CASSAVA IN ASIA: A POTENTIAL NEW GREEN REVOLUTION IN THE MAKING

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ABSTRACT

Over the past decade the cassava planting area in Asia has slightly increased while yields have markedly increased, resulting in a steady increase in production, from 45.10 million tonnes in 1998 to 78.75 million tonnes in 2008. Due to a serious drought in Thailand in 2004, cassava production there temporarily dropped to 17 million tonnes in 2005 but increased again to 26.9 million tonnes in 2007, and 27.6 million tonnes in 2008. In most countries cassava is utilized domestically, but in Thailand it is mainly for the export market. China is presently a major importer, importing about 80% of its domestic requirement. In several countries in Asia, cassava is still principally used as food, but in Thailand, China and Vietnam it is mainly used for animal feed or industrial purposes.

Potential markets for cassava are mainly in the area of starch and starch-derived products, for domestic animal feed, and for processed food. Cassava starch can generally compete with other sources of starch on the basis of price in the mass market, and on the basis of its functional properties in certain specialized markets. However, recently there has been major interest in the use of cassava as a raw material for the production of ethanol, mainly as a "bio-fuel" to mix with gasoline to produces "gasohol". In this market cassava has to compete with sugarcane in tropical countries and with maize in the temperate zone.

Due to the increasing use of maize for ethanol production in the US, the price of maize and maize-derived products have markedly increased over the past 2-3 years. Thus, animal feed factories and farmers alike are looking at cassava roots as a cheaper source of energy and at cassava leaves as a protein source in animal feed rations. Similarly, the high price of maize starch has made cassava starch more competitive, increasing its price to unprecedented levels of over $500 per tonne in 2010. Finally, the construction of many cassava-based bio-ethanol factories, particularly in China but also in Thailand, Indonesia and Vietnam, have markedly increased the demand for cassava fresh roots and dry chips. Unfortunately, the recent accidental introduction of a new mealybug species, *Phenaccocus manihoti,* from either Africa or southern Latin America into Asia has seriously affected cassava yields in Thailand in 2009/10. In spite of significant increases in yields throughout much of Asia during the past few years, this problem will inevitably affect the supply of cassava in the region this year. This reduced supply will not be able to satisfy the increasing demand, resulting in marked increases in the prices of all cassava products. But since these lower yields have resulted in high root prices many farmers in Asia will still be able to obtain a good income from selling cassava. This in turn may stimulate the use of greater inputs in fertilization, weeding and even investments in drip irrigation to further boost yields. It also provides an incentive to increase the cassava planted area, in some cases on steep slopes or in previously forested areas. To make the current Cassava Revolution indeed a "Green" Revolution, urgent measures need to be taken to reduce negative environmental impacts by enhancing the adoption of soil conservation measures to prevent erosion and soil degradation. The recent introduction into Thailand of a parasitic wasp, *Anagyrus lopezi,* to control the new mealybug species gives hope that this problem will soon be resolved. In addition, there is an urgent need to breed and select higher yielding varieties that will increase farmers' yields and income, lower root prices and satisfy the needs of producers, consumers

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and processors alike, without the need to further encroach on steep slopes and forested areas. This truly "Green" Revolution will benefit all involved.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) has its origin in Latin America where it has been grown by the indigenous Indian population for at least 4000 years. After the discovery of the Americas, European traders took the crop to 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 crop in southern India, as well as on Java island of Indonesia and in the southern Philippines, while in Malaysia and parts of Indonesia it was also used for extraction of starch. After the Second World War it became an important industrial crop in Thailand, mainly to produce starch for local consumption, and dried chips and later pellets for the rapidly growing European animal feed market. In Indonesia the crop remains first and foremost a food crop, used in a great variety of dishes, but in southern Sumatra it is now mainly grown for starch extraction.

PRESENT SITUATION

1. Cassava Production Trends

Table 1 indicates that in 2008 about 51% of cassava in the world was produced in Africa, 34% in Asia, and only 15% in the Americas. Cassava production in Asia increased at a fairly high rate of 1.7% annually during the late 1970s and early 80s, slowed down considerably during the 90s, and has been growing very rapidly again at 5.7% per year during the past ten years (**Table 2**) (**Figure 1**); this was due to a modest increase in harvested area, as well as a remarkable increase in yields, averaging 3.8% per year; the latter compares with annual yield increases of 1.7% in Africa and 1.5% in Latin America during the same period.

Figure 2 shows the production and yield in the main cassava producing countries in Asia from 1961 to 2008. In some countries, cassava production kept pace with increases in population, while in others it decreased as a result of rapid urbanization and a more secure supply of the preferred food, rice. A marked exception is Thailand, where cassava production increased rapidly in the 1970s and 80s in response to a rapidly growing demand for animal feed in Europe, as well as a favorable tariff structure. But when the Common Agricultural Policy (CAP) in the EU changed in the late 80s, cassava became less competitive with locally produced barley, and exports of cassava pellets declined rapidly, from a peak of 9.1 million tonnes in 1989 to about 260,000 tonnes in 2005. In 2007 and 2008 it increased again to 1.6 million tonnes (**Figure 3**).

Table 1. Cassava production, area, and yield in the world, the continents and in various countries in Asia in 2008.

	Production ('000 tonnes)	Area ('000 ha)	Yield (t/ha)
World	**232,950**	**18,695**	**12.46**
-Africa	118,049 (51%)	11,989	9.85
-LAC	35,904 (15%)	2,718	13.21
-Asia	**78,754 (34%)**	**3,968**	**19.85**
-Cambodia	3,676	180	20.43
-China	4,362 [1)]	269	16.24
-India	9,054	270	33.55
-Indonesia	21,593	1,193	18.09
-Laos	233	11	21.19
-Malaysia	430	41	10.49
-Myanmar	211	16	12.79
-Philippines	1,942	212	9.17
-Sri Lanka	241	24	9.92
-Thailand	27,566	1,184	23.29
-Timor-Leste	49	12	4.14
-Vietnam	9,396	556	16.91

1) Chinese data indicate a production of 7.94 million tonnes, an area of 387,000 ha, and a yield of 20.52 t/ha.
Source: *FAOSTAT, Feb 2010.*

Table 2. Annual growth rates (%) in cassava production, area and yield, by continent, 1978-2008.

	Production			Area			Yield		
	'78-88	'88-98	'98-08	'78-88	'88-98	'98-08	'78-88	'88-98	'98-08
Africa	2.8	3.6	2.7	1.4	2.9	1.0	1.4	0.7	1.7
Asia	**1.7**	**-1.6**	**5.7**	**0.7**	**-2.0**	**1.9**	**1.0**	**0.4**	**3.8**
Americas	-0.8	-0.5	2.7	-1.2	-0.2	1.2	0.4	-0.3	1.5

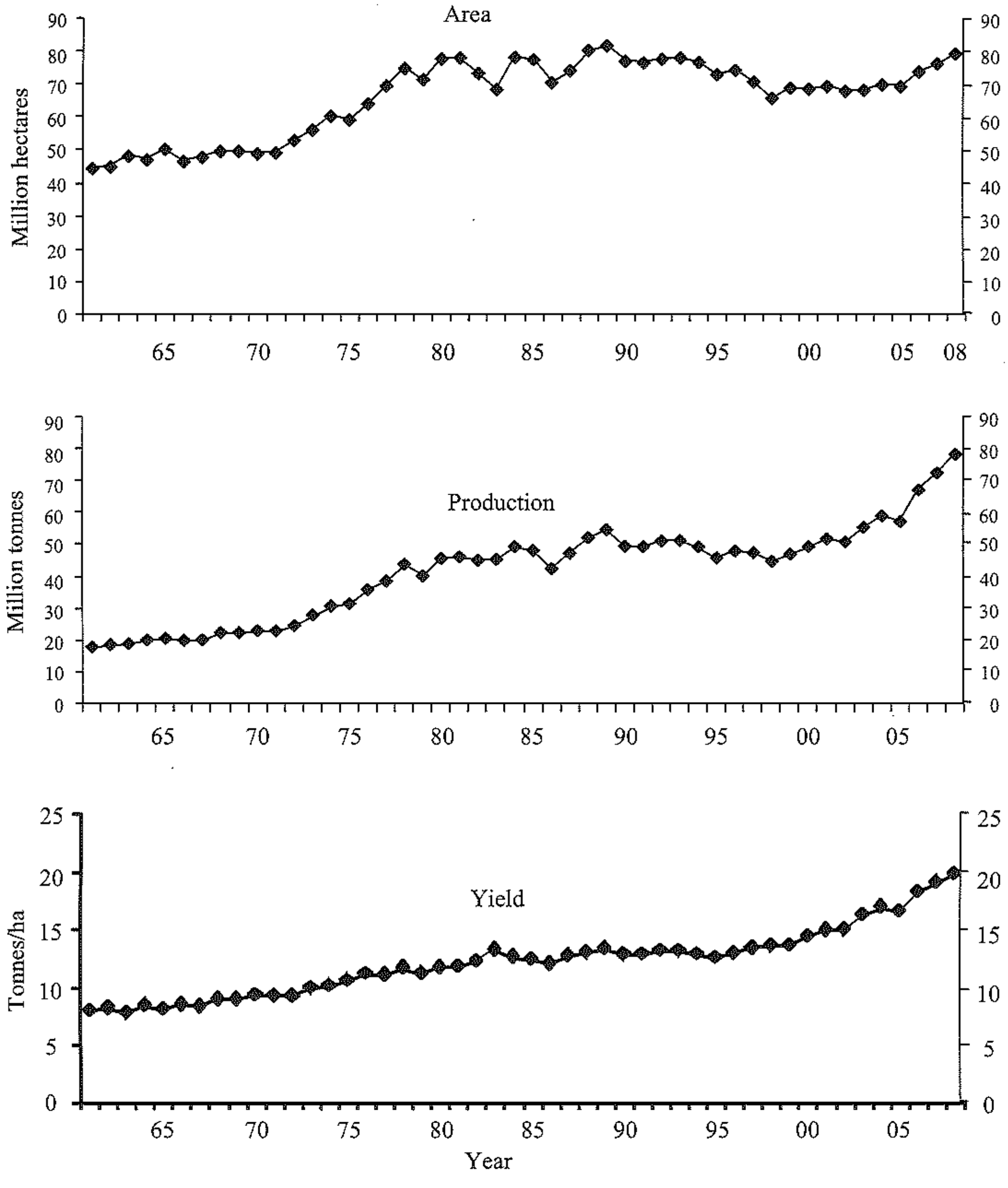

Figure 1. Total harvested area, production and yield of cassava in 12 countries growing cassava in Asia, 1961-2008.
***Source:** calculated from FAOSTAT, Feb 2010.*

