

# Transforming Subsistence Cropping in Asia

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## Abstract

The Green Revolution has benefited many people in Asia, but not everyone. This paper examines how many farmers have increased their productivity with more intensive cropping systems of fruit, vegetables, and in some cases, flowers. Total area under these crops more than doubled between 1977 and 1997. Case studies to highlight the transformation include vegetable production to feed Asia's booming cities, diversification of export crops in Thailand, vegetable production in Malaysia's Cameron Highlands, flower production in Yunnan Province of China and opium replacement in the Golden Triangle. Access to the market is necessary for transformation, but changes are also driven by farmers' own innovations combined with contributions from last century's crop science, from phytohormones to hybrid technology. Other inputs are irrigation, fertilizers and pesticides, with overuse of the last two a serious threat to the environment as well as to human health. Concerns have also been raised regarding soil erosion caused by cropping on steep slopes. In addition to building roads and airports, government support has also come in the form of cheap credit for orchard establishment and more efficient quarantine procedures to facilitate exports. Cross-border trade that brings opportunities to inaccessible border regions will be further enhanced by regional free trade policy, particularly when liberalization of trade in fruit and vegetables is specified such as that just signed by ASEAN and China. Finally, a case is made for the need to improve cropping systems in less favorable environment with limited access to the market and the means through which crop scientists can work with farmers to bring this about.

## Media summary

Asia's cropping systems have been transformed by major expansion in the production of high-value fruit and vegetables. Regional trade liberalization now brings opportunities for similar productivity gains in remote border regions with limited access to market in the capital city and more developed areas in each country.

## Key Words

Fruit, vegetable, flower, crop diversification, intensification of cropping systems

## Introduction

Crop science has contributed much to the growth in Asia's agriculture in the past century. The land-saving technology, which began as semi-dwarf rice and wheat in Japan in the early 1900s, and evolved into the Green Revolution from the 1960's, is a truly magnificent return from public investment in crop science. The other is hybrid technology. China's phenomenal success with hybrid rice, which soon spread to Vietnam and other countries in Asia, was quickly followed by a breakthrough in hybrid tropical maize resulting in further major yield gains. Not everyone, however, was able to benefit from these technologies. Many have been moving off the land. The most recent wave is just now being recorded in China, where the share of the rural labour force (in China includes those who have migrated to booming cities and industrial regions as well as those who stay closer to home) working on non-farm jobs increased to 35% in 1999 from 7% in 1978 (Zhang Linxiu, 2003). For all this, many more people still remain on the land. This paper focuses on less well-known productivity gains in Asia's cropping systems, showing how growth in crop production first came from diversification into fruits, vegetables, and in some cases flowers to meet demand in growing cities. Specific aspects of the change are highlighted with case studies that include diversification through exports and transformation of cropping systems in the highlands. Technological and other inputs associated with the change will be examined. Future promises and potential problems will be reviewed with contributions from publicly-funded crop science in mind.

### *Diversifying away from cereals and pulses*

Almost all of the land in Asia that can be cropped has now been brought under cultivation. Recent growth in crop production has come largely from productivity gains. In addition to the well-publicized yield growth in rice, maize and wheat, another source of growth has come from diversification of the cropping systems. This is reflected in a decline in relative importance of cereals and pulses, indicated by a major decline in the proportion of area they occupy (Kaosa-ard and Rerkasem, 2000). Although respectable yield growth of 1-2% per year has been achieved in some of the non-cereal crops, most of the growth has resulted from expansion in planted area. While fibers, oils, sugar, tea, coffee, tobacco and rubber contributed significantly to diversification, the largest gain came from fruits and vegetables (Table 1). By one estimate (Feng Lu, 1998), labour requirement for fruits and vegetables is 4.5-5 times that of grain crops and the output value is 5-6 times. On this basis, combined with slightly higher labour productivity, fruits and vegetables in Asia now contribute about as much to employment and output value as rice and wheat combined. The area growth may have significantly underestimated productivity gains from vegetables because of their generally high cropping intensity. For example, short duration leafy vegetables such as Chinese kale, certain Oriental cabbages and mustards and convulvulus may be grown 9-10 times on the same plot of land in one year.

**Table 1. Changes in contribution to total crop area in Asia from individual crops between 1977 and 1997.**

Crop	% of total crop area <sup>a</sup>		Increase, % of area in 1977
	1977 <sup>b</sup>	1997	
Cereals and pulses	73.84	63.6	0.96
Rice	30.84	27.44	4.29
Wheat	14.35	13.82	12.88
Maize	8.39	8.36	16.79
Others	26.16	36.40	63.09
Fruits and vegetables	4.45	8.01	110.98
Fibres	3.72	6.19	95.04
Oils <sup>c</sup>	9.89	14.20	68.29
Beverages	0.64	0.82	50.18
Sugar	1.52	1.90	46.52
Tobacco	0.47	0.55	37.16
Rubber	1.24	1.34	26.67
Roots	4.23	3.38	-6.34
Total <sup>d</sup> (million ha)	412.49	483.49	

<sup>a</sup> harvested area <sup>b</sup> three-year mean <sup>c</sup> including oil palm <sup>d</sup> Asia total in this data set excludes the Middle East  
Source: Kaosa-ard and Rerkasem (2000)

Fruit, vegetables and flowers are preferred over field crops for several reasons. Firstly, unlike grains and cotton, fruit and vegetables are generally not subjected to the grossly unfair competition from heavily subsidized imports from the EU and USA. Secondly, labour-intensive fruit and vegetables are not threatened by the economy of scale such as that favors soybean from the Americas. Thirdly, competitiveness of imported perishable fresh fruits, vegetables and flowers from overseas is lessened by the added cost of long distance transportation. Fourthly, local tastes and preferences have given rise to robust growth in demand for common Asian fruits, vegetables, flowers, herbs and spices. Area under many of Asia's fruits (Table 2) and vegetables (Table 3) has been expanding rapidly. Many more new species continue to emerge to contribute to further growth and diversification as some old favorites of the 1970's and 1980's such as apple, citrus, grape, pineapple and green corn are leveling off.

