The shape of rice agriculture towards 2050

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Abstract:

The rice consumption growth is very slow in Asia during 1961-2013 and has slowed down in other continents except Africa. The consumption growth in Africa is strong during recent years. Future additional demand will come mainly due to population growth in Africa and Asia. The production growth during last fifty years led by growth in yield has helped in achieving food security in many Asian countries. Many countries have turned out to be exporters due to impressive yield growth. But, the yield growth has slowed down considerably. The demand for rice by 2050 has been estimated as 506, 562 and 607 million tons at three levels of consumption. Scientists have been able to break the yield ceilings in the last decade, which has brought new hopes of achieving the targeted production. With increasing diversification towards high value crops/commodities, Asia may lose 4 million ha of rice area by the year 2050. However, due to strong rice consumption growth in Africa, the area in that continent will increase by 8 million ha. The speed of rice area expansion and yield enhancement in Africa depends on the level of investment in research and development of infrastructure.

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1. Introduction

Rice is the staple food of about fifty of global population and more particularly in Asian countries. Human consumption accounts for 85 percent of total production for rice, compared with 72 percent for wheat and 19 percent for maize (Mc Lean *et al.,* 2002). The crop is important from the global food security point of view, as it is consumed by majority of global poor. The crop is being grown on small farms (< 2 ha), which are subsistence or semi-subsistence in nature, in Asia and in larger parts of sub-saharan Africa (SSA). In USA, Australia, Southern Europe and parts of South America, the crop is grown on large sized farms. This crop has wide adaptability and is being grown in a wide range of environments *i.e.* temperate to humid and sub-humid climate. Besides provisioning services to millions of population around the globe, the crop also provides a wide range of ecosystem services (Bouman *et al.,* 2007; Kaoyama, 2001; and Kato *et al*., 1997).

Rice is considered as a strategic commodity by many governments as it is the staple food of the poor and an important source of employment and income for them. Therefore, governments intervene promptly in their country's rice market to stabilize rice prices. The interventions may be in the form of providing subsidies on input, procurement at pre-determined prices, distribution of grains, control on international trade *etc*. The high income countries also provide production and procurement support to their rice producers to keep them in farming occupation.

The global population is 7.55 billion presently and is expected to reach 9.77 billion by the year 2050 (United Nations, 2017). The population as well as consumption demand for rice is growing in Africa (Larson D. F. *et al*., 2010). In order to feed the increasing population, the production of rice has to match with the consumption growth, where rice is the staple food crop. In the past fifty years, the growth in production has originated from technological progress in rice cultivation in irrigated and favorable rainfed lowland areas. Irrigated rice production supplies 75 to 80 percent of global rice requirements. However, the yield in irrigated areas has reached a plateau and it is time to break the yield ceiling in those areas to feed the growing population. As the land frontiers for many countries have been exhausted, diversification of land

to other crops is taking place due to higher returns and consumer demand (Pingali and Rosegrant, 1995), and more land is being diverted for non-agricultural purposes, the growth in many countries has to come from increase in productivity of arable land. Therefore, proper strategies need to be developed for the coming years to meet the demand for rice by the policy makers in different regions of the globe. The purpose of this paper is to build up scenarios on consumption, production and area for the year 2050 based on recent trends in different parts of the world, so that appropriate planning can be made in different regions of the globe to achieve desired level of production with increase in yield and expansion of area. The specific objectives are to forecast global rice production and area estimates in different continents by the year 2050 with recent research developments scenario, so that global demand by that year will be met.

The area, production, yield (1961-2016) and consumption (1961-2013) data of rice for this paper has been obtained from FAO database. The trade data (2014-2016) has been obtained from the Rice Yearbook, 2017 of USDA. Growth rate in consumption, area, production and yield of rice has been computed by using the popular log-linear functional form ($y = ab^t$). The production, consumption and yield data mentioned in this paper are in terms of milled rice.

