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AGRICULTURAL INNOVATIONS AND FOOD SECURITY IN SRI LANKA

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ABSTRACT

Food insecurity in terms of food availability, accessibility and affordability is a core issue in many developing countries. Sri Lanka is also faced this challenge and had been followed various strategies to tackle the problem since independence in 1948. Technological advancement in food crop agriculture sector is one of the main strategy adopted in this regard and consequently it was able to increase the availability of staple food by gaining self-sufficiency in paddy/rice production. At the same time, it was able to minimize poverty and other obstructions in relation to economic development of the country. However as a developing country, still Sri Lanka faces a greater challenge in assuring its food security under rapid globalization in production and marketing system and alarming threats of climatic changes. So the main purpose of this paper is to review the present status of food security in Sri Lanka with special reference in how technological advancement programs implemented in Sri Lanka were able to minimize food insecurity. The analysis of the paper was based on the inductive method and secondary source of information. Thus the analysis was focused on three issues i.e. reviewing present status of food security, innovative technological programs adopted in Sri Lanka and implications of technological innovations on enhancing food security in Sri Lanka. The research phenomena that highlight the interrelationship between food security and technology advancement in Sri Lanka indicated that food security in Sri Lanka has improved gradually in the past mainly due to technological advancement programs applied for domestic food production. However, improved food production is not sufficient enough to avoid food insecurity in relation to food accessibility and affordability. The paper also highlights some implications that need to be addressed by policy makers in view of domestic and global food production, climatic changes and other negative externalities of technological advancement. Finally it suggests suitable policy recommendations to be considered by policy makers in improving domestic food security in Sri Lanka.

KEYWORDS

food security, technological advancement, food availability, productivity.

1. INTRODUCTION

The idea of food security simply means that availability of foods and individuals' ability access to it (Google, 2015). More broadly it was defined as "food security exists when all 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 (Raj Patel, 2013). Food insecurity is divers from shortages of food to famine. The World Food and Agricultural Organization (FAO) recognized that famine and hunger are main features of the food insecurity (FAO, 2006). According to the FAO estimates, nearly 2 billion people in the world are suffered from lacked food or inability to access nutritious food. Stunting and chronic nutritional deficiencies were recognized as the common symptoms of food insecurity. So assuring food security becomes the sole responsibility of the governments and takes every actions to avoid food insecurity from natural or manmade hazards. Like many developing countries Sri Lanka is also faced this challenge to feed the nation with minimum risk under global climatic changes and high fluctuation of world food prices.

As a small island the government of Sri Lanka has implemented numerous programs in order to ensure domestic food availability and food security over the past six decades. Though these programs were included in increased food production, food distribution and food stability in the country, still food insecurity remain as a core issue in Sri Lanka because food availability is linked with various uncertain factors in relation to physical, climatic and institutional aspects (Somaratne, 2011,196). However, owing to welfare oriented development strategies followed by the successive governments in Sri Lanka, it was able to increase the domestic food security substantially compared to many other developing countries. Nonetheless, still nearly 8 percent of population is living under poverty line (Department of Census of Statistics, 2014). Food insecurity is high in rural and estate sectors and subsequently hunger and malnutrition has increased in these sectors (Silva, R. P. 2006, 79)). At the same time, cultivation pattern has disrupted by climatic changes occurred in the country. Changes in monsoon rainfall pattern has made a greater influence in changing domestic rice production in Sri Lanka during 2012/13 and 2013/14 Maha seasons (Central Bank of Sri Lanka, 2013). Similarly global agricultural production changes were also substantially affected for assuring domestic food security (Somaratne, 2012, 188).

Hence the main objective of the paper is to review the present status of food security in Sri Lanka with special reference in adopting technological advancement programs for increasing production and productivity and thereby the food security in Sri Lanka. Thus the analysis was focused on three issues. First, it reviews present status of food security in view of food availability, food access and food use. Secondly, it examines the innovative technological programs adopted in Sri Lanka with a view to increase domestic food production and thirdly, it assess the impact and implications of technological innovations on enhancing food security in Sri Lanka.

The methodology of the paper was based on inductive research method and used secondary sources of information published by the Department of Agriculture, Department of Census and Statistics and Central Bank of Sri Lanka.

The paper is consisted of five sections. The section one explains the background and the importance of the topic. The section two explains the methodology followed for data collection and analysis. The section three presents the results of data analysis in accordance with objectives mentioned above. The discussion was followed in the section four. It highlights effects and implications of the issue reflecting the need for special food policy framework for improving domestic food security. Finally, the section five concludes the paper along with policy recommendations

2. BACKGROUND

As defined above food security is physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life. It also considers the total food requirement fulfilled by imports. Bulk of literature in relation to conceptual base, measurements and case studies of food security in different countries are available (Wikipedia, navigation, search). Basically there are four pillars of food security has identified. It includes food availability, food access, food use, and food stability" (FAO,2009). World Health Organization (WHO) has recognized the first three pillars (WHO, 2014) and it was elaborated by the FAO by adding a fourth pillar as food stability at the World Summit on Food Security in 2009.