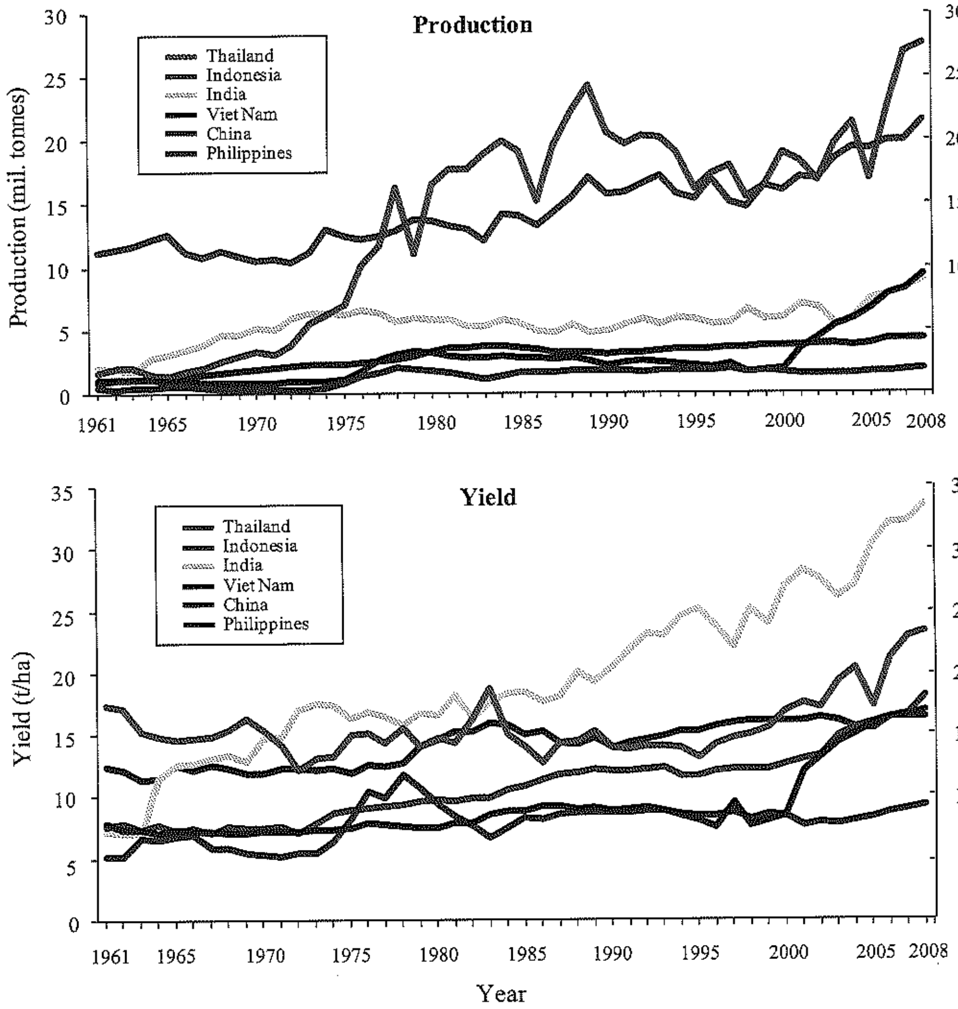

Figure 2. Cassava production and yield trends in Asia's principal cassava producing countries, 1961-2008.
Source: *FAOSTAT, Feb 2010.*

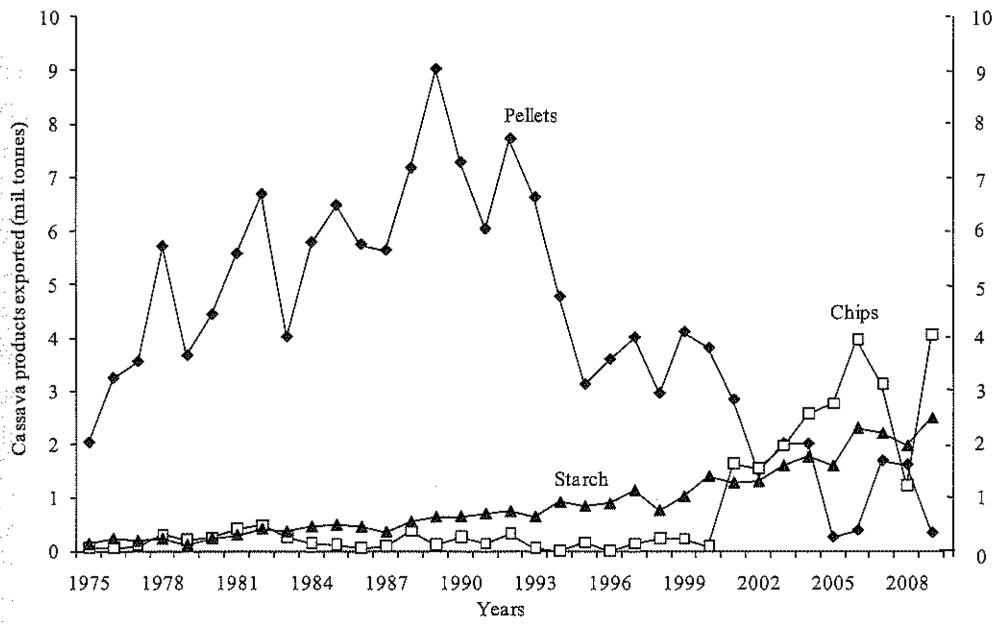

Figure 3. Quantities of cassava products exported from Thailand from 1975 to 2009.
***Source:** Adapted from TTTA, 2008 and 2009.*

This near-collapse of the export market in Europe was partially offset by accelerated growth in the production of starch and starch derivatives, as well as by increasing demand for cassava chips in China. Meanwhile in Vietnam, cassava production was in decline during the 1980s and 1990s as the economy improved and production of rice increased. But during the past eight years, cassava production suddenly increased from about 2 million tonnes in 2000 to over 9.4 million tonnes in 2008, in order to meet buoyant internal demand for starch, and for export of chips and starch. This ability to increase production was a result of a substantial increase in planted area, from 237,600 ha in 2000 to 555,700 ha in 2008, as well as a remarkable increase in yield, from 8.36 t/ha in 2000 to 16.91 t/ha in 2008. In both Thailand and Vietnam, the yield increases achieved during the past 10 years, are mainly due to a concerted effort to distribute widely the new high-yielding and high-starch varieties, as well as to the adoption of improved cultural practices, such as more balanced fertilizer use and soil conservation measures. In Thailand, new varieties are now planted in nearly 100% of the area, while 80-90% of farmers apply chemical fertilizers; in Vietnam the new varieties are now planted in about 60% of the cassava area while about 80% of farmers apply chemical fertilizers and/or organic manures. These two factors combined more than doubled yields in Vietnam over the past eight years.

2. Production Systems

Cassava is known to be a very drought-tolerant and water-efficient crop, while the crop is also exceptionally tolerant of high soil acidity and low levels of available phosphorus (P). Thus, cassava can compete with other, more valuable, crops such as maize, soybean and vegetables mainly in areas of acid and low-fertility soils, and those with low or unpredictable rainfall, such as the northeast of Thailand, the central coast of Vietnam and in east Java.

Until very recently there were no economically important pests or diseases in Asia – with the exception of India – so there was no need for the use of pesticides. Fertilizers or organic manures are commonly used on cassava, but not necessarily in adequate amounts or in the right proportions of N, P and K. Usually, responses to organic manures can be greatly enhanced by additional application of chemical fertilizers high in N and K.

During the past five years, and particularly during the past year, cassava production costs in Thailand have increased rapidly, about 75% from 2003/04 to 2007/08 in US dollar terms (**Table 3**). But root prices have increased about 140% during the same period, resulting in a five-fold increase in the net income for farmers, from $ 112/ha in 2003/04 to $ 629/ha in 2007/08.

Production costs vary significantly across the region. Production costs for advanced farmers in Indonesia, India and China seem to be higher than in Cambodia, the Philippines and Thailand, while they are lowest in Vietnam. When calculated per tonne of fresh roots, production costs in Vietnam and Thailand are lower than in India, Cambodia or the Philippines, and much lower than in Indonesia and China (**Table 4**). It is clear that cassava products from Thailand remain competitive because farmers increased their yields through the use of improved varieties and better production practices (Howeler, 2001; 2005).

After years of stagnating or declining profit margins, farmers in Thailand, as well as in other parts of Asia, are finally making a good income from growing cassava. This is due to an ever increasing demand for cassava roots, which currently far outstrips supply, resulting in record-high prices for all cassava products, and a "boom" in cassava production all over Asia. Cassava is becoming a "high-value crop", which encourages and enables farmers to intensify production practices to increase yields.