2. Growth in population

The global population during 1960 to 2016 has increased by 4.5 billion. The share of continental population in the global population at present is 59.8 percent, 16.5 percent, 9.9 percent, 7.7 percent, 5.6 percent and 0.5 percent for Asia, Africa, Europe, North America, South America and Australia respectively (Table 1). Rice is the major staple food for Asian population and the demand for rice among African population is growing. Asian and African population together accounts for more than **three**-fourth of global population. The growth in global population has slowed down from 2.0 percent during 1960s to 1.2 percent during the last 10 years (2007-16). However, the growth story is different in different regions of the globe. Except Africa, the population growth in other continents has decelerated during the last 57 years (1960-2016). Asia's population growth has decelerated from 2.3 during 1960s to 1.1 during the last decade (2007-2016), while that of South America decreased from 2.65 percent to 1.04 percent during the above period. However, Africa's growth rate has remained strong and more or less constant during the last 57 years (2.5 to 2.8) and was 2.61 percent during the last one decade. There is no sign of deceleration in population growth in the African continent. As Asia's

population growth has decelerated, the growth for consumption demand in this region will also decelerate in coming years. Strong growth in rice demand in future will come from Africa.

Asia accounts for 88 percent of global rice area and contributes 90 percent to the global rice production (Table 1). Within Asia, South Asia, Southeast Asia and East Asia regions together contribute 89.6 percent of world rice production and accounts for 88percent of global rice area. The other continent in order of importance are Africa, South America, North America, Europe and Australia, which accounts for about 6.9, 3.0, 1.2, 0.4 and 0.05 of global area, respectively. Africa, South America and North America contribute 3.9, 3.4 and 1.7 of global rice production. The per capita per year rice consumption level of Asian continent is highest (78 kg) followed by South America, Africa, Australia, and North America with least consumption in Europe (5 kg).

Table 1: Rice area and production by continent

Continent	No. of Countries	Rice Area (million ha)	Rice Production (in million tons)	Population in 2016 (millions)	Per capita Rice consumption 2013 (kg/year
Asia	50	143.89 (88.4)	438.2 (90.4)	4463 (59.8)	78
Africa	54	11.27 (6.9)	18.7 (3.9)	1225 (16.5)	24
South America	12	4.87 (3.0)	16.4 (3.4)	420 (5.6)	29
North America	23	1.90 (1.2)	8.1 (1.7)	578 (7.7)	11
Europe	51	0.68 (0.4)	3.0 (0.6)	741 (9.9)	5
Australia	14	0.08 (0.05)	0.5 (0.1)	401 (0.5)	13
World	204	162.70 (100.0)	484.9 (100.0)	7467 (100.0)	54

Source: FAOSTAT database. Figures in parentheses indicate percentage of global total.
Note: Rice area and production figures are average for the period 2010-2016.

3. Trends in consumption

Growth in rice demand is driven by growth in population, the level of per capita income, urbanization and availability of other foods. While growth in population has positive effect on demand, the growing urbanization has negative effect on demand due to sedentary nature of jobs in urban areas, where rice is the traditional staple food. However, the urban areas (Africa), where rice and wheat are not the traditional staple food and the consumption base of rice is very low, the demand for rice is positive. At high income levels, rice becomes an inferior good and the income elasticity become negative (Ito *et al.*, 1989). Further, consumers diversity their food baskets towards high value commodities like fish, meat, egg, milk, fruits, vegetables *etc.* at high levels of income. This level of income has already reached in Japan, South Korea, Taiwan, Malaysia and Thailand and therefore, per capita rice consumption has declined in those countries. There are signs of plateauing or declining level of per capita consumption of rice in China and India, the two largest rice consumers in the world. At low level of income, the income elasticity of demand for rice is positive in regions where rice is the staple food. However, for African consumers, where coarse cereals/roots and tubers are the staple food, the demand for rice is positive for all types of consumers as the consumption base of rice is low.

The consumption of rice has increased from 40.70 to 54.02 kg per capita per year globally, an increase of 33 percent, during the last 53 years (1961-2013). In Asia, North and South America, the increase in per capita consumption was very less. The average Asian per capita consumption has increased by 15 percent, while that of South America only 14 percent over a period of 53 years (Table 2). In North America, Europe and Australia, with low consumption base, the increase was 122, 94 and 198 percent, respectively. The Asian per capita per year rice consumption has declined slowly after reaching a peak of 82 kg during 1980s. However, in Africa, the consumption has increased by 147 percent i.e. from 9.6 kg to 23.7 kg per capita per year, an increase of 147 percent, during the last 53 years.