**Table 2. Trends in area planted to selected fruits in Asia, 1992-2002.**

	1992		2002		Growth
	ha	% total	ha	% total	% per yr
Plum	808,043	4.65	1,561,233	6.69	9.29
Peach, nectarine	845,402	4.86	1,553,893	6.66	8.33
Pear	686,854	3.95	1,375,653	5.89	8.28
Cashew nut	829,949	4.77	1,296,880	5.56	5.07
Mango	1,811,314	10.42	2,622,070	11.23	4.74
Banana	1,446,171	8.32	1,955,248	8.38	4.12
Citrus	2,335,466	13.44	2,899,150	12.42	2.10
Grape	1,773,815	10.20	1,767,793	7.57	0.17
Apple	2,934,786	16.88	3,554,476	15.23	-0.08
Persimmon	209,890	1.21	340,162	1.46	7.48
Walnut	191,281	1.10	345,516	1.48	6.40
Papaya	97,288	0.56	149,978	0.64	5.59
Almond	140,881	0.81	218,611	0.94	5.10
Pistachio	244,637	1.41	359,254	1.54	4.67
Betel nut	423,176	2.43	539,354	2.31	3.39
Chestnut	183,580	1.06	216,600	0.93	2.45
Apricot	165,616	0.95	199,816	0.86	2.07
Pineapple	340,969	1.96	381,456	1.63	0.52
Grapefruit, pomelo	66,208	0.38	87,586	0.38	3.48
<b>Asia total<sup>a</sup></b>	<b>17,383,075</b>	<b>100</b>	<b>23,341,355</b>	<b>100</b>	<b>2.94</b>

<sup>a</sup>Asia total in FAOSTAT counts 49 countries, including the Middle East.

Source: data from [www.fao.org](http://www.fao.org)

**Table 3. Trends in area planted to selected vegetables in Asia, 1992-2002.**

	1992		2002		Growth
	ha	% total	ha	% total	% per yr
Carrot	206,087	1.19	506,229	2.17	14.72
Cabbages	974,493	5.05	2,179,494	6.54	13.15
Pea, green	244,873	1.27	547,518	1.64	13.14
Eggplants	660,389	3.42	1,505,241	4.52	12.73
Asparagus	461,568	2.39	1,033,875	3.10	11.66
Cucumber	820,557	4.25	1,647,071	4.94	10.64
Tomato	1,254,209	6.50	2,237,900	6.72	8.30
Watermelon	1,458,113	7.56	2,456,753	7.38	7.74
Cauliflower	348,144	1.80	609,457	1.83	7.38
Chili pepper	576,547	2.99	971,590	2.92	6.75
Mushrooms	6,654	0.03	12,203	0.04	6.48
Garlic	596,731	3.09	908,668	2.73	5.25
Ginger	111,939	0.58	155,695	0.47	4.01
Pumpkin, squash, gourd	614,574	3.19	827,902	2.49	3.85
Melons	568,630	2.95	758,062	2.28	3.49
Onions, shallots	99,602	0.52	111,411	0.33	1.55
String bean	20,487	0.11	22,889	0.07	1.20
Green corn	121,824	0.63	109,085	0.33	-1.28
<b>Asia total<sup>a</sup></b>	<b>19,290,436</b>	<b>100</b>	<b>33,310,020</b>	<b>100</b>	

<sup>a</sup>Asia total in FAOSTAT counts 49 countries, including the Middle East.

Source: data from [www.fao.org](http://www.fao.org)

The aggregate data only partially describe Asia's rapidly diversifying cropping systems. Major differences exist among the countries in the scale of production and rate of growth (Table 4). Region-wide totals and trends tend to be dominated by production in the larger countries. For example, the moderate area growth of pumpkin, squash and gourd for the whole of Asia tells nothing of the importance that squash production has become for the small island country of Tonga. Although production is recorded at less than 2,000 ha per year in the FAO database (FAO, 2003), Tonga exported squash worth US\$ 5 million in 2000, earning half of its entire export income (ADB, 2001). Similarly, Nepal's expansion of citrus fruit production and growth of export to India does not even register in the FAO database. General statistics have no record of uncommon specialty crops of some countries and regions.

Better insights into Asia's rapidly diversifying cropping systems may be gained by closer examination of specific cases.

**Table 4. Growth in fruit and vegetables production in selected Asian countries between 1975 and 2001.**

	Harvested area (million ha)		Growth (%/year)	
	1975	2001	1975-1987	1988-2001
China	4.896	28.281	9.923	10.051
India	5.930	9.594	2.373	2.652
Indonesia	1.260	1.717	3.344	1.579
Pakistan	0.361	0.999	7.545	4.213
Philippines	1.014	1.569	1.954	1.964
Thailand	0.807	1.122	0.690	1.914
Vietnam	0.428	1.026	3.074	5.851
<b>Asia</b>	<b>17.350</b>	<b>49.148</b>	<b>4.470</b>	<b>6.340</b>

Source: FAO database

#### *Feeding the growing cities*

Asia's urban population, some 1.2 billion at the turn of the century, is expected to continue growing at about twice the rate of total population (World Bank, 2000). Cropping systems have converted to vegetables to serve fast-growing urban centres as a matter of course. Rice farmers around the Shenyang-Dalian extended metropolitan region in China's Liaoning province made a complete shift to vegetables within 15 years (Wang, 1997). The issue of urban and peri-urban agriculture has begun to be raised (e.g. FAO, 2000; Midmore and Jansen, 2003; CGIAR, 2003). However, the spatial boundary of the vegetable production area to feed cities is somewhat blurred by improved transportation, technological development in packaging and storage and the fast rising urban purchasing power. Aggregate data are rare for most common local species, but many, e.g. Chinese kale, the Oriental mustards and cabbages, bean sprout to mushrooms, are common everyday items in Asia's local markets. The production of rice-straw mushroom in tropical Southeast Asia is estimated at 270,000 t/year, worth US\$ 300 million, and there is even greater volume for the pricier shiitake, Japanese mushroom, grown in cooler regions of East Asia and the highlands of Southeast Asia (DOA, 2000).