3. Products and Markets

Both cassava roots and leaves (or young plant tops) have multiple end-uses, including direct human consumption of fresh roots and leaves (after boiling), on-farm animal feeding, commercial production of animal feed, and production of starch or starch derivatives. **Figure 4** shows in more detail the various products made from cassava starch and dried chips, as well as from the peels and pulp, which are by-products from the starch industry.

a. Fresh roots for human consumption

In Kerala state of India, as well as in East Timor, Lao PDR, Cambodia, the Philippines and in some areas of China and Vietnam, fresh cassava roots are consumed directly after boiling or roasting. In most other parts of Asia cassava is not consumed as fresh roots, but only after some form of processing.

Table 3. Average cassava production costs in Thailand from 2003/04 to 2007/08 (US $/ha).

	2003/04	2004/05	2005/06	2006/07	2007/08
1. Variable Costs ($/ha)	**313.49**	**350.80**	**393.12**	**478.09**	**575.01**
1.1 Labor costs	***187.84***	***206.70***	***239.43***	***292.86***	***354.59***
-land preparation	45.61	50.72	59.09	75.18	95.00
-planting	21.26	25.31	28.47	34.36	40.21
-crop maintenance	53.94	62.99	70.98	84.99	104.85
-harvest	67.03	67.68	80.89	98.33	114.53
1.2 Agricultural input costs	***97.15***	***112.21***	***126.26***	***151.88***	***180.30***
-planting material	31.86	35.08	37.66	44.10	51.02
-fertilizers	42.36	50.19	58.17	70.85	85.35
-insecticides/herbicides	20.90	24.90	28.25	34.02	40.51
-fuel and lubricants	1.04	1.05	1.15	1.60	1.83
-machinery and others	0.73	0.73	0.76	0.96	1.18
-machinery repair/maintenance	0.26	0.26	0.27	0.35	0.41
1.3 Interest on production costs	***28.50***	***31.89***	***27.43***	***33.35***	***40.12***
2. Non-variable costs ($/ha)	**52.16**	**52.28**	**52.47**	**59.60**	**67.28**
-land rental	50.48	50.60	50.78	57.69	65.12
-machinery depreciation	1.50	1.50	1.51	1.71	1.93
-interest on machinery	0.18	0.18	0.18	0.20	0.23
3. Total Production costs ($/ha)	**365.65**	**403.08**	**445.59**	**537.69**	**642.29**
Production cost per tonne	18.03	23.46	21.13	23.45	28.67
Cassava yield (t/ha)	20.28	17.18	21.09	22.93	22.40
Cassava root price (B/kg) [1)]	0.95	1.32	1.42	1.21	1.77
Cassava root price (US$/t) [1)]	23.56	32.92	35.62	34.51	56.74
Gross income (US$/ha)	477.80	565.57	751.22	791.31	1,270.98
Net income (US$/ha)	112.15	162.49	305.63	253.62	628.69
Exchange rate (baht/US$)	40.16	40.06	39.92	35.14	31.13

[1)] Estimated at 90% of the root price at 30% starch (TTTA, 2007)

Source: *Office of Agricultural Economics (OAE) of Thailand, 2008.*

Table 4. Estimated cost of cassava production for advanced farmers in several countries in Asia in 2008.

	Cambodia	China	India	Indonesia	Philippine	Thailand	Vietnam
1. Variable Costs ($/ha)							
Labor cost ($/manday)	2.93	5.80	4.35	3.87	3.33	4.41	2.[illegible]
-land preparation. (md/ha)	-	*5*	*31*	-	*8*	*6*	
-stake preparation	-	-	*5-*	*5*	*6*	-	
-planting	*15*	*5*	*12*	*18*	*10*	*10*	
-fertilizer application	*10*	*5*	*6*	*5*	*4*	*6*	
-manure application	*2*	*0*	*75*	*5*	*0*	*6*	
-irrigation	-	-	*17*	-	-	-	
-weeding	*29*	*30*	*86*	*17*	*8*	*11*	
-plant protection	-	-	*0.5*	-	-	-	
-harvesting	*34*	*20*	*37*	*33*	*30*	*14*	
-loading	*10*	*10*	*9*	*1*	-	*12*	-
Total mandays/ha	*100*	*75*	*210.5*	*84*	*66*	*65*	[illegible]
Total Labor Costs ($/ha)	**293.00**	**435.00**	**915.68**	**325.08**	**219.78**	**286.65**	**312.[illegible]**
Other Costs							
-fertilizers	156.10	137.00	88.50	402.76	355.56	110.29	131.[illegible]
-manures	73.17	0	96.50	66.30	0	99.91	43.[illegible]
-planting materials	88.62	107.00	15.78	0	111.13	99.91	
-plant protection chemicals	-	-	3.33	-	-	-	
-other materials	8.94	64.00	10.00	37.57	0	0	30.[illegible]
-fuel	71.95	0	16.00	0	0	0	
-transportation of roots	73.17	60.00	-	173.35	16.67	22.06	
-land prep. by tractor	102.44	107.00	96.35	119.34	177.77	82.72	
-land prep. with bullocks	-	-	24.35	-	-	-	
Total Other Costs ($/ha)	**574.39**	**475.00**	**350.81**	**799.32**	**661.13**	**414.89**	**205.[illegible]**
Total Variable Costs ($/ha)	**867.39**	**910.00**	**1,266.49**	**1,124.40**	**880.91**	**701.54**	**517.[illegible]**
Land rent or taxes ($/ha)	97.56	220	31.80	331.00	0	99.91	
Total Product. Costs ($/ha)	**964.95**	**1,130.00**	**1,298.29**	**1,455.40**	**880.91**	**801.45**	**517.[illegible]**
Production Costs ($/tonne)	**35.74**	**41.85**	**38.75**	**55.98**	**35.24**	**28.62**	**19.[illegible]**
Yield of cassava (t/ha)	**27**	**27**	**33.5**	**26**	**25**	**28**	[illegible]
Root price ($/tonne)	**77.24**	**66.20**	**87.00**	**80.11**	**44.44**	**56.74**	**56.[illegible]**
Gross income ($/ha)	**2,085.48**	**1,787.40**	**2,914.50**	**2,082.86**	**1,111.00**	**1,588.72**	**1,462.[illegible]**
Net income ($/ha)	**1,120.53**	**657.40**	**1,616.22**	**627.46**	**230.09**	**787.27**	**945.[illegible]**
Exchange rate (currency/ $)	R 4,100	RMB 7.00	Rp 46.00	Rp 9,050	P 45.00	B 33.00	D 16,0[illegible]

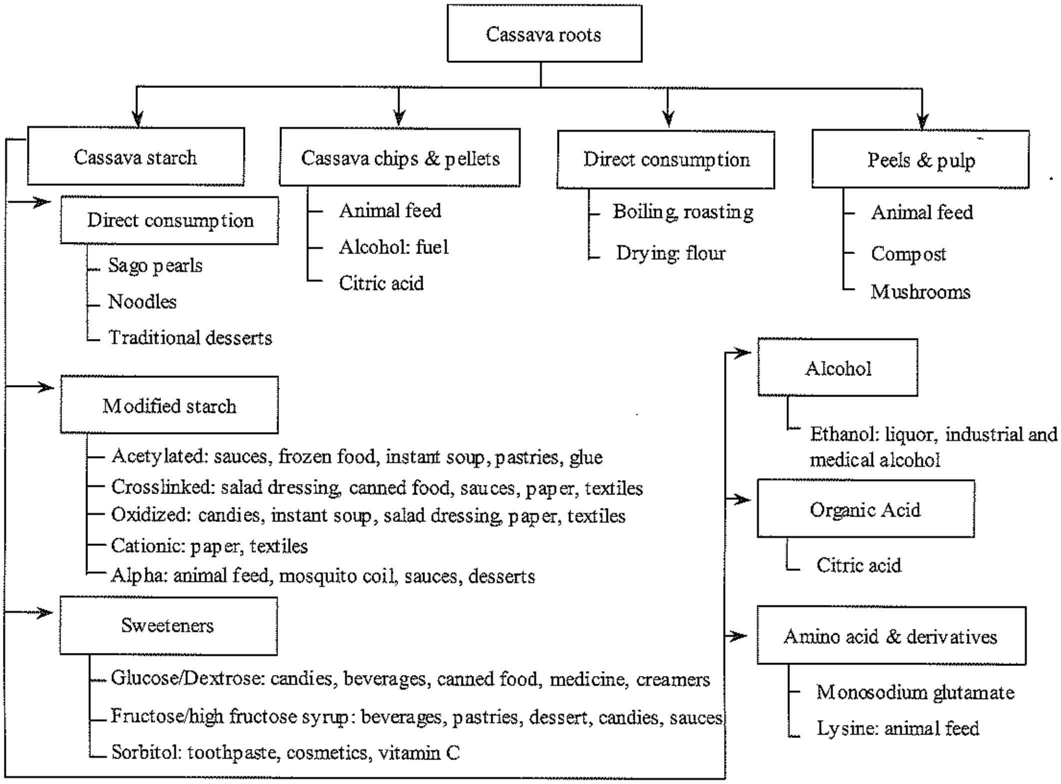

Figure 4. Cassava root processing into value-added products.
***Source:** Adapted from TTFITA, 2000.*

b. Flour for human consumption

The simplest and most common form of processing, used widely in Indonesia, is to peel the roots, wash and slice and then sun-dry for 2-3 days to produce dry cassava chips or chunks, in Indonesia known as *gaplek*. *Gaplek* can be stored and is traded in village markets. When needed, the dry root pieces are pounded into a flour, which is shaken on a bamboo screen with some warm water to produce granules, called *tiwul*. The size and shape of these granules is similar to rice grains and the *tiwul* is often cooked together with rice to extend the family's limited supply of rice. Presently, small processing plants in Indonesia buy fresh roots to be processed directly into various flour mixes (supplemented with vitamins and flavors) as well as semi-cooked *instant tiwul*. These are mainly destined for urban consumers.

c. Chips and pellets for animal feed.

