

IMPACT OF CLIMATE CHANGE ON FOOD SECURITY IN SRI LANKA

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ABSTRACT

Ensuring food security is the core endeavor behind development of food crop sector in Sri Lanka. This sector has achieved a significant growth due to implementation of pro agriculture policies and subsidy schemes, availability of better varieties and associated technologies and better climate which increased productivity and the area under cultivation by many major food crops. Sri Lanka has attained self-sufficiency or near self-sufficiency in many food crops especially rice, vegetables and few upland crops. However, increased consumption of processed food, meat, fish and dairy products has created an additional pressure on food and feed supply while food producers are facing an increasing competition for land, water and energy. Exploiting new lands for increasing food production would be an unlikely costly solution as biodiversity and public goods provided by the natural ecosystems must be protected thus productivity must be increased to increased food production.

Changes in both global and local scale climate have a profound impact on local agriculture production which has a potentially serious consequence for food security as food production systems interact very closely with water, climate and land resources. In future, food crops will be exposed to greater atmospheric CO₂ which would increase productivity. However, many abiotic constraints such as increased maximum and minimum air temperatures above threshold during the cropping season, reduction in the quality and quantity of irrigation water resulting an increase in the frequency of water stress periods while deteriorating soil environment such as reduction in organic carbon and increased buildup of soil salinity and biotic stresses such

as shifting insect and pathogen behavior and virulence and changing weed pressure etc. would have a profound negative impact on the food production in Sri Lanka. Impact of extreme weather events on crop production would also have a serious negative impact on food security.

Due to changes in rainfall and other parameters in Mahaweli river catchment and extraction of water for nonagricultural uses, the average annual water availability has decreased by more than 27 mcm per year in the recent past depriving water for agriculture in the dry zone of Sri Lanka. Increased temperatures have hastened the phenology and reduced biomass production. Rice spikelet temperature above 32°C has decreased pollen fertility, increased spikelet sterility and empty grains. Crop models have predicted that with currently available cultivars and technologies, there will be a reduction in rice yields by over 20% in the next 20-30 years and the magnitude of reduction would be different between seasons. Decreased pollen fertility has increased rate of out crossing of many self-pollinated crop affecting seed industry as seeds produced would create segregating populations. Increased evapotranspiration exposed rainfed crops to frequent water stress periods while increased soil salinity would further decrease productivity. These negative impacts are inevitable and would have serious negative implications on food production systems and food security in Sri Lanka. Thus options lie on minimizing the impacts through changing agricultural practices which has negative impacts on the food production system environment. Novel short season cultivars which can withstand moisture stress and biotic stresses with reduced exposure of reproductive organs to direct solar radiation are needed. Climate smart cultivation techniques, irrigation systems and cropping systems with changed cropping calendars have

proved an increased resilience to climate change which would ultimately decrease negative impacts of climate change on food security in Sri Lanka. Therefore, uninterrupted focus towards developing adaptation technologies / varieties to face these future climate change challenges is needed for ensuring food security and sustainable agriculture development.

INTRODUCTION

The first Millennium Development Goals is to eradicate extreme poverty and hunger while ensuring food security of the nation. However, ensuring food security, defused as “when all its people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life” (FAO, 1996), is challenged by a complex of highly connected problems including the impact of climate change. Climate change is now considered as a worldwide development challenge. Sri Lanka is no exception even though our contribution to climate change is negligible. The food production systems of Sri Lanka are highly vulnerable to climate change. Further, survival of organisms which support human beings by providing critical ecosystem services are being threatened. It is predicted that, there would be a definite warming of the atmosphere and changes in the rainfall patterns which would have a serious negative impact on food production in the island (IPCC, 2007). Even though many other challenges would threatened humanity, global food and nutritional security is the major regional as well as global concern as the world prepares to face ever increasing population.

The demand for food is increasing steadily and the share of agriculture to the Sri Lankan GDP would decrease up to 8% while the per capita income would increase to well over US\$ 4000 (Central Bank of Sri Lanka, 2012). These would certainly change the food habits and demand for meat and meat based food would increase placing additional burdens on grain production systems.

Climate change and its impact

Increased concentration of atmospheric greenhouse gases with the global industrial revolution and other man made activities have led to a continuous change in climate. Atmospheric CO₂ concentration increased gradually and reached to around 400 $\mu\text{mol/mol}$ in 2013 and is predicted to increase to about 550 $\mu\text{mol/mol}$ by the end of this century (IPCC, 2007). Further the increased atmospheric concentration of methane, nitrous oxide and other greenhouse gases have led to an increase in the air temperature. The global mean surface temperature change for the period 2016–2035 relative to 1986–2005 will likely be in the range of 0.3°C to 0.7°C while for 2081–2100, relative to 1986–2005 will likely be in the range of the 2.6°C – 4.8°C with RCP 8.5 scenario (IPCC, 2013). It is very likely that the number of cold days and nights has decreased and the number of warm days and nights has increased on the global scale. It is projected with medium confidence that over the period 1901–2010, global mean sea level rose by 0.19 m [0.17 to 0.21]. Global mean sea level rise for 2081–2100 relative to 1986–2005 will likely be in the ranges of 0.45 to 0.82 m for RCP8.5 (medium confidence) with a rate of 8 to 16 mm yr^{-1} (IPCC, 2013).

The rate of increase in maximum and minimum air temperatures in Sri Lanka vary between location and season. Almost continuous warming has occurred since 1930 s until 2007 in several locations representing the major agro-ecological zones in Sri Lanka (De Costa, 2008). In the major agricultural area in the dry zone, Anuradhapura, the rate of increase in air temperature has been around 0.0078°C per year (De Costa, 2008). There was an increase in both maximum and minimum temperatures in all major agricultural areas over the last century. The increase in minimum air temperature from 1900 to 2000 at an elevation of 1894 m at *Nuweraeliya* was 2°C while at sea level at *Puttalam*, it was 1.35°C (Premalal, 2009) which are significantly greater than global average of 0.6°C. Similarly, the maximum temperature in these locations also increased by 0.7°C during this period (Premalal, 2009). It was also observed that there was a

significant increase in the number of warm days and reduction in number of cold nights (Premalal, 2009). There was a significant fluctuation in both maximum and minimum temperatures in both dry (*Yala*) and wet (*Maha*) seasons in the dry zones which are the major crop growing environments. Therefore, these changes are expected to create far-reaching impacts on food crops grown in all ecosystems in Sri Lanka.

The uncertainty of the North-East monsoon which brings rain to the dry zone has increased but slight change in annual total rainfall over the island was observed (Premalal, 2009). There was a continuous reduction in rainfall received in the catchments in the up and mid country (Premalal, 2009). This has a direct impact on the water flow of the major river, the “*Mahaweli*” which divert water to the dry zone.