A growing portion of the fruits, vegetables and flowers from many countries has also been exported. Hong Kong and Macao's entirely urban population of 7.5 million is everyone's favorite export market. Rising urban income pushes up demand for 'exotic' fruits, vegetables and flowers. Temperate fruits, walnut and chestnut from China, for example, are popular in Southeast Asian tropical cities. Similarly, demand for tropical and subtropical crops such as mangosteen, longan, durian and orchids is growing in Asia's more temperate cities. Other opportunities for export of Asian fruits, vegetables and herbs are provided by increasing demand created by growing popularity of ethnic Asian foods in Europe and the US and migrant workers and immigrants hungering for a taste of home. Thailand provides an example of further diversification through export.

#### *Diversification through export: example from Thailand*

Production of field crops in Thailand has stabilized at about 14 million ha since the 1970's. The area under fruits and vegetables, however, has grown steadily by about 5% per year, from less than 400,000 ha in 1961 to 1.14 million ha in 2002 (data from FAO, 2003). The value in US\$ of fruits, vegetables, flowers and seeds exported increased 50% in the last decade (Table 5). In Thai *baht*, the export earning grew by more than 12% per year. This probably better indicates associated growth in farm income, especially after a massive devaluation of the local currency in 1997. The extent of diversification in the country's export crop is reflected in the rise of new crops and the growth of those labeled miscellaneous. These include products of all other fruit and vegetable crops not listed individually in Table 5, the export value of which have been growing at 6% and 18% per year, respectively.

**Table 5. Trends in Thailand's export earning from fruits, vegetables, flowers and seeds, 1991-2002.**

	1991†	1995†	2001†	2002†	Growth % per yr
	Export earning (m. US\$)				
<b>Total</b>	<b>889.4</b>	<b>1,073.4</b>	<b>1,097.7</b>	<b>1,208.2</b>	<b>2.62</b>
Mangosteen	1.3	4.5	10.0	8.8	60.84
Durian	11.4	48.2	61.5	54.0	33.44
Longan	18.1	60.1	84.9	86.6	32.97
Banana	0.7	1.1	3.0	2.6	30.34
Ginger	4.6	5.2	11.5	8.8	12.13
Lychee	7.6	16.6	13.3	20.4	10.08
Mango	6.8	7.1	11.3	9.1	4.96
Asparagus	9.5	7.2	11.1	13.8	4.17
Onions and garlic	5.3	10.8	5.9	7.3	-0.06
Rambutan	8.4	15.7	9.4	11.1	0.03
Baby corn	38.5	42.9	41.5	38.2	0.01
Pomelo, other citrus	3.4	5.1	3.3	3.5	-1.34
Pineapple	123.1	114.7	88.9	102.8	-2.07
Spices	8.5	6.1	4.1	4.1	-4.69
Bamboo shoot	57.0	50.5	18.3	15.3	-7.13
Tomato	8.3	10.5	2.9	2.3	-8.04
Miscellaneous	577.1	667.1	716.7	819.4	3.16
Other vegetables	79.2	162.3	224.2	246.7	18.02
Other fruits	121.6	180.1	179.7	235.0	6.37
Seeds	27.0	22.5	37.4	39.4	4.97
Orchids	30.1	34.6	41.6	46.2	4.50
Flowers, ornamentals	2.8	5.1	3.8	5.6	5.53
<b>Sub-total</b>	<b>260.6</b>	<b>404.7</b>	<b>486.7</b>	<b>573.0</b>	<b>9.54</b>
<b>% of total</b>	<b>29.31</b>	<b>37.70</b>	<b>44.34</b>	<b>47.42</b>	

†US\$ 1 = 25 baht in 1991, 1995 and 43 baht in 2001, 2002.

Source: data from OAE (1996) and OAE (2003)

Improved air transportation, including rapid and efficient quarantine inspection, has opened up export opportunities to meet growing demand overseas. Diversity of the species exported is indicated by a shipping list of almost 100 plants species, from *Acasia pennata*, *Altheranthera sessilis*, *Anethum graveolens*, *Angiopteria erecta* to *Zingiber officinale*, *Zizypus rotundifolia*, processed in one day, in the plant quarantine office at Bangkok International airport before being air freighted to Japan, Taiwan, Europe and the US (C. Maneechote, pers. comm). Two other sectors of the miscellaneous export crops are orchids and seeds, both of which have been growing at 4-5% per year since 1991. A very large fraction of the seed export is made up of custom hybrid vegetable seeds (Xumsai, 2002). These seeds, mainly of tomato, pepper, watermelon and cucumber, are produced under contract with overseas seed companies who also provide the necessary technology including inbred lines. Seeds of indigenous vegetables, locally-developed F1 hybrids and open-pollinated, are finding market in the US and Europe as well as in other Asian countries.

#### *Transformation of subsistence cropping in the mountains of mainland Southeast Asia*

The production of temperate vegetables, fruits and flowers in many of Asia's mountainous areas has begun since colonial times. Many hill stations were developed, with good access roads and sometimes railways, as early as the 1800's for expatriates to escape the heat and humidity of the lowlands (Reed, 1985). After relatively small beginnings, the production of temperate vegetables, fruits and flowers began to take off from the 1960's to meet growing demand from the local population in lowland cities who were becoming increasingly affluent and cosmopolitan. Highland production also provides an important supplement of common tropical species during the monsoon season when lowland production is constrained by high temperature, excessive rainfall and too many insect pests (Midmore and Poudel, 1996). The Cameron Highlands exemplifies the trend that has continued from the earlier development. Growth of flower production in Yunnan, and opium replacement in the so-called Golden Triangle illustrate transformation in recently isolated places.

#### *Malaysia's Cameron Highlands*

The Cameron Highlands, together with the Penang Hill and Fraser Highlands, were the hill stations for the colonial British in the Malay Peninsula and Singapore. The area has long been developed with good

roads that now also serve a thriving tourist industry. Vegetable production in Malaysia's Cameron Highlands has been expanding since the early 1970's. On the fragile steep land, farmers are given a special tenure called a Temporary Ownership License, with a nominal fee of about M\$ 300 (US\$ 117 in 1992), accompanied by reviews of land use and management practices and is held for 5-15 years. In spite of a near absence of soil conservation measures, of complaints from researchers regarding soil erosion, and the associated cost in sedimentation of waterways and reservoirs estimated at M\$ 2 million per year, licenses seem to have been routinely renewed and cases of the license being revoked are rare (Midmore et al, 1996).

