CHAPTER 1

GENERAL INTRODUCTION

1.1. WORLD RICE INDUSTRY AND THE CHALLENGES

Domesticated rice belongs to the genus *Oryza* of the family Poaceae*,* order *Glumiflorae*, class *Monocotyledoneae*, and division *Angiospermae.* There are only two species of the cultivated rice in the world, *viz*. *Oryza sativa* and *O. glaberrima* which are true indigene to tropical and subtropical southern Asia and southeastern Africa, respectively (Crawford & Shen 1998). *Oryza sativa* is grown all over the world, while *O. glaberrima* has been cultivated in Africa for the last 3500 years (IRRI 2008). Rice is widely cultivated in over 140 countries in the world, and rice has a large number of varieties with over 100,000 rice accessions (Smith 2000). These accessions are stored in the International Rice Genebank at IRRI (Kahn 2005).

Rice can grow under many different conditions and production systems. In most countries, rice is grown as a monocarpic annual plant yet in tropical areas it can survive as a perennial annual crop, and can also produce a ratoon crop (IRRI 2008). However, submerged in water is the most common method of cultivation used worldwide. Rice is the only cereal crop that can grow for long periods of time in standing water (Ito 2004). About 57% of rice is grown on irrigated land, 25% on rain-fed lowland, 10% on the uplands, 6% in deep water and 2% in tidal wetlands worldwide (Crawford & Shen 1998).

Paddy plants grow up to 1.0 –1.8 m tall, depending on the variety and soil fertility. The plant has long, slender leaves of 50–100 cm long and 2–2.5 cm wide. Paddy produces small wind-pollinated flowers in a branched arching to pendulous inflorescence for about 30–50 cm long. The seed which are also known as the grain (caryopsis) is 5–12 mm long and 2–3 mm thick (Ridley 1925; Metcalf 1960).

Paddy plants have many morphological characteristics, some of which are plastic (*sensu* Harper 1977) in nature. As paddy plants can grow in many different environments, they have many varieties, with one or more varieties suitable in one region than another.

The grain size can be short, medium or long. It can also be waxy or non-waxy and also has in many different colours such as brown, red, purple and black (Zhao 1998).

Rice is cultivated on many parts of the world in Asia, Australia, Africa, Europe, as well as North and South America (Fig. 1.1). Rice has been productively grown in cold places with a cold temperature of 8-13^{o}C such as the Himalayan foothills of Nepal, Japan, Korea, United States, and in the European countries such as Spain, Portugal, Italy, and Greece. Rice can be grown under irrigated conditions even in dry places like Australia and Egypt. Rice also can be cultivated in a country with an altitude of 3,000 meters above sea level like Nepal.

1.1.1. Acreage

Rice is one of the most important staple foods in the world for ca. 2.5 billion people, providing more than one fifth of the calories consumed by the populace worldwide by especially in East, South and South-East Asia (Smith 1998). As the oldest domesticated grain for over 10,000 years (Crawford & Shen 1998), at least 114 countries grow rice and more than 50 countries have an annual production of 100,000 tons or more (Table 1.1). Harvested area for rice is the largest single use of land for producing food, covering 9% of the earth's arable land (Table 1.2) and rice provides 21 percent of the world's dietary energy supply and 15% of per capital protein (Smith 1998).

Since 2000, harvesting area in most countries in Asia remains unchanged (FAO 2009). Some countries such as Japan and Korea, which are not dependable o rice industry as an economic crop, seem to slowly reduce their acreage from year to year. Besides the unchanged area, the rice production seems to be increased in most countries especially in China, India, Vietnam, Thailand, Philippines and Indonesia.

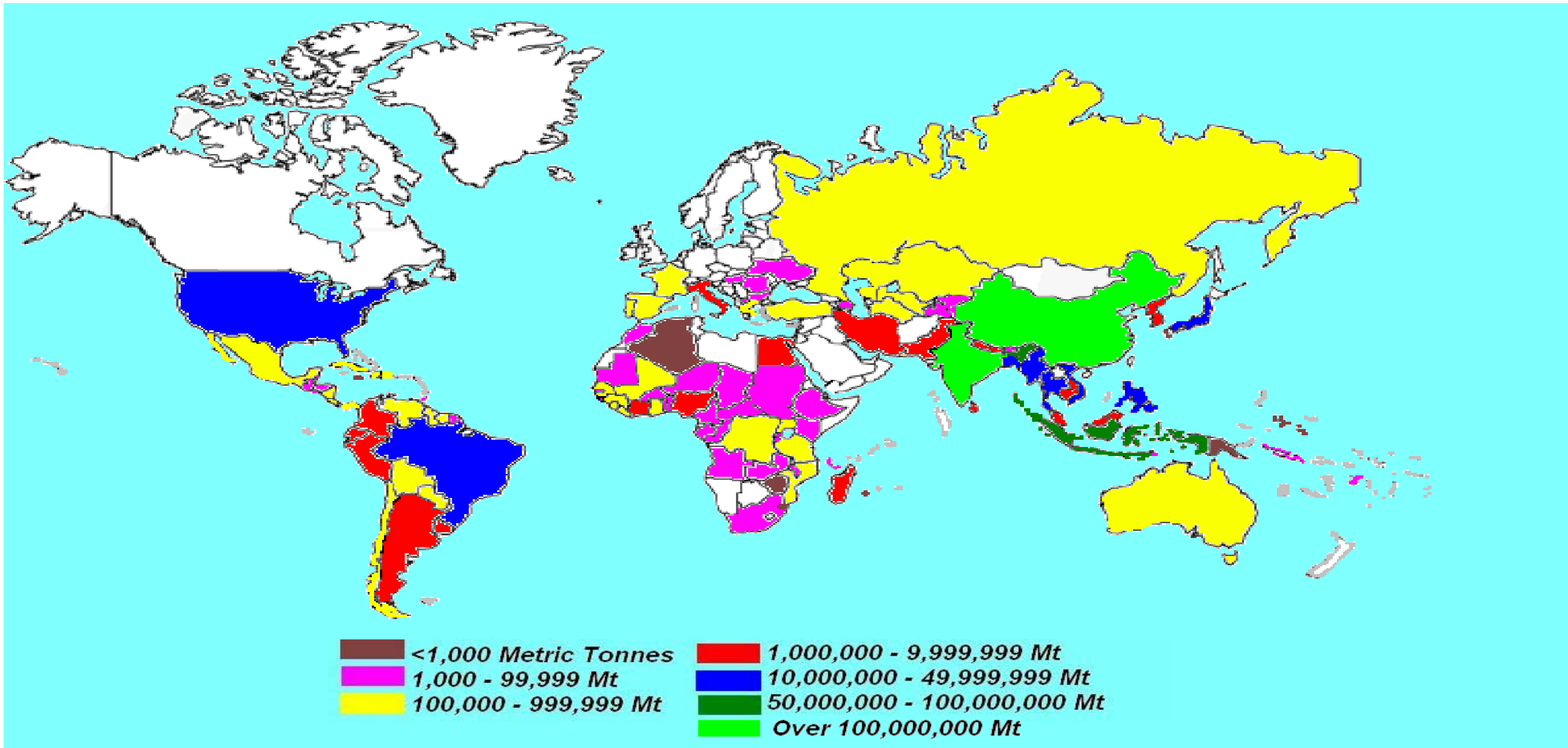

Fig. 1.1. Rice production in the world for year 2005. *source from 2006 FAOSTAT data (www.faostat.fao.org/).

Table 1.1. World's rice rough production ('000 tonnes) in selected countries and regions from 1990 to 2005*.

Year		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
World		518229	518405	528262	529572	538598	547205	569466	611321	579466	611321	599098	597981	569035	584272	606268	618441
Asia		477697	475200	483366	485789	491682	499456	521694	528604	532201	555088	545482	544630	515255	530736	546919	559349
	Bangladesh	26778	27242	27373	26928	25124	26399	28182	28152	29710	34430	37628	36269	37593	39090	37548	40054
	Cambodia	2500	2400	2221	2383	2224	3448	3404	3415	3510	4041	4026	4099	3823	4711	4170	4200
	China	191615	185693	188292	179747	177994	187298	197033	202772	200572	200403	189814	179305	176342	162304	180523	183354
	India	111517	112204	109001	120400	122640	115440	122500	123700	129055	134496	127400	139900	107600	132200	128000	130513
	Indonesia	45179	44688	48240	48181	46642	49744	51102	49377	49237	50866	51898	50461	51490	52318	54088	53985
	Japan	13124	12005	13216	9793	14976	13435	12930	12531	11200	11469	11863	11320	11111	9740	10912	11342
	Korea Rep	7722	7293	7303	6507	6882	6387	7121	7312	6779	7033	7197	7407	6687	6015	6945	6435
	Malaysia	1885	1926	2013	2104	2139	2127	2228	2120	1944	2037	2141	2095	2197	2259	2196	2215
	Myanmar	13972	13204	14840	16763	18199	17957	17680	16651	17078	20126	21324	21916	21805	23146	23700	24500
	Philippines	9885	9673	9513	9434	10541	10541	11284	11268	8554	11787	12389	12955	13271	13500	14497	14615
	Thailand	17193	20400	19917	18447	21111	22016	22332	23580	23450	24172	25844	26523	26057	27038	23860	27000
	Vietnam	19225	19622	21590	22837	23528	24964	26397	27524	29146	31394	32530	32108	34447	34569	35888	36341
South America		13421	15338	16567	16914	18152	19232	16949	17032	16000	22059	20482	19784	19601	19973	23726	24020
	Brazil	7421	9488	10006	10107	10541	11226	8644	8352	7716	11710	11090	10184	10457	10335	13277	13141
	Columbia	2117	1739	1735	1590	1657	1743	1661	1830	1898	2185	2286	2385	2348	2543	2721	2602
	Ecuador	840	848	1030	1240	1420	1291	1270	1072	1043	1290	1247	1256	1285	1263	1346	1376
	Peru	966	814	829	968	1401	1142	1203	1460	1549	1959	1892	2027	2119	2136	1817	2466

* Source: Production, Supply and Distribution Online (PSD online) of Foreign Agricultural Services of United States Department of Agriculture (USDA) in www.fas.usda.gov/psdonline accessed on January 2008

Table 1.1. Cont'd

Year		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
N&C America		9235	9311	10350	8869	10999	9965	10149	10864	10642	11795	11164	12260	12195	11623	12816	12537
	Cuba	474	428	376	186	388	396	573	614	442	559	553	601	692	716	489	650
	Dominican Rep	428	466	566	443	376	487	474	509	475	567	581	722	731	608	577	566
	USA	7080	7230	8149	7081	8971	7887	7784	8301	8364	9344	8658	9764	9569	9034	10470	10126
Africa		12355	13451	13712	14222	13854	14696	16081	16857	16116	17719	17669	16493	17556	18223	18765	18851
	Madagascar	2420	2342	2450	2550	2357	2450	2500	2558	2447	2570	2480	2662	2604	2800	3030	3030
	Nigeria	2500	3226	3260	3065	2427	2920	3122	3268	3275	3277	3298	2752	3192	3373	3542	3542
Europe		2404	2303	3123	2800	2810	2700	3200	3167	3170	3247	3181	3150	3217	3258	3468	3340
	Italy	1291	1236	1272	1305	1361	1321	1424	1442	1394	1427	1230	1273	1379	1402	1523	1413
	Russian Fed	na	na	754	688	523	462	389	328	413	444	586	497	490	451	471	572
	Spain	571	582	553	323	408	330	734	776	796	845	827	876	819	855	900	846
Oceana		951	817	1145	978	1101	1156	969	1406	1338	1412	1119	1664	1211	459	574	344
	Australia	924	787	1122	955	1082	1137	951	1388	1331	1390	1101	1643	1192	438	553	323

Table 1.2. Some attributes on rice industry in the selected regions in the world in 2007*.

Region	Area Harvested	Milled Production	MY Imports	MY Exports	Total Consumption	Yield (Rough)
Caribbean	276	661	1,055	0	1,749	2.39
Central America	290	558	566	0	1,107	1.92
East Asia	33,066	144,332	2,446	1,670	143,245	4.36
European Union	407	1,681	1,100	150	2,750	4.13
Former Soviet Union - 12	425	967	436	30	1,373	2.28
Middle East	845	2,778	4,259	20	7,232	3.29
North Africa	684	4,421	225	950	3,666	6.46
North America	1,172	6,514	1,673	3,585	5,155	5.56
Oceania	2	13	325	20	475	6.50
Other Europe	3	10	120	0	135	3.33
South America	4,929	14,605	1,310	1,810	14,243	2.96
South Asia	59,995	133,100	1,765	6,400	128,030	2.22
Southeast Asia	44,281	104,067	5,267	14,650	95,356	2.35
Sub-Saharan Africa	7,218	9,230	7,415	108	16,580	1.28
World	153,593	422,937	27,962	29,393	421,096	2.75

* Source: Production, Supply and Distribution Online (PSD online) of Foreign Agricultural Services of United States Department of Agriculture (USDA) in www.fas.usda.gov/psdonline accessed on January 2008.

The increase in rice production and area appears to be shifting back to Asia's major river deltas, where water is plentiful and labour is cheap. Many countries will face pressure from the World Trade Organization (WTO) to engage in free trade and also the domestic pressure to protect the rice industry in the countries (Barker & Dawe 2001). The Food and Agriculture Organisation (FAO 2009) predicted the global paddy production in 2008 season would rise to 683 million tonnes, 3.5 per cent more than in 2007 and the fastest rate of growth in three years. The improved production would be the result of a 2.2 per cent increase in the area cultivated globally as farmers and governments reacted to high prices. The 2008 rice harvest ends around May in northern hemisphere countries of Asia (FAO 2009).