Food requirement

Rice production in Sri Lanka in 2010 was 4.3 Mn. tons, which is about 5% greater than the total rice

requirement for over 20 million Sri Lankans (Fig. 1), however, fell below the requirement in subsequent years. This shows the vulnerability of this sector to changes in environmental fluctuations which highlight the importance of a buffer stock. With the present population growth rate of 1.1%, present *per capita* consumption, requirements for seed, and wastage in handling, Sri Lanka needs about 4.07 and 4.29 Mn. tons of rice in the year 2015 and 2020 respectively (Fig. 1).

Sri Lanka is self-sufficient in its vegetables requirement. In 2009, the total quantity of vegetables produced exceeded 800,000 tons which were produced from over 90,000 ha of land area. Eventhough total quantity produced is sufficient for the consumption, there is a seasonal fluctuation in the production of these perishables leading to a glut or scarcity in the market (Fig. 2). However, the per capita consumption is well below the required quantity. It is projected that production of all kinds of vegetables must be increased to meet the future demand.

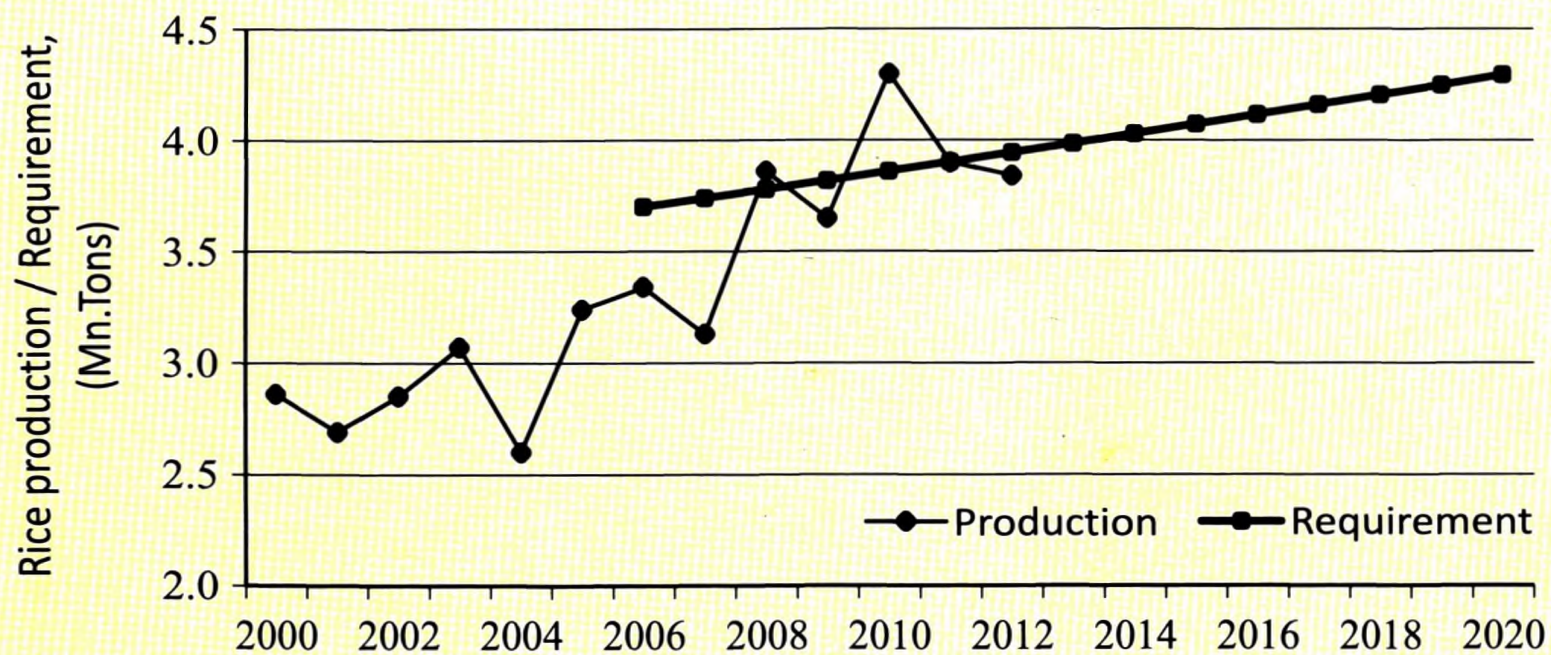


Fig. 1. Annual rice production and requirement of rice in Sri Lanka (Mn. tons).

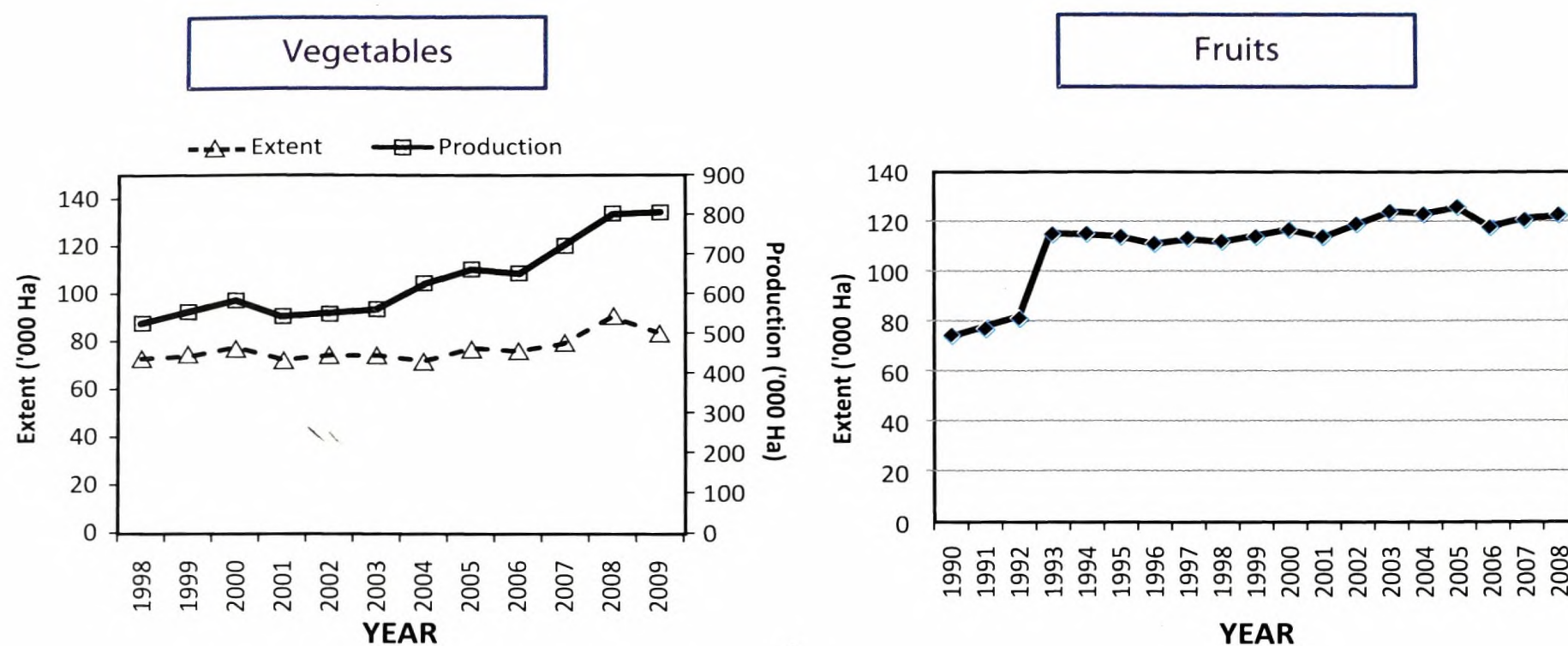


Fig. 2. Extent of vegetables and fruits cultivated in the island and the production from 1990 to 2009

