early stages of product conversion. These are the stages closest to the producer, and more likely to bring benefit to the rural poor. They are the stages where a product is converted to something that is more likely to be used by an already-developed industry. For example, the animal feed industry can very readily use hard cassava pellets in balanced rations. No new technology is required. However, converting fresh roots to hard pellets came from a series of innovations specific to cassava's characteristics. Likewise, the efficient extraction of high quality starch from cassava requires technology specific for cassava, but the use of that starch in any number of industries is often the same as for any other starch. A major focus of cassava R&D institutions should be on innovations that bring additional value to growers.

The animal feed export sector, which so much defined the dynamics of the Asian cassava industry for more than twenty years, is still a major force for economic development. It is, however, a market that will require every innovation and efficiency just

to retain current market share, because of the increasing competitiveness of coarse grains on world markets. No country of Asia is basing its plans for the cassava sector on dramatically expanded possibilities for export of cassava pellets.

Demand for animal feed will continue rapid expansion in developing countries. It is a growth sector for which several cassava-growing countries should be able to create viable *internal* industries. These industries may be successful across a range of scales of operation -- from rudimentary on-farm feeding of pigs to large, intensive poultry operations. There is, however, as in most industries, a continual move toward larger operations that exploit economies of scale.

Domestic use of cassava roots for production of animal feed in Thailand is presently minimal, mainly because of the absence of a relatively cheap source of protein to mix with the roots to produce an adequately balanced ration. Recent research at Khon Kaen University, Thailand, has shown that chopped and dried cassava shoots (leaves, petioles and non-lignified stems) contain up to 25% crude protein; its use as a supplement in dairy and beef cattle has given excellent results (Wanapat, 2001). Similarly, ensiled cassava leaves mixed with dry cassava root powder has given very good results in chicken, pig and dairy cattle feeding trials in Vietnam (Le Duc Ngoan, 2001), and with pigs in southern China (Liu Jian Ping and Zhuang Zhong Tang, 2001). The animal feed market will thrive with or without a cassava component. For cassava to reach its full potential participation, however, will require aggressive R&D input, mainly to find ways of economically growing, harvesting and drying cassava leaves, so these can be mixed with dry cassava chips to form pellets of balanced feed for specific animal species.

The animal feed market for cassava is a very mature market. The potential for additional market share lies in cost reductions, and added value by way of conversions that target specific markets. For example, the pelleting industries could develop capacity to mix complete rations, or even begin contracting the growing of chickens or pigs.

Because of the technical level of the starch and starch derivatives industries, there are possibilities for adding value at the farm level for this sector, by improving the level and consistency of root quality. The starch industry will contribute to rural development mainly through a higher demand for raw roots, and premiums for starch content and quality. Research should continue to focus on pre- and post-harvest crop management that meets the increasingly demanding standards of industry.

Markets for flour substitution seem to be more difficult to penetrate on a large scale. Quality and supply are very critical. There has been a tendency for demand to fluctuate too widely to interest major commitment from processors. This market needs continued research because of its high potential if price-competitiveness, high quality, and constant supply can be assured.

3. Improved Production Systems: Increasing Efficiency and Profitability for Farmers

In broad terms, producers have three possible alternatives to increase their net income from growing cassava: (1) *increase yields*, to reduce per-unit production costs; (2) *reduce costs*, while maintaining production levels; or, (3) *increase the value* of the product offered for sale while keeping costs and production levels the same.

Of course these are not mutually exclusive pathways, and each category has a number of possible variations. Successful crop technology in this century has been overwhelmingly based on the first of these -- on use of inputs to increase yields. The *green revolution* set the tone for crop improvement strategies, with emphasis on *total system output*. Consumers have been the greatest beneficiaries, with more abundant food at lower prices. It is a strategy that is eminently sensible in a world of food shortages, where increased supply has high social priority. The developing world is now a mosaic of food shortages and food surpluses, and a monolithic strategy for increasing agricultural production is clearly not a universal goal. In Asia's comparatively mature market economy, cassava producers can benefit economically from expanded areas of production, lowered production costs, higher productivity per unit of production cost, higher market value, or value-added features. They can benefit nutritionally both from the greater purchasing power of higher income, and from nutritional enhancements to cassava itself. Indirectly, they can benefit nutritionally from an increase in production that permits feeding cassava to animals. Less tangibly, technology provides avenues for lifestyle improvements such as less arduous physical labor inputs, or more time to pursue education or leisure.