Up until very recently, cassava chips and pellets were the mainstay of the Thai "tapioca" trade, mainly for export to Europe (**Figure 3**). However, in 2009, Thailand exported only about 17,000 tonnes of cassava pellets to Europe, down from 6.0 million tonnes in 1989; but unlike in 1989 it exported considerable quantities of dry chips, about 4 million tonnes, to China, where these are used mainly for production of commercial animal feed and alcohol. **Table 5** shows that the export of dry cassava products is still dominated by Thailand, while China is the main importing country, both for cassava chips and starch. Chip imports were 4.672 million tonnes in 2007, but increased to over 6 million tonnes in 2009, mostly from Thailand and Vietnam, with smaller quantities from Indonesia and other countries (**Table 6**).

Table 5. Total world trade in cassava products in 2007.

	Exports ('000 t)					
	Fresh root equivalent	Dry products ('000 t)				
		Starch	Tapioca pearls	Chips+ pellets	Flour	**Total**
World	**27,212**	**1,572**	**32**	**6,497**	**6**	**8,107**
-Americas	573	46	1	127	2	**176**
-Europe	970	16	0	256	1	**273**
- Africa	99	1	1	24	2	**28**
-Asia	**25,560**	**1,510**	**30**	**6,088**	**0**	**7,628**
-Cambodia	7	3	-	0	-	**3**
-China	38	4	13	0	-	**17**
-India	10	1	2	1	0	**4**
-Indonesia	839	23	11	210	0	**244**
-Japan	0	0	0	0	0	**0**
-Korea (ROK)	0	0	0	0	0	**0**
-Malaysia	4	0	0	1	0	**1**
-Philippines	4	0	0	1	0	**1**
-Thailand	19,738	1,422	0	4,559	0	**5,981**
-Vietnam	4,789	-	-	1,317	-	**1,317**

	Imports ('000 t)					
	Fresh root equivalent	Dry products ('000 t)				
		Starch	Tapioca pearls	Chips+ pellets	Flour	**Total**
World	**29,181**	**1,956**	**50**	**6,783**	**16**	**8,805**
-Americas	589	85	13	98	4	**200**
-Europe	6,266	113	2	1,650	3	**1,768**
- Africa	143	29	1	19	2	**51**
-Asia	**22,127**	**1,706**	**35**	**5,013**	**8**	**6,762**
-Bangladesh	129	51	7	-	0	**58**
-China	19,002	892	14	4,672	-	**5,578**
-India	2	0	1	0	0	**1**
-Indonesia	680	306	0	0	0	**306**
-Japan	420	143	2	27	0	**172**
-Korea (ROK)	1,176	35	0	302	0	**337**
-Malaysia	281	118	2	4	0	**124**
-Philippines	89	40	0	0	0	**40**
-Thailand	11	0	0	3	0	**3**
-Vietnam	-	-	-	-	-	**-**

Source: *FAOSTAT, Feb 2010.*

Table 6. Importation of cassava chips from various countries by China in 2009.

Country	Dry cassava chips ('000t)
Thailand	3,863
Vietnam	2,011
Indonesia	143
Laos	2
Others	0.3
Total	**6,019**

Source: *Boonmee Watanaruangrong, 2010. (from* www.chinajci.com.)

Tables 7 and **8** show that in 2007 China was the main domestic consumer of cassava products and that over 80% of its requirement of 22.3 million tonnes of fresh root equivalent was imported from other countries in Asia. Most of the cassava was imported in the form of dry chips (**Table 5**) and used for production of animal feed and other (mostly industrial) uses (**Table 7**). Only about 10% was used for food. In contrast, Indonesia had a similar domestic requirement of about 20 million tonnes, but about 50% of that was used for food.

Table 7. Production, supply and domestic utilization of cassava in 13 cassava producing countries in Asia in 2007. Data are in fresh root equivalents.

	Domestic supply ('000 t)				Domestic utilization ('000 t)			
Country	Production	Import	Export	Domestic uses	Food	Feed	Other uses	Waste
Asia	**72,914**	**22,629**	**23,515**	**66,093**	**24,379**	**19,214**	**17,411**	**5,087**
-Thailand	26,916	10	18,404	2,676	883	135	312	1,346
-Indonesia	19,988	1532	991	20,529	9,974	400	7,555	2,600
-India	8,232	6	16	8,222	7,811	-	0	412
-Vietnam	8,193	-	3,762	4,431	623	3,399	-	410
-China	4,362	18,188	318	22,262	2,015	15,098	5,018	131
-Cambodia	2,215	-	12	2,203	364	<1	1,728	111
-Philippines	1,871	161	5	2,027	1,791	75	161	-
-Malaysia	430	610	3	1,036	398	21	595	21
-Lao PDR	233	13	-	126	79	23	-	23
-Sri Lanka	220	22	<1	242	154	55	22	11
-Myanmar	211	2	-	213	192	-	-	21
-East Timor	41	-	-	41	40	-	-	1
-Bangladesh	-	235	-	235	29	-	206	-

[1] Much of the "waste" (peels, solid residue from starch extraction etc.) is used for industrial purposes or animal feed.

Source: *FAOSTAT, Commodity Balances, July 2010.*

Table 8. Total domestic food supply (in fresh root equivalents, '000 t) and utilization (%) of cassava, as well as the per capita supply as food and its contribution to the diet in 13 cassava producing countries in Asia in 2007.

Country	Population (mil.)	Domestic utilization (%) Food	Feed	Other uses	Waste	Total food supply ('000 t)	Per capita supply Fresh equiv. (kg/yr)	Energy (kcal/d)	Protein (g/day)	Fat (g/day)
Asia (13)	**3,108**	**36.9**	**29.1**	**26.3**	**7.7**	**24,379**	**6.15**	**16.15**	**0.09**	**0.04**
-Thailand	63	33.0	5.0	11.7	50.3	888	13.18	39.89	0.31	0.07
-Indonesia	223	48.6	1.9	36.8	12.7	9,974	44.39	121.67	0.70	0.29
-India	1,081	95.0	-	-	5.0	7,811	6.71	15.19	0.07	0.02
-Vietnam	82	14.0	76.7	-	9.3	622	7.23	20.01	0.14	0.06
-China	1,313	9.1	67.8	22.5	0.6	2,014	1.51	4.44	0.04	0.01
-Cambodia	14	16.5	0.1	78.4	5.0	364	25.43	70.37	0.49	0.21
-Philippines	81	88.4	3.7	7.9	-	1,791	20.19	55.85	0.39	0.17
-Malaysia	25	38.5	2.0	57.5	2.0	398	14.99	40.86	0.29	0.11
-Lao PDR	6	63.2	18.4	-	18.4	79	13.04	35.63	0.23	0.10
-Sri Lanka	19	63.6	22.7	9.1	4.6	154	7.74	32.45	0.15	0.04
-Myanmar	50	90.1	-	-	9.9	192	3.91	10.81	0.08	0.03
-East Timor	<1	97.6	-	-	2.4	40	37.57	91.36	0.38	0.15
-Bangladesh	150	12.3	-	87.7	-	29	0.19	0.46	0.00	0.00

[1] much of the "waste" (peels, solid residue from starch extraction etc.) is used for industrial purposes or animal feed.

Source: *FAOSTAT, Food Supply, July 2010.*

In India, East Timor, Myanmar and the Philippines practically all cassava was domestically produced and used for human consumption, mostly after boiling of fresh roots, or in the form of processed products such as sago, starch and a variety of snack foods. In Vietnam cassava is mainly used for animal feeding, either on-farm or in commercial animal feed rations, but much cassava is also used for starch production, which is not shown in **Table 7**.

Table 8 shows that per capita consumption of cassava-based foods was highest in Indonesia, followed by East Timor, Cambodia and the Philippines. It is an important source of calories, especially for the poorer and rural segments of the population, while it is an important ingredient in many snack foods consumed by the general population of Indonesia. While Thailand is the largest producer of cassava in Asia, only about 10% is used domestically, mainly for production of food, commercial animal feed and various industrial (non-food) products such as modified starch for the paper and textile industries, and recently for production of fuel-ethanol (**Table 9**). Thai data show up to 30% domestic use of cassava in the country, much higher than the FAO data in **Table 7**.

Table 9. Estimated use of cassava starch in various industries in Thailand in 2007.

Industries or products	Starch usage ('000 t)	Starch usage (%)
Glucose, high fructose, sorbitol	460	35.4
Monosodium glutamate	250	19.2
Food factories and cooking	200	15.4
Modified starch	150	11.6
Paper	120	9.2
Tapioca pearls (sago)	60	4.6
Textiles	10	0.8
Others (glue, medicine, plywood)	50	3.8
Total	**1,300**	**100**

***Source**: Office of Agricultural Economics, Ministryof Agriculture and Cooperatives..*

In China the total annual consumption of starch and derived products in 1998 was about 4.03 million tonnes, of which 3.32 million tonnes (82.3%) was maize starch, 470,000 tonnes (11.7%) cassava starch, 96,000 tonnes (2.4%) each of sweet potato and wheat starch, and 48,000 tonnes (1.2%) potato starch (Tian Yinong *et al.*, 2001). In 2007, China imported about 4.67 million tonnes of cassava chips and 892,000 tonnes of starch. Most of the chips are used for production of alcohol and animal feed, respectively, while the starch is used mainly for production of modified starch, sweeteners and MSG.

d. Starch for food and industry

Cassava starch can be divided into *native starch* and *modified starch*. The production of native starch is a relatively simple process, that can be done at many scales, either at the household level, such as in some villages in north Vietnam, Cambodia and on Java island of Indonesia, up to very large and fully-mechanized starch factories, such as those in Thailand, south Vietnam, and in Lampung province of Indonesia. One tonne of fresh roots usually results in 250-300 kg of starch. During the past decade, the cassava starch industry in Thailand has expanded very rapidly (**Figure 3**), and total production in 2009 was approximately 3.8 million tonnes consuming about 50% of the total production of 27.7 million tonnes of cassava roots. Of the 3.8 million tonnes of starch produced, about 2.5 million tonnes were exported, of which 1.8 million tonnes was native starch and 0.7 million tonnes modified starch, with a value of 488 and 376 million US dollars, respectively. Most of the starch was exported to China, Japan, Taiwan and Indonesia.