The production of many other field crops (OFC) is well below the requirement (Table 1) thus heavily dependent on the imports to meet the dietary needs. About 60%, 99%, 40%, 95% of the onion, soybean, green gram and dry chilli requirements respectively are not produced in the country while there is an excess production of maize. Further

there is a large fluctuation in annual production of OFC's in the country (Fig. 3). A sizeable quantity of legumes is also being imported to the island to meet the domestic requirement (Table 1). Therefore, to maintain the supply of OFC's to the market and stabilize prices a buffer stock of OFC is very much needed.

Table 1. National self-sufficiency requirement, realizable national productivity, present production and the land extent required for self-sufficiency with targeted productivity in 2015 and 2020.

Crop	Requirement to be self-sufficient, '000 tons			Realizable national productivity, t/ha			Present (2012) production, '000 tons	Land requirement to be self-sufficient, '000 ha	
	2012	2015	2020	2012 (actual)	2015	2020		2015	2020
Paddy	3900	4000	4290	4.3	5.0	6.0	3840	800	715
Kurakkan	7.44	10.25	11.89	1.1	1.5	2.0	5.98	6.83	5.95
Maize	205.1	185.1	194.6	2.7	4.0	5.0	202.3	46.28	38.91
Greengram	19.87	25.56	29.63	1.1	1.3	2.0	11.9	19.66	14.82
Cowpea	15.31	13.16	13.83	1.2	1.3	2.0	14.8	10.12	6.92
Soybean	216.9	240.5	292.5	1.7	1.9	2.5	1.67	126.55	117.02
Blackgram	13.41	13.36	14.04	0.9	1.3	2.0	10.2	10.28	7.02
Gingelly	12.52	16.26	18.85	0.7	0.85	0.9	12.4	19.13	20.94
Groundnut	23.28	22.66	23.82	1.5	1.8	2.0	21.9	12.59	11.91
Red onion	80.97	82.71	86.93	11.7	15.0	18.0	73.9	5.51	4.83
Big onion	229.6	234.5	246.4	14	18.0	20.0	83.5	13.03	12.32
Green chilli	57.29	59.86	62.91	3.4	4.5	7.0	61.5	13.30	8.99
Dry Chilli	39.78	41.57	43.69	0.85	1.2	1.75	-	34.64	24.97
Total*	921.4	945.5	1039.2					317.9	274.6

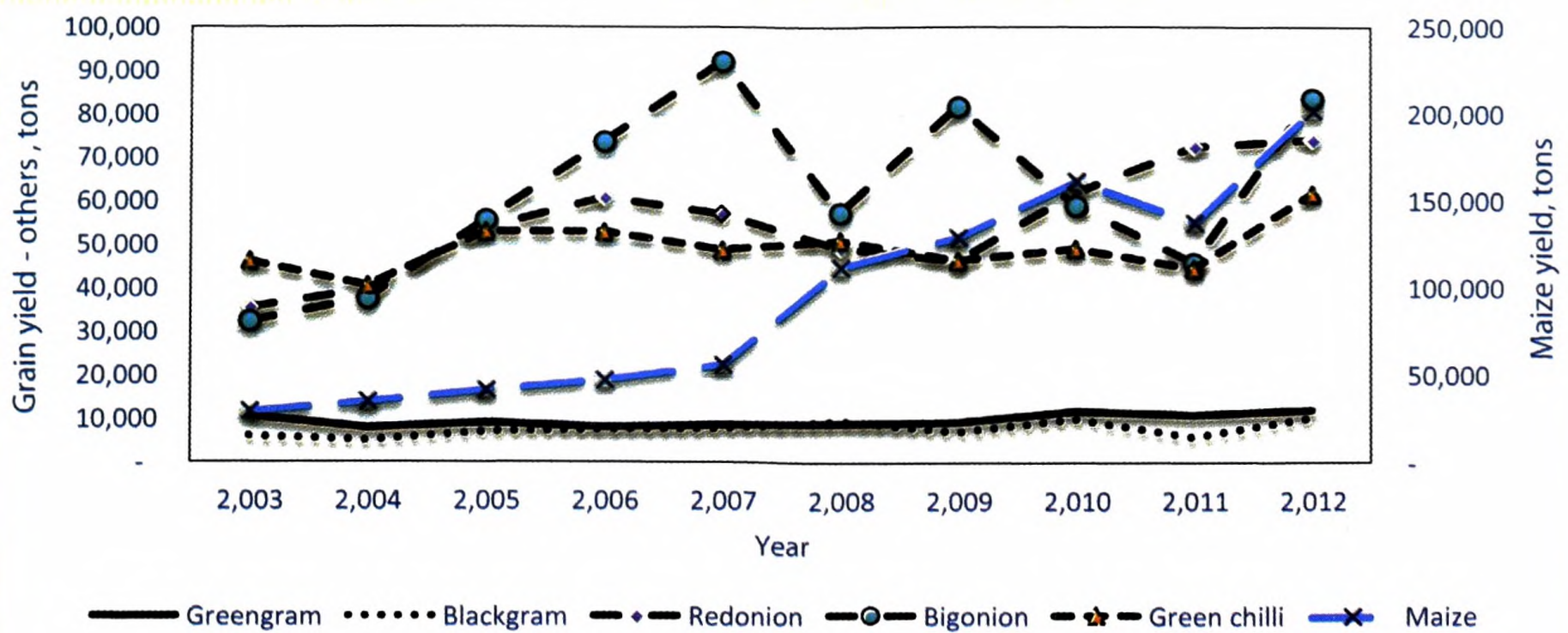


Fig. 3. Annual production of major Other Field Crops in Sri Lanka from 2003 to 2012

With the increasing per capita income it is expected that the social needs and behaviors would change leading to changes in food habits. The consumption of meat which is around 5.7 kg/person would increase to over 8 kg/person per year in 2016. Consumption of rice may remain the same or decrease while consumption of rice based food products would increase. Consumption of vegetables and fruits which is 40 and 30 kg/person/year respectively needs to be increased. Further the increasing demand for meat and meat based products would create and additional demand for animal feed thus, local grain production of all crops should be increased.