During the last ten years rice cultivation area in the world has remained almost unchanged at *ca.*150,000,000 ha (Table 1.3). India has the largest harvesting area for rice followed by China, Indonesia, Bangladesh, Thailand and Vietnam (Fig 1.2). However, world production of rice has risen very well from about 220,612,000 tons of paddy rice in 1960 to 626,657,000 tons in 2007 (Table 1.1). Milled rice also shows increment from 150,821,000 tons in 1960 to 420,618,000 tons in 2007 (Table 1.3). The top ten rice producers in 2007 were China (185,000,000 tons), accounting for *ca.* 31% of world rice production, followed by India (22%), Indonesia (8%), Bangladesh, Vietnam, Myanmar, Philippines, Brazil and Japan (Fig 1.3).

1.1.2. Rice Production and Trade

Rice production growth rates showed a drop over time from 1960 to 2007 (Fig 1.4). The production growth declined steadily from 7% in 1960-1965 to *ca*. 2% in 2000-2005. The drop also gives an impact to the growth of yield per annum with a decline of 5% in 1960-1965 to 2% in 2001-2005.

Table 1.3. Total world harvested rice area, rice production and production growth rate from 1960-2008*.

	1960/1961	1965/1966	1970/1971	1975/1976	1980/1981	1985/1986	1990/1991	1995/1996	2000/2001	2005/2006	2007/2008
Area Harvested (1000 HA)	120,138	123,967	132,655	142,887	144,389	144,819	146,727	148,191	151,668	152,605	153,660
Milled Production (1000 MT)	150,821	172,901	213,012	243,144	269,908	317,971	351,026	368,759	398,724	417,643	420,632

	1960-1965	1966-1970	1971-1975	1976-1980	1981-1985	1986-1990	1991-1995	1996-2000	2001-2005	2006-2007
Production Growth Rate	22080	40111	30132	26764	48063	33055	17733	29965	18919	2989

*Generate from Production, Supply and Distribution Online (PSD online) of Foreign Agricultural Services of United States Department of Agriculture (USDA) in www.fas.usda.gov/psdonline on January 2008.

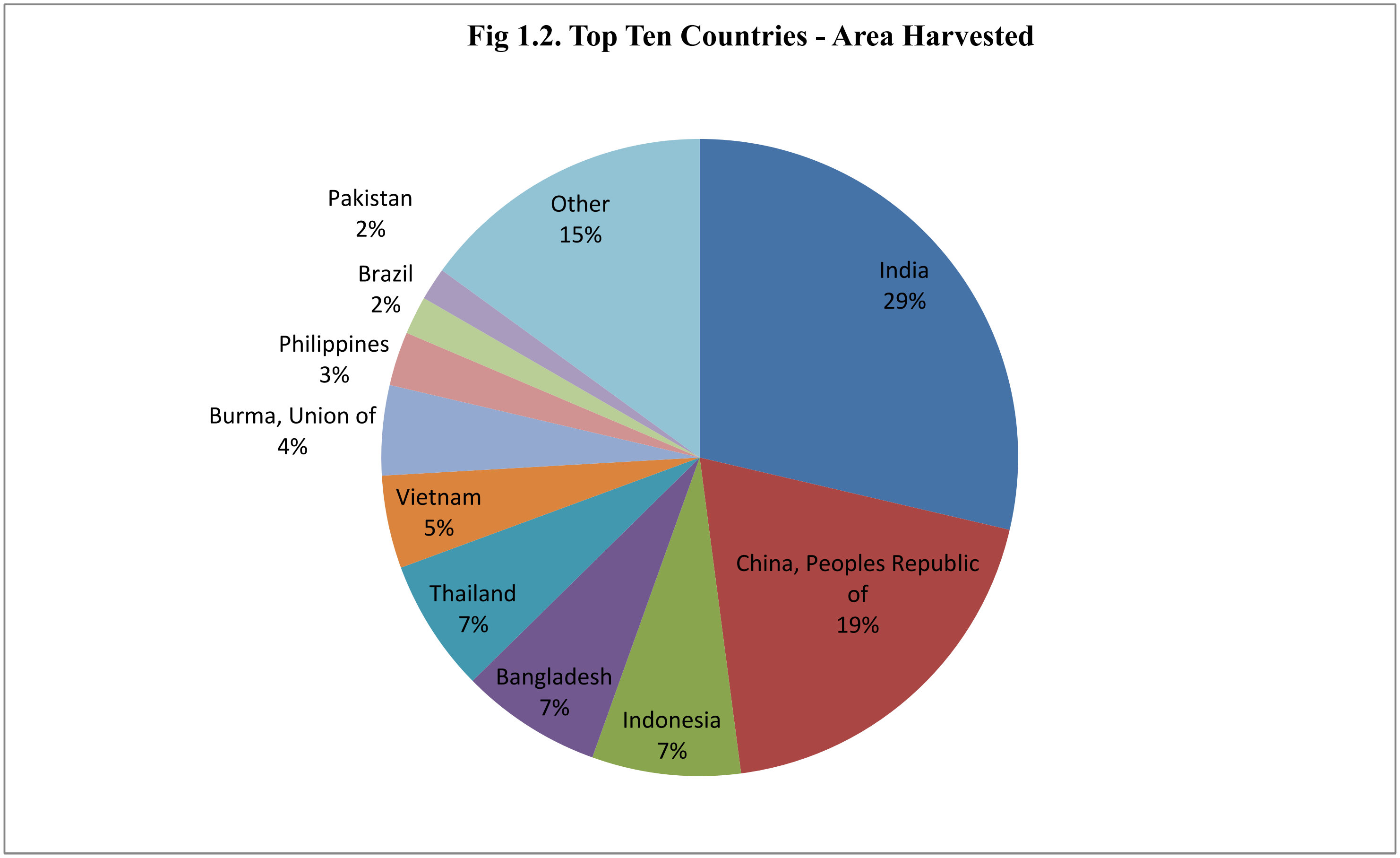

Fig. 1.2. Top ten countries of the largest rice cultivated area in the world. Source: Production, Supply and Distribution Online (PSD online) of Foreign Agricultural Services of United States Department of Agriculture (USDA) in www.fas.usda.gov/psdonline on January 2008.

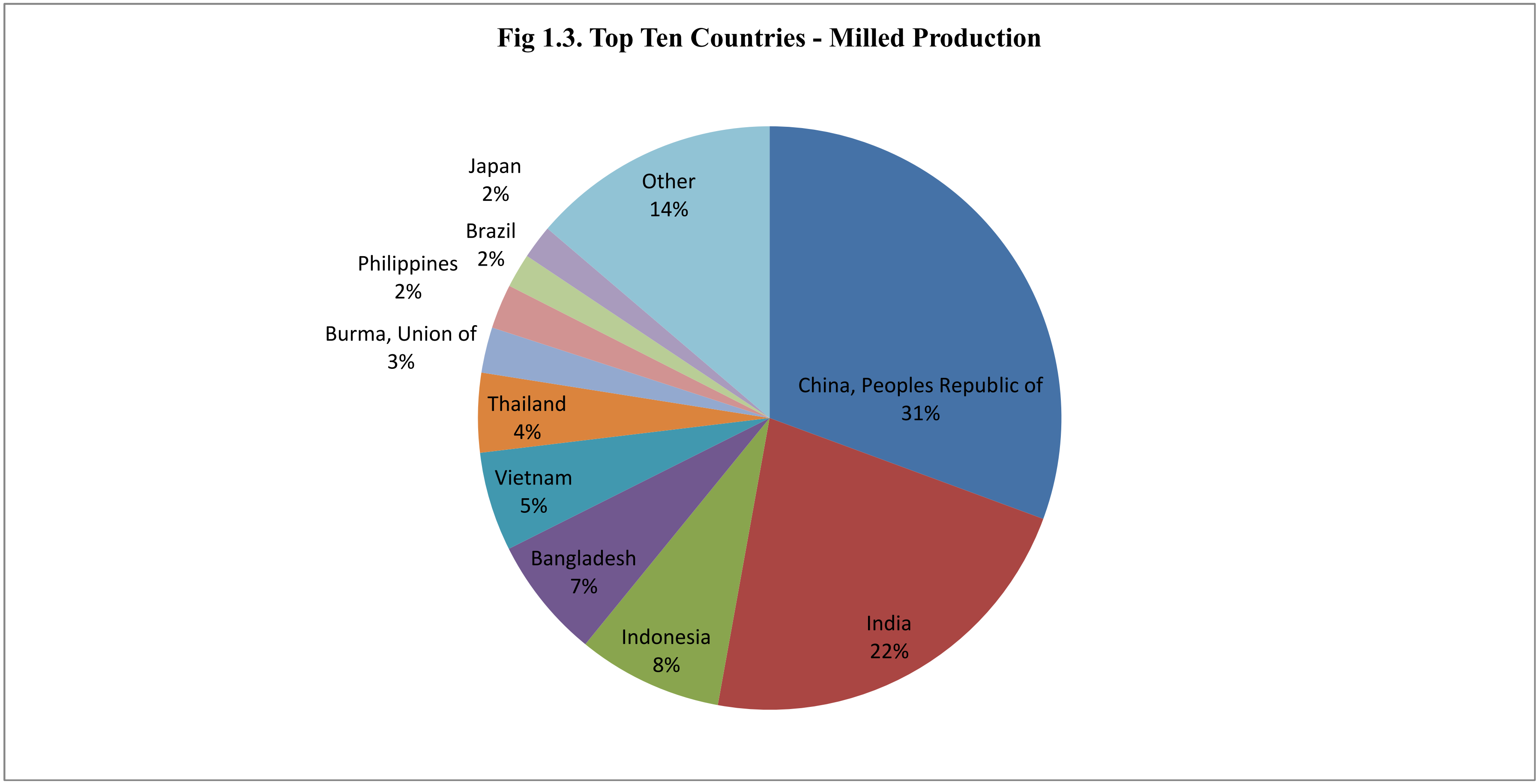

Fig. 1.3. Ton ten highest rice milled production countries in the world. Source: Production, Supply and Distribution Online (PSD online) of Foreign Agricultural Services of United States Department of Agriculture (USDA) in www.fas.usda.gov/psdonline on January 2008.

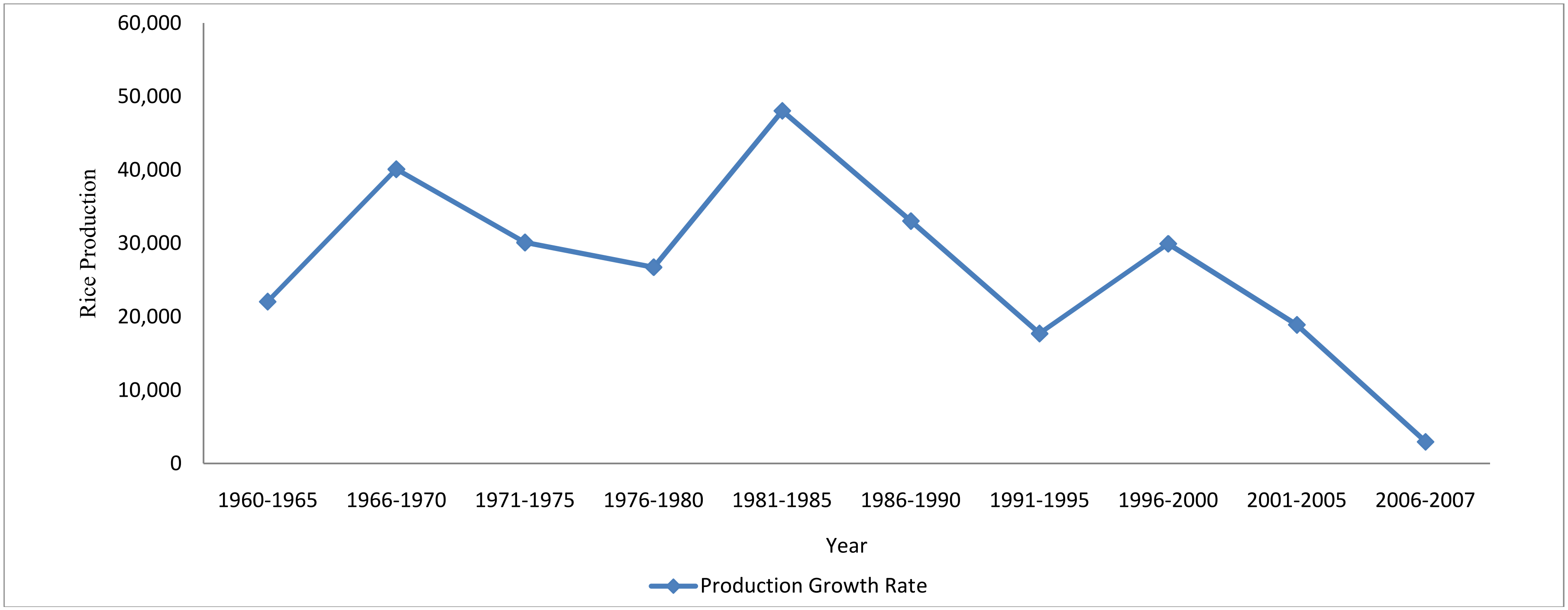

Fig 1.4. World's rice production growth rate from 1960-2007. *Generate from Production, Supply and Distribution Online (PSD online) of Foreign Agricultural Services of United States Department of Agriculture (USDA) in www.fas.usda.gov/psdonline accessed on January 2008.

A decline in growth rates of both productions and yield (Fig. 1.5) has taken place in all the major rice producing countries in the world especially in Asia. However, in India the growth rates increased significantly during 1990-95 (Table 1.1). It is believed that the improvement of water management and irrigation facilities to the rain-fed eastern regions helped for the increment.

While rice is planted on over 153 million ha all over the world, the global trade figures are very different. It is only about 11-14% of rice produced in the world is traded internationally. Thailand contributed *ca*. 26% of world's exports followed by Vietnam (17%), and the United States (12%), representing the top three exporters of rice in the world, while the largest three importers are Philippines, Nigeria and Indonesia (Fig. 1.6; Fig. 1.7).

The low volumes in rice trade compared with the productions can be attributed to that rice is planted for domestic consumption in most countries. In spite of the limited global rice market, there has been a substantial increase in the total amount of its trade, over the years. Rice production has grown from 7 million tons in 1961 to 19 million tons in the 1990s and to more than 28 million tons in 2003 (Table 1.4; Fig. 1.7).