a. Environmental resources

Farming practices are inextricably linked to environmental resources. Characteristics of the environment set limits on the types of agriculture that are economically feasible; and in turn agriculture can enhance or degrade the environment where it is practiced. Tradition, education, regulation, and economics all influence a farmer's attitude and relationship with the land. Generally, education and regulation can be applied successfully to environmental stewardship only if the economics are favorable. On the other hand, farm profitability is not in itself necessarily an incentive for adopting practices that improve the environment.

This interlacing of attitude and economics is a complex target for R&D institutions. Often the technology for preserving the environment is not complex, but there are inadequate economic incentives.

b. Crop management

The greatest returns to research investment in crop technology development should be for interventions that lower the very high labor inputs into cassava, increase yield, and increase starch content.

(1) *Agronomic practices.* Crop management is already more intensive in Asia than elsewhere. Rearrangements of existing practices or resources (i.e., if no *new* external inputs are applied) probably offer limited potential for improved productivity or profitability. For example, changes in stake planting position or plant density normally offer little advantage, unless in conjunction with another major system modification. There are good possibilities for increasing profitability with management in the areas of fertilizer application and efficient weed control. There are, nonetheless, substantial environmental concerns with both these inputs, and these must be addressed as part of any technology development. The fact is, however, that cassava will have great difficulty competing in the marketplace with crops where high efficiencies of production are achieved with intensive inputs, unless some of those same inputs are applied to cassava.

The economic response of cassava to fertilizer application is well-established (Howeler, 2001a). The constraints to increased use are socio-economic rather than technical. Farmers usually do not have cash reserves that can be tied up for a full year, between planting and harvest. Commercial or government-supported credit are not common. Nonetheless, most farmers now have experience with purchase and use of fertilizer on rice, and translating this to use with cassava should not be an insurmountable obstacle when the economic return is favorable.

(2) *Mechanization*. Cassava is still a very labor-intensive crop for most growers. Labor productivity has not been a major goal for cassava research, often based on the assumption that public institutions should be wary of technology that displaces labor in situations where underemployment is already high.

In any case, mechanization is typically difficult for cassava -- *economically* because of small landholdings, and *physically* because of cultivation on slopes and uneven terrain, or intercropping. While no-til systems have had limited success in cassava, there may be more potential for *zone tillage* systems, where a type of deep-penetrating tool is pulled through the soil only along the row to be planted. This leaves nearly all the residue on the surface for erosion control, while creating a tilled, aerated zone for rainwater penetration and root development.

c. Varietal development

Cassava has moved through three *mega-phases* of genetic improvement, characterized by a focus on: (1) yield potential; (2) production efficiency under conditions of environmental stress; and (3) incorporating value-added traits with (1) and (2). This latter phase is in the initial stages, and will probably define cassava genetic improvement in Asia for the next several years.

Many Thai farmers have had considerable exposure to new varieties through various promotion channels. Elsewhere, the practice of introducing and evaluating varieties through extensive on-farm trials is less common. The initial tests by farmers that prove the value of a new variety can translate into a continued, long-term interest in variety evaluation, and thereby greatly simplify the job of the extension service. If the momentum for adopting new varieties grows strong enough, there could eventually be motivation to bring the private sector into the picture to develop and sell varieties. This will be difficult, however, given the ability of farmers to save their own seed from one planting to the next.

The bottom line is that public support for cassava breeding will need to remain strong. The ongoing success of new varieties is significant. This will generate widespread interest in accelerating the pace of variety development, and in expanding the options in terms of varietal characteristics offered. Response to these demands will only be possible with continued, and increased, investments in research.