In Indonesia the cassava starch industry suffered significant losses after the 1997 economic crisis, but has now mostly recuperated. In 2002, total production was 1.34 million tonnes of starch (P.T. Corinthian, 2004). Practically all cassava starch produced in Indonesia is for the domestic market. In India, most cassava starch is produced in Tamil Nadu (about 90%) and Andhra Pradesh (10%) with a total annual production of cassava starch and tapioca pearls (or sago) of 330,000 tonnes (Edison, 2001). In China, cassava starch production was about 900,000 tonnes in 2007, while an additional 500,000 tonnes of cassava starch were imported (Tian Yinong, 2010). In Vietnam cassava starch production is increasing rapidly and for 2003 it was estimated at about 500,000 tonnes, of which 70% was exported (mainly to China, Taiwan and Korea) and 30% used domestically (Hoang Kim, personal communication).

e. Modified starch

Native starch can be modified by either physical, chemical or enzymatic processes, producing different forms of "modified" starch with distinctly different properties and different uses. Modified starches are used in many different types of foods as well as in industry, mainly for production of high quality paper, for textile sizing and some animal feeds (**Figure 4**). One of the main users of modified starch is the paper industry. Cationic starches made from cassava starch are particularly suitable for the sizing and coating of paper in high-speed paper making machines (Jin Shuren, 2001). Other main users of modified starch are in the food industry, textiles, in agriculture and in animal feed, while smaller amounts are used in construction materials, in casting, oil drilling and medicines.

f. Starch-based sweeteners

Cassava starch can be used for the production of many types of sweeteners after hydrolyzation by either acids or enzymes, or both. These sweeteners include maltose, glucose syrup, glucose and fructose, which can be further processed into various oligo-saccharides (Jin Shuren, 2001) or into ethanol.

g. Hydrogenated sweeteners.

These include sorbitol, mannitol and maltol. They are produced by treating starch with hydrogen gas in high-pressure tanks, using a special catalyst and ion-exchange resins. Sorbitol is used mainly for the production of vitamin C and as a moisture conditioner in toothpastes (Jin Shuren, 2000).

h. Organic acids

Organic acids made from cassava starch include citric acid, acetic acid, lactic acid and itaconic acid, which are used in the food industry as well as for the production of plastics, synthetic resins, rubber products etc. Lactic acid is produced by the fermentation of starch with *Lactobacillus amylovorus* (Wang Xiaodong *et al.*, 1997; 2000).

i. Monosodium glutamate (MSG) and Lysine

MSG is a well-known flavor-enhancing agent used in many Asian kitchens. It is made through the microbial fermentation of starch or sugar (molasses) in the presence of ammonium salts. In Thailand, MSG production is one of the main consumers of native cassava starch (**Table 9**). Lysine is an important amino-acid used as a supplement in animal feed, especially for pigs.

j. 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% ethanol) for which no motor modification is required, or as pure anhydrous ethanol, in which case the carburator and some other parts need to be modified (de Souza Lima, 1980). Both result in less atmospheric pollution than the use of 100% gasoline.

In China, several factories in Guangxi have been using the solid waste (pulp) of the cassava starch industry for the production of ethanol (Gu Bi and Ye Gozhen, 2000). Other alcohol factories in China are switching from the use of molasses to that of cassava chips for alcohol production, because of strict pollution control requirements that makes the use of molasses uneconomic. In Guangxi there are now about 200 alcohol factories, most of which still use molasses as the raw material. But about 20 factories use mainly cassava fresh roots, supplemented with cassava dry chips and molasses when no fresh roots are available. In 2008 these produced about 150,000 tonnes/year of hydrous ethanol (95% ethanol), mainly for drinking or industrial use (Tian Yinong, 2010).

Since about 2002 the Chinese government has promoted the use of "gasohol" instead of gasoline, in order to reduce the importation of oil and reduce air pollution from greenhouse gasses. There are presently four large companies producing anhydrous or fuel-ethanol in four provinces, mostly located in the north and northeast. Three of these use maize and one uses wheat as the raw material. Together they produce about 1 million tonnes of fuel-ethanol per year, or 3.35 million liters per day. Since maize and wheat can be better utilized as food or animal feed, the government is now phasing out the use of these crops for production of fuel-ethanol. Instead, they are promoting the use of sweet sorghum in the northern provinces and cassava in the south. Thus, in the southern provinces of Guangxi, Guangdong, Hainan and Yunnan, major investments are now being made in the construction of large factories to produce anhydrous (99.5%) ethanol for the production of "gasohol E10", i.e. 10% ethanol mixed with 90% gasoline. One factory, located in Beihai is producing about 840,000 liters per day from cassava, while at least two others are under construction or in the planning phase (**Table 10**).

Table 10. Actual or planned factories for the production of anhydrous ethanol from cassava in Asia (July 2010).

Country/Company	Location	Capacity ('000 l/day)	Date completed	Fresh root requirement ('000 t/year)[1)]
Cambodia				
MH Bio-Energy Co.	Kandal	144	2008	270
China				
China Food Comp (COFCO)	Beihai, Guangxi	840	2007	1,575
China Food Comp (COFCO)	Wuzhou, Guangxi	1,260	planned	2,362
Other Company	Longan, Guangxi	420	planned	787
		2,520		4,724
Indonesia				
Medco	Lampung	200	2009	375
Indonesia Ethanol		167		312
EN 3 Green Energy	South Sulawesi	600	2013	1,125
		967		1,812
Thailand				
Thai Nguan Ethanol Co.	Khon Kaen	130	Aug 2005	244
Ratchaburi Ethanol	Ratchaburi	150	Jan 2009	281
Supthip	Lopburi	200	May 2009	375
Taiping Ethanol	Sra Kaew	150	July 2009	281
PSB Starch Production	Chonburi	150	Aug, 2009	281
Khon Kaen Alcohol	Kanchanaburi	150	Jan 2010	281
Sima Inter Products	Chachoengsao	150	Mar 2010	281
Double A Ethanol	Prachinburi	250	Oct 2010	469
PTK Ethanol	Nakhon Ratchasima	1,020	Dec 2010	1,912
Impress Technology	Chachoengsao	200	Oct 2011	375
		2,550		4,780
Vietnam				
Petrosetco+Itochu Co.	Phu Tho	333	Dec 2011	624
Petrosetco+Itochu Co.	Binh Phuoc	333	Mar 2012	624
Petrosetco+Itochu Co.	Quang Ngai	333	Mar 2012	624
		999		1,872

[1)] based on 300 working days per year and a conversion of 160 l ethanol/ t fresh roots

In Thailand "gasohol", containing 10% ethanol, is presently available in most gas stations and this has become a popular fuel because of its lower price ($0.12-0.13/liter lower than gasoline). Initially almost all ethanol was made from molasses, but recently many factories have been completed or are under construction that will use fresh or dried cassava, or can use either cassava or molasses, depending on the price of raw materials (**Table 10**). In mid 2010 six factories have been completed that will use cassava or cassava/molasses as the raw material, but most of these are currently not operating because of the exceptionally high price and low availability of cassava. When all fuel ethanol plants that are currently under construction are completed by the end of 2011, Thailand will have an installed capacity to produce 4.55 million liters of ethanol per day, of which 2.25 mil. liters from cassava, 1.67 mil. liters from molasses/sugarcane and the remaining 625,000 liters from either molasses or cassava (**Table 11**).

Table 11. Current and future ethanol production capacity in Thailand.

1. Factories having received licenses to produce anhydrous ethanol.

	No. of factories	Production capacity (mil. liters/day)	Actual production (mil. liters/day)
Total	45	12	
-from molasses or cane juice	20	3.49	
-from cassava	25	8.51	

2. Factories completed (March 2009).

	No. of factories	Production capacity (mil. liters/day)	Actual production (mil. liters/day)
Total	19	2.93	
-from cassava	4	0.63	
-from cassava or molasses	6	1.00	
-from molasses/sugarcane	9	1.30	

3. Factories completed or under construction (to be finished in 2011).

	No. of factories	Production capacity (mil. liters/day)	Actual production (mil. liters/day)
Total	24	4.545	
-from cassava	9	2.250	
-from cassava or molasses	5	0.625	
-from molasses/sugarcane	10	1.670	

Source*: Dept. of Alternative Energy Development and Efficiency (DEDE); www.dede.go.th.*

k. Degradable plastics

Various types of starches are being used for the production of bio- or photo-degradable plastics, either by mixing starch or modified starch with polyvinyl hydrocarbons, or by polymerization of starch, which is then blended with various other polymers (Sriroth *et al.*, 2001). The use of cassava starch for these processes still requires much research.

FUTURE POTENTIAL

Cassava-based products can only be competitive in the world market if the cost of processing and the cost of the raw materials is lower than those of competing crops. The competitiveness also depends on government policies, on import duties, tariffs and other trade barriers. Thus, during the 1970s and 80s the Thai tapioca export industry benefited from relatively low import duties into the European markets as well as artificially high prices of domestic coarse grains; but those policies changed in the late 80s. With ever increasing trade liberalization, products will more and more have to compete on the basis of price and quality characteristics. **Table 12** shows the relative potential for growth of various cassava-based products in the seven major cassava producing countries in Asia.

Table 12. Summary of market potential[1)] for cassava by country in 2008.