It is projected that the current population in Sri Lanka in 2030 will be about 23 Mn. while world population may reach 9 Bn. These changes would create a serious impact on global food needs and decrease the quantity available for trade. Therefore, there is a need to produce our own food to face the growing demand in the island.

To achieve these targeted food requirements, both productivity and area under cultivation of all crops have to be increased. The land area available is very limited as many agricultural as well as non-agricultural activities demands more land. To meet the present total demand of rice and other field crops at present productivity levels, a land area of 0.90 and 0.37 Mn. ha respectively are needed. By 2015 and 2020 the land area required would increase to 0.93 and 0.99 Mn. ha

respectively for paddy and 0.397 and 0.446 million ha for other field crops. The area expansion with other field crops would be an unrealistic target. Therefore, the only option lies with increasing national productivity by further increasing potential productivity and bridging the yield gap of OFC (Table 2) and rice (Table 3).

Around 30% in the dry and intermediate zone minor irrigation and intermediate zone rainfed systems and almost all the rice area in the dry zone rainfed ecosystems were not cultivated during *Yala* due to scarcity of water. Further a considerable extent of land cultivated to rice was not harvested and the difference between the cultivated and harvested extents varies with the availability of water during crop growth. As cultivation of rice demand more water, these lands could be converted to OFCs during the *Yala* season.

At present, increasing productivity of all food crops is challenged with many abiotic and biotic constraints. Compared to the recent past, there is a reduction in the availability of water for agriculture, soil nutrient supplying capacity and availability of nutrients while there is an apparent increase in soil toxicities in many agricultural lands in addition to increased day and night air temperatures and changes in weed, insect and disease composition and pressure. Therefore, even at present, with the available varieties and technologies, these changes would result

Table 2. Average yield, realizable potential and targeted realizable potential in 2015 and 2020 of other field crops under favorable growing conditions in the Dry Zone of Sri Lanka.

Crop	Present national average yield t/ha	Realizable Potential yield, t/ha	Targeted realizable potential, t/ha		% increase	
			2015	2020	2015	2020
Green chili	3.4	15.0	16.5	20	10.0	33.3
Dry chili	0.85	3.0	3.5	4.0	16.7	33.3
Maize	2.5	6.0	7.0	8.0	16.7	33.3
Big onion	14.0	20.0	22.0	25	10.0	25.0
Red onion	11.7	14.0	15.0	18	7.7	23.1
Ground nut	1.5	2.5	2.5	2.8	4.0	12.0
Finger millet	1.1	3.5	4.0	4.5	14.3	28.6
Black gram	0.9	2.0	2.0	2.2	5.0	25.0
Green gram	1.1	2.0	2.2	2.5	10.0	25.0
Cowpea	1.2	1.8	1.9	2.0	5.6	11.1
Soybean	1.7	2.5	2.8	3.0	12.0	20.0
Finger millet	1.1	3.5	4.0	4.5	14.3	28.6

 Table 3. Rice land area, productivity and realizable yield potential productivity in 2012 and targeted realizable yield potential in different rice ecosystems in wet (*Maha*) and dry (*Yala*) seasons in 2015 and 2020.

Ecosystem	Season	Area cultivated '000 ha	Present productivity t/ha	Realizable Potential t/ha	Target yield, t/ha	
					2015	2020
Dry & intermediate zone major irrigation	<i>Maha</i>	319,776	4.94	8	6.50	7.00
	<i>Yala</i>	240,381	4.43	7	6.00	6.50
Dry & intermediate zone, minor irrigation	<i>Maha</i>	142,919	4.03	8	5.50	6.50
	<i>Yala</i>	55,251	3.11	7	5.50	6.00
Dry zone rainfed	<i>Maha</i>	88,891	3.36	6.5	4.00	4.50
	<i>Yala</i>	4,334	-	5.5	4.00	4.50
Intermediate zone rainfed	<i>Maha</i>	51,392	3.83	6	4.50	5.00
	<i>Yala</i>	16,848	2.85	6	4.50	5.00
Wet zone	<i>Maha</i>	99,097	3.70	5	4.00	4.50
	<i>Yala</i>	47,728	3.11	5	4.00	4.50
Total		1,066,617				

significant negative impacts on the productivity of the food crops sector. In addition, food crop sector is faced with dearth of labor, social resistance to use of agro chemicals and other environmental issues.

Rice is grown under a wide range of elevations, soils and hydrological conditions. The rainfall, temperature and soil conditions vary widely in these different rice ecosystems in the island. Thus a wide variability in realizable potential and actual productivity exists in different rice ecosystems (Table 1). There is a significant yield gap between the present average yield and the realizable potential which is the yield of progressive farmers in these different rice eco systems. The yield gap between average farmer yield and realizable yield potential was around 40%, suggesting that the national average yield could be increased considerably by bridging this gap. In addition, to meet the rice demand by 2015, the realizable potential of rice lands should also be increased by 20% to 30% in the dry and intermediate zone and 30% to 40% increase in the wet zone using new rice varieties and technologies. By 2020, these values should increase to about 40% in the dry and intermediate zones and over 50% in the Wet Zone (Table 3).

In the national agricultural system, Chillie, Onion, Maize, Greengram, Soybean, ground nut and Cowpea are given the highest priority while the rest are considered equally important but with medium priority in allocating resources. The yield gap between the realizable potential and the farmer yield vary between these crops (Table 2). Most of these crops are grown both under irrigation and under rainfed conditions. Therefore, there is a wide variability in the farmer yields. To achieve the national targeted production, realizable potential of future varieties of OFC's should be increased by 5% to 34%, through crop improvement programs (Table 2). However with the negative impacts of climate change, the overall probability of achieving above targets in the future with available crop varieties and technologies is significantly lower as the positive effect of increased atmospheric CO₂ on productivity is nullified with increased maximum

and minimum air temperatures, water scarcity, buildup of soil toxicities and changing pest, a disease and weed complexes.

Impact of increased atmospheric CO₂ concentration

The benefits of increased atmospheric CO₂ are greater for C₃ species, such as rice, than for C₄ species such as *Maize* (Lawlor and Mitchell, 1991; Kimbal *et al.*, 2002). If N does not limit growth, increased atmospheric CO₂ increases photosynthesis and growth of terrestrial plants (Lawlor and Mitchell, 1991, Weerakoon *et al.*, 2005). Therefore, increased atmospheric CO₂ concentration will have a positive direct impact on all agricultural crops grown in Sri Lanka. Eventhough, increased atmospheric CO₂ increased leaf photosynthesis, canopy photosynthesis and Radiation Use Efficiency (RUE) of all varieties of rice (Baker, 1990, Weerakoon *et al.*, 1999a) it was dependent on leaf N concentrations (Weerakoon *et al.*, 2000). Therefore, the beneficial effects of increased atmospheric CO₂ will also depend on the soil nutrient supply.