Rice is a suitable crop for the tropical Asia climate as its amount of available water from rainfall throughout the year creates favourable habitat for a successful cultivation. Asian farmers produce about 90% of the total rice production in the world, with China and India, growing more than half of the total crop in Asia (Table 1.5).

India has the largest harvested area of rice in the world with 44 million ha. This is followed by China, Indonesia and Bangladesh (Table 1.5). However, China produces the highest milled rice compared to India (Table 1.6).

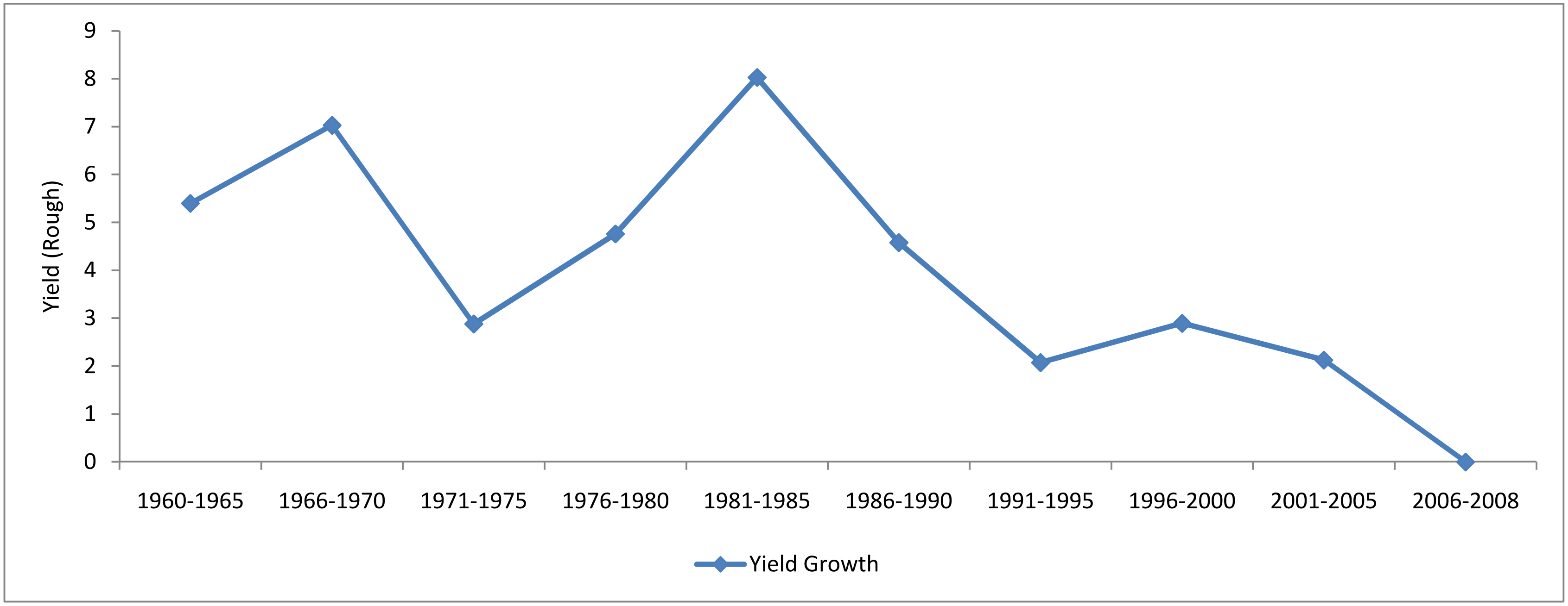

Fig. 1.5. World rice yield growth from 1960-2008. *Generate from Production, Supply and Distribution Online (PSD online) of Foreign Agricultural Services of United States Department of Agriculture (USDA) in www.fas.usda.gov/psdonline accessed on January 2008.

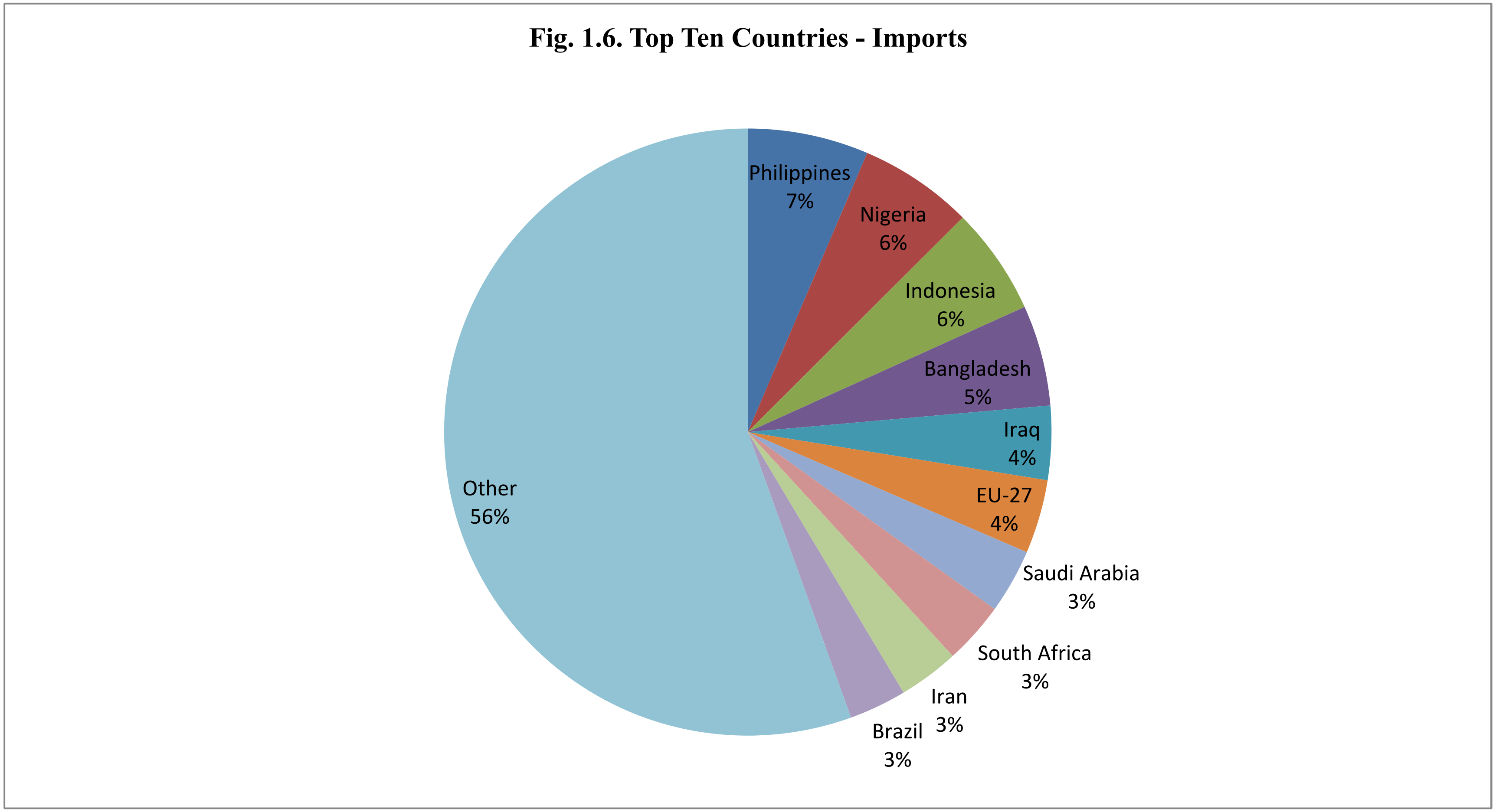

Fig. 1.6. Current top ten rice exporter countries in the world. *Generate from Production, Supply and Distribution Online (PSD online) of Foreign Agricultural Services of United States Department of Agriculture (USDA) in www.fas.usda.gov/psdonline on January 2008.

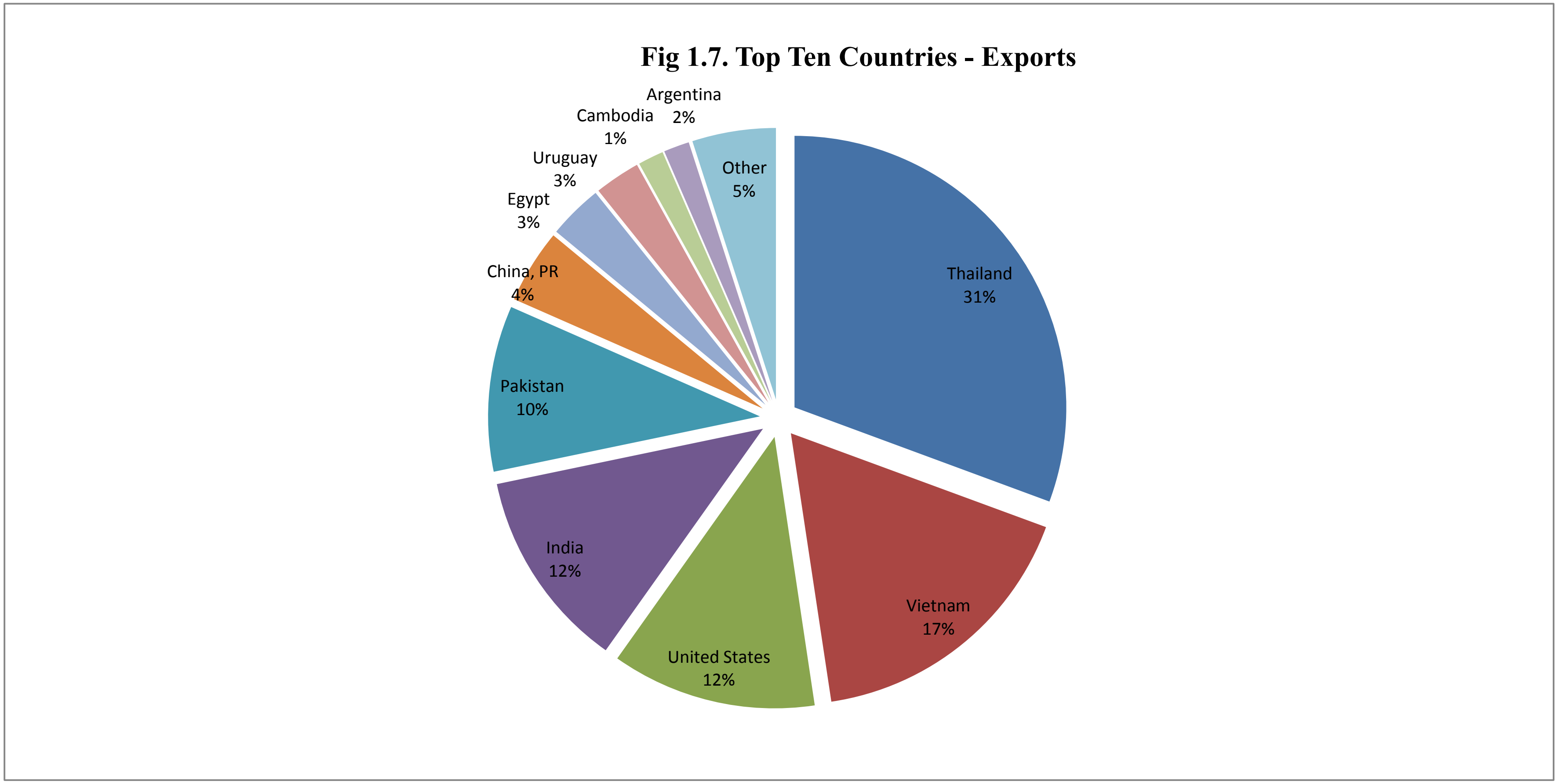

Fig. 1.7. Current top ten rice importer countries in the world. *Generate from Production, Supply and Distribution Online (PSD online) of Foreign Agricultural Services of United States Department of Agriculture (USDA) in www.fas.usda.gov/psdonline on January 2008.

Table 1.4. Total exported rice since 1999 by top rice exporting countries*.

Country	1999/2000	2000/2001	2001/2002	2002/2003	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008
China	2,951	1,847	1,963	2,583	880	656	1,216	1,300	1,300
India	1,400	1,685	6,300	5,440	3,100	4,569	4,688	4,200	3,400
Thailand	6,549	7,521	7,245	7,552	10,137	7,274	7,376	9,500	9,000
United States	2,804	2,590	2,954	3,860	3,310	3,496	3,660	2,943	3,486
Vietnam	3,370	3,528	3,245	3,795	4,295	5,174	4,705	4,600	5,000
World	22,837	24,117	26,882	28,660	27,354	28,459	30,159	29,249	29,257

*Generate from Production, Supply and Distribution Online (PSD online) of Foreign Agricultural Services of United States Department of Agriculture (USDA) in www.fas.usda.gov/psdonline accessed on January 2008.

Table 1.5. Rice harvested area ('000 ha) in Asia since 2000*.

Country	2000/2001	2001/2002	2002/2003	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008
Bangladesh	10,887	10,666	10,777	10,902	11,000	11,100	11,200	11,090
Cambodia	1,903	1,980	2,000	2,240	2,100	2,400	2,400	2,450
China	29,962	28,812	28,200	26,508	28,379	28,847	29,295	29,600
India	44,361	44,600	40,400	42,400	42,300	43,400	44,000	44,000
Indonesia	11,600	11,600	11,500	11,900	11,650	11,800	11,400	11,600
Japan	1,770	1,706	1,688	1,665	1,701	1,706	1,688	1,650
Korea, DRP	550	550	585	585	585	585	585	585
Korea, Republic of	1,072	1,083	1,053	1,016	1,001	980	955	950
Malaysia	665	643	667	672	652	660	645	660
Philippines	4,030	4,080	4,100	4,094	4,100	4,163	4,180	4,200
Thailand	9,891	10,125	10,158	10,315	9,995	10,220	10,270	10,360
Vietnam	7,493	7,471	7,463	7,468	7,450	7,314	7,211	7,250

*Generate from Production, Supply and Distribution Online (PSD online) of Foreign Agricultural Services of United States Department of Agriculture (USDA) in www.fas.usda.gov/psdonline on January 2008.