Although the vegetables are grown on one of Asia's acidic upland soils with pH 4.2, acidity is of little consequence since liming accounts for less than 2% of total input cost (Midmore et al, 1996). The area under vegetables and flowers had reached 1,453 ha by 1986 and more than doubled to 3,327 ha by 1990. Cabbage accounts for about half of the planted area, followed by tomato, lettuce, onion, pea and various other European and Oriental species. By the early 1990's the relatively small area, which supported about 4,000 farms, produced vegetables valued at M\$ 56 million according to one estimate (Midmore et al, 1996) and M\$ 100 by another, with flowers contributing another M\$ 20 million (Dumsday et al., 1991, cited in Midmore et al, 1996). A significant portion of the vegetables, mainly tomato, chili and cabbage were exported to Singapore, earning M\$ 50 in the early 1990's (Midmore et al, 1996).

### *Blooming Yunnan*

Until recently Yunnan was one of China's least accessible provinces. Average speed on its narrow, poorly surfaced and congested roads was only about 40 km per hour. However, the late 1990's have seen enormous improvement in the province's transport system by road, rail, air and river. The province now boasts 10 airports, with two new ones soon to be built. Transportation of produce from the prefectures to Kunming has been speeded up to just a few hours instead of days. Conversion of paddy land to higher-valued crops of fruits, vegetables and flowers that began around Kunming in 1980 is now spreading to other parts of the province, right to the borders with Myanmar, Laos and Vietnam. The shift from rice and sugar cane in a small far-western village of Baihualing on the Myanmar border accounted for an eleven-fold increase in the combined area under walnut, chestnut, coffee and longan from 177 *mu* (12 ha) in 1997 to 2,032 *mu* (135 ha) in 2000 (Dao et al, 2001). The trend is expected to accelerate as a result of two developments. Firstly, China's policy to make Yunnan and neighboring Guangxi into the bridge between its prosperous eastern seaboard and the hinterlands, including Tibet and Southeast Asia is translating into even more investment in the province's transport system (CCTV, 2003). Secondly, cross-border trade in the region will be greatly facilitated by the recently signed China and ASEAN free trade agreement (see below). Yunnan is finally able to exploit its numerous microclimates for the production of a diverse range of higher-valued crops of vegetables, fruits, flowers, spices, medicinal plants and tree nuts. Production in Yunnan can also take advantage of the off-seasons elsewhere in China, i.e. during the northern winter and the monsoon season when typhoons sweep the lowland vegetable growing areas in the eastern provinces and Hainan Island. The rapid progression of change in cropping systems in the province is illustrated by the development of Yunnan's flower industry.

The introduction in 1979 of the 'household responsibility system', when Chinese farmers were allowed to respond to market signals, quickly led to conversion of rice land around Kunming City to vegetable production. However, the city's population of about just one million at the time (currently 3.5 million) was unable to absorb all the increased production and price fell sharply by the end of the 1980's. While fellow villagers were suffering losses from the glut in the vegetable market, one farmer from Dounan village near Kunming was actually prospering by growing flowers. From this one farmer who became very rich by local standards, 100 ha of the village's crop area was quickly converted to flowers. In less than 5 years Daonan became the national leader in cut flower production and is now a wholesale center (Jiang Xuejun, 2001). Flower production in the whole of Yunnan has grown exponentially in planted area and value since 1995 (Yunnan Flower Association, 2000). In addition to the main temperate flower region around Kunming and nearby Yuxi, production now encompasses orchids, tropical cut flower species and indoor potted greenery in Xishuangbanna and Yuanjiang to the south, and winter bulbs in Diqing and Lijiang in the colder north. By 1999, annual output of cut flowers was recorded at 1.1 billion stems, placing Yunnan firmly as China's foremost flower-producing province. Four fifths of the production is shipped to more than 70 cities in China, and one tenth is exported to Japan, Thailand, Singapore, South Korea, Taiwan, Hong Kong and other countries. A flower grower earns on average

15,000 *yuan* per *mu* (US\$ 27,136 per ha), fifteen times that from tobacco, Yunnan's once leading cash crop, and 3.75 times the earning from vegetables (Jiang Xuejun, 2001). The change to flower production has increased farm income most spectacularly. The record income from flowers of 30,000 *yuan* per *mu* (US\$ 54,933 per ha), was made in Daonan, which is now also the record holder as Yunnan's richest village.

From a simple experiment with gladiolus bulbs bought on a trip to Guangzhou by the first Dounan farmer, flower production in Yunnan has undergone major technological changes in just a few years (Yunnan Flower Association, 2000). By the early 2000's a total area of 14 ha was under imported greenhouses. Steel framed, made-in-China greenhouses covered another 150 ha. Fully automated irrigation systems were installed on 30 ha, and 200 ha were equipped with semi-automatic or simple drip irrigation. Four fifths of Yunnan's flower production now passes through the central Dounan Wholesale Flower Market in Chenggong County. The average daily volume of trade in the wholesale market is 2-3 million stems of cut flower plus 12 t of cut greenery, involving 4,000 traders. During peak periods, of important Chinese occasions and increasingly western ones too, daily transaction volume rises towards 3.5-4 million stems of cut flowers and 18 t cut greenery, involving more than 6,000 traders.