Food availability means supply of food through production, distribution, and exchange (Gregory et al, 2005). Thus food production is determined by various factors such as land distribution and use; soil management; crop selection, breeding, and management; livestock and management. Food production is changed often by physical and climatic factors. At the same time the opportunity cost of growing food or agricultural land utilization is high when it compared with other alternatives such as urbanization or nonagricultural purposes. Environmental impact of agricultural land utilization such as desertification, salinization, soil erosion and sedimentation has affected badly for sustainable food security in the long run. Food distribution is also an important activity that relates to food storage, processing, transport, packaging, and marketing of food (FAO, 1997). Similarly market infrastructure and storage technologies and facilities may influenced the amount of food wasted in the distribution process. Food exchange is also an important concept and it relates with domestic and international trading.

The FAO has suggested a "twin track" approach to minimize food insecurity in developing countries. As an inclusive growth approach it combines with sustainable development and short-term hunger relief while included investing in rural markets and rural infrastructure (FAO, 2006). It has also emphasized the use of public policies and programs that promote long-term economic growth and alleviating poverty with conditional and unconditional programs. The World Food Program (WFP) that implement under United Nations (UN) is supported developing countries to promote food security and to eradicate hunger and poverty. It provides food aid to refugees and to other groups that required food emergencies (UN, 2013). Similarly, United States Agency for International Development (USAID) has intermediated to increase agricultural productivity in developing countries particularly in view of increasing rural income and reducing food insecurity (USAID, 2015). The USAID program was based on three aspects i. e; boosting science and technology for improving agricultural productivity, securing property rights and access to finance and enhancing human capita through education and improved health.

A healthy sustainable food system focused on environmental health, economic viability and social equity and human health is presently advocating by countries with a view to ensure more balanced system with the environment in food production, food distribution and food consumption (FAO, 2003).

Sri Lanka is a small island with an area of 65,628 sq. km. and a population of 20,338 million as estimated in 2013. The nominal value of GNP per capita income (2013) was US\$ 2866 (Rs.365600) and the value of Purchasing Power Parity was Rs. 570000. The contribution of agriculture sector is still important and accounts for 10 percent of gross domestic product (GDP), 24 percent of total exports and 31 percent of total employed labor force. Nearly 70 percent of people lives in rural areas and engaged in agriculture and related activities. The agricultural sector characterize with two main sectors such as plantation and non-plantation sectors. The plantation sector consists of tea, rubber and coconut plantations mainly for the export market and non-plantation agriculture consists of cultivation of paddy, grains, vegetables, tubers and fruits that based mainly on the domestic market. This analysis was focused on the non-plantation or domestic food crop sector concerning the food supply of the nation.

The successive governments of Sri Lanka that came to power since independence (1948) have implemented two policy options in increasing domestic food production (Henegedara, 2004).

1. Horizontal expansion; Increase the extent cultivated through expanding uncultivated lands in dry zone areas. Thus Total paddy land extent has increased from 390,310 Hectares in 1951/52 to 1067,000 Hectares in 2011/12.
2. Vertical Expansion; improving production efficiency and factor productivity. Through improving technology and cultivation practices. Thus, average paddy production per acre has increased from 2929 kg in 1980 to 4528 kg in 2010.

Though both strategies were greatly influenced in increasing domestic food production, main focus of this paper is laid on assessing the effects of using technological innovations on increasing domestic food security. Along with the huge irrigation infrastructure development and land settlements programs, the initial technological advancement programs have introduced since late 1960s. As in many countries initial technological advancement programs that based on biological and chemical improvements were known as "green revolution" and recognized as the miracle of doubling food production. Thus technological innovations were considered as the focal point of increasing food security than the other policy options such as price policy, trade policy and institution policy. According to available literature, it was revealed that food availability has increased mainly due to increased factor productivity associated with technological advancement programs. (Zoyza, and Silva, 2007, Sandaratne, 2011).