The growth in consumption has decelerated in all the continents except Africa. The growth trends in rice consumption by continents can be seen in Table 2. The average growth in global rice consumption was 0.50 percent for the period 1961-2013 and the growth has slowed down to 0.23 percent during the current period (2004-2013), for which data is available. In Asia, the growth is 0.16 percent per year during 1961-2013, while the growth in Africa, South

America, North America, Europe and Australia was 1.75, 0.29, 2.54, 0.91 and 2.69 respectively. The growth has slowed down in four continents in recent period (2004-2013) except Africa and Asia. In Asia the growth is constant at 0.16 percent, while in Africa, the growth has increased to 2.18 percent per year.

The region wise detail analysis of Africa shows that West Africa is the leading producer, consumer and importer of rice.

Table 2. Growth in rice consumption by continents

Continent	Average Consumption per capita per year in kg		percent increase	Growth rates (percent per year)	
	1961-63	2011-2013		1961-2013	2004-2013
Asia	67.91	78.07	15.0	0.16	0.16
Africa	9.57	23.67	147.3	1.75	2.18
S. America	25.25	28.83	14.2	0.29	-0.88
N. America	5.08	11.26	121.7	2.54	0.88
Europe	2.40	4.66	94.2	0.91	0.30
Australia	4.37	13.03	198.2	2.69	0.62
World	40.70	54.02	32.7	0.50	0.23

It was found that the increase in per capita rice consumption is maximum in West Africa (24 kg), followed by Southern Africa (12 kg), Middle Africa (11 kg), North Africa (6 kg) and Eastern Africa (4 kg), when data for the period 1960s and the recent period (2010-13) was considered. However, few countries like Madagascar, Guinea Bissau, Cote d'Ivoire, Senegal, Sierra Leone, the Gambia, Guinea, and Gabon have high levels of rice consumption like Asian countries and increase may not be much in future. The growth in per capita consumption in different region of Africa was found out to be 2.35, 4.22, 3.34, 1.30, 0.46 in Western, Southern, Middle, Northern and Eastern Africa, respectively during 1961-2013. Within Asian regions, the maximum growth in consumption was observed in West Asia region i.e. by 12 kg per capita per year in the same period (1960s and 2010-13) and continued to grow above 2 per cent per year.

The major three regions viz. South Asia, Southeast Asia and East Asia has shown declining trend in rice consumption during last one decade (2004-1013).

4. Growth in rice production

Before 1960s, increases in rice production were mostly from expansion of cultivated land (Barker and Hardt, 1985). The yield growth was mainly confined to East Asian countries due to intensive cultivation and spread of high yielding *japonica* rice varieties. The advent of *indica* rice varieties like IR-8 and TN-1 during mid 1960s containing semi dwarf gene and high yielding ability changed the situation in late 1960s. The significant achievements on global rice production over the last 50 years were largely due to technological breakthrough leading to high yield in rice and alleviates hunger to a large extent. IRRI scientists developed IR-8 in 1966, a semi-dwarf, fertilizer responsive variety with sturdy stems that become quickly popular among farmers and initiated the green revolution in rice cultivation in Asia. Using IR-8 and TN-1 as parents, a number of second and third generation varieties were developed in subsequent years with the help of national agricultural research system. These varieties are photoperiod insensitive and of lesser duration than the traditionally cultivated varieties. As a result, they fit well to different cropping systems across Asia and farmers find it's cultivation profitable than traditional counterparts. These varieties were subsequently found suitable in dry season also and therefore, the rice area, production and yield expanded in developing countries of Asia.

The growth experience of area, production and yield of rice by continent can be seen in Table 3. The overall growth in production in different continents during the period 1961-2016 varied from 0.86 in Europe to 3.33 in Africa with global average of 2.17. Asia's production growth was 2.14 per year. During 1960s, 1970s and 1980s, the production in Asia has expanded at the rate of 3.68 and 2.36 and 2.57 per year, respectively and thereafter, the production growth has decelerated. During the recent period (2010-16), the growth was only 0.68. Besides 1960s, when area growth was a significant contributor, the production growth was mainly driven by yield increase in subsequent decades. During recent period (2010-16), the area growth has became negative for Asia (-0.31 percent), though the yield growth is one leading to an overall production growth of 0.68 percent per year. The production in Asia has increased more than 2.5 times, when average data for the period of 1960s (158 million tons) and the recent period (438

million tons) is compared, thus, improving food security and alleviating poverty in Asian continent.