Table 1.6. Rice production ('000 t) in Asia since 2000*.

Country	2000/2001	2001/2002	2002/2003	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008
Bangladesh	25,086	24,310	25,187	26,152	25,600	28,758	29,000	28,500
Cambodia	2,536	2,583	2,400	2,960	2,630	3,780	4,000	4,075
China	131,536	124,306	122,180	112,462	125,363	126,414	127,800	129,500
India	84,980	93,340	71,820	88,530	83,130	91,790	92,760	92,000
Indonesia	32,960	32,960	33,411	35,024	34,830	34,959	33,300	34,000
Japan	8,636	8,242	8,089	7,091	7,944	8,257	7,786	7,943
Korea, DRP	1,300	1,350	1,450	1,460	1,540	1,600	1,550	1,450
Korea, Republic of	5,291	5,515	4,927	4,451	5,000	4,768	4,680	4,408
Malaysia	1,410	1,350	1,418	1,470	1,415	1,440	1,400	1,450
Philippines	8,135	8,450	8,450	9,200	9,425	9,820	10,085	10,010
Thailand	17,057	17,499	17,198	18,011	17,360	18,200	18,250	18,600
Vietnam	20,473	21,036	21,527	22,082	22,716	22,772	22,894	23,261

*Generate from Production, Supply and Distribution Online (PSD online) of Foreign Agricultural Services of United States Department of Agriculture (USDA) in www.fas.usda.gov/psdonline accessed on January 2008.

Rice trade in Asia is very active especially among Asian countries. Even though China and India are the most productive countries, international rice trades in these countries are almost inactive. With total production of 18.5 million tons in 2007, Thailand becomes the most active exporter of rice in Asia and the world. Over 9 million tons of rice or half of their productions every year since 2006 are exported in many countries. Vietnam is the second highest exporters followed by India and China (Fig 1.8).

The demand of rice is very high in some countries in Asia. The Philippines was, and still is the highest rice importer in Asia. In 2007, 1.8 million tons of rice was imported by the Philippines (Fig 1.9). Other countries with high imports of rice are Indonesia, Bangladesh and Malaysia.

It is believed that 1.2 billion new rice consumers will be added in Asia between 2005 and 2020 (Table 1.7). This will be a challenge for the rice industry in the coming years as rice production capacity does not seem to be able to support the increasing population and the parallel demand of the growing populace, and at the same time rice acreage is declining and the remaining fields seem to be "wearing out" in productivity . It will be hard to feed all the people in Asia if the production of rice is kept unchanged. It is estimated that the rice production must be increased to *ca.* 420 million tons to meet the needs in 2020. This is equivalent of extra 3.7 million tons rice production annually.

Since the early 1980s, the rice-producing nations of Asia enjoyed annual rice yield increases of 2.5% and production gains of over 3%. However, between the middle of the 1980s and the late 1990s, the rate of annual yield increase was nearly halved, and the rate of production decreased even further (Table 1.8).

Obviously we can separate two different groups of nations which produce rice in Asia. The first group is the developed countries, which have more resources and high technology capabilities plus the economic power in the world stage such as Japan and

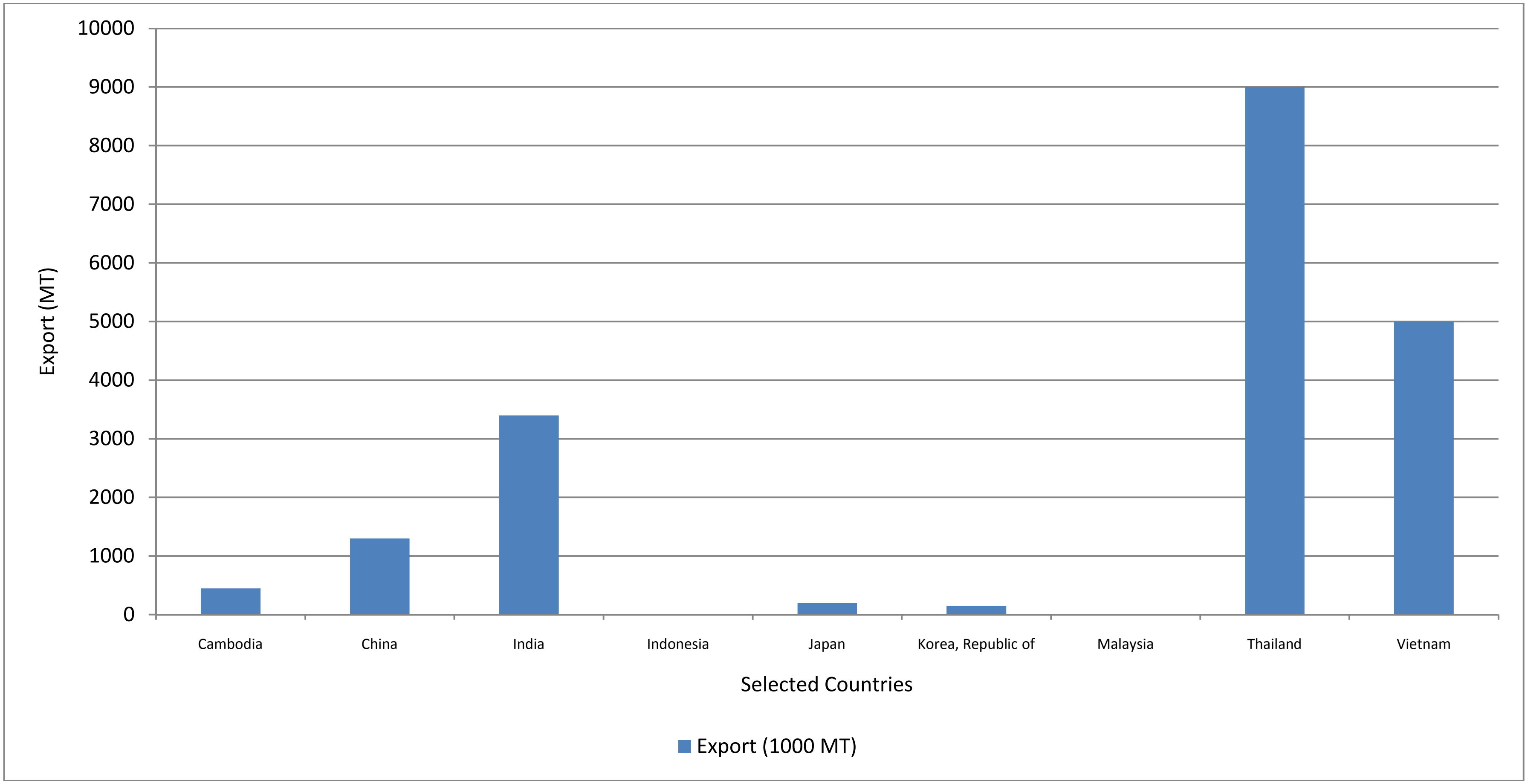

Fig. 1.8. Total rice export ('000 t) for 2007 in selective Asian countries. *Generate from Production, Supply and Distribution Online (PSD online) of Foreign Agricultural Services of United States Department of Agriculture (USDA) in www.fas.usda.gov/psdonline accessed on January 2008.

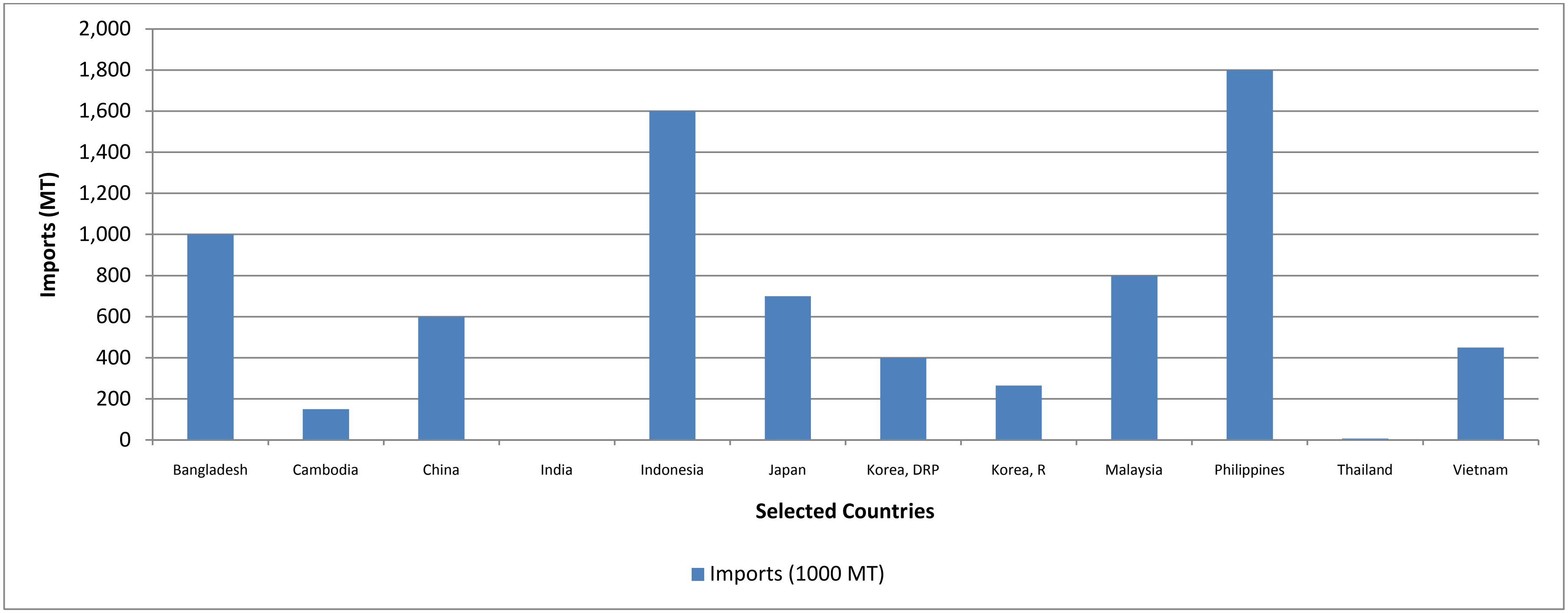

Fig. 1.9. Total rice import ('000 t) for 2007 in selective Asian countries. *Generate from Production, Supply and Distribution Online (PSD online) of Foreign Agricultural Services of United States Department of Agriculture (USDA) in www.fas.usda.gov/psdonline accessed on January 2008.

Table.1.7. World estimate population and the projection to 2030*.

Continent	Population estimate/projected			
	1950	**1975**	**2000**	**2025**
N. America	172,000,000	243,000,000	314,000,000	396,000,000
S. America	167,000,000	322,000,000	519,000,000	723,000,000
Oceania	13,000,000	21,000,000	31,000,000	42,000,000
Europe	548,000,000	676,000,000	727,000,000	670,000,000
Asia	1,399,000,000	2,397,000,000	3,672,000,000	4,950,000,000
Africa	221,000,000	406,000,000	794,000,000	1,489,000,000
World	2,520,000,000	4,065,000,000	6,057,000,000	8,270,000,000

*Source: United Nations, World Urbanization Prospects, the 2001 Revision

Table 1.8. Rough yield of rice in Asia since 2000*.

Country	2000/2001	2001/2002	2002/2003	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008
Bangladesh	3.46	3.42	3.51	3.6	3.49	3.89	3.88	3.86
Cambodia	2.12	2.07	1.91	2.1	1.99	2.5	2.65	2.64
China	6.27	6.16	6.19	6.06	6.31	6.26	6.23	6.25
India	2.87	3.14	2.67	3.13	2.95	3.17	3.16	3.14
Indonesia	4.44	4.41	4.5	4.56	4.64	4.59	4.53	4.54
Japan	6.7	6.64	6.58	5.85	6.42	6.65	6.34	6.61
Korea, DRP	3.43	3.56	3.81	3.84	4.05	4.21	4.08	3.81
Korea, Republic	6.71	6.84	6.35	6.05	6.73	6.57	6.62	6.27
Malaysia	3.26	3.23	3.27	3.37	3.34	3.36	3.34	3.38
Philippines	3.11	3.19	3.17	3.46	3.54	3.63	3.71	3.67
Thailand	2.61	2.62	2.57	2.65	2.63	2.7	2.69	2.72
Vietnam	4.14	4.27	4.37	4.48	4.62	4.72	4.81	4.86
World	3.91	3.95	3.85	3.94	3.96	4.08	4.07	4.08

*Generate from Production, Supply and Distribution Online (PSD online) of Foreign Agricultural Services of United States Department of Agriculture (USDA) in www.fas.usda.gov/psdonline accessed on January 2008.

Korea. The other one is the developing countries which are both weak in resources and technologies, and also with less bargaining power. Developed countries usually can support their rice farmers with subsidies and funding even though importing rice from other countries is far cheaper. For example, in America, the amount of subsidies given to their rice farmers in each year is massive, and this only involves *ca.* 10,000 households of rice farmers. In the case of Thailand, there are 4 million of households rice growers, who are weaker both in terms of economic strength and are lower in standard of living (Vanichanont 2004).

The United Nations has declared 2004 as the International Year of Rice (FAO 2004c). This is to recognize its economic, social, political and cultural importance of the commodity as the daily staple food for half of world's population. Rice supports hundreds of millions of people. Therefore, improving farmers' ability to grow rice efficiently and their sustenance are necessary for food security, alleviating poverty and improving the difference between rural and urban populations.

Modeled on the oil cartel of the Organization of Petroleum-Exporting Countries (OPEC), Organization of Rice Exporting Countries (OREC) was formed in 2008 as a project that to organize 21 rice exporting countries to create a homogeneous organization.

The group is mainly and currently made up of Thailand, Vietnam, Cambodia, Laos and Myanmar, but still, OREC is inviting other rice exporting countries to join in. The unfounded rumors and baseless worries that the organization was created in order to increase rice price like OPEC, the objectives of OREC are in fact very humane, noble and reasonable to help in harmonizing rice supply and demand, stabilizing rice price and beneficial to both consumers and producers.