Increased atmospheric CO₂ increased root density due to increased tillering, resulted an increase in N uptake and fertilizer N recovery but the partitioning towards leaves decreased (Weerakoon *et al.*, 2005). Ultimately positive impact of elevated atmospheric CO₂ on rice, which is the grain yield, could be as high as 30% (Figs. 4 and 5).

The benefit of increased atmospheric CO₂, irrespective of the crop species were automatically gained by the crop varieties grown. Breeders have developed rice and other crop species to capture the impact of increased atmospheric CO₂. However, the impact varied between crops and the rice growing eco systems. For example, in the irrigated rice system, the increase in grain yield per unit increase in atmospheric CO₂ over the past 40 years was 0.042 t/ μ mol of CO₂ while in the rainfed system it was 0.019 t/ μ mol of CO₂ (Fig. 6). This suggest that varieties and technologies developed in Sri Lanka since 1960 were able to effectively capture the beneficial effect of increased

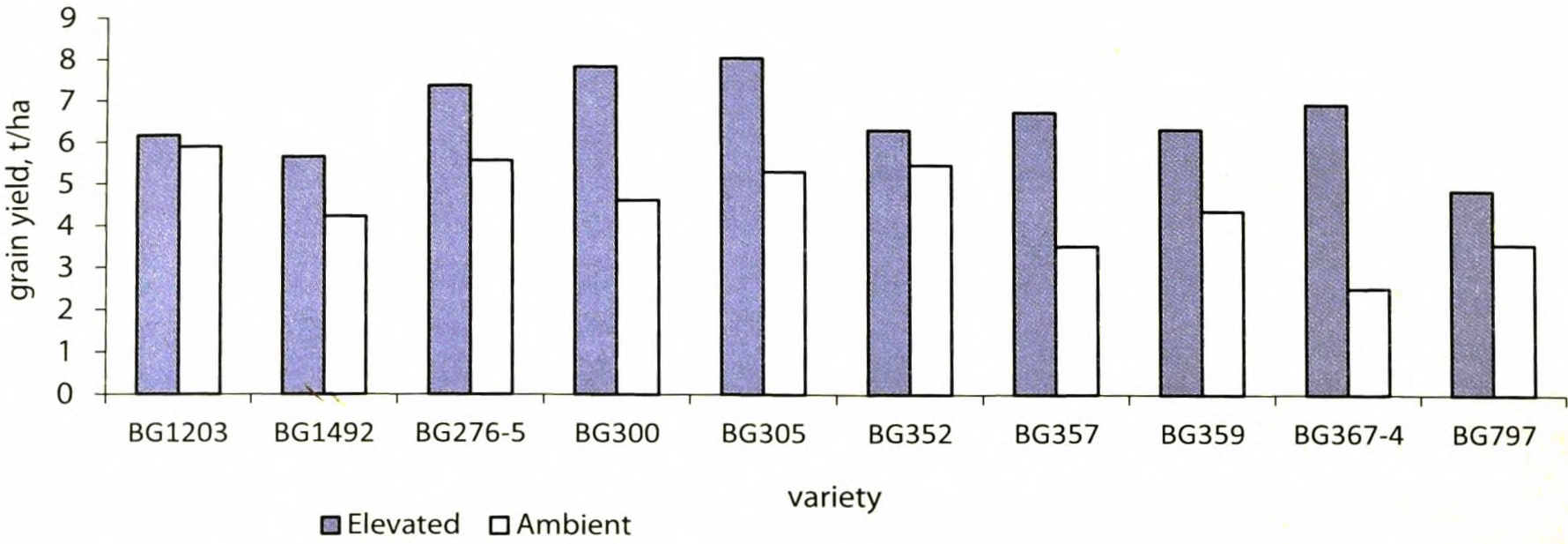


Fig. 4. Change in grain yield of different rice lines with increased atmospheric CO₂ concentration

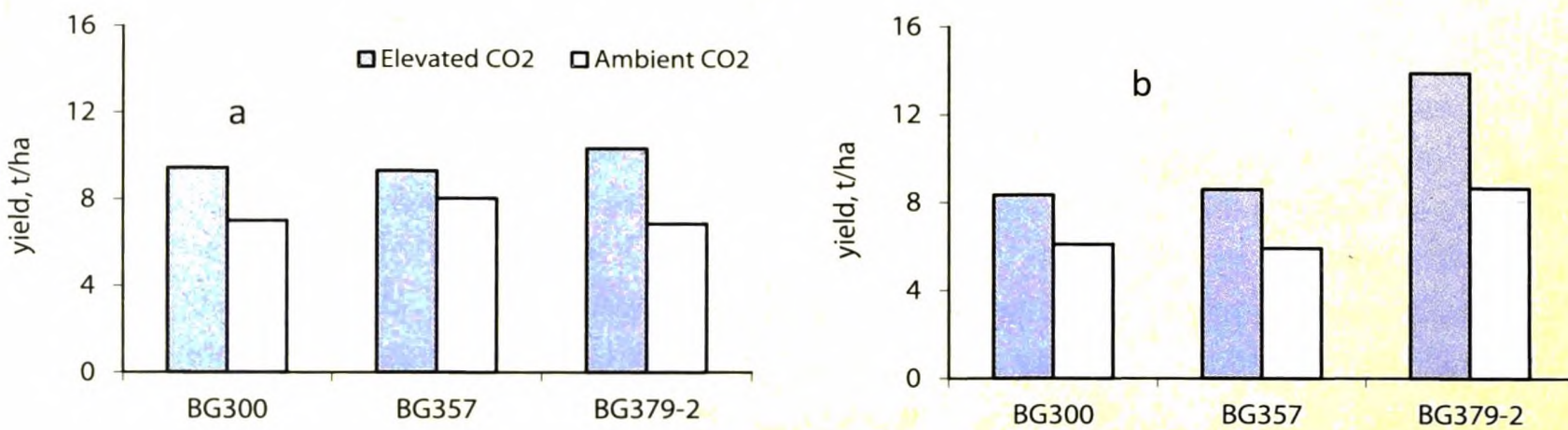


Fig. 5. Grain yield response of rice varieties of different age classes to increased atmospheric CO₂ during 2000/2001 *Maha* (a) and 2001 *Yala* (b) seasons.