Rice production in Africa, South America, North America, Europe and Australia also expanded significantly during 1960s due to area expansion. The growth rate in production was 3.33, 2.25, 2.08, 0.86 and 1.69, respectively for the above continents. A significant part of growth in production in North America and Australia was due to yield growth during that period also. During 1970s, the production growth was significant in all the continents but slow in Africa due to decrease in area. Area growth in Asia and North America contributed to production growth significantly during 1970s. During 1980s onwards, with exception of Africa, the production growth was mainly driven by yield growth. The yield growth is strong in North and South America during the recent period (2010-16). The green revolution varieties of Asia did not perform satisfactorily in African agro-climatic condition and hence the yield level is low even now. The growth in yield was 0.73 percent only during 1961-2016 and 0.94 percent during the recent period (2010-16). A technological breakthrough is much needed for Africa, which will alleviate the food security situation in the continent. It is estimated that, there are about 239 m ha of wet lands, which can be brought under cultivation in Africa (Balasubramanian et al., 2007). Due to increasing demand of rice in African diet and easiness to cook rice in comparison to coarse cereals and root crops, the area under rice expanded in African continent by 3.5 times during 1960s and the current period (2010-16). As a result, rice production in Africa has also increased from 5.9 million tons to 28.1 million tons, an increase of 4.7 times during the above period. The area growth in Africa varied from 2.27 to 3.25, while that of yield varied from -0.79 during 1970s to 1.66 during 2000s. The area in South America reached its peak during 1980s (7.07 million ha) and decreased thereafter due to land policies followed by Brazilian government (Dawe et al., 2010). During the last 50 years, North America area under rice has increased moderately (1.36 million ha to 1.90 million ha). Europe's area has decreased to 0.68 million ha (2010-2016) after reaching its peak during 1980s (1.04 million ha). Australian continent has very less area and fluctuates violently from year to year and has insignificant contribution to production in the global scenario. It is observed from the last 50 years data analysis that the scope of area expansion is limited around the globe except Africa and future growth in production has to come from yield increase.

Table 3. Growth in rice area, production and yield by continents

	Period						
Continent	1960s	1970s	1980s	1990s	2000s	2010-2016	1961-2016
PRODUCTION							
Asia	3.68	2.36	2.57	1.72	1.91	0.68	2.14
Africa	4.94	1.72	4.01	3.09	4.15	3.73	3.33
S. America	3.06	3.44	2.87	3.06	2.52	0.02	2.25
N. America	6.28	5.19	-0.19	2.25	0.23	-0.53	2.08
Europe	5.93	3.11	1.11	-2.84	2.43	-0.88	0.86
Australia	8.73	10.50	0.79	4.98	-30.15	2.57	1.69
World	3.76	2.45	2.54	1.79	1.94	0.76	2.17
AREA							
Asia	1.27	0.73	0.19	0.64	0.57	-0.31	0.43
Africa	3.25	2.53	2.75	2.27	2.45	2.77	2.58
S. America	4.14	3.03	-0.43	-1.12	-0.49	-2.81	-0.22
N. America	2.55	3.85	-2.14	1.70	-0.79	-1.42	0.69
Europe	6.77	2.99	0.97	-5.91	1.01	-1.67	-0.20
Australia	3.43	11.32	-1.03	4.36	-25.85	1.08	0.58
World	1.47	0.95	0.22	0.64	0.61	-0.20	0.50
YIELD							
Asia	2.38	1.61	2.38	1.07	1.33	1.00	1.70
Africa	1.64	-0.79	1.23	0.80	1.66	0.94	0.73
S. America	-1.04	0.40	3.31	4.27	3.00	2.91	2.49
N. America	3.64	1.29	2.00	0.52	1.01	2.12	1.43
Europe	-0.78	0.12	0.14	3.26	1.41	0.80	1.05
Australia	5.12	-0.73	1.84	0.60	-5.79	1.48	1.11
World	2.26	1.48	2.31	1.14	1.32	0.96	1.66

Note: 1970s refers to the period 1970 to 1979 and so on except 1960s, which refers to the period 1961-1969.