#### *Opium replacement in the Golden Triangle*

Opium was once the main cash crop for many living in the adjoining mountainous regions of Myanmar, Thailand and Laos, so-called the Golden Triangle, and in the northern mountains of Vietnam. While opium was a cash crop, it was traditionally grown as a component of cropping systems designed to meet the farm family's subsistence needs, in addition to rice bought with cash from opium sale. Efforts to eradicate opium, mounted with international pressure as well as support, began in Thailand in the 1970's and in the following decades in the other countries. Cash crops promoted by opium-replacement projects, from temperate vegetables, fruits and flowers to potato and red kidney bean, in the beginning almost always had to be financially supported with free or subsidized inputs, marketing assistance and price support. Very few survived when support ceased. Opium continued to be cultivated until eradication was strictly enforced, in Thailand by the army from 1985 and a few years later in Vietnam and Laos by directive from the central government. Change to alternative crops on a large scale came only with improved market access and clear competitive edge for the opium-replacing crops. For those without viable alternatives, life has become much harder than before. Market access generally means a network of buyers who often provide inputs on credit along with technical inputs as well as better roads. In Thailand villages that are connected to the transport system are able to take advantage of the more temperate climate at higher altitudes in supplying vegetables, flowers, fruits and Arabica coffee to lowland markets. It is more difficult if potential opium replacement crops are already being grown on a large scale elsewhere. For example in Myanmar, growers who wish to replace opium with alternative crops must compete with other farmers who are already growing these crops in more accessible areas of the Shan and Kachin State. The free trade agreement between ASEAN and China, which took effects on October 1, 2003 and covers most of the opium-replacement crops will definitely lead to more competition from across the borders. The market in Laos, Vietnam, Cambodia and Thailand are already being flooded with temperate fruits from China.

#### *Technology and public investment behind diversification*

Research at the Asian Vegetable Research and Development Centre has produced improved varieties of yard long bean, tomato, chili pepper and cucumber (Kaosa-ard and Rerkasem, 2000). However, compared with rice and wheat which has received major international and national public investment in research, diversification of Asia's cropping systems into vegetables, fruits and flowers is driven largely by privately funded research, directly transferred technology and farmers' experimentation. 'The farmers are regarded as principal actors' in the astronomical success of the flower industry in Yunnan (Yunnan Flower Association, 2000), can very well be said for the transformation of Asia's cropping systems in general. The technology exploited is based mainly on 'old' science, with innovations developed locally, often adapting together local practices and those commercially and privately transferred. Modern inputs of chemical fertilizers, including trace elements, and insecticides, fungicides and herbicides are widely used, technical inputs related to these coming mainly from sales people.

The old, simple and inexpensive biotechnology of tissue and microbial culture are widely exploited for the propagation of orchids, other flowers, ornamental plants and mushrooms. Phytohormones are

commonly used, from encouraging root growth in propagation, growing pot plants, stimulating off-season fruit production, to thickening the shoot in bean sprouts. Hybrid technology is used to create new forms and colors in orchids and other flowers, new fruit varieties and flavors as well as in many of the flowers and vegetables that are propagated by seeds. The seed of most vegetables grown are F1 hybrids. Local innovations, often of individual farmers, contribute to new varieties of indigenous fruits, vegetables and flowers and new crops. Farmers in Yunnan routinely graft improved varieties onto local wild rootstocks of tree crops such as walnut, chestnut, persimmon, pears and berries (Dao et al, 2001). Economic gains are sometimes associated with quality and timing rather than yield growth. For example, orange farmers throughout eastern Asia strive to catch the high season during the Chinese New Year.

Seed of many flower and vegetable hybrids is directly transferred from developed countries and continue to be imported. For example, cabbage production in the highlands of northern Thailand took off 25 years ago because farmers found success with a hybrid cabbage from Japan named Hayadori 1. Today, imported hybrid seed still accounts for all of the cabbage produced in Thailand, 90% from Japan according to one importer (interview by C. Prom-u-thai and K. Coffey). Similarly, imported hybrid seeds are so important to Yunnan's flower industry that the central government has granted a special privilege to the province in conducting its own quarantine procedures for imported flower seeds (China Daily, 2000). Hybrid seed technology has also been extensively exploited for improving indigenous species as well as for custom seeds of tomato, pepper and cucumber.

Adaptation of traditional practices and indigenous technologies comes in many different forms. Local varieties that have become popular, e.g. *Hmong* glutinous corn, *Karen* chili, are commercialized. This trend is likely to grow with increasingly easy transportation and export to distant markets. For example, a buyer has been reported in highland villages near Chiang Mai, searching for *Hmong* cabbage to supply *Hmong* communities in California. Rotations are modified. The method of cultivating crops in the forest, long common in Southeast Asia and upwards into tropical areas of China, have been expanded to incorporate cash crop in major ways. Durian, langsat and longong are cultivated in the forest in some parts of Thailand. Some tea production has been developed from stands of wild tea, a traditional practice of the Dai (China), Tai (Myanmar) and Thai (in Thailand) that goes back more than a thousand years. Cultivation of other species, e.g. *Calamus* spp. and *Baphicacanthus cusia*, in the forest was a traditional practice of ethnic minorities in China. Since the 1970's various cardamoms (*Ammomum villosum*, *A. tso-ko* and *A. kravanh* of the family Zingiberaceae) have been introduced into the system. By the mid 1990's more than 3,700 ha of *A. villosum*, a highly priced medicinal plant, was being cultivated under China's precious tropical forests, including very close to the core zone of Xishuangbanna Tropical Natural Reserve (Guan et al., 1995). Shifting cultivation systems with 10-20 years fallow period in Thailand have evolved into shorter rotations of cabbage and upland rice, with a doubling or tripling of the rice yield due to residual effects of clean weeding and heavy fertilization in cabbage (Rerkasem et al, 2002).

Down in the flood plains, various local methods to keep crop roots above the water table, from the *Sorjan* system of Indonesia, the floating gardens of Inle Lake in Myanmar to *Rong Suan* in Thailand's Chao Phya Delta have been adapted to facilitate new cropping systems. The various inputs into the transformation are illustrated by the latter case, a system involving beds that were raised above the water table, alternating with ditches. A traditional practice for developing *suan* (fruit orchards and vegetable gardens) on the flood plain, it was also the means by which acid sulphate soils were improved by liming, manuring and leaching. Thus some fruit and vegetable farmers were able to take advantage of the expanding purchasing power of nearby Bangkok. The technology also enables the conversion of more low-lying rice land into *suan* as those nearer the city were overtaken by the growing urban sprawl. Some farmers in this area are descendents of Chinese farmers who migrated to Thailand at various times through 200 years of Bangkok's history. Indeed, the system of raised beds is sometimes referred to as *Rong Chin* or Chinese raised bed (Phupaibul et al, 2002). Some traditional practices have been discontinued, e.g. the use of organic fertilizers and night soil transferred from China, and the local green manuring practice with *Erythrina*. Others are still in practice today with some modification. Splash irrigation for the ditches is now motorized. The meticulous methods of crop husbandry now incorporate heavy doses of chemical fertilizers (see below) as well as herbicides and insecticides.