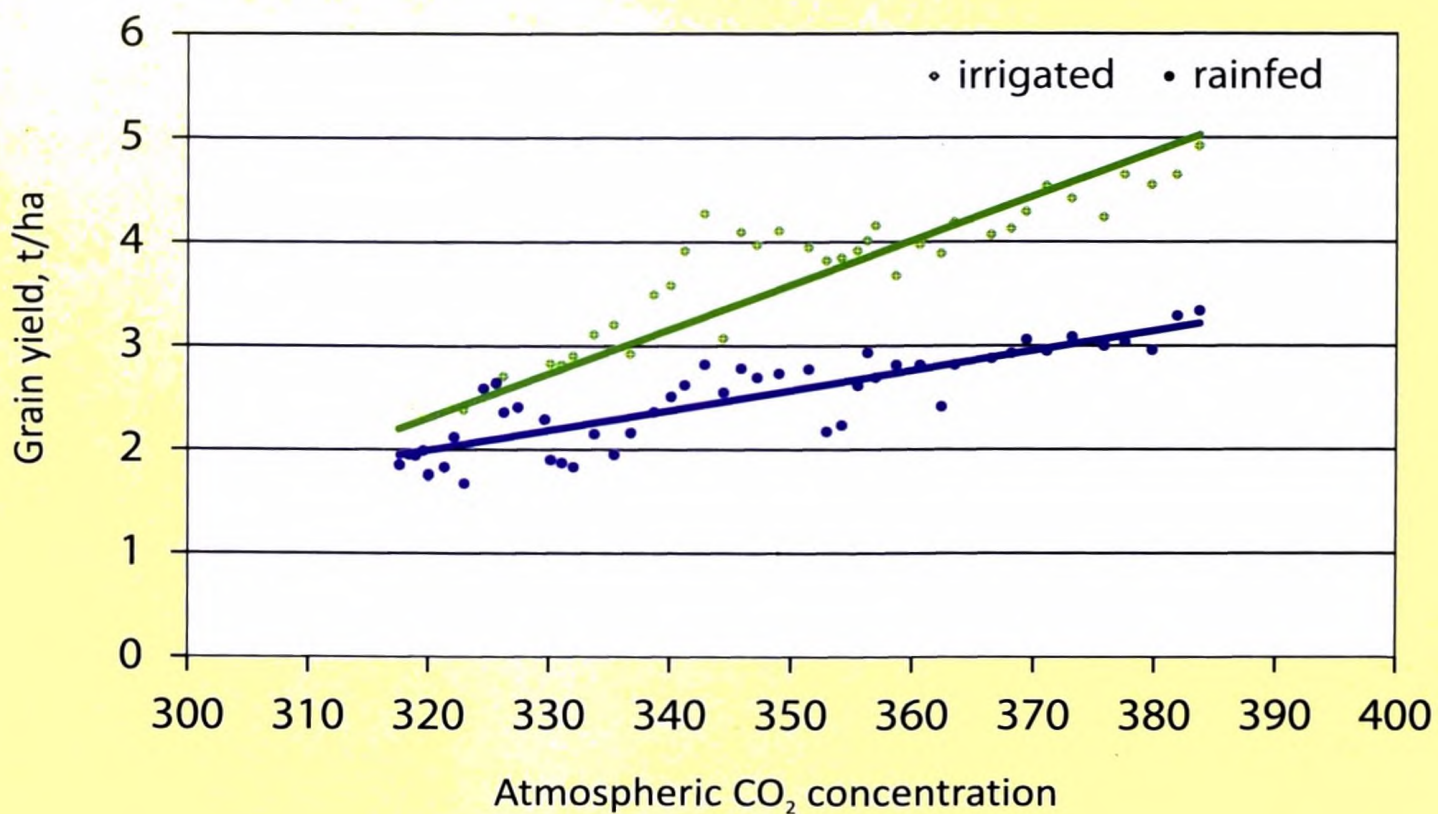


Fig. 6. Increase in average grain yield of both irrigated and rainfed rice ecosystems with the increase in atmospheric CO₂ concentration since 1960. (The change in atmospheric CO₂ concentration since 1960 was obtained from the records of the Maunaolao observatory.)

atmospheric CO₂ efficiently in the irrigated rice ecosystem than the rainfed system.

In the rainfed system, because of its high heterogeneity and greater abiotic constraints, most of the available varieties which were suitable for the non-stressed environments did not perform at expected level. Therefore, with the future changes in climate, the rainfed system will be more vulnerable, thus the productivity from these lands could be severely affected.

Eventhough, these phenomenon were not tested for other food crops cultivated in Sri Lanka, same impact could be expected for all C₃ crops depending on its growing environment and the growth duration. As the climate change impact on rainfed rice is greater mainly due to scarcity of water, these lands could be cropped with more droughts tolerant OFC's.

Impact of increased air temperature

Temperature is the driving variable for growth and development of plants. A change in few degrees in temperature often leads to a change in rate of development. In most instances, crops grown in Sri Lanka, especially at reproductive stage, air temperatures are not at its optimum level. Optimum temperature for vegetative as well as fertilization of rice is around 30°C (Yoshida, 1980). Onion as a cool season crop requires temperatures between 13- 25°C. Chilli grows best at day temperatures between 20-30°C and when night temperature increased above 24°C, fruit setting decreases (Berke *et al.*, 2005). In contrast maize as a C₄ crop could tolerate high temperature stress than other C₃ species grown in Sri Lanka. However the reported optimum temperatures were; maize 28°C, soybean 30°C and cotton 31°C.

In all major crop growing ecosystems in Sri Lanka, both maximum and minimum air temperature has increased over years (Premalal, 2009). In certain ecosystems, during the season, air temperature has reached to maximum threshold levels of many crops. These increases in temperature had already showed profound negative impacts on the productivity of these crops.

It is a common belief that rice varieties at present

have shorter crop duration than those were at the time of release. It could be due to genetic drift over the years but major reason could be the increase in both maximum and minimum air temperatures. To correct this shortening of the age of crops, a special breeding effort is not necessary as the continuous identification of new rice varieties would eventually select for a specific duration in a particular environment. However, it could be very important to identify optimum age under different temperature scenarios. Minimum air temperature which is the night time air temperature has a significant negative impact on grain yield of rice (Peng *et al.*, 2004). This suggest that the rice productivity would decrease with the possible increase in night temperatures, thus need adjusting cropping calendar to avoid periods of high minimum air temperatures. It is therefore very important to study the seasonal variation of minimum air temperatures in dry and intermediate and wet zones and adjust cropping calendar on cropping system basis rather than for just one crop. A recent study done on the impact of climate change on productivity of rice varieties available in major rice growing district of Kurunegala suggests that there will be a reduction in grain yield by over 20% due to changes in climate as predicted by GCM's using RCP 8.5 scenario in the mid-century.

With increased RH, increasing air temperature from 30/24°C to 36/30°C, average spikelet fertility decreased from about 95% to 25% and magnitude of impact differed significantly among varieties. (Weerakoon *et al.*, 2008). Spikelet fertility was also curvilinearly related to spikelet temperature with an average critical spikelet temperature of about 31°C and varieties differ in their response (Fig. 7).