5. Global rice markets and trade

The world rice market is segmented, thin and volatile. Consumer preferences for variety types guide the direction of exports to different regions of the world. While Asian countries like Japan, South Korea and North Korea prefer *japonica* rice, Middle East and Europe demand Basmati rice. There are limited substitution possibilities across varieties in consumption due to strong regional preferences. African countries demand *indica* rice. East Asian countries *japonica* demand is met by USA, Australia and China and Africa's *indica* demand is met mainly by India, Thailand and Vietnam. The major importers of basmati rice are by Middle East and West Asian countries and are of parboiled and white types. Other importers of basmati rice are European Union and USA. However, small quantities of basmati are imported by many countries around the globe. Similar is the case for jasmine rice, which is exported by Southeast Asian countries. These *aromatic* rice varieties are mainly consumed by higher income consumers around the globe. The SSA countries mainly imports lower quality *indica* rice. European Union imports high quality *indica* mainly from USA. The glutinous rice market is very less and mainly confined to Southeast Asia. Worldwide *indica* rice accounts for 75 to 80 percent of global rice trade followed by *japonica* rice (10-12 percent) and aromatic rice (10 percent) with glutinous rice accounting for the rest 1-2 percent (Gulati and Narayanan, 2003).

The global rice market is thin in comparison to other cereals like wheat and maize. Currently, about 42 million tons of rice are traded, which is 8.5 percent of total production in comparison to 21 percent for wheat and 12 percent for maize. This is because of the fact that much of the rice is consumed where it is produced and partly because of the policies followed by national governments pertaining to rice sector across the globe.

Besides segmentation and thinness, rice market tends to be highly concentrated. Currently, more than 80 percent of the exports of rice are made by five countries – India, Thailand, Vietnam, Pakistan and USA (Table 4). From import side, although the importing countries are many, here too there are large importers like China, Nigeria, European Union, Philippines, Saudi Arabia, Iran, Indonesia, Cote d' Ivoire, Malaysia, Senegal and South Africa. China, which was a major exporter during 1970s and 1980s, have become a major importer during recent years due to diversification policies followed by the government, similarly, Myanamar, which was a major exporter during 1960s relegated to 6^{th} position due to their

national policies in the past 50 years. However, Myanamar and Cambodia will increase their export volumes looking into the present policy scenario. The first ten importers accounted for 41 of the total global imports, while that of first ten exporters 92 of total exports. The thinness and concentration of markets imply that changes in production and consumption in major countries have amplified effect on world prices. The price spikes in international market have happened several times in the past, thus, affecting poor importing countries and threatening food security in those countries.

The thinness, segmentation and concentration leads to volatility of rice markets. Achieving self-sufficiency in food grain production is a major objective because of lack of foreign exchange to finance imports in poor countries. It is a general tendency that prices tend to be high in years of deficit and low in years of surplus. Therefore, governments consider it risky to depend on international markets and try to achieve self-sufficiency in food grain production. Even middle and high-income countries with no financial constraint to import rice also aim to maintain self-sufficiency by providing high degree of support to farmers.

Table 4. Average level of exports and imports of major rice exporters and importers across the globe (2014-16)

Country	Quantity of exports (million tons)	Percent of global export	Cumulative	Country	Quantity of imports (million tones	Percent of global import	Cumulative
India	10.89	25.7	25.7	China	4.73	11.2	11.2
Thailand	10.21	24.1	49.8	Nigeria	2.43	5.7	16.9
Vietnam	6.01	14.2	64.0	European Union	1.72	4.1	21.0
Pakistan	4.00	9.4	73.4	Philippines	1.53	3.6	24.6
USA	3.28	7.7	81.1	Saudi Aribia	1.49	3.5	28.1
Myanamar	1.57	3.7	84.8	Iran	1.27	3.0	31.1
Cambodia	1.02	2.4	87.2	Indonesia	1.19	2.8	33.9
Uruguay	0.89	2.1	89.3	Cote d'Ivoire	1.13	2.7	36.6
Brazil	0.80	1.9	91.2	Iraq	1.01	2.4	39.0
Guyana	0.46	1.1	92.3	Malaysia	1.00	2.3	41.3
World	42.38	100.0	100.0	World	42.38	100.0	100.0

Source: Rice Yearbook, 2017, United States Department of Agriculture.