Irrigation is developed largely on farmers' own initiative. This ranges from furrow irrigation and flooding, gravitation fed sprinkler systems for the highlands to motorized or manual splashing from

ditches between raised beds to drip irrigation and the most modern equipment that also applies plant nutrients. In some countries, e.g. Thailand, the government sometimes provides soft loans for orchard establishment. Good roads are essential for long distance transport of the perishable produce, but many farmers still depend on more traditional transports of bullock carts and boats to bring their crop to the point of sale. Farmers in distant villages are now able to obtain the most recent prices through the telephone.

#### *Emerging opportunities and problems*

The very diverse nature of all these new cropping systems makes for a very diverse set of opportunities and problems. For example, the natural tea gardens of the Dai/Tai/Thai that have never received any inputs except for some occasional weeding and pruning are now beginning to be sought after as a source of organic tea. High profitability from the cultivation of *Ammomum villosum* under tropical forest canopies in Yunnan has, on the other hand, led to encroachment into protected areas and greatly altering the species structure and composition (Guan et al, 1995). Vegetable growing on the unique floating beds on Myanmar's Inle lake are facing their own special set of ecological and human problems. In Tonga, competition is threatening its valued export earning from squash and vanilla (ADB, 2001). From all this diversity, however, some common trends may be observed. With the growing Asian economies and continually improving conditions for export within Asia as well as to Europe, America and elsewhere, the potential appears limitless for Asia's vegetables, fruits, flowers and the various herbs, spices and medicinal plants it can produce. In addition to continued demand growth in the more common species, prospects are also bright for newly popular indigenous species and varieties. The freeing of trade in fruits and vegetables will bring new opportunities as well as problems. There are also concerns with overuse of chemicals and special problems of highland cropping systems.

#### *Challenges and promises of free trade – examples from China and ASEAN*

For various political and historical reasons, Asia has so far had relatively restricted cross border trade. Border areas are among the most inaccessible and often poorest regions in most countries. Liberalization of cross border trade brings opportunities for transformation of local cropping systems in such places while access to the capital and the country's more developed regions awaits improvement. Long before the China-ASEAN free trade agreement was formalized, cropping systems in the border regions of Cambodia, China, Laos, Myanmar, Thailand and Vietnam had already begun to be influenced by cross-border exchanges. Rising demand for maize is driving local concerns from China and Thailand to develop maize production, complete with transfer of the latest hybrids, in the border regions of Cambodia, Laos and Vietnam. Chinese interests are supporting efforts to expand rubber production into the Wa Special Region in eastern Shan State of Myanmar, with 20,000 *mu* (1,332 ha) of plantation already established in 1999 (Kanok Rerkasem, pers. comm). The implementation of the regional public policy embracing free trade in fruits and vegetables in ASEAN and China promises great opportunities to the remote border regions of each country. Thus cropping systems in Cambodia's west and northwest from the Tonle Sap region can now look towards the much bigger and sometimes more accessible market in Thailand as well as Phnom Penh. Farmers in northern Vietnam with limited access to markets in Hanoi and the south will be able to take advantage of China's booming economy. Similarly, Lao farmers in border regions with limited access to Vientiane can now look forward to the much larger and closer markets over the Chinese and Thai borders. The Shan and Kachin States in Myanmar, only nominally integrated into the rest of Myanmar because of political unrest and inadequate transportation, already begin to benefit from cross-border trade with China and Thailand.

The down side of the cross border trade has two elements. The first is increased competition for those crops that have long enjoyed the protection of impermeable borders. Thailand has for years been futilely spending hundreds of millions *baht* every year to prop up local garlic and onion prices against cheaper illegal imports over the northern borders. Crops that will face tougher cross border competition include more temperate species from the highlands in the lower latitudes and more tropical ones in the higher latitudes. However, competition could be avoided for some of the more perishable crops from different regions that come to market at different times because of microclimate differences. The other possible danger is development of cropping systems that are exploitative. Unsustainable harvesting for China and Thailand markets has decimated wild populations of many valuable species such as eaglewood (*Aquilaria spp*) and *Dracaena cambodiana* in Laos (Kanok Rerkasem, pers. comm.). Many are disturbed by the expansion, far from possible scrutiny, of maize production in northwest Cambodia and northern Laos,

rubber plantations in Yunnan and expansion into Myanmar, and similarly lucrative cropping systems on fragile landscape on steep slopes. However, it might be noted that a somewhat similar development in the uplands of northern Thailand in the 1970's has turned out to be quite sustainable. Thanks to the success of hybrid tropical maize, productivity growth is currently more than 4% per year, after a more moderate yield growth of 1.4% per year between 1977-1986 (Kaosa-ard and Rerkasem, 2000). The yield of tropical rubber in China is now twice that of long established producers such as Malaysia and Indonesia. Nevertheless threats from exploitative practices are real and should be closely monitored.