Even at present, rice spikelets in certain locations in Sri Lanka are facing air temperatures above minimum threshold, which could produce sterile pollen grains. It was reported that pollen fertility of Bg 357 and Bg 358 decreased with increased air temperature above 34°C (Weerakoon *et al.*, 2005). Thus, there is a great chance of increasing sterile or empty grains with the change in climate. Therefore, with future increase in air temperature,

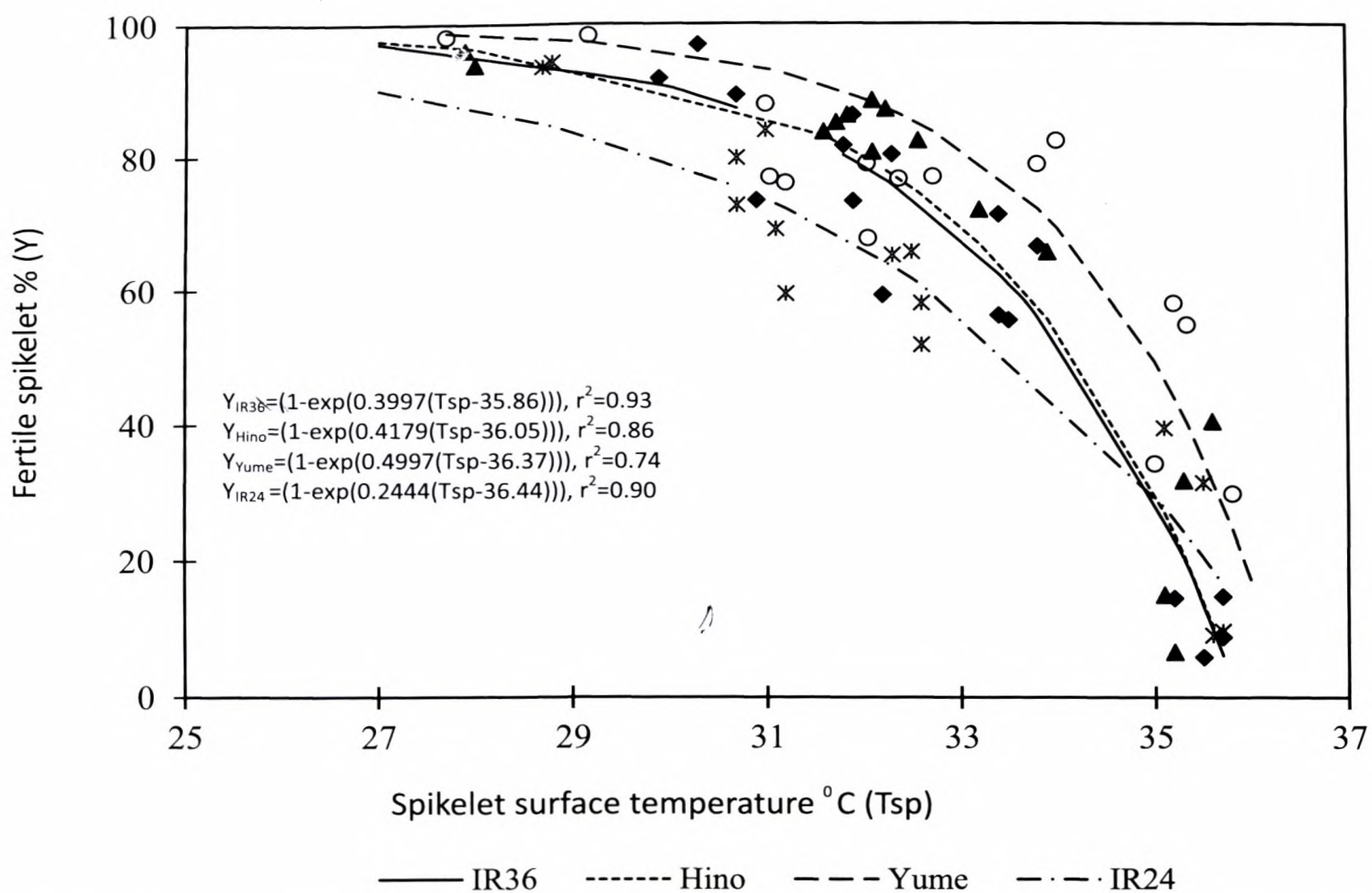


Fig. 7. Change in spikelet fertility of two *Indica* and two *Japonica* rice varieties with the change in spikelet surface temperature.

(Lines indicate the nonlinear relationship between spikelet surface temperature (T_{sp}) and spikelet fertility (Y) for different varieties. Spikelet surface temperature was measured just before the opening of spikelet using an infrared thermometer. (Weerakoon *et al.*, 2008).

the sterility of rice spikelets would increase leading to reduction in grain yield in Sri Lanka.

With the increase in air temperature, low temperature regions which are not suitable for rice cultivation would become favorable for rice cultivation. Therefore, in an extreme situation of climate change, crops may shift from its traditional ecosystems to higher elevations where they cannot be grown at present due to low temperature stress. Eventhough not investigated, in general all crops grown in the dry and intermediate zone would be affected with high temperature stress. Since no systematic program to screen crop varieties for high temperature stress, we are compelled to grow the existing available varieties.

In the vegetable sector, majority of varieties grown as commercial crops are hybrids or inbreds imported, mostly from temperate region. It was reported that these lines would be suitable for up

and mid country cooler regions but farmers grow them in the dry zone. When temperature increases in the dry zone, excessive evaporative demand would trigger mid-day wilting. The situation would deteriorate further towards fruit setting leading to reduction in yield.

High temperature induced sterility may affect self-pollinated crops by way of pollen sterility. However, the style remains receptive under such situation allowing cross pollination between plants. Abeywickrama *et al.*, (2009) also has reported out crossing of rice varieties grown in Sri Lanka. Similarly, under farmer's field conditions when spontaneous pollen sterility occurs due to increased air temperature and humidity above threshold level, pollen from adjacent rice plants or from the same panicle could deposit on stigma making the spikelet fertile. However if these seeds are used for cultivation, they start segregating under farmer field conditions at generations beyond F_2 .

These observations suggest that impact of climate change on pollen sterility in rice could be a common occurrence in high temperature and humid eco systems. However, the temperature increase is not enough to affect the stigma thus cross pollination occurs making the impact of climate change not visible. Thus at present, there cannot be any decrease in productivity and thereby the national production. However, the segregating population would cause a significant impact on the quality of rice produced for both consumption and as seed paddy for next cultivation season. Therefore, the impact of climate change is expected to cause a serious impact on the quality of paddy produced in the sub humid tropics while in the long term, it will affect productivity.

Further with the increase in air temperature we could expect an increase in insect and pathogen pressure which ultimately end up in reducing productivity of all agricultural crops. Further, a shift in weed flora towards temperature tolerant C_4 weeds would create an additional burden on weed management in all crops. These impacts will have a more negative effect on the food security of the island if adaptation measures are not implemented.