Assurance of domestic food security is still a big challenge to Sri Lankan government because it related to economic stability and the macro economic imbalances of the country. Food prices are changed very often as variation of supply factors and global price changes (Somaratne, 2011). Thus many governments are concerned about food insecurity and vulnerability, Vulnerability to a food insecurity relates to wide range of factors which make people at risk of becoming food insecurity (Silva, R. P. De, 2006, 3). Therefore, increase food availability, purchasing power and the food access were considered as the key factors of the government policy (Mahinda Chintana, 2005). The need for innovative technological advancement program was emphasized by researchers. According to Somaratne (2011), "food security in Sri Lanka will be directly threatened by the food crisis. However situation could be avoided through supply side stimulants, food self-sufficiency drives, investment in R&D, technological developments and innovative approaches to enhance productivity" Ekanayake, A (2011) has also emphasized that it is time for Sri Lanka to seriously consider changes in the way food is cultivated. Thus there are reasonable facts to identify the relationship between technological advancements and food security in Sri Lanka. So this paper will examine how food security in Sri Lanka has achieved through innovative technology advancement.

3. METHODOLOGY

The methodology of the paper was based on the deductive method. Required data was based on the secondary data published by the Department of Census and Statistics, Central Bank of Sri Lanka, Department of Agriculture and the Hector Kobbekaduwa Agrarian Research and Training Institute. Indicators of measuring food security were aimed to capture its main components such as food availability, food access, food affordability, production process and technology adopted. Thus indicators such as food production, food consumption, rice self Sufficiency ratio, poverty line, Head Count Ratio, food imports, income decile, Nominal and Real mean food values, Per Capita rice Consumption, Labour Absorption ratio, Food expenses, were used to measure food security while mechanization cost, new varieties and labor use and factor productivity were used as the indicators of technology advancement. Tables and graphs were used in this regard.

4. ANALYSIS AND RESULTS

Data analyses was concentrated mainly on two aspects. The first part of the analysis is focused on food availability, per capita income, per capita consumption and food access. Adoption of new technology and its impacts on increasing domestic food crop production in Sri Lanka is analyzed in the second part.

4.1 FOOD AVAILABILITY

Household food availability in Sri Lanka is assessed considering key indicators such as availability of main food items, domestic food production, and self-sufficiency of rice production and imports of essential food items.

4.1.1 AVAILABILITY OF MAIN FOOD ITEMS

Domestic food availability was measured by valuing local food production and imports of main food items required consumption for the nation. According to estimates of the Department of Census and Statistics (2012), though domestic rice production has fulfilled more than 90 percent of domestic food requirements, it was able to fulfill only 84% of domestic availability of total cereal requirements. The balance cereal requirement is fulfilled from imports of wheat and wheat flour. However, the domestic availability of other food items such as roots and tuber, vegetables, fruits, meat, fish, eggs and milk is somewhat adequate (Ekanayaka, 2011, 347). According to estimates of the Department of Census and Statistics of Sri Lanka (2008), the country is able to produce 79% of root and tuber, 30% of pulses and nuts, 82% of vegetables, 83% of fruits, 98% of meat, 100% eggs, 90 % of fish, 81% milk , 98% of oil and fats and 7% of sugar. The annual report of the Central Bank of Sri Lanka (2012) indicates that nearly 10 percent of total imports were allocated for food and beverages that include the items such as rice, flour, sugar, milk and milk products and fish. Though the imports of rice has declined significantly, imports of wheat flour, sugar, milk and milk products has increased annually as increased the demand. Thus the domestic food supply is maintained through local production and imports, which determined on the principle of Comparative Advantage.

TABLE 1: VARIATION OF LOCAL PRODUCTION AND IMPORTS OF ESSENTIAL FOOD ITEMS AS A PERCENTAGE OF NATIONAL FOOD REQUIREMENTS

	Local Production (Mt)		Imports (Mt)		Imports as a % of national requirement	
	1996	2006	1996	2006	1996	2006
Rice (000Mt)	1402	2272	336	11	19.4	0.5
Green Gram	16,885	7975	22	11995	0.1	59
Maize	32,824	47523	92457	84043	74	64
Kurakkan (millet)	3906	6296	499	1933	11	24
Soya bean	726	5177	285	212	28	4
Black Gram	7365	6923	4033	1589	35	19
Potato	100,755	78484	25784	46556	20	37
B. Onion	19367	73612	89158	119478	82	62
Wheat	-	-	-	-	100	100
Sugar	-	-	-	-	-	06
Milk products	-	-	-	-	-	28

Source: Hector Kobbekaduwa Agrarian Research & Training Institute, Commodity Review (2008)

Table 1 presents local production and imports of some key food commodities for 1996-2006 period. Accordingly domestic production of rice, green gram, maize, millets, soya bean, potato and big onion have increased and the imports of green gram, potato and millet have increased. Consequently, imported quantity of rice, maize, soya bean and big onion has decreased. It is noteworthy to see that imports of rice have declined from 19% to 1% during the respective period. However, domestic rice production has been increased after 1970s due to extensive and intensive programs implemented by the government and subsequently rice import ratio had dropped within the range of 1-8 percent during the respective period.