	Food		Animal feed		Starch and starch-based products	Ethanol
	Fresh	Processed	Domestic	Export		
China	*		**		***	***
India -Kerala	*	**				
- Tamil Nadu					***	
Indonesia	*	**	**	*	**	***
Malaysia		***	**		**	
Philippines	*	**	**		***	**
Thailand			***	**	***	***
Vietnam-North	*	**	**	*	***	**
-South		**	**	*	***	***

1) * = maintenance of existing consumption levels
** = growth in existing markets
*** = unexploited growth potential

1. Food

Fresh cassava for human consumption does not have major growth potential as rice remains the preferred food in the region. Total food demand may increase due to increases in population, but as Asian societies become more affluent, they are likely to reduce their consumption of high-energy staples like rice and cassava in preference for meat products or convenience foods. Moreover, in Asia, as in other parts of the developing world, there is an unrelenting trend for rural populations to move to the cities. It is expected that after 2020 more than 50% of the population in Asia will be urban rather than rural. This will have profound effects on food consumption patterns as urban populations have to buy all their food, and they prefer clean, attractively packaged and convenient foods. For that reason, there is likely to be a greater future potential for processed foods and snack foods, where cassava-based products may find a niche market.

2. Feed

Table 12 shows that in all countries in Asia except India there is likely to be a substantial growth in the domestic animal feed market. This market is still largely untapped in Thailand, which has traditionally concentrated on the export of cassava-based animal feed. However, during the 1990s, due to changes in the CAP policies the export of cassava pellets to Europe became increasingly more difficult. But, the recent sharp increases in the price of maize, barley and soybean and the comparatively smaller increases in the price of cassava chips and pellets (at least up to 2010) (**Figure 5**), has made the latter more attractive again in the European animal feed market, thus reversing the previous downward trend in exports to Europe (**Figure 3**) In addition, there is a large potential to develop the use of both cassava roots and leaves for the domestic animal feed market, adding value to an otherwise cheap export product. Previously, this was unattractive due to large domestic supplies of other sources of feed ingredients, such as maize, rice bran and soybean. But, starting in the 1990s Thailand became an importer of maize and especially soybeans. While world soybean prices have been in decline since 1997, they have increased again since 2004 and especially in 2007 (**Figure 5**) due to high demand in China. Cassava leaves may be a good alternative source of protein, which could be incorporated, together with root meal, into animal feed rations. When cassava is grown specifically for leaf production and is well-managed, cassava tops can be cut five times in a one-year crop cycle, producing 13-15 t/ha of dry leaves and 2.5-2.8 t/ha of crude protein; this is 3-4 times higher than a good crop of soybean!!! Roots can still be harvested at 11-12 months with yields of 15-20 t/ha.

During the past four decades both chicken and pig production in Asia increased markedly as increasing affluence in many countries increased demand for meat products, and thus for animal feed. Even though production of the major food and feed crops, i.e. rice, maize and cassava, increased dramatically in Asia, this still could not satisfy the high demand for feed ingredients, resulting in major increases in grain imports, especially of maize and soybeans. Whether or not locally produced cassava chips and pellets can compete with maize as a major feed ingredient depends largely on the prices of maize, cassava chips and soybean, as the latter will need to be mixed with cassava at a ratio of about 85:15 to obtain the same protein content of a maize-based feed (**Table 13**). Since the mid 1990s the prices of nearly all feed ingredients (not adjusted for inflation) have shown a downward trend, but during the past four years these prices have increased substantially, especially the price of soybean. While the cassava–soybean mix tended to be cheaper than locally produced barley in Europe during the 1990s, this was not the case in the early 2000s; this may have reversed again in 2007.

In spite of recent price increases of all three crops, the cassava-soybean or cassava chips-leaf meal-soybean mixes are now considerably cheaper than maize-soybean mixes with the same crude protein contents (**Table 13**). Further research is urgently needed concerning the large-scale production and utilization of cassava leaves as a protein source in commercial feeds.

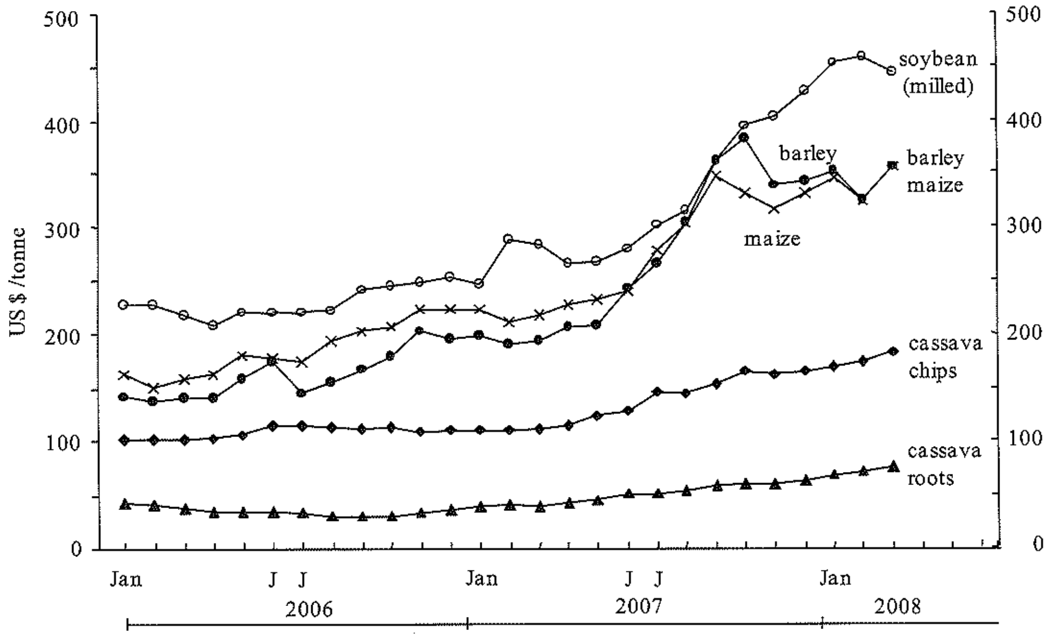

Figure 5. Change in the price of milled soybean, barley, maize, dry cassava chips and fresh cassava roots from January 2006 to March 2008
Sources: *Thai Trade Center, the Netherlands (soybean, barley, maize) and Thai Customs Department (cassava products).*

3. Starch and Derivatives

Table 12 indicates that most countries foresee the greatest future potential for cassava in the area of starch and starch-based products. This is due to the increasing demand for starch in processed food, in the paper and textile industry, as well as a very large potential demand for biodegradable plastics. In most of these markets cassava has to compete with maize, wheat, and potato. Up until 2009 Thai cassava starch was very competitively priced in comparison with maize, wheat or potato starch in the US market. Thus, for products where cassava starch could substitute for these other starches in terms of starch characteristics, there is little doubt that cassava starch was the cheapest source. However, in cases where specific starch characteristics, such as low-amylose content, are required, as in the production of biodegradable plastics, cassava starch may lose its competitive edge to waxy (low-amylose) maize or potato starches. Intensive research is under way to breed for low-amylose cassava or to produce these varieties through genetic transformation. On the other hand, cassava starch is characterized by a neutral taste and odor, and the transparency, smoothness and viscosity of the gel, making it particularly suitable for many processed food items. Native cassava starch is also very resistant to acid conditions, it is intermediately resistant to freezing but very unstable during heating (sterilization), making it suitable for some and unsuitable for other applications (Dufour *et al.*, 2000).

Table 13. Approximate prices of various feed ingredients and the final cost and protein content of feed mixes in Thailand in March, 2008.

	Protein (%)	Price (baht/tonne)	Price (US$/tonne)
Ingredients			
-Maize	8.5	7,480	238
-Cassava chips or pellets	2.5	5,200	166
-Soybean meal	44.0	16,820	536
-Cassava chips (85.5%) + soybean meal (14.5%)	8.5	6,884	219
-Cassava leaf meal-1	20.0	6,500	207
-Cassava leaf meal-2	25.0	8,125	259
Feed mixes			
-Milk cows:			
Maize (82%) + soya (18%)	14.9	9,161	292
Cassava chips (70%) + soya (30%)	15.0	8,686	277
Cassava chips (56%) + leaf meal-1 (24%) + soya (20%)	15.0	7,836	250
Cassava chips (59%) + leaf meal-2 (24%) + soya (17%)	15.0	7,877	251
-Pigs:			
Maize (76%) + soya (24%)	17.0	9,722	310
Cassava chips (65%) + soya (35%)	17.0	9,267	295
Cassava chips (61%) + leaf meal-1 (7%) + soya (32%)	17.0	9,009	287
Cassava chips (62%) + leaf meal-2 (7%) + soya (31%)	16.9	9,007	287
-Chickens:			
Maize (73%) + soya (27%)	18.1	10,002	318
Cassava chips (63%) + soya (37%)	17.9	9,499	302
Cassava chips (60%) + leaf meal-1 (5%) + soya (35%)	17.9	9,332	297
Cassava chips (60%) + leaf meal-2 (6%) + soya (34%)	18.0	9,326	297

[1)] 1 US$ is 31.404 baht in March 2008.

4. Fuel-Ethanol

Due to the dramatic increases in world oil prices in 2006 and 2007 and the growing concern about global warming as a result of the production of greenhouse gases, especially from car exhausts, many governments are looking for alternative energy sources, especially renewable and domestically produced bio-fuels. These include mainly ethanol, made mostly from maize, wheat, sugarcane or molasses and cassava, as well as bio-diesel, made mostly from soybean and palm oil. The fuel ethanol is usually mixed with gasoline in a ratio of 1:9 or 2:8 to produce "gasohol" E-10 and E-20, respectively. However, "flexi-fuel" cars can run on E-85, while "total-flex" cars, made in Brazil, can run on anything between pure gasoline and pure ethanol (E-100).