OREC is a reflection of the frustration of Asian countries. Despite accounting for more than 60-70 per cent of world rice production, in several Asian countries, the prices of rice have jumped more than doubled in a year. Thailand and Vietnam produce half of the of the world's rice. Rice has been produced in almost all Asian countries and if all the Asian rice exporting countries get united and decide to form a cartel, they can control the prices of rice in the region and the world.

However, several questions may arise from such a move. In what way the rice cartelization like OREC will help Asian countries? Typically any cartel leads to oligopoly as the cartel will be able to influence the supply of the cartel led commodity in the market. Members of any cartel will be able to fix the price of the commodity for which it was formed. Though competition policies of most countries ban the formation of cartel and so in India, cement industry is being blamed to form a cartel and kept prices of cement artificially at high level.

The formation of cartel of rice exporting countries will help the member countries to earn more foreign exchange, as cartel will be able to keep the prices at high level. Countries like Bangladesh, Pakistan can bargain better price of their rice produce. Good foreign exchange earnings from rice export will improve the economic status of these countries, as capital formation in agriculture will increase in these countries.

In whatever reasons, OREC should be studied deeply so it will not backfire on us especially the poor Asian rice producing countries in which rice is a staple food.

1.1.3 Consumption

Rice is consumed by more than 50% of the world's population especially in Asia (Table 1.9). About 95% of the global production of rice is produced and consumed in developing countries mainly in Asia. Calories from rice are very essential in Asia, particularly among the poor which summarized around 50-80% of daily caloric intake (FAO 2004a). In Bangladesh, Cambodia, Indonesia, Laos, Myanmar, Thailand, and

Table 1.9. Total rice consumption of selected rice producer countries from 1999 to 2008 *.

Country	1999/2000	2000/2001	2001/2002	2002/2003	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008
China	134,200	134,300	136,500	135,700	132,100	130,300	128,000	127,800	129,100
India	82,650	75,960	87,611	79,860	85,630	80,861	85,088	87,650	88,800
Indonesia	35,400	35,877	36,382	36,500	36,000	35,850	35,739	35,550	36,150
Bangladesh	23,766	24,958	25,553	26,100	26,700	26,900	29,000	29,764	29,800
Vietnam	17,552	16,932	17,966	17,447	18,230	17,595	18,392	18,669	18,717
Philippines	8,400	8,750	9,040	9,550	10,250	10,400	10,722	11,550	12,060
Myanmar	9,500	9,700	9,900	10,100	10,200	10,300	10,400	10,560	10,700
Thailand	9,050	9,250	9,400	9,460	9,470	9,480	9,544	9,870	9,600
Brazil	8,025	8,050	8,300	8,100	8,687	8,860	8,974	8,789	8,900
Japan	9,426	8,297	8,779	8,742	8,357	8,300	8,250	8,250	8,150
Others	59,217	60,729	62,807	63,580	64,786	66,397	67,403	69,349	69,827

*Generate from Production, Supply and Distribution Online (PSD online) of Foreign Agricultural Services of United States Department of Agriculture (USDA) in www.fas.usda.gov/psdonline on January 2008.

Vietnam rice provides 50-80% of the total calories consumed. However, countries like Egypt, Nigeria, and Pakistan, only take 5-10% of daily caloric intake from rice.

There is nothing more important for any country to have their own ability to feed themselves. In Indonesia, for example, it means that they should grow enough rice for their own population. However, the food security and rural development are an important agenda to the national security. In this case, all countries should prevent shortage of supply of this staple food to their consumers.

The plentiful supply of rice and low prices we enjoy today may not sustain in a long time. Regional population growth is now exceeding the rice production and the worse thing is the rice industry in Asia is approaching a crisis in the supply of such essential resources as land, labour and water. To make it worse, many nations are having trouble developing sustainable ways to provide decent livelihoods for 100's of millions of poor rice farmers and consumers.

In order to alleviate this problem, an investment of just U.S. $0.40 per farmer for each of the next 20 years would go a long way toward ensuring that they can earn a decent living sustainably supplying poor rice consumers with plentiful supplies of affordable, nutritious rice (Vanichanont 2004).

Barker and Dawe (2001) echoed familiar concern that major structural transformation in the Asian rice economy over the past three decades has been part and parcel of the transition process towards an industrial economy. Indicators of this transformation are a decline in percentage gross domestic product and labour force in agriculture, a decline in population growth rate, change in dietary habit among population, a decline in percentage calories from rice in the diet, the change in rice production practices, the decline in percentage of farm income from rice, and a decline in the percentage of households below the poverty line.

If we want to alleviate rural poverty and suppress the instability in rice production and income publicly funded rice, research needs to be rejuvenated. The challenge ahead is massive and comes at a time of meager support for public rice research. Asian farmers have been funded and also influenced by the developed countries in the research system especially in delivering knowledge and new technologies for more than four decades. This effort is visibly success. However, nowadays many donors are taking their resources elsewhere, such as Africa.

As an example, in 1999, The International Food Policy Research Institute reported that every US$1 million invested in research for development conducted by the International Rice Research Institute (IRRI), lifted more than 15,000 rural poor in India, and 800,000 rural poor in China, above the poverty line. These poverty-reduction effects were even greater in previous years (Bonilla & Gulati 2003).

1.1.4. Problems and challenge of rice industry

1.1.4.1. Land

Rice farming areas are reduced until it becomes a threat to rice production in the world. When most of rice production countries try to generate national income, most rice granaries were converted for other activities especially in high profit industry such as to accommodate more profitable agriculture, to enable factory construction, or to increase urbanization. The low income activities such as rice have always been left behind or becoming the second priority by most countries (FAO 2004b).

Therefore, the focus should now be directed to the awareness of food security. Nowadays, the demand for rice for world population is still mounting. Though, the supply of rice is still limited. The rice crisis in 2008 is one of the examples of this shortage. Countries like Philippines, Malaysia and Indonesia which depend a lot on rice imports may face a huge problem when the rice supplier countries like Thailand and Vietnam could not meet the supply. This problem leads to the increment of rice price. This situation may bring social unrest among the populace in those countries leading perhaps to political instability as well.

One way to increase rice production is to maximize land acreage. However, to increase the rice area needs a lot of cost and effort. Farmers can be landlords but run a small scale rice farm and their income just enough for their own use so they hardly to expand their farm and some others are land tenants. For the farmers, reduction of production cost is an easiest way to improve standard of living. Therefore, reduced application of chemical fertilizers and pesticides and using self-made bio-fertilizers is good for the farmers and also to the environment. If this is implemented, there is no worry about the market price as long as the income is adequate as the cost of production goes down (Cassman & Dobermann 2001). Despite the rice consumer and producer countries think on how to increase the rice production area, the other way to reduce this problem is by introducing good commercial rice. Good quality and tasted rice could add a big amount of money to the country (IRRI 2008).

1.1.4.2. Labour

Labour availability for rice farming also becomes one of the challenges in rice industry today and possibly in the future. Most of the world's rice farms are too small to justify or pay for mechanization. The increase of cost of living and demand for better lifestyle makes most farmers changed their profession to more attractive and high income job. Since the late 1980s, many small rice producers have left their rice farms for urban areas because farm earning has not kept pace with those earned in industries. The consequential reduction in cultivated rice area, a likely irreversible trend, places the onus of future increases in production on the success that can be achieved in raising yields. As most of the man going for better job and pay for the family, the left farms are managed by other family members especially woman and children. Women become the important entity in most developing countries in rice industry (FAO 2004b). This scenario gives us an idea that rice industry is becoming the least important in farmer's economy.

Child labour has also becomes a challenge to the rice industry. Even though the number involved in rice industry was not as much as in other economy sector, child labour still exists in most of rice farms in the world (Edmonds & College 2002). Children in rice industry basically were involved to help their own family in reducing the burden of risen living cost. The high case of child labour on rice farm exists in Vietnam. Child labour started obviously after the Vietnam War when many men died in the war. Fortunately, the number of child labour decreased over the years and this was the positive move by Vietnamese government, FAO and IRRI (Edmonds & College 2002).

Rice industry also involves various people such as rice farmers, millers, post harvest operators and consumers (FAO 2004a). However, a majority of rice farmers has low income, and at the same time equipped with out-dated planting technologies. This can lead them to have less opportunity to improve their lives. In the same way, the problem also faced by poor consumers as many of them are poor, and rice is the only cheapest staple food available. The challenge is very tough when the focus to help the poor farmers is obstructed by the poor consumers demand. For example, the increase in rice price definitely can help to increase the farmers' economy, but this in turn will burden the poor consumers who cannot afford to pay for high rice price *vice versa*.

1.1.4.3. Water shortage and aerobic rice

The declining of water availability is threatening the sustainability of the rice irrigation system. The reasons for this decline are diverse and location-specific, but include decreasing quality, decreasing resources, and increased competition from urban and industrial users (Postel 1997). Water supply to rice granaries also creates an issue. With traditional, irrigated rice farming, it could take up to 5,000 liters of water to produce just one kilogram of rice (Bouman & Tuong 2001). Even though research has helped to greatly reduce this amount, but many rice farmers are facing many other problems such as drought and heavy flood which causing damage to their crop.

The new development of aerobic rice varieties seems to be the solution of this problem. While the cultivation of flooded lowland rice required about 1,300 mm of water, the aerobic rice used only 470 to 644 mm. The highest yield of aerobic rice was 4.7-5.3 t/ha, compared with 8.8 t/ha of flooded lowland rice. However, the water productivity (grains per kg of total water used) of aerobic rice was 64-88% higher than the flooded lowland rice. It was concluded that aerobic rice is a viable option where the shortage of water does not allow the growing of lowland rice (Guang *et al.* 2005).

According to IRRI, the aerobic rice could be considered as a mature technology in temperate countries like northern China or Brazil, where breeding programs since the 1980s have resulted in the release of several high-yielding aerobic rice varieties (Maclean *et al.* 2002). Though, on average, the yield of aerobic rice was 27-35% lower than flooded lowland rice but the water usage was 55-66% lower. The use of family labour was 47-77% less in aerobic rice than in lowland rice, mainly because the latter rice planting technology required a lot of labour for wetland preparation, transplanting and irrigation (Baoman *et al.*2002).

China is the pioneer in aerobic rice. Before, water shortage was already taking its toll on lowland rice in China, with the average yield dropping to 6 t/ha from 7.5 metric tons. About a third of 4.6 million ha planted with lowland rice in northern China faced water shortages, while drought led to damage to lowland rice in the south, the country's major rice areas. Furthermore now, China plans to expand the acreage for it to about 30 percent from about 1 percent now as the water shortage limits expansion of traditional water-flooded rice, or lowland rice (Guang *et al.* 2005).

While labour, land and water-priority areas must be clearly identified to be solved even with the declining of financial support for research and the rising cost of resources, the rice productivity must be increased to continue the foundation of rural development in Asia and a key component of sustainable poverty improvement (Barker & Dawe 2001).

1.1.4.4. Poverty

While each of these problems presents huge challenges that will take the very best to find solutions, poverty is one of problems which the most frightening of them all. From the FAO statistics, there are more than a million people are in these lower strata of income brackets. Both men and women have participated in the rice production in the world. A majority of rice growers have low income, equipped with low planting technologies and have less opportunity to improve their lives (FAO 2004a).

In both Asia and rice-producing areas of sub-Saharan Africa, farmers face low and very unstable yields and high risks of harvest failure from drought, flood, and other stresses. Reliable and high yields can be achieved only by growing varieties that tolerate these stresses. New genetic knowledge technologies now permit rapid breeding and deployment of improved varieties tolerant of environmental stresses. Reliable, high yields alone will not lift rice farmers from poverty. But, they will provide the financial opportunities and security for farmers to diversify and seek other sources of income (IRRI 2008).

The number of poor farmers in rice producing Asia is nearly three times that of sub-Saharan Africa, the second largest locus of poverty. To some extent, Asia has more poor people than Africa simply because its population is much larger. Yet some key indicators suggest that the incidence of poverty is worse in large parts of Asia than in sub-Saharan Africa (Dawe 2003).

The rural landless and urban poor spend most of their income on rice. To keep the rice price affordable, rice supply must match growth in demand. For the medium term, the favorable irrigated ecosystem will remain the major source of rice supply for urban markets. In irrigated systems, yields have plateau at high levels, but will require research to maintain them. Yields can be further increased through hybrid rice development and major changes in plant physiology. Crop management and postharvest technologies are needed to reduce the unit cost of production, which helps maintain profits for farmers and keep the price affordable to poor consumers (Barker & Dawe 2001).

These issues are concerning the future directions for rice research and development to accommodate the need of rice in the world. Rice remains the dominant food crop in Asia and a major source of livelihood for many poor consumers and producers (Barker & Dawe 2001). Positively, projections of rice research to the year 2007 indicate that the ability to meet global demand in the medium and longer term hinges substantially on improvements in yields however the planted area under rice would probably contract in the future and this improvement becomes prudently unsure.

Although better yields would help keep supply at the global level in balance with global demand, the problem of starvation would remain a main concern. The need to increase paddy yields however is only one aspect of the massive amount of problems that are likely to confront the rice economy in the future. Poor distribution systems arising from inadequate transportation facilities and deficient infra-structures are expected to limit the access of the poor to rice and the unstable market of rice increase the difficulty for rice-deficit countries to import rice to support the demand of rice shortage (Bonilla & Gulati 2003).

1.1.4.5. Pest management

One of the challenges for better yield is to develop rice pest management techniques which can manage crop pests in such a manner and sustainable that future rice production is not being threatened (Jahn *et al.* 2001). Rice pests are any organisms or microbes with the potential to reduce the yield or value of the rice crop (Jahn *et al* 2007). Rice pests include weeds, pathogens, insects, rodents, and birds.