Breeding offers possibilities of adding value to the products that growers move to the marketplace. A prime example is development of the high starch varieties developed jointly between national programs and CIAT. Although higher starch varieties were available early in Thailand's breeding program, the real impetus for their adoption and further development did not come until industry began paying premiums for this trait. The time is now ripe to move into more advanced value-added traits – because the diversification and specialization of industry create a demand, and also because the

technology for targeted genetic modification of cassava is on the horizon. Genetic transformation and regeneration will open the door for applying technologies that are already routine in other crops (insect resistance, herbicide resistance), but more importantly for mapping a future for cassava that meets its specific production and market needs and opportunities. Partnerships involving all sectors will be the key to identifying appropriate research goals, as well as funding and executing the research. Some of the areas with highest potential to provide broad benefits through value-added traits are genetic modification of starch characteristics, tailored to specific markets; and increased post-harvest root storability by genetic means.

4. Institutional Support

Viability of the cassava sector in Asia has been very much the result of both private and public interests. Process, product and internal market development has been primarily in the hands of the private sector. Export development, on the other hand, has had very strong governmental support. While there are some notable examples of private sector participation in support to cassava research, the movement in this direction has been very slow. There is no doubt that in Asia cassava will continue as a basic energy source for food, feed and industry. If public support to research were to decline substantially, there may even be private funding to take on some of the research needs. Certainly, though, the private sector will have a very different development agenda, which would likely include lower priority for directing benefits to the rural poor. Social goals such as food security, poverty alleviation, equity and environmental protection, do not normally attract large sums of private sector investment. On the other hand, private enterprise seems to have a far better track record than does government, of successfully establishing efficient and profitable business practices. It is apparent that the potential synergy between public and private sectors is worth developing further.

R&D institutions can have an important role in policy analysis, as an educational resource for policy-makers who need to have access to comprehensive and unbiased information. With few exceptions, cassava producers have little political clout to influence policy that affects their ability to earn a livelihood. Development organizations can take the role of empowering the cassava sector to effectively present its interests before policy-makers. Farmers' organizations can be highly effective policy lobbyists, but these are still not common. Industry and commodity organizations are often well-positioned to speak for the interests of growers, processors and marketers. They usually recognize the need for a healthy total system, for any one sector to benefit. Prominent examples of such groups are the various Thai trade associations. Their principal activities are in the realm of industry promotion and trade, but they also promote supply-side benefits such as training of cassava farmers and the distribution of new varieties by the Thai Tapioca Development Institute (TTDI).

Cassava networks have not been active in policy debate, but this is a role for which they have some unique qualifications. The Asia Cassava Research Network, as the only one with a strictly regional focus, is in the best position to take on policy issues. While an international network would have limited direct voice in national policy debates, it is well-positioned to provide individual members with information and technical backup.

E. CONCLUSIONS: ORGANIZING FOR SHARED SUCCESS IN A COMPETITIVE WORLD

Market competition is becoming the defining trend that drives success in agriculture. Competition, brought about in large part by the global trend of more open markets, is almost universally welcomed by consumers, who benefit from more choices and lower prices. But it is a *double-edged sword* for growers. Market alternatives may be greatly expanded, but successfully entering any of them may require substantial adaptation in production, processing and distribution systems. In particular, cost efficiencies become critical, along with quality and timeliness of production. This can be a major challenge for cassava, when it confronts a commodity like maize, with a long history of global commerce and a massive research support system. On the other side of the equation, more demanding markets also open opportunities for specialized products outside the mainstream commodities trade. Cassava has particular possibilities in snack food and specialized starch markets, where it does not compete directly with other energy sources.

Perhaps the most profound lesson of the past is the critical importance of integrated development of production, processing and marketing components of the system. There are now several models where this type of broad integration has shown both some of the potential pitfalls and the benefits of an integrated approach.

The urgency of finding solutions to today's problems in food and agriculture is clear, and the tools to accomplish this are at hand. The greatest scientific advances in recent years have often been the outcome of partnerships -- between public and private concerns, among countries sharing common problems, and among thousands of motivated people sharing complementary skills and information. Communications technology now allows breaking many of the seemingly intractable barriers to developing effective partnerships -- across geographic distance, across professions and institutions, and across belief systems. Unless connections are made between the best of science and a general benefit to all of society, we are investing poorly in our future.

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