In the US and Canada most fuel-ethanol is made from maize or wheat, in Brazil it is made almost entirely from sugarcane; in Argentina from sugarcane and maize; in Europe mainly from wheat, rye and barley, in China from maize and wheat; and in Thailand from sugarcane (or molasses) and cassava. While India is presently not producing much fuel-ethanol, it is likely that in the future it will use both maize and sorghum. China, on the other hand, is phasing-out fuel-ethanol production from maize and wheat and is switching to sweet sorghum and cassava. In Indonesia there are also plans for the construction of fuel-ethanol factories, mainly on Sumatra and Sulawesi islands

The choice of crops to be used depends mainly on what crop is readily available for year-round production, and at a competitive price. **Table 14** shows that in the US sugarcane would produce the highest ethanol yield per ha, but cassava fresh roots or molasses would be the cheapest raw materials for production of ethanol. But, since none of these are abundantly available, maize is the preferred raw material. In contrast, **Table 15** shows that in 2006 in Thailand molasses and dry cassava chips were the cheapest raw materials for production of ethanol, followed by fresh cassava roots. Since dry chips can be readily stored and cheaply transported, while the supply of molasses is limited and seasonal, cassava dry chips are considered the most promising raw material for ethanol production in Thailand.

Table 14. Ethanol yield and raw material costs of various crops potentially used for ethanol production in the US.

	Yield (t/ha)	Market price (US$/t)	Gross income (US$/ha)	Ethanol yield (liter/t)	Ethanol yield (liters/ha)	Raw material costs US$/1000 l	Valuable co-products
Maize	8.5-9.0	70-100	595-900	385-400	3,272-3,600	175-260	DDGS[1)]
Wheat	2.5-4.9	114-118	285-578	378-390	945-1,911	292-312	Gluten, yeast, bran
Sugarcane	70-75	15-20	1,050-1,500	90-100	6,300-7,500	150-222	Bagasse, yeast
Molasser	3.2-3.4	35-40	112-136	250-300	800-850	116-160	-
Cassava							
-fresh roots	20-30	20-30	400-900	160-180	3,200-5,400	111-187	DDGS[1)]
-dry chips	9-13.5	60-70	540-945	330-400	2,970-5,400	150-212	DDGS[1)]

[1)]DDGS = distillers dry grain with solubles

Source: *adapted from Shetty , 2006, by R. Howeler.*

Table 15. Raw material costs per liter of ethanol produced from various crops potentially used for ethanol production in Thailand in 2006.

Crop	Planted area ('000 ha)	Production ('000 t)	Yield (t/ha)	Conversion ratio (kg/liter ethanol)	Price of raw material (US$/t)	Raw material cost (US$/1000 l ethanol)
Maize	1,258	4,461	3.55	2.7	104	281
Rice	9,761	25,608	2.62	-	-	-
Broken rice	-	-	-	2.7	150	405
Sugarcane	1,065	62,828	58.99	14.3	17	243
Molasses	-	3,000	-	4.0	37	148
Cassava						
-fresh roots	1,101	18,265	16.59	6.5	26	169
-dry chips	-	-	-	2.5	62	155

Source: *adapted from Sriroth and Piyachomkwan, 2005, by R. Howeler*

Table 16 shows a breakdown of processing cost of ethanol using either molasses or fresh cassava roots as the feedstock. Processing costs for cassava are clearly higher than for molasses due to the higher costs of enzymes and energy. **Table 17** shows that while cassava was the cheaper source of raw material for ethanol production as compared to maize in both the US and Thailand in 2006, the lower processing cost of maize as well as the greater value of its high-protein by-products, results in a lower total cost of production of ethanol from maize as compared to cassava in the US, but a much lower production costs for cassava as compared to maize in Thailand in 2007. However, due to the high price of cassava and low price of molasses and sugarcane in 2007, ethanol production from cassava became uneconomic, while that produced from molasses was only barely economic due to a decrease in the price of ethanol (**Figure 6**). Thus, in different countries different crops may have a comparative advantage, while this may also change from year to year. It seems, however, that in southeast Asia, where cassava yields are relatively high and production costs are relatively low, cassava will have a cost advantage over most other crops. Moreover, cassava can be grown on poor soils and under drought conditions where other crops may perish. Also, cassava roots – either fresh or as dry chips – are available during most of the year, and the waste water ("stillage") and solid residues resulting from cassava processing into ethanol are much less polluting than those from molasses; they are also used to produce valuable by-products such as biogas and animal feed.

Thus, it appears that the production of fuel-ethanol opens a huge new market for cassava. According to **Table 18** the efficiency of conversion of starch to ethanol varies considerably among varieties and with plant age. Average figures of 160 to 180 l/t fresh roots are often used to calculate the raw material requirement. Naturally, varieties with a higher starch content require less raw material per liter of ethanol produced, which in turn reduces ethanol production costs (**Table 19**).

Table 16. Processing cost of ethanol from molasses and cassava in Thailand in 2007.

	Molasses	Cassava	Molasses	Cassava
	(baht/liter)		(US$/1000 liter)[1]	
1. Labor	1.0	0.50	31.05	15.52
2. Chemicals	0.25	1.50	7.76	46.57
3. Energy	1.35	2.00	41.91	62.09
4. Maintenance	0.25	0.30	7.76	9.31
5. Insurance	0.15	0.15	4.66	4.66
6. Administration	0.50	0.30	15.52	9.31
7. Water	0.05	0.05	1.55	1.55
8. Depreciation	0.97	1.00	30.11	31.05
9. Waste water treatment	0.65	0.50	20.18	15.52
10. Benefit from biogas	-[2]	-0.30	-[2]	-9.31
Total	**5.17**	**6.00**	**160.50**	**186.27**

[1] 1 US$ = baht 32.21 in 2007

[2] already substracted from energy costs

Source: *Phetphirum, 2008.*

Table 17. Cost of production of ethanol using either dry maize grain, fresh cassava roots, molasses or sugarcane as the raw material for ethanol production under US and Thai conditions in 2006 and 2007, respectively.

	USA (2006)		Thailand (2007)			
	Maize	Cassava	Maize	Cassava	Molasses	Sugarcane
Crop yield (t/ha)	11	35	3.8	22	2.82	60
Crop price ($/tonne)	81	25	257	51	70	21
Ethanol yield (liters/t raw material)	379	180	379	166	250	70
Raw material costs ($/liter ethanol)	0.21	0.14	0.67	0.31	0.28	0.30
By-product credit ($/liter ethanol)	-0.063	-0.004	-0.063			
Processing costs ($/liter ethanol)	0.16	0.21	0.16	0.19	0.16	0.16
Ethanol production costs ($/liter)	0.31	0.35	0.83	0.50	0.44	0.46

Note: Ethanol price in Thailand in 2007: US$ 0.48-0.55/liter

Source: *adapted from Shetty, 2006, by R. Howeler*

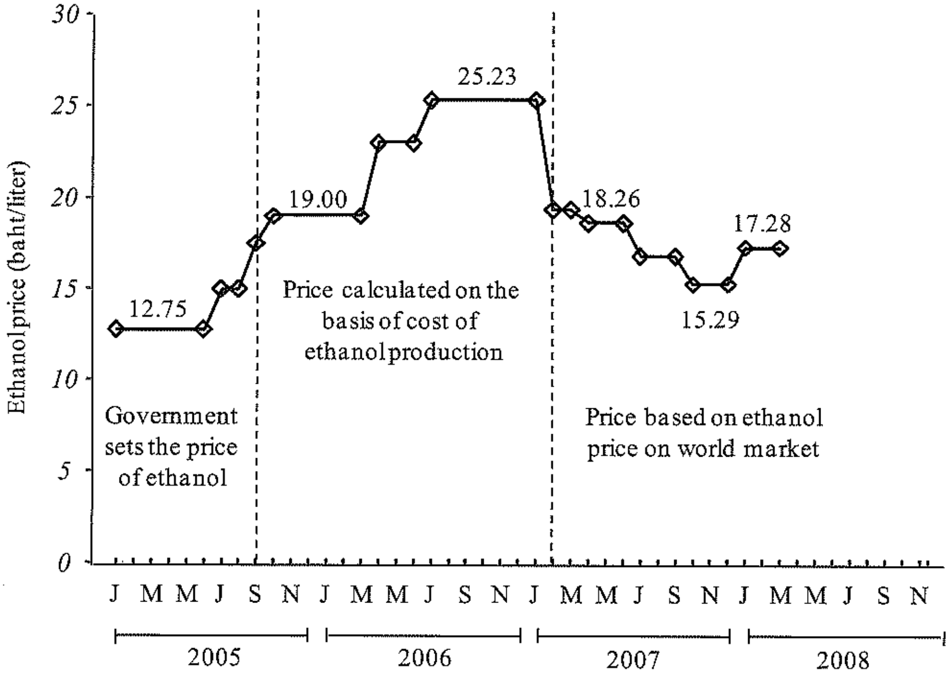

Figure 6. Change in the price of fuel ethanol in Thailand from 2005 to 2008.

Table 18. Cassava varietal differences in root yield, starch content and ethanol conversion efficiency when harvested at 12 and 18 months after planting in Thailand.

Months at harvest Variety	Root yield (t/ha)	Starch content (%)	Ethanol conversion (l/t fresh roots)	Ethanol yield (l/ha)
12 months				
Rayong 5	30.1	25.5	147	4,425
Rayong 9	30.9	30.8	208	6,427
Rayong 72	34.1	23.5	145	4,944
Rayong 90	31.2	27.5	174	5,429
Kasetsart 50	31.2	25.6	154	4,805
18 months				
Rayong 5	43.3	23.5	139	6,019
Rayong 9	48.7	29.3	194	9,448
Rayong 72	40.6	20.9	135	5,481
Rayong 90	41.0	25.6	155	6,355
Kasetsart 50	45.9	23.8	137	6,288

Source: *Charoenrath et al., 2006.*

Table 19. Ethanol production costs using two Thai cassava varieties in 2007.