Availability of water for agriculture

Crops grown in the dry zone depend on the availability of irrigation water and the rainfall received during the season. Over the years, even though irrigated farming was the predominant method of farming with higher productivity, rainfed farming in the dry and intermediate zone was mostly confined to the wet (*Maha*) season. During dry (*Yala*) season, it was predominantly irrigated agriculture.

The reliability of the North East monsoon has decreased with an increase in consecutive dry days in the dry zone (Premalal, 2009). Even though the reduction in annual total rainfall over the island is negligible, increased dry days and less reliability on the monsoon would increase demand for irrigation water, especially in the dry and intermediate zones. With the change in climate, the demand for water from sectors other than

agriculture also would increase, resulting a reduction in the availability of water for agricultural purposes.

There were significant changes in rainfall pattern in the catchments of major rivers in Sri Lanka (Premalal, 2009). Further, changes in catchment characteristics have also changed the water retention by the soil which had affected the water flow of rivers. In addition, there was a significant increase in extraction of water from rivers for domestic and industrial needs. As a consequence, water availability in rivers has changed. For example there was a significant decrease in the water flow in the *Mahaweli* River over the last decade. In 1985, the average annual river flow of the *Mahaweli* River at *Polgolla* was about 2500 mcm, but decreased to 1400 mcm in 2008. Even though there is a reduction in the total river flow, there was no change in the amount of water diverted towards the dry zone and the drop in water flow over time in the *Mahaweli* River was compensated by reducing the water discharge towards *Victoria* depriving water for hydro power generation and downstream agriculture. Further, increased domestic and industrial demand for water in the dry zone due to increased population and urbanization has effectively reduced the water available for agriculture.

Further, there is also an increase in the discharge of polluted water towards rivers which ultimately end up in the dry zone resulting a buildup of salinity. Therefore, the adverse impact of climate change on agriculture will be further aggravated with the reduction in quality and quantity of irrigation water. Hence, there is an urgent need to reduce irrigation water pollution while increasing irrigation water use efficiency. Therefore, varieties of all crops which can withstand moisture stress and salinity and water saving cultivation technologies must be identified and disseminated.

Field crops require different quantities of water to complete its life cycle due to differences in crop duration and their inherent moisture stress tolerant capabilities (Table 4). Therefore, as far as possible, crops for different agro ecologies should be selected based on the crop water requirement and the availability of rain water to avoid excess

Table 4. Crop duration, crop water requirement and irrigation water requirement for OFCs with different irrigation methods during a dry (*Yala*) season

Crop	Duration (days)	Crop water requirement (mm)*		Irrigation water requirement for <i>Yala</i> (mm) **		
		<i>Yala</i>	<i>Maha</i>	Surface	Drip/Trickle	Sprinkler
Chilli	150	920	590	3067	1150	1840
Onion	95	700	-	2333	875	1400
Maize	115	825	460	2750	1031	1650
Cowpea	90	770	370	2567	963	1540
Soya bean	105	710	390	2367	888	1420
Mungbean	75	460	245	1533	575	920
Black gram	90	560	300	1867	700	1120
Groundnut	110	735	395	2450	919	1470

Based on data at FCRDI, Mahailuppallama

** Irrigation efficiency: Surface - 30 %, Drip - 80 %, Sprinkler - 50 %

use of irrigation water. Further water saving irrigation technologies should be adopted to decrease irrigation water use (Table 4).

Water requirement for the production of food crops are much lower than that required for the production of animal meat. For example, to produce one kilogram of beef, pork and chicken requires 3790, 1540 and 960 liters of water respectively while in rice pulses such as ground nut, soybean and pigeon pea requires 650, 440 and 88 liters of water respectively. Therefore, in the future, protein requirement of humans may have to be supplemented mainly with pulses as competition for water may increase. Therefore, the overall food habits may have to be changed to ensure carbohydrate, protein and other food needs of the human diet.

Impact of sea level rise

It is expected that towards the end of this century, the projected mean sea level rise under RCP 8.5 climate scenarios would vary between 0.45 to 0.82 cm (IPCC, 2013). The rice land extent under inland flood plain and coastal saline flood plain ecosystems in Sri Lanka are approximately 16,000

ha and 6000 ha respectively. There could be a direct impact of sea level rise through submergence and sea water intrusion may increase paddy soil salinity levels in the coastal rice lands. There could be a serious indirect impact with difficulties in draining water in the inland flood plain depriving cultivation in adjoining areas too leading to a reduction in production of food crops.

Mitigation options to ensure food security

Climate change is a slow process and its impact is gradual. The positive impact of climate change, which is the increase in atmospheric CO₂ will be automatically captured through the continuous long term crop improvement programs. However, the impact of temperature, water stress, salinity and other depleting resources cannot be captured through natural selection. Thus a well-focused program is needed to develop high yielding, pest and disease tolerant / resistant, short duration varieties which are water and fertilizer efficient, high temperature tolerant and salinity tolerant

Further, suitable agronomic and cultural management for climate smart agricultural practices are also needed.

1. Identify crop suitability for different agro-ecological zones based on optimum use of available natural resources and food needs,
2. Identify varieties for different growth durations having tolerance to high temperature stresses, poor soil quality and water stress,
3. Identify different farming systems and management options to overcome / avoid biotic and abiotic stress while increasing overall productivity,
4. Increase water and nutrients use efficiencies by developing proper varieties and management options,
5. Develop technologies to prevent buildup of salinity in both upland and lowland ecosystems while improving irrigation infrastructure to reduce wastages and increase use efficiencies.

CONCLUSIONS

Even at present the world is facing difficulty in meeting food needs of its people while the challenges for the future with climate change looms large. The first decade of the 21st century saw several indications of a troubled future for global food security. The food price spike of 2008, with its consequent food riots and resulting political changes in several countries, re-established the need to address the threat to human well-being and social harmony. In the past, with the green revolution in the mid-1960s, a dramatic increase in food production and land productivity led to complacency about the remaining challenges ahead. The assured supply of food which ensured food security resulted in reduced attention and reduced public sector investments in agricultural productivity. However, population numbers continued to increase with increased food demand while climate change is reducing productivity of crop lands depriving much needed food to feed nations.

Increased incomes in poor countries will lead to increased food demand, which in turn place additional pressures on sustainable food

production. Climate change adds further pressure. Because food production is critically dependent on local temperature and precipitation conditions, any change requires farmers to adapt their practices accordingly. Therefore, farmers everywhere will need renewed technologies to adapt to climate change. If not, the agricultural system as a whole will decrease productivity and will have difficulty supplying adequate quantities of food to maintain constant real prices. Therefore, uninterrupted policies and investments towards developing adaptation technologies / varieties to face these future climate change challenges are needed for ensuring food security and sustainable agricultural development.

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