#### *Chemical overuse*

Concerns about fertilizer overuse in Asia have been raised by many (e.g. Morris, 1997a; Matsuda, 1998). Measurements of nutrients in soils and water confirm that there is indeed a cause to worry in temperate (Zhang et al, 1996) as well as tropical areas. Throughout tropical Asia, from Malaysia to Sri Lanka and Taiwan, heavily fertilized vegetables take up only small a fraction of the nutrients applied (see various papers in Morris 1997b). For example, a survey of vegetable farms in Suphan Buri and Nakhon Pathom north of Bangkok found up to 600 kg N and 250 kg P /ha applied per year (Phupaibul et al, 2002). Recovery of applied nitrogen in the harvested crop ranged from 23% in Chinese kale to only 3% in chili, and even smaller percentages of applied phosphorus, at 6% in Chinese kale and only 1% in chili. The soil under the vegetables was found to contain enormous amounts of phosphorus,  $605 \pm 349$  mg  $P_2O_5$  per kg of soil (by Bray II) compared with  $36 \pm 24$  mg  $P_2O_5$  per kg of soil under rice. Analysis of river water indicated that phosphorus was beginning to accumulate in the environment. Only small amounts of nitrogen were detected in the ditch, canal and river waters, but additional information might be gained from analysis of ground water beneath the raised beds. Phosphorus accumulation and soil acidification are common signs of over fertilization in fruit orchards. Based mainly on outdated horticulture textbooks that still teach that fruit trees should be fertilized with nitrogen for leaves, phosphorus for flowers and potassium for fruit, phosphorus especially is heavily applied in the hope of encouraging early flowering and fruit production while price is still high. There are, however, promising signs that soil and tissue analyses are beginning to be used in fertilizer management in fruit orchards (e.g. see Poovarodom et al., 2002), as they have long been used in rubber and oilpalm plantations in Malaysia and Indonesia.

Even more frequently raised are alarms about pesticide poisoning and pollution from fruit and vegetable production (e.g. see various papers cited by Midmore et al, 1996; PANUPS, 2003; Unmacht, 2003). The following list reported the magnitude of the problem in China:

- In 2001, the Chinese government found 47% of domestically produced vegetables had pesticide residues in excess of government standards.
- Residues of two highly toxic pesticides banned by the government were found in 34% of vegetable samples taken in Kunming and 100% in Baoshan prefectures of Yunnan Province from 1994 to 2001.
- The Japanese Ministry of Health found residue of pesticides in some vegetables imported from China that was four times higher than the agreed-upon limits (PANUPS, 2003).

Farmers who cultivate the famous floating gardens in Myanmar's Inle lake were found to apply 15 to 60 times recommended rates of some insecticides to their tomato crop (Butkus and Myint, 2001). Using a model for "Loading Capacity Analysis", the study estimated that monocrotophos, which is now banned in many developed countries, was applied at more than 100 times the rate at which the lake can absorb and dissipate it.

Farmers tend to apply much more pesticides than necessary to vegetables and fruits, because of the importance of product appearance to price. Rapid development of pesticide resistance in the insects has the most undesirable consequence; farmers increase the dose. In Thailand this unfortunate response has resulted in the application rate being increased to 8 times the recommended rate (Jungbluth, 1997). One survey in the early 1990's found insecticide residues in 37% of vegetables and 73% of tangerine in local markets (Palakool et al, 1995, cited by Jungbluth, 1997). Those that exceeded the FAO's allowable maximum residue level included 20% of the Chinese kale, 10% of yard long bean and 10% of tangerine samples examined. Villagers commonly complain that their neighborhood fruit orchards are ruining their health and environment because of insecticide spraying. In a recent case involving tangerine orchards north of Chiang Mai, pesticide residues have been found in villagers' blood as well as the area's soil and water (Bangkok Post, 2003).

An integral part of the boom in fruit, vegetable and flower production, is Asia's burgeoning pesticide market and industry. The most popular pesticides (monocrotophos, methamidophos, methyl parathion, methomyl, glyphosate, 2,4-D, atrazine ametryn and paraquat) tend towards the "cheaper and most hazardous", some of which are now banned in developed countries. In most Asian countries the pesticides are imported, from Japan, the US and Europe, with China emerging as a new producer. A major constraint to safe use is the inability of many farmers to comprehend or read the instructions. Much confusion is added by the proliferation of trade names. For example, in Thailand alone monocrotophos is sold under 274 different trade names, methyl parathion under 296 and paraquat under 55 (CIRAD 1990, cited by Jungbluth, 1997). The low cost of pesticides, at 10-20% of total variable cost of vegetable and fruit production, is an important incentive to overuse. The conclusion reached for Thailand that farmers generally do not care about or are not aware of potential hazard pesticides to themselves and consumers (Jungbluth, 1997, citing Grandstaff, 1992), unfortunately applies for Asia in general.

The concern has been raised that pesticide residues may threaten exports of vegetables, fruits and flowers to developed markets such as Europe, the US and Japan (e.g. Jansen, 1994; PANUPS, 2003). Tea farmers in Zhejiang Province of China suffered a loss of US\$ 125 million in 2001 when about half of China's tea export failed to meet the new EU standard for pesticide tolerance that was reduced to one hundredth of the original level. Catastrophic as this was to individual farmers, quality control in export crops is one effective means by which pesticides overuse in Asia may be somewhat moderated. Signals from lucrative overseas markets are beginning to stimulate development of local standards as well as procedures for quality control. In more and more countries, the export shipping routine now includes check for pesticide residues, along with quarantine and other quality control measures demanded by the market such as checks for genetic modification as well as antibiotic residues in the case of meat and fish. The system also appears to learn very quickly. For example, after a few rejections from overseas, Thailand is now developing a system to monitor and control the level of antibiotic residues in its shrimp and meat exports. Similarly, a few well-publicized rejected shipments of products such as soybean milk, soy sauce, tuna in oil have also led to screening for genetically modified ingredients such as soybean or corn. A country's own effective, irrefutable quality control facility is also a powerful weapon in the fight against unfounded protectionist ruses from importing countries. The exporters/importers of produce into developed markets may provide help with quality control, which includes a minimum limit for pesticide residues, e.g. as in asparagus and vegetable soybean for export to Japan. These, however, do not normally cover fertilizer overuse and nutrient loading into the environment. Another trend that may eventually help to reduce chemical overuse significantly is the promotion of organic fruits and vegetables for domestic as well as export market, but the volume is still very small. Genetic modifications (GM) using modern biotechnology are now being developed, e.g. tomato, brinjal (eggplant), potato, cabbage and cauliflower in India (Lakshman, 2002), may provide a solution with better resistance to insect pests. Obvious harms to human health and the environment already caused by pesticide overuse in vegetables may then be weighed against potential hazards from GM crops.