	Rayong 9	Rayong 90
Starch content (%)	30	27
Fresh root requirement (t/1000 l)[2)]	4.81	5.7
Fresh root price (US$ /t)[1)]	50.84	48.05
Cost of raw material (US$/1000 l)	244.54	276.29
Ethanol processing cost (US$/1000 l)[3)]	186.27	186.27
Total cost of ethanol production (US$/1000 l)	430.81	462.56

[1)] Baht 1.64/kg ($ 50.84/t) fresh roots at 30% starch with 0.03 baht ($ 0.93) reduction for every 1% reduction in starch content

[2)] ***Source:*** *Charoenrath et al., 2006.*

[3)] ***Source:*** *Phetphirum, 2008.*

Similarly, in China the current installed capacity for cassava processing into starch and derived products, including hydrous ethanol, will require about 13 mil. tonnes of fresh roots in 2005/06. This is likely to increase by another 7.2 mil. tonnes to a total of 20 mil. tonnes fresh roots with the production of 1 mil. tonnes (1.2 bil. liters) of fuel-ethanol from cassava in the next 3-4 years. This is still only a fraction of the 5 mil. tonnes of fuel-ethanol that China is expected to need when all cars are running on gasohol E 10.

Since the cassava harvested area can not expand to keep up with increasing demand, this will require major increases in cassava yields, from the current levels of 20-22 t/ha in Thailand (**Table 20**) and 18-19 t/ha in China to about 28-30 t/ha in both countries. This will require major efforts to develop new higher yielding varieties with a higher starch content and a higher conversion efficiency to ethanol (from the current 160-180 liters/tonne fresh roots to at least 200 l/t), as well as improved agronomic practices that will allow these varieties to reach their full yield potential. Both the Thai and Chinese governments are fully committed to support the necessary research and extension activities, while the private sector will also need to contribute to support the research and to work closely together with cassava farmers to make this a reality. In 2010 the required yield increases have not yet materialized; in fact, yields in Thailand were markedly reduced in 2010 due to the damage caused by the mealybug attack, resulting in a short-fall in root supply and marked increases in the prices of fresh roots, dry chips and starch (**Figure 7**).

Table 20. Cassava production, harvested area and yield in Thailand from 2004/05 to 2009/10 and expected results of 2010/11.

Parameters	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11[1]
Harvested area ('000 ha)	986	1,071	1,174	1,184	1,327	1.168	1.120
Production ('000 tonnes)	16,938	22,584	26,916	25,156	30,088	21,941	19,988
Yield (t/ha)	17.18	21.09	22.92	21.26	22.68	18.78	17.84

[1] expected

Source: *Office of Agric. Economics (OAE) of Thailand, 2010.*

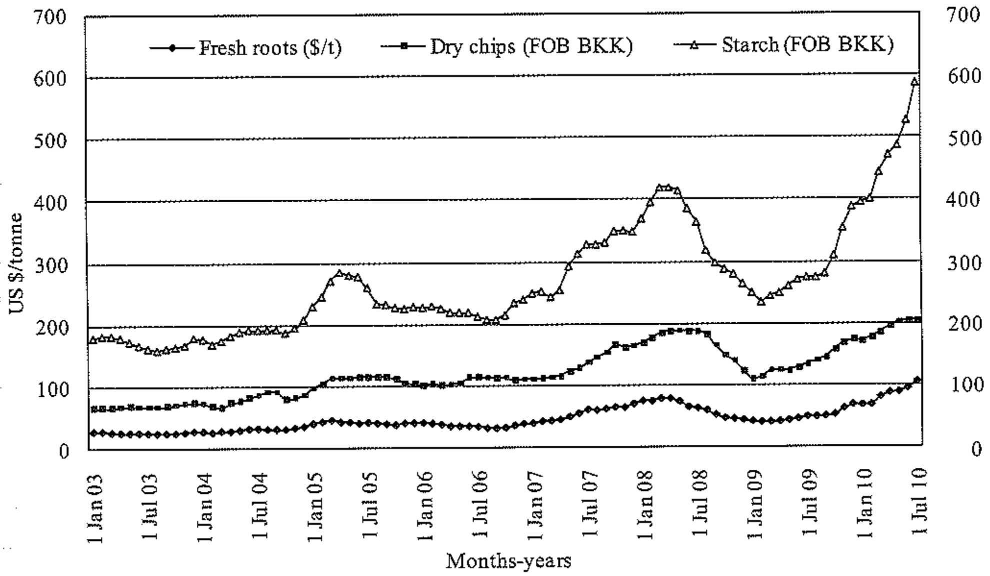

Figure 7. Change in the price of fresh cassava roots, dry chips and starch in Thailand from January 2003 to July 2010.
Source: *Thai Tapioca Trade Association Annual Reports 2008 and 2009.*

MAINTAINING A COMPETITIVE EDGE

To keep cassava-based products competitive in domestic as well as world markets is a real challenge. While cassava has many favorable attributes in the area of production, it also has some negative attributes, especially in terms of post-harvest handling due to its high water content and rapid deterioration. The content of cyanogenic glucosides in the roots is an important consideration in the use of cassava for direct human consumption, but is of less importance for production of processed food, animal feed or starch. The low content of protein in cassava roots increases the efficiency of starch extraction, but also means the absence of a valuable high-protein by-product, as is the case for maize starch. Finally, since cassava cannot be grown in temperate climates, it has never received the same research attention in developed countries as for instance maize, rice, wheat, soybean and potato. Research on cassava had been minimal until the early 1970s when the international research centers – CIAT in Colombia and IITA in Nigeria – received the mandate for cassava research and development, which in turn triggered the formation of many national cassava research programs. Nevertheless, the number of researchers working on cassava, and the research budgets dedicated to this crop, are minimal in comparison with those for most of the competing crops.

Still, cassava thrives in Asia because of the ability of farmers, processors, traders, researchers and policy makers to adapt to rapidly changing physical, biological, economic and social conditions. To maintain this competitive edge will require special attention in three areas: 1) improving the production system in order to reduce the cost of raw material while maintaining reasonable profit margins for farmers; 2) adding post-harvest value by the development of new products and more efficient processes; and 3) stimulating higher demand for cassava-based products by market development. While the development of new markets was an important activity a few years ago, it now seems less urgent as demand for cassava in Asia seems to far outstrip supply. With the rapidly increasing use of cassava as a renewable energy source to replace fossil fuels – both for production of ethanol in the transport sector and for production of many chemicals, such as biodegradable and non-degradable plastics (Samai Jai-In *et al.*, 2010) – the demand for cassava roots are expected to remain very high in the near future. Unless cassava yields can be markedly improved there will continue to be a shortage of supply. In case of Thailand, the government may encourage the use of cassava for the production and export of ethanol and other value-added products and restrict the export of less valuable products like dry chips and pellets. **Figure 8** shows that this could markedly reduce the export of cassava chips from Thailand to other countries, especially to China, which in turn may stimulate more cassava production in neighboring countries in Asia.

While this cassava "boom" in Asia is a welcome development, which is likely to benefit many cassava farmers and improve their livelihoods, it may also stimulate a rush to expand cassava planting to less suitable areas, especially to steep slopes, which may cause serious erosion and soil degradation, or trigger further and more rapid deforestation in those areas where land is still available. To prevent this long-term detrimental effect on land and forest resources, it is essential to increase investments in cassava research – both at the national and international level – so as to obtain increases in production without having to increase the planting area. This will require that governments start considering cassava as a strategically important crop, similar to rice, maize, rubber and sugarcane, and markedly increase investments in research in cassava breeding, soil fertility management and erosion control, as well as in integrated pest and disease management, coupled with increased efforts in farmer participatory research and extension in order to enhance adoption of new technologies and increase cassava yields, to the benefit of both cassava farmers and society at large. This will be the only way to prevent future environmental destruction and make the current cassava "boom" into a truly new "Green" Revolution in Asia.

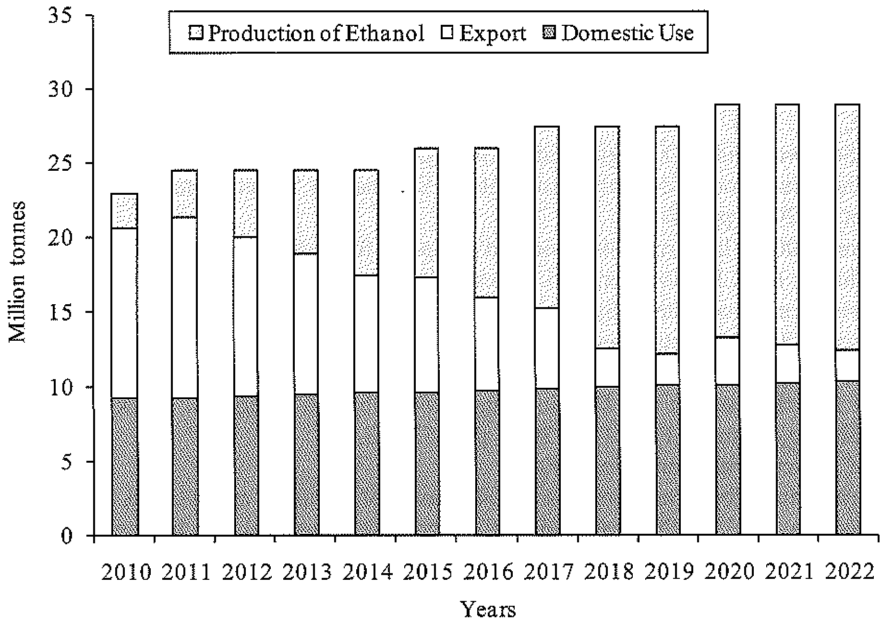

Figure 8. Estimated use of fresh cassava roots in Thailand for domestic use, ethanol production and export from 2010 to 2022.
Source: *Dept. of Alternative Energy Development and Efficiency; www.dede.go.th*

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