Rice pest represent a cost in many other respect and adversely affects the production of rice yield. In Malaysia, weed competition with rice reduce 10-35% of grain yield (Karim *et al.* 2004) and for about 5-72% yield loss of rice due to weeds infestation in the world (Kuan *et al.* 1990). This can cost a lot of expenditure to manage and control of rice pest. It was estimated that about US$ 4.1 million is spent annually just on herbicides alone and this sum approximately 7% of the total expenditure on herbicides (Karim *et al.* 2004).

Thailand for example has to spend many million dollars to import all these herbicide and pesticides products every year. Therefore, in Thailand, the Integration Pest Management (IPM) has attracted more attention in the farm level in order to reduce these chemical products or use them wisely. This could help the growers and farmers cut their production cost and are friendly to environment (Vanichanont 2004).

The agricultural production trend now is to turn back to nature by using bio-fertilizers etc. There are many interesting activities such as Integration Pest Management (IPM), Good Agricultural Practice (GAP) and Organic Rice have become increasingly popular in many parts of the country, because this is the good ways to help the farmers sustain their living life (Vanichanont 2004).

We must be aware that using chemical fertilizers and pesticides to the plant are the same as using drug in human. If more usage in the farm, the more resistant the plant will be and the more chemical is needed to the plant. The scenario nowadays seems like without all these chemical resources rice and all the plants cannot grow to a perfect condition. In this extent, production cost for rice farmers is increasing rapidly and to a far high level than necessary (FAO 1994).

1.1.4.6. Food Security and Food Safety (FSFS)

Again, no other economic activity feeds so many people, supports so many families, is so crucial to the development of so many nations, and has more impact on so much of our environment. Rice production feeds almost half the world every day, provides most of the main income for millions of poor rural households, can topple governments, and covers 11 percent of the earth's arable area. However food safety and food security in this economic activity seems not to be the main issues in world's economical discussion. Until the rice price crisis in early 2008, it has opened the world's eyes about the important of rice industry to secure hunger and poverty especially to many poor countries.

As we continue to tackle with the problems of not enough land, labour, water scarcity and low income in rice farming the FSFS is the consequent of these discussions. It is clear that we need to have the knowledge, skills, and tools to solve these problems. Perhaps the real challenge in FSFS is to ensure that the research, technologies and opportunities that in many cases are already taken for granted in rice developed countries can reach the rice farmers of the developing countries. This will require a lot of resources, commitment, and vision. The Green Revolution showed that rice research can help solve even our biggest and most difficult problems and so what we need now are the same resources, commitment and vision between developed and developing countries to finally solve the big problems that remain (Cantrell 2002*)*.

IRRI has lead to make sure the FSFS issue in rice industry does not affect much for rice farmers. IRRI through the strategic plan for 2005-2007 will ensure to reduce poverty and hunger, improve the health of rice farmers and consumers, and ensure environmental sustainability through collaborative research, partnerships, and strengthening of national agricultural research and extension systems (IRRI 2006).

The rice trade in the world is also one of the reasons why FSFS lives in scarcity. Rice crisis in early 2008 is one of the impacts of the uncontrolled rice trade in the world, lead to increasing of poverty and burden for rice farmers and even to the poor consumers. Both tariff and non tariff trade barriers are applied in many countries. Moreover, the challenge in the free market system, which we hope is fare to everyone, is seemed not to be in the farmers or poor consumers' sight. Therefore, the trade subsidy and unreasonable barriers are the challenge for the world rice market and also the challenge for the fair and free trade system to ensure the FSFS.

With a heavy rice subsidy from developed countries to their own farmers, rice selling price in the world market is depressed to the lower level than it should be. This situation is pressing the rice farmers in developing countries which are relatively poor and need financial aid. Currently, with the same political reasons, governments of developing countries, who are low cost producers, for instance, India, Vietnam, Cambodia and Thailand, have adopted schemes to support rice at higher price. On the other hand, globalization pressures under World Trade Organization (WTO) obligations to reduce both internal and export subsidies have prompted the government to implement measures that ensure competitiveness without any interventions (Vanichanont 2004).

The rice price need to be controlled so it will benefit both rice producers and consumers to have a better price as rice is the most important and staple food in poor and developing countries. The function of middle man between farmers and consumers need to be controlled so they can't take advantage and to speculate the rice supply in the world market. WTO must play an intensive role to make sure the rice price is stable and the crisis in 2008 not be happened again.

1.2 RICE INDUSTRY IN MALAYSIA

Rice in Malaysia is planted mainly in gazette areas, grown in eight major granaries (Table 1.10). The government supports the industry and makes available all infrastructures requirements as well as water supply to the farmers. Rice cultivation in Malaysia was closely connected with the rural and traditional farmers. However, in the last 30 years, rice was cultivated as a commercial crop and highly regulated and subsidized by Malaysian government. Rice granaries areas constitute 57% of all planted area and produce 72% of the total national rice production. The remaining is grown in non-irrigated areas, mainly in East Malaysia (Table 1.10).

Rice is an important industry in Malaysia. Apart from being the main source of food, the industry also provides the main livelihood to about 296,000 farmers of whom 116,000 are exclusively rice farmers (Anon 1999).

The harvested area of land for rice production is currently close at 660,000 ha (Table 1.11), mainly done by small-scale farmers with ca. 3.38 (t/ha) of yield. The rice acreages dropped when entering the year 2007 from 665,000ha in 2000 and in 2007, only

Table 1.10. Acreages and rice production in Malaysian granaries in 2007*.

Rice Granaries	Acreage	Production	
	(Ha)	Tonne/Ha	Percentage
Mada	96,558	861,032	37.27
Kada	32,167	188,645	8.16
Kerian Sungai Manik	27,829	175,482	7.6
Barat Laut Selangor	18,482	184,115	7.97
Pulau Pinang	10,305	100,041	4.33
Seberang Perak	8,529	47,258	2.05
Ketara	5,156	42,707	1.85
Kemasin Semerak	5,220	13,651	0.59
Total	**204,246**	**1,612,931**	**69.81**
Other granaries	211,545	697,497	30.19
Grand Total	**415,791**	**2,310,428**	**100**

*Source : Malaysian Agriculture Department Investigation Report of Rice Production 2008.

Table 1.11. Some attributes of rice in Malaysian rice industry since 2000*.

Attribute	2000/2001	2001/2002	2002/2003	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008
Area Harvested (1000 HA)	665	643	667	672	652	660	645	660
Milled Production (1000 MT)	1,410	1,350	1,418	1,470	1,415	1,440	1,400	1,450
Rough Production (1000 MT)	2,169	2,075	2,182	2,262	2,177	2,215	2,154	2,231
MY Imports (1000 MT)	596	633	480	500	700	751	900	800
MY Exports (1000 MT)	0	13	0	13	0	0	13	0
Total Consumption (1000 MT)	1,946	2,010	2,020	2,030	2,050	2,150	2,175	2,300
Total Distribution (1000 MT)	2,431	2,468	2,343	2,293	2,365	2,506	2,656	2,718
Yield (Rough) (MT/HA)	3.26	3.23	3.27	3.37	3.34	3.36	3.34	3.38

*Generate from Production, Supply and Distribution Online (PSD online) of Foreign Agricultural Services of United States Department of Agriculture (USDA) in www.fas.usda.gov/psdonline on January 2008.

660,000ha left (Table 1.11). However, according to Malaysian Agriculture Department Investigation Report of Rice Production 2008 data, it is more worrying when the rice acreage is only 415,000ha (Table 1.10). On the other hand, rice production increased from 1.4 million tons in 2000 to 2.3 million tons in 2007 (Table 1.10). This is because the emphasis made by Malaysian government to support the industry.

The government through various government bodies has improved the productivity of rice especially by turning from manual to mechanical, new technologies, R&D and rice price control. Most major rice granaries in Malaysia have been using mechanical technique of rice cultivation rather than manual and traditional methods. The labour requirement in the farms also dropped from 47 man days/ha to 15 man days/ha and at the same time, yields are likely to increase to 2.8 million tons in 2005 (Anon 2004). The Malaysian government also has guaranteed the price of RM1,200/ton. This scenario has made Malaysia to have rice production valued at RM 1.6 million and RM2.3 million in 2000 and 2005, respectively.

A good irrigation system facilities and infrastructure can produce around 10 tons/ha of rice in all paddy granaries in Malaysia. The capability of some of the rice farmers from Sekinchan, Selangor for instance can produce ca. 13 tons/ha with a good infrastructure, a systematic irrigation system and with implementation of high quality fertilizer. Most of our granaries have an optimum input usage. In this case, there is a need to increase the capability of existence infrastructure. Efficient soil and irrigation managements need to be in place so the rice production can be as what has been produced in Sekinchan with an average yield of no less than 8 tons/ha, and some farm blocks produce up to 12 t/ha.

Malaysia through Malaysian Agricultural Research and Development Institute (MARDI) also has moved fast forward to produce various rice varieties to increase rice production in all rice fields. Rice variety such as MR219 is widely use by farmers (70%)

while others are planting varieties like MR220 and MR232. MARDI also is now researching into aerobic rice plantation to reduce water usage which is one of the main problems in Malaysian rice plantation. The pilot projects are now being tried out in Jeli, Kelantan and Seberang Perai, Pulau Pinang. Such production hopefully can help Malaysian consumers to reduce the dependence on import of rice in the future.

However, a majority of rice farmers in Malaysia are seriously dependent on support prices, input subsidy, and government intervention in marketing. They are not concerned and well-informed with the implications of AFTA, where they would no longer be heavily protected. The government may protect the industry even though efforts to liberalize the industry are being made. The so-called “rice crisis” currently prevailing in Malaysia nowadays needs to be taken seriously by Malaysian farmers and government so the impact will not seriously affects both farmers and consumers.

Malaysian government promotes domestic production of rice as a security crop in the country. However, local production of rice can only supply 60-65% of domestic consumption because the average yield for the whole country is low at just around 3.0 tons per hectare (Table 1.11). Therefore, to accommodate this shortfall, government has to import rice from other countries up to 800,000 tons/year (Table 1.11). The new policy is to have 100% self sufficiency level by 2015.

Rice price in Malaysia rose in the middle of 2008. It is reported widely in local Malaysian newspapers and mass media that price of imported rice was badly infected by rice crisis in the world. As Malaysia only attains on ca. 65% of self-sufficiency level of rice production to meet the needs of total consumption, there is a need to import the rice from exporting countries to meet the shortfall in production. The current shortage of rice produced by the main exporters has affected rice price in Malaysia. It has shown that the price of Thai white rice had increased 175% while Vietnamese white rice had gone up 181%. The price of basmati was up 69%, Thai fragrant (76%) and glutinous rice (78%).

Thailand is a major exporter for Malaysia with 40% of the total 800,000 tons of annual imports of rice in 2007. This scenario is shown in Fig. 1.10 – Fig. 1.14 as Malaysia can only produce around 1.4 to 1.6 million tons of milled rice per year while the total consumption has reached up to 2.3 million tons. This brings to the issue that rice production in Malaysia only can sustain around 60% to 69% of total consumption needed by the people. Even a lot of support from the government especially through National Agricultural Policies (NAP) in terms of financial subsidies and price support systems, and logistic supports and research, but rice production capacity is still far below the national needs (Anon 2006). This shortfall of rice production is aggravated by the temporal increase in consumption by the increasingly burgeoning population (Baki 2005).

Rice policies in Malaysia are strongly connected with poverty elevation and priorities for production growth. Although rice production remains an important sector in the Malaysian economy, the contribution to the GDP declined over the years. Since the 1970's the government invested a lot of funds on infrastructure development in all rice granaries. Subsidies for fertilizer, price control and support and price subsidy are offered to rice farmers by the government to ensure a good yield and sufficient and consistent income for the farmers, especially the lower income group (Anon 1999).

The Third National Agricultural Policy (Anon 1999) has given a very strong emphasized in Malaysian agriculture especially in paddy and rice production. Basically, this new policy is aimed to develop agricultural through research and development (R&D) and try to increase the production of major agriculture to improve food security, food quality and food safety as it can be at the affordable and reasonable cost.

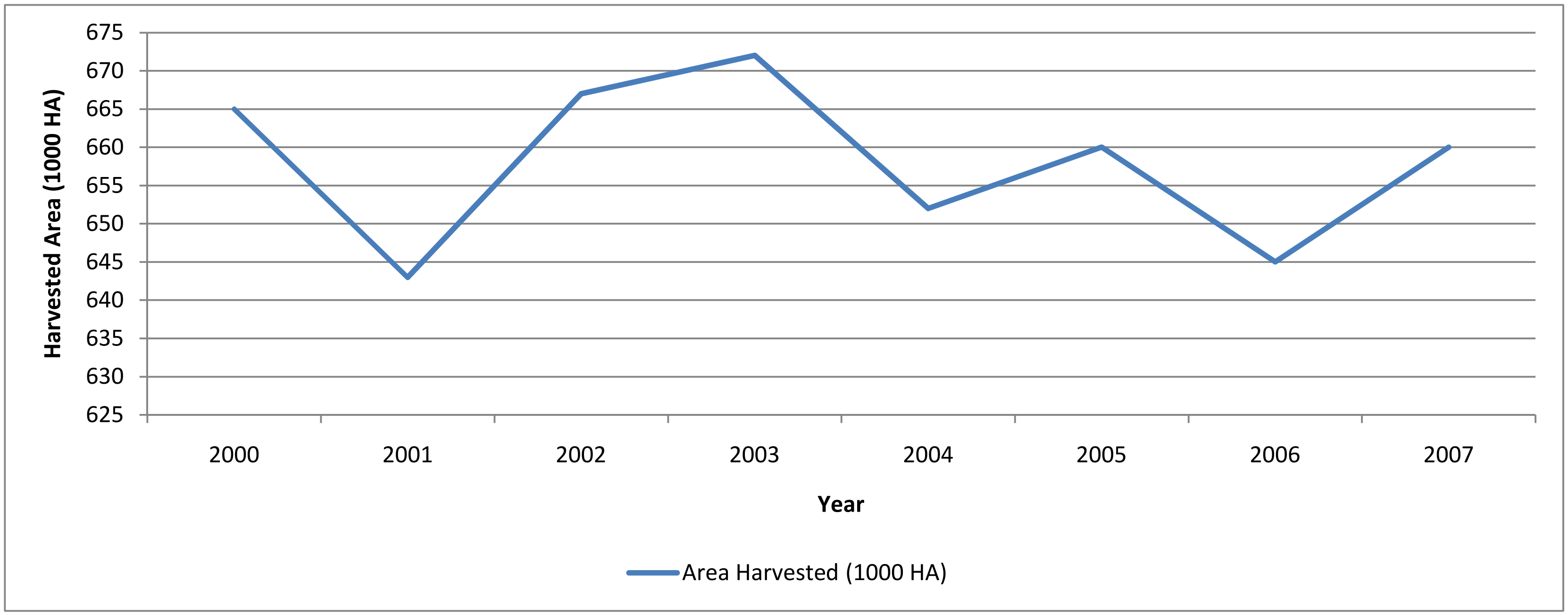

Fig. 1.10. Diagrams of area harvested of rice in Malaysia from year 2000 to 2007. *Generate from Production, Supply and Distribution Online (PSD online) of Foreign Agricultural Services of United States Department of Agriculture (USDA) in www.fas.usda.gov/psdonline on January 2008.