6. Shape of future rice agriculture

As per the estimates of the United Nations, by 2050, the world population will increase by additional 2.2 billion. This increase will happen mostly in African and Asian countries. Therefore, additional rice will be demanded largely by these two continents to meet the burgeoning population, as rice is the staple food of larger section of Asian population and growing demand of rice from African consumers.

The shape of future rice agriculture depends on the pace of increase in population in Asia and Africa, level of consumer preferences for rice as a staple food, level of per capita income, and availability of ready to eat food in the markets. In Asia, rice will continue to be staple food because of consumer preferences. However, the quality of rice demand will be different as per capita income increases in Asia. The major source of growing demand will be from population increase. Africa will demand more rice due to growing consumer preferences and population increase. African women find rice to cook easier than coarse cereals, roots and tubers, which are major source of calorie supply in Africa. The capacity of area expansion exists in Africa and it is estimated that 239 million ha of wetlands can be developed for cultivation of crops (Balasubramanian et al., 2007). These wetlands consist of inland basins/depressions (45 percent), inland valleys (36 percent), river flood plains (12 percent) and coastal wetlands (7 percent). These land can be made cultivable with investment in irrigation and other infrastructure development including markets, transport, communication and processing industries. The quality of rice which SSA countries produce is inferior to imported rice, for which urban consumers prefer imported rice. In South America, the growth in consumption demand is slow during the last 50 years and per capita income is more. As numbers of other foods are available in the markets and there is absence of strong consumer preference for rice, the chances of increase in the level of consumption of rice is less and therefore, the growth in total volume depends on the extent of increase in population. At present, South America is a net exporter of rice due to less internal consumption, though excess capacity exists to expand area in this continent.

Several authors like Abdulla et al., 2008, Timmer et al., 2010, and von Braun and Bos, 2005 have projected world rice demand to the year 2050. Von Braun and Bos, using computed information from IFPRI's IMPACT model, have projected the rice demand to be 590 million tons by 2050, while other two projections are far less due to differential assumptions. China and

India are the largest consumers of rice and the growth in per capita consumption has slowed down to 0.43 percent per year in China and 0.23 percent per year in India in the last one decade (2004-2013). The absolute consumption has decreased from 86 kg (1983) to 77 kg (2013) in China and 75 kg (1996) to 69 kg (2013) in India. The consumption growth in other Asian countries has also decelerated or become negative. We also asses rice requirements to the year 2050 in three levels of average rice consumptions at global level i.e. 45 kg, 50 kg and 55 kg per capita per year with global population level of 9.77 billion. The first level assumes reduction in consumption due to diversification of diet by Asian population at moderate level, the second one assumes very low level of reduction in rice consumption by Asian population and the third one is at current level of consumption i.e. 54 kg at global level. Besides human consumption, allowances have been given at the rate of 15 percent extra for seed, feed and other uses of rice. The computed rice requirements are 506, 562 and 607 million tons of milled rice by 2050 in three scenario of consumption mentioned above. The required yield level to obtain the above production levels at 160 million ha global area is 3.16, 3.50 and 3.79 tons per ha of milled rice, respectively. At present, the global yield level is 2.97 tons per hectare and therefore, with the present level of yield growth, it is not difficult to achieve the above target. However, this requires continuous investment in research and development and more so in Asian and African continents.