#### *Special problems of highlands cropping systems*

According to an FAO (1995) estimate, some 440 million ha of Asia's cropland is affected by water erosion, the kind of soil erosion that is common on steep slopes in the highlands. For many years now concerns have been raised about potential sustainability problems and impact on the environment of crop production in the highlands in Asia, especially Southeast Asia (e.g. see relevant chapters in Kunststadter et al, 1978; Allen, 1992; Midmore et al, 1996). However, very little information is available on how the new intensive cropping systems of fruits, vegetables and flowers compare with alternative cropping systems in terms of their contribution to soil erosion. Neither is there much documented evidence of productivity decline in any of these more intensive highland cropping systems that have been in operation for at least 25-30 years, or the many that began in colonial times in the 19<sup>th</sup> century. Many former opium-growing villages in Thailand have actually been able to reverse the catastrophic trend of resource degradation of the 1970's and 1980's by changing to cash cropping with land-saving vegetables and fruits (Rerkasem et al, 2002).

Apart from soil erosion, the immediate and serious threat facing many intensive cropping systems in the highlands is competition for dry season water. The problem is illustrated in well documented conflicts between upstream and downstream water users in northern Thailand (Kaosa-ard et al, 2001). Irrigation is

essential to intensive cropping in these areas with just one monsoon per year. Expansion in planted area following commercial success of fruit orchards and vegetables invariably leads to increasing upstream demand for water. The streams may dry out completely during the long dry season, causing serious hardship to downstream users. Ugly confrontations between highlanders and lowlanders have erupted in many areas. In Thailand the problem is accentuated by the absence of legal protection for water users' right and a lack of framework to settle conflicts fairly among users, or to compensate those, whose traditional rights to water, in quality or quantity, have been infringed upon. Since ethnic minority groups make up most of the highland population, many disputes are also aggravated by racial prejudices. Most unfortunately the conflict is sometimes further inflamed by different groups of water users being incited to more confrontation by NGO's with opposing agendas, as is the case in Mae Klang, south of Chiang Mai (Kaosa-ard et al, 2001).

### *Less favorable environments*

For all recent changes, subsistence cropping remains in many parts of Asia. Traditional cropping systems may be found that are adequate in meeting the people's needs. But in general even those found to be ecologically sound and sufficiently productive in the 1960's and 1970's, e.g. the rotational shifting cultivation of the Lua and Karen (Kunstadter 1978; Nakano, 1980), are increasingly unable to keep up with rising demand from the fast growing population. The government and society at large sometimes exacerbate this by restricting people's traditional land use rights through the implementation of various conservation policies. Without access to market for higher-valued crops, farmers are unable to afford even the relatively small cost of remedying natural constraints such as soil infertility and acidity. In Southeast Asia alone, acid upland soils cover almost 200 million ha, 40% of the region's total land area; in Laos, the proportion is two thirds (Garrity and Augustin, 1995). Crop science has successfully helped to develop sustainable cropping systems on such problem soils in other parts of the world. Much wheat in Brazil is grown on acid soils, 95 percent in the state of Rio Grande do Sul (CGIAR, 1995). Throughout South America, acid-tolerant crop varieties are used in conjunction with acid tolerant legume cover crops and no-tillage practices that together protect the soil surface against erosion and draw nitrogen from the atmosphere. Cropping systems in Southeast Asia of course are on much smaller scale, so direct transfer of technology may not be possible. China's success with rubber demonstrates that public investment in crop science can also yield remarkable returns in less favorable environments this region. By matching the tropical rubber tree with the right microclimates, the Kunming Institute of Botany of the Chinese Academy of Science has developed a system for growing rubber at the relatively high latitudes of 22-23 °N and high altitudes. From nowhere China was producing almost half a million tons of rubber per year by 1997 (Kaosa-ard and Rerkasem, 2000).

Successful improvement in crop production in difficult environments often depends on the involvement of farmers, as has been shown for acid upland soils in Latin America (Schiøler, 2002). Similar experience can be observed in the successful increase in farmers' yield on acid sulphate soils in flood-prone areas in Thailand, one of the most difficult environments for rice. Farmers' skill and knowledge contributed most significantly to the yield increase to 2-3 t/ha by 2000 (Sommut, 2003), from 0.3 to 0.9 t/ha in the 1980's (Chareonchamratcheep et al, 1988). The choice of rice variety is crucial, as it must match the specific flood condition that may vary between year, locations and duration/intensity. A total of 31 local rice varieties were found in 242 fields covering 1,138 ha in 2000, with characteristics such as submergence tolerance, elongation ability and adaptation to specific location and flood regime readily recognized by farmers (Sommut, 2003). Judicious application of marl and fertilizers (N and P in particular) are necessary, especially in order to get maximum return from applied nitrogen to the crop that is standing in water that may rise to 2-3 m. Improvement in situations such as this cannot be expected without the insights and intimate understanding into the local condition. It is also impossible for crop scientists to master all of these themselves. Closer collaboration between crop scientists and farmers may be the only way through which crop production in Asia's less favorable environments can be improved. For a start anyone venturing to improve upland rice production on some of Asia's acidic, phosphorous deficient upland soils should be aware that there are already local traditional cropping systems capable of producing upland rice yields of 3.5 – 4.0 t/ha, on soils with 2 ppm of available P (by Bray II) and a pH of 4 (in 1:5 water) under upland conditions for over a hundred years (Yimyam et al., 2003).

## Conclusions

Significant productivity growth in Asia's cropping systems in the past 30 years has been achieved through diversification into fruit, vegetables and flowers. These have contributed to major increases in rural employment and total output value. The future appears bright for these new, high-value, intensive cropping systems, which are an integral part of Asia's general economic development. Regional trade liberalization brings further opportunities for intensification and diversification of cropping systems to remote border regions. However, these intensive cropping systems require public investment in good market access and supporting infrastructure. There are two problems requiring attention that are unlikely to be taken care of by market forces. First is the impact of intensive cropping systems on human health and the environment, especially those arising from abuse and overuse of fertilizers and pesticides and soil erosion on steep slopes. The second concerns cropping systems in less favorable environment that are unable to convert to higher value crops because of limited access to market. Both issues await innovative contributions from crop science.

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