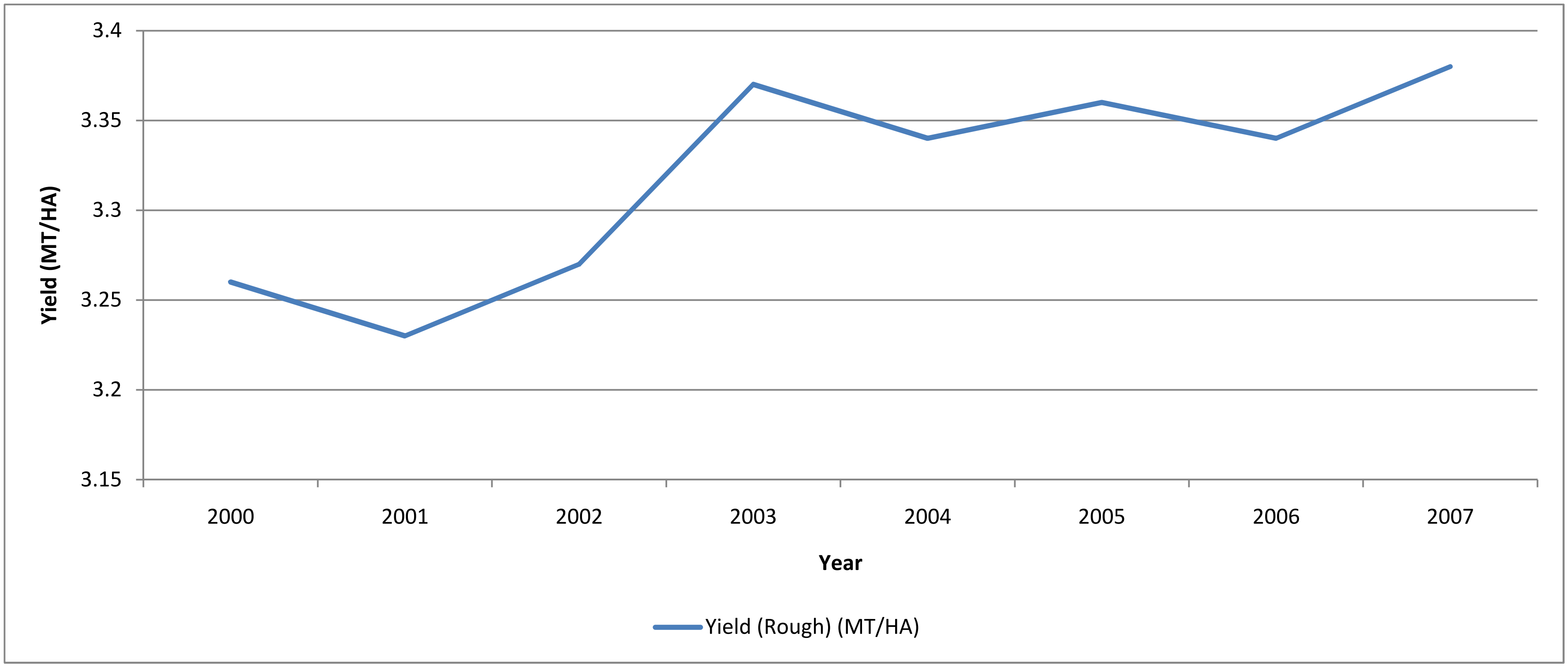

Fig. 1.11. Diagrams of rough yield of rice in Malaysia from year 2000 to 2007. *Generate from Production, Supply and Distribution Online (PSD online) of Foreign Agricultural Services of United States Department of Agriculture (USDA) in www.fas.usda.gov/psdonline accessed on January 2008.

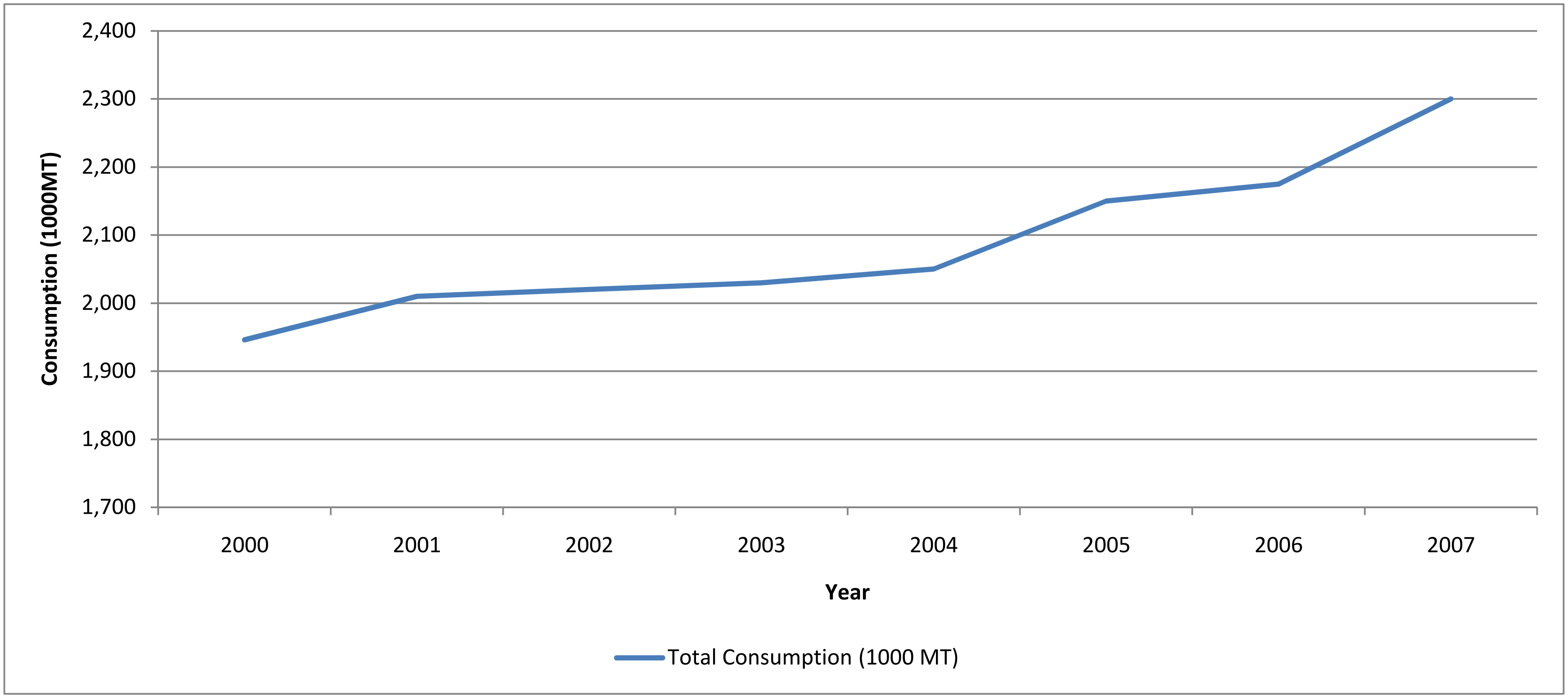

Fig. 1.12. Diagrams of total consumption of rice in Malaysia from year 2000 to 2007. *Generate from Production, Supply and Distribution Online (PSD online) of Foreign Agricultural Services of United States Department of Agriculture (USDA) in www.fas.usda.gov/psdonline on January 2008.

Fig. 1.13. Diagrams of milled production of rice in Malaysia from year 2000 to 2007. *Generate from Production, Supply and Distribution Online (PSD online) of Foreign Agricultural Services of United States Department of Agriculture (USDA) in www.fas.usda.gov/psdonline on January 2008.

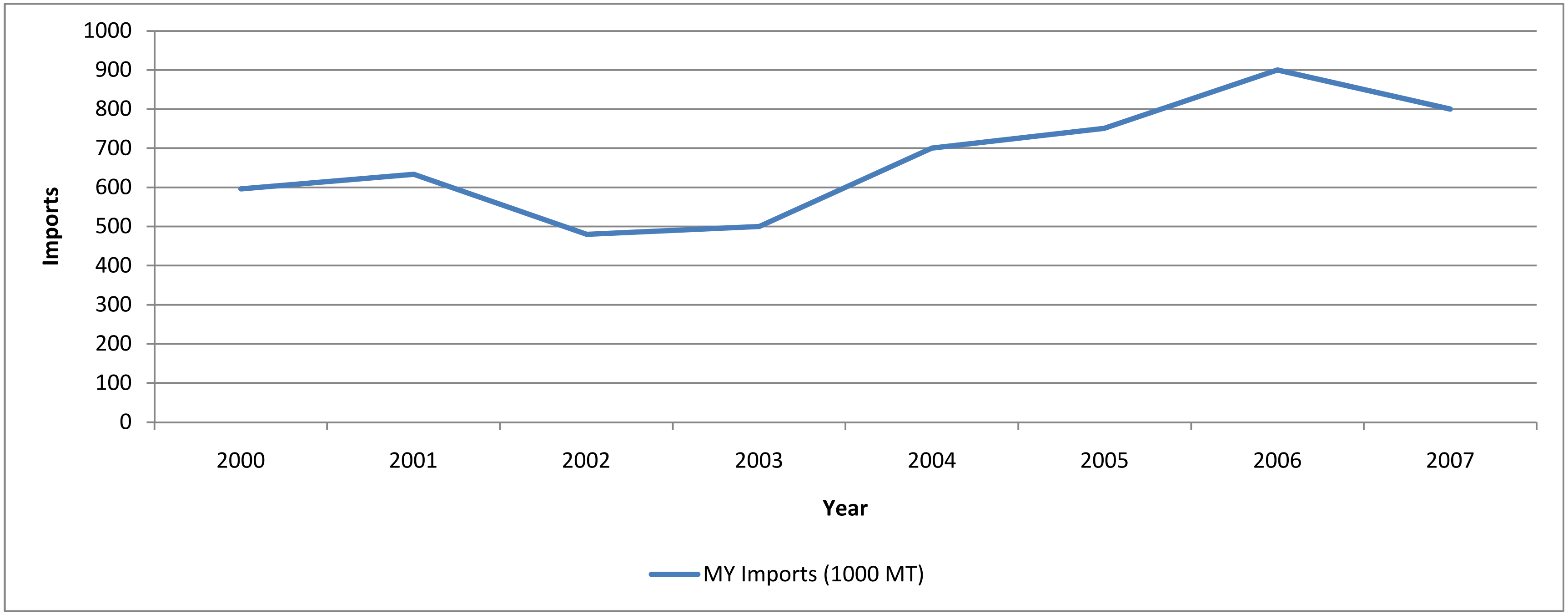

Fig. 1.14. Diagrams of import of rice in Malaysia from year 2000 to 2007. *Generate from Production, Supply and Distribution Online (PSD online) of Foreign Agricultural Services of United States Department of Agriculture (USDA) in www.fas.usda.gov/psdonline accessed on January 2008.

The Malaysian government is very protective of the rice industry. It bears a major proportion of the cost of production, by spending a substantial amount of money on subsidies. This may appear to be beneficial to farmers in assuring a sizeable profit margin, consistent income and assurance of price of rice. Nevertheless, since the production of rice is not competitive due to high production costs and low yields, the sustainability of the rice industry is questionable especially with the advent of ASEAN Free Trade Area (AFTA) in year 2007.

In the rice industry, Malaysian government trough this national agriculture plan, will try to settle down a few major issues such as the high food demand which is brought to increment of food prices, low labour productivity of only 60% as the comparison in manufacturing sector, greater competition to other countries as results to WTO and AFTA, and also rice farms converted to industrial, housing and urban uses.

A lot of organizations, government sectors, NGOs and even private sectors have contributed in helping rice growers to increase their yield. Most of it is through R&D, introduction to new technology and developing an effective management system. However, the main issue which can obstruct this effort is the attitude of farmers themselves. Most of farmers are not prone to change from their customary practice. They are skeptical as to the practicality and possible returns from the adaptation of new technology. When a new practice is introduced, they keep themselves to wait and see other farmers to do it first. Even if it is successful, they sometimes amend the practice to meet their need and such amendments may not be optimal to produce good yields.

Basically, this happens because farmers always try to cut as much cost as possible as new practice and technology always require additional costing for example extra labour work and expensive products. From a random informal survey with a few farmers in Selangor North West Project granaries, most of the farmers want a technology or management system where can reduce labour work (reduce amount of fertilizer, herbicide and pesticide applications). If possible they want a practice that can mix fertilizer, herbicide and pesticide in one time so they can cut the chemical application cost to their farms and at the same time can reduce labour cost. If the cost of labour can be reduced, it will help them to reduce the overall cost and raise their income.

1.3 WEEDY AND WILD RICES: ENTITY AND SPATIO-TEMPORAL DISTRIBUTION IN MALAYSIA

Weedy rice and red rice become are some of the millennial weed species in rice granaries and ecosystems all over the world (Baki 2006a). Weedy rice is found all over the world with various local names such as “red rice” in USA and some European countries, “akamai” in Japan, “tao” in China and “” in Vietnam (Vaughan 1994) or “padi angin” in Malaysia (Wahab & Suhaimi 1991).