Hossain (2007) has discussed on how the demand for rice was met by adoption of yield enhancing technologies around the globe in the past and raises concerns regarding the world's ability to meet the food-population balance in the coming decades. He advocates raising the yield ceilings of varieties in irrigated ecosystem and developing high yielding varieties for the rainfed ecosystems that are tolerant to drought, submergence and problem soils using biotechnological tools. There are positive developments in the rice research arena during the last two decades (Mckill et al., 2010) like breaking yield ceiling in irrigated rice, use of molecular breeding in developing varieties tolerant to abiotic stresses like submergence, drought and salinity etc. for rainfed ecosystem. The submergence tolerant varieties have been developed with *sub-1* gene in the background of popular cultivars and the varieties are widely adopted by farmers (Bailey-Serres et al., 2010). Similarly *saltol* gene has been identified for salinity tolerance and varieties are being developed using that gene. Molecular breeding is being deployed to develop varieties tolerant to biotic stresses and some developed varieties using this method are already adopted by

farmers. The ideotype approach has been used in breeding programs by scientists of International Rice Research Institute and China by crossing elite *indica* with improved tropical *japonica* and developed new plant types that have raised yield ceilings (Peng et al., 2008). Several new plant type lines are under field testing in different countries and yields upto 12 tons per hectare under on-farm situations. There is lot of hope that if these lines are found popular among farmers, the future of rice demand will be met easily with reduced area.

Increasing demand for high value commodities with increase in per capita income is the major driver in diverting rice land for raising other commodities in Asia. Therefore, it is expected that Asian rice area will reduce in future years. With the technological development in the last decade as discussed in the above paragraph, much land may not be needed to achieve desired level of production in different countries. However, in Africa due to growing rice demand, the area under rice is expected to increase in the coming decades. We expect the area under rice will decrease by 4.0 million ha in Asian continent and increase by 8.0 million ha in African continent by 2050 looking into the recent trends in area expansion (Table 5). The area under other continents will remain more or less same. The total global rice area will be about 164 million ha towards 2050. However, if varieties with superior yield are developed with 30 to 50 yield advantage, the area under rice will remain below 160 million ha by that year and reduction in area will be more in Asian countries.

Table 5. The shape of rice agriculture in different continents towards 2050.

Continent	Area in 2016 (million ha)	Expected area in 2050 (million ha)	Area gain (million ha)
Asia	140.5	136.5	-4.0
Africa	12.5	20.5	8.0
South America	4.2	4.2	0.0
North America	1.9	1.9	0.0
Europe	0.6	0.6	0.0
Australia	0.03	0.03	0.0
World	159.8	163.7	4.0

The scientific manpower engaged and research funds directed towards rice research is very less in Africa (Balasubramanian et al., 2007). In Asia also, in many regions/countries, the investment in rice research is less. Therefore, for development of new technologies, more

research funds should be mobilized to achieve targeted yields. In SSA, eastern India, Myanamar, Cambodia, Laos etc., the development of infrastructure is poor leading to slow adoption of technologies resulting in low yield. Therefore, more development funds are needed for these regions for infrastructure development including irrigation.

7. Conclusion

The largest rice consumers inhabit Asian and African continent. To meet the demand of consumers, Asian continent has also the largest rice area under cultivation. The growth in consumption of rice among Asian population has slowed down and there is growing demand of rice among African consumers. The consumption demands in other continents are limited. In the past, the growing demand for rice was met by the use of semi-dwarf, fertilizer responsive high yielding varieties from mid-1960s onwards resulting in high yield growth. Many countries have turned out to be major exporters due to breakthrough in yield. However, the growth in production has been decelerated in the recent past due to slow yield growth, and negative area growth in many parts of the globe. Due to increasing per capita income, consumers have diversified their food to high value commodities. Therefore, through diversification of production systems, other commodities are being grown by diverting rice land in many Asian countries. The future demand for rice to the year 2050 has been estimated to be 506, 562 and 607 million tons based on three levels of consumption. Scientists in the past decade have made breakthrough in yield ceilings in irrigated ecosystem by developing new plant types with yield advantage of 30 to 50 and developing resilient varieties, which can withstand abiotic and biotic stresses. This positive development has brought hopes that future rice production requirement will be met by using these technologies around the globe. Due to diversification of area away from rice, these varieties have shown promise and if adopted widely, the rice area in Asian continent will decrease by 4 million ha by 2050. However, due to fast growing demand for rice in Africa, the area in that continent will increase by 8 million ha by that year.

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