Weedy rice populations have been reported in many rice- growing areas in the world where the crop is directly seeded (Parker & Dean 1976; Ferrero & Finassi 1995). Weedy plants can also adapt to a wide range of environmental conditions. In most rice areas the spread of weedy rice became significant mainly after the shift from rice transplanting to direct seeding, and has started to become very severe over the last 15 years, particularly in European countries, after the cultivation of weak, semi-dwarf indica-type rice varieties (Ferrero 2003). The spread has generally been favoured by the planting of commercial rice seeds that contain grains of the weed. Weedy rice infestations are reported for 40-75 percent of the rice area in European countries (Eleftherohorinos *et al.* 2002), 40 percent in Brazil, 55 percent in Senegal, 80 percent in Cuba and 60 percent in Costa Rica (Ferrero 2003).

In tropical Asia, weedy rice has been reported in countries like Vietnam, Philippines, India and Myanmar (Oka 1988; Vaughan 1994). Weedy rice also occurs in many others Asian countries such as Malaysia, Thailand, China, Korea, Nepal and Surinam (Watanabe *et al.* 2000). While in the temperate climate, red rice is the most common weedy accession.

In Malaysia, weedy rice is very well known as “padi angin” (literally translated to mean “windy rice”) because of their easy shattering ability even by the blowing wind as they reach the maturity. The *“padi angin”* has posed a serious problem to the farmers causing reduction of yield up to 40% (Azmi 2000). The distribution of weedy rice in Malaysia is very dynamic from season to season. It was found for the first time in Tanjung Karang granaries in 1988 (Wahab & Suhaimi 1991).

However, the weedy rice infestation was moving to MADA (Kedah), Kerian-Sg. Manik (Perak), Ketara (Terengganu) and Seberang Perak (Baki *et al.* 2000). In Tanjung Karang, Selangor and Besut, Terengganu, more than 50% of their granaries were infested with weedy rice (Azmi *et al.* 2000). While in Muda, it has been reported that in 2004, weedy rice was prevalent in all Muda areas with the majority of areas registered infestation level of 0-10% with infestation level ranging from 0-10%, 11-20% and more than 20% (Azmi *et al.* 2005b).

Baki *et al.* (2000) reported that most weedy rice accessions have a variance to mean ratio and Lloyd’s patchiness index less than 1, giving indication that the weedy rices have restricted distribution while some others showed a uniform distribution throughout the rice granaries in Peninsular Malaysia.

1.4 DESCRIPTIVE ANALYSES AND GROWTH PATTERN OF WILD AND WEEDY RICES

Weedy and wild rice are weeds belonging to the same genus of *Oryza* making it as a weed which belongs to the same genus with the cultivated crop. Even though weedy rice belongs to different varieties, all these plants share the ability to disseminate their grains before rice harvesting. Weedy rice grains frequently have a red pigmented pericarp and it is for this reason that the term ‘red rice’ is commonly adopted in international literature to identify these wild plants. This term, however, does not seem very appropriate as red-coat grains are also present in some cultivated varieties, but also absent in various weedy forms (Bres-Patry *et al.* 2001).

Weedy rices are very dangerous weeds and are distributed all over rice growing areas in the world. Generally it mimics the commercial rice or becoming as red rice or weedy forms with a range of varieties belonging to numerous species (Ferrero 2003). The weedy rice generally mimics the japonica and indica type and probably the wild species of *Oryza barthii, Oryza longistaminata* and *Oryza glabberima*. These species have been reported that as the serious weeds in West Africa. While in South-East Asian countries, the worst weedy rice species are *Oryza granulata, Oryza officinalis, Oryza rufipogon* and *Oryza nivara.*

Weedy rices also have a wide range of morphological and physiological characteristics among themselves. Weedy rice can be differentiated with cultivation varieties only at the tillering and post tillering stages with weedy rice has more numerous, longer and slender tillers, leaves are more often hispid on both surface, taller plant stature, easy shattering deciduousness traits of grains, pigmentation of several plant parts principally the pericarp and the presence of awns of variable lengths (Baki 2005a). These characteristics make weedy rice distinguishable comparatively with the cultivated varieties of rice.

Since 2005, new biotypes of weedy rice accessions have been found in some of paddy fields in Malaysia. Weedy rice in rice-growing field in Malaysia usually grows taller than cultivated rice and easily identified. This new generation of weedy rices becomes a new threat for the rice production in Malaysia because these new accessions bear similar morphological traits as cultivated rice especially in term of plant height and grain characteristics. This strong display of crop mimicry among NBWRs has led Baki, B.B. (*pers comms*.) to label NBWRs as "They stand among equals" with those common rice varieties presently planted in the Malaysian rice granaries.

1.5 IMPACT OF WEEDY RICE COMPETITION ON THE RICE CROP

The Malaysian agricultural areas are estimated to cover 4.64 million ha, and about 14% of these areas are for rice cultivation (Anon 2004). Malaysia has more than 0.5million ha of rice fields, out of which more than 0.2million ha are double-cropped in the 8 granary areas. Outside the granary areas, and in areas where rice fields are still rain fed, much of those areas are single cropped. Farmers in those areas grow conventional rice with low chemical input (Abdul Rahman *et al.* 2004). However, the new millennium saw rice acreages dropped from 686,200 ha in 1990 to 674,400 ha in 2000. In 2005, rice acreages dropped further to 611,000 ha (Anon 2004).

Weeds population and species diversity are dynamic in nature, and they change their abundance and dominance according to changes in rice agro-ecosystem. Measurable increases in the weed infestation and population density, especially grassy weed species such as weedy rice (Azmi *et al.* 2005b).

Weedy rice (*Oryza sativa* complex) in Malaysia was first observed at Sekinchan, Selangor in 1987 (Wahab & Suhaimi 1991). It is one of the most serious threats to rice production in Malaysia. Nowadays it has spread throughout Peninsular Malaysia in majority paddy field regions (Azmi *et al.* 2005a). The loss caused by weedy rice in Malaysia was estimated about RM137, 876,375 per year just by 5% field infestation of weedy rice (Baki 2004). This will lead to an economic impact in yield lost of *ca.* 64,880 tons of rice per year.

Noldin (2000) estimated that only two red rice seeds per kg planted in a rice field free of red rice could produce 100kg red rice per ha within 3 seasons. Infestation of weedy rice raise to 40-50% would cause more than 50% rice yield loss (Maneechote *et al.* 2005).

The term weedy rice generally includes all the species of genus *Oryza* which behaves and mimics like the rice crop but have the ability to disseminate their grains before rice harvesting which can reduce the production of rice in the paddy field. Weedy rice populations have been reported in many paddy areas in the world where the crop is directly seeded (Parker & Dean 1976).

Weedy rice also refers to populations of annual *Oryza* species that reduce farmer income both quantitatively through yield reduction and qualitatively through lowered commodity value at harvest (Mortimer *et al.* 2000). Weedy rice populations are easy-shattering weedy types of rice and are unwanted plants among cultivated rice.

These weedy rice populations are found in Malaysia, Vietnam, and Thailand. In Malaysia, a close relationship between weedy rice and cultivated varieties has been shown, giving a strong indication that evolutionary forces are still present in the rice ecosystems (Karim *et al.* 2004). Weedy rice also occurs in all the major rice growing areas in the tropics, being a particular problem in the direct-seeded rice agriculture of Latin and North America, the Caribbean, Africa, South and Southeast Asia (Guo-qin 2004).

In America, weedy rice also called as red rice and also occurs in temperate regions, especially where direct seeding and intensive production prevail (Bres-Patry *et al.* 2001). This red rice such as weedy rice shows weedy traits such as phenotypic plasticity, high seed dispersal ability and seed dormancy (Federici *et al.* 2001). Seeds of weedy rice usually have a red pericarp and this is the reason why the term 'red rice' is commonly used in international literature to identify these plants, display earlier tillering and flowering than cultivated rice, and show anthocyanin pigmentation of different plant parts, such as the collar, ligule, grain apiculus, stigma and awns (Suh *et al.* 1997). This term, however, does not seem very appropriate as red-coat grains are also present in some cultivated varieties, but also absent in various weedy forms (Bres-Patry *et al.* 2001).

Reports suggest that weedy rice may include other *Oryza* species including *O. barthii*, *O. glaberrima*, *O. longistaminata*, *O. nivara*, *O. punctata*, *O. sativa*, and *O. latifolia* (Holm *et al.* 1997). In addition to seed shattering, weedy rice seeds may possess secondary dormancy and some types are morphologically indistinguishable from rice varieties yet still shatter seed (Lentini & Espinoza 2005). Natural gene flow estimates in the field from herbicide-resistant rice into weedy rice under temperate conditions indicate hybridization rates of under one percent (Chen *et al.* 2004), as confirmed by genetic analysis (Estorninos *et al.* 2002).

Oryza sativa has a tendency to become weedy in areas where wild and cultivated rice plants grow sympatrically. In these areas, wild and cultivated rice plants can hybridize, producing plants that compete with the cultivars and produce inferior seed, thus decreasing the yield from the rice crop (Anon 2005). However, weedy rice can also develop in areas without native wild rice populations (Bres-Patry *et al.* 2001). The origins of weedy rice under these conditions are currently under investigation, but they are believed to be derived from hybridization between different cultivars, selection of weedy traits present in cultivars, relics of abandoned cultivars, or to have been brought into the growing region through contaminated seed stocks (Vaughan & Morishima 2003).

Weedy rice tends to mimic the growth attributes of the cultivars with which it grows, germinating simultaneously and growing at a similar rate, although earlier maturity is not uncommon. This mimicry is likely to be due to their origins in hybridization between those cultivars and the wild species. Populations of weedy rice tend to be genetically diverse and highly heterogeneous (Chang 2003). They have a high seed shedding rate and buried seeds will germinate with the crop the following season. In addition, their seeds can contaminate farmers' seed stocks and be sown with the cultivar each season (Anon 2005)

According to Mortimer *et al.* (2000), three factors that determine the population of weedy rice are seed remaining dormant in the soil over crop seasons, dissemination through crop seed contamination and seeds returning from plants in the previous crop. No single control measure will effectively control weedy rice. An integrated approach involving cultural, physical, and chemical interventions is expected to be effective in managing the weedy rice problem in a sustainable manner. Unless the problem is addressed, weedy rice in many areas poses a major threat to sustainable direct-seeded rice production (Karim *et al.* 2004).

According to Baker 1965 a number of general characteristics have been described that can increase the propensity of a plant to become a weed. It does include adaptation to different habitats, out-crossing versus selfing ability, dormancy and persistent seed bank, efficient seed dispersal and vegetative regeneration.

Weedy rice also occurred by gene transfer. Gene transfer can occur within a species (between cultivars and/or weedy varieties of the same species) or between different species of the same or other genera. These are referred to as intraspecific and interspecific gene transfer respectively. Successful gene transfer requires that three criteria are satisfied. The plant populations must overlap spatially, overlap temporally including flowering duration within a year and flowering time within a day and be sufficiently close biologically that the resulting hybrids are able to reproduce normally (Anon 2005).

Studies on genetic diversity of weedy rice have been reported. Federici *et al.* (2001) investigated Uruguayan weedy rice using AFLP markers and found that weedy rice adapts either to the natural environment or to cultivation. Several studies, based on morphological and physiological traits, isozymes, RFLP, and RAPD markers, indicate that weedy rice strains appear to be differentiated into *indica* and *japonica* types (Suh *et al.* 1997). A recent study using SSRs shows that some weedy rice is closely related to *O. sativa* while others are related to *O. rufipogon* (Vaughan *et al.* 2001). Thus, as pointed out by Watanabe *et al.* (2000), different rice-growing locations often show different patterns of genetic diversity, depending on the specific combination of germplasm from which weedy rice emerges (Guo-qin 2004).

There is no simple method for the control of weedy/red rice. Only through the integrated control approach can weedy/red rice infestation be effectively reduced. The main sources of weedy/red rice infestation are: rice seeds contaminated with weed seeds, and weedy/red rice seed bank in soil. Therefore, any control measure should be aimed at the reduction of infestation from these sources. In some countries the presence of weedy/red rice seeds is tolerated in rice seeds. However, experience in the control of this weed in countries that use advanced technologies shows that not even one single weedy/red rice seed should be tolerated in rice seeds (Labrada 2002).

1.5 OBJECTIVES OF STUDIES

The objectives of research undertaken are:

a) To identify and ascertain new biotypes of weedy rice (NBWR) prevailing in the Selangor North-West Project,

b) To carry out descriptive analyses on NBWR prevailing in the Selangor North-West Project.

c) To assess spatial distribution of NBWR in the Selangor North-West Project.

d) To study the seed germination and growth pattern of NBWR as influenced by agronomic practices and environmental variables.

e) To determine the differential competitive ability of NBWR *vis-à-vis* MR220 in a series of replacement and additive pot experiment.

1.6 STRUCTURE OF THESIS

The work embodied in this thesis is described in six chapters. The General Introduction (Chapter 1) focused on some brief discussion of rice industry in the world and Malaysia with emphasis on acreage, productivity, consumption, problems and challenges, and some discussion on wild and weedy rice.

The spatial distribution of new biotypes of weedy rice (NBWR) in the Selangor North West Project generated through field surveys conducted in 2006 to 2008 is described and discussed in Chapter 2.

Chapter 3 will be focused on descriptive analyses on the prevailing NBWR in the Selangor North West Project including a section on multivariate analysis.

In Chapter 4, seed germination and growth patterns of NBWR were described and discussed. The competitive ability of NBWR with cultivated rice *var.* MR220 will be discussed in Chapter 5. The quantitative growth indices of NBWR *vis-à-vis* MR220 were recorded and computed as appropriate in this chapter. A path analysis was also performed on the competitive data between NRWR and MR220.

Chapter 6 is a general discussion on all chapters previously discussed. Opinions and some conclusion will be discussed through the chapter.