4.1.2. PER CAPITA CONSUMPTION AND DOMESTIC RICE PRODUCTION

Per capita rice consumption is an important indicator to Sri Lanka because it shows the availability and the accessibility to staple food by nation. Table 2 shows that total rice requirements, local rice production, per capita rice consumption and the domestic rice self-sufficiency ratio have increased continually during 1973-2012. It implied that population and the food demand have increased during the respective period and food supply has also increased subsequently.

TABLE 2: PER CAPITA RICE CONSUMPTION AND RICE SELF SUFFICIENCY RATIO* IN SRI LANKA 1973-2012

Year	Total Rice Requirements (000 Mt)	Local Rice Production (000 Mt)	Per capita rice Consumption (Kg/Year)	Self-sufficiency Ratio*
1973	1187,160	867,394	86.80	0.73
1978	1293,055	1233,017	86.80	0.95
1983	1619,413	1585,855	101.30	0.98
1988	1583,298	1583,298	103.66	0.89
1993	1642,105	1642,105	103.66	0.88
1998	1720,726	1720,726	106.14	0.84
2003	2113,666	1692,983	106.20	0.93
2008	2182,223	2476,900	107.94	0.92
2010	2229285	2749,199	107.94	1.19
2012	2234611	2176003	108	0.95

Source: Department of Census & Statistics (2012)

*Rice Self Sufficiency Ratio = $\frac{\text{Total Rice Production}}{\text{Total rice requirements}}$

The Rice self-sufficiency ratio is a vital indicator influenced in determined the availability of local rice production. Table 2 shows how local rice production and rice availability has increased during 1973-2012 period. Table 2 also highlights that per capita rice consumption and Rice Self Sufficiency ratio also increased gradually during the period. Thus per capita rice consumption has increased from 86.0 kg in 1973 to 107 kg in 2012 and thereby Rice Self Sufficiency Ratio has increased from 0.73 in 1973 to 0.95 in 2012. It also reflects a high variation in production and consumption indicators after 1980s.

Though the average per capita rice consumptions ratio remains around 107 Kg since 2007, it has changed extensively according to rural, urban and estate sectors as well as the income deciles (Table 3). Thus, the lowest per capita consumption has reported from high income decile groups in urban sector, especially above Rs. 22,037 as minimum income. The Table 3 also illustrates that food availability among lowest income deciles in all sectors are below the average food consumption value. Thus it shows that food insecurity is high among poor categories. At the same time, it shows that the average rice consumption level of middle income decile groups is high.

TABLE 3: VARIATION OF PER CAPITA RICE CONSUMPTION ACCORDING TO INCOME DECILES AND URBAN, RURAL AND ESTATE SECTORS

Income Decile	Minimum Income(Rs)	Maximum Income(Rs)	Urban Sector (Kg)	Rural Sector(Kg)	Estate Sector(Kg)	All sectors (Kg)
1	0	4520	74.65	105.98	106.37	104.28
2	4527	6214	84.61	109.71	105.43	107.95
3	6220	7728	82.62	112.71	105.99	110.55
4	7733	9430	88.45	111.71	112.58	110.29
5	9435	11350	76.23	111.00	116.80	107.09
6	11357	13755	80.07	113.44	114.06	109.79
7	13757	17271	84.21	112.01	107.88	108.24
8	17275	22036	77.00	107.39	103.12	102.48
9	22037	32778	82.86	109.80	126.89	104.70
10	32793	825694	74.00	107.72	136.86	97.77
Average	12513	95078	79.17	110.28	109.72	107.94

Source: Consumer Finance Survey (2003/2004), Central bank of Sri Lanka

The characteristics of household food security is not simply mean that food availability and production, it also includes factors such as deforestation, seasonal variations in food supply, availability of fodder and forest foods, shifts from subsistence to the cash economy, and cash out flow requirements. In rural Sri Lanka, forests and farm trees play an important role in household food security. It provides critical support to agricultural production by providing food and fuel, cash income and insurance against drought and crop failure. Thus forestry related activities have made a great impact on rural household's food security directly and indirectly

4.1.3. FOOD ACCESS AND USE

Food access which indicates the food use and affordability is viewed as the important aspect of food security analysis. It is measured by three indicators i.e. household income, food expenditure and poverty level.

HOUSEHOLD INCOME

According to Table 4 nominal and real mean monthly per capita income of the country has increased during 2002-2009/10 period. Thus nominal mean per capita income has increased from Rs. 12803 to Rs. 36451 and the real mean values have changed from Rs. 12803 to Rs. 17129. Similarly mean household expenditure is

also increased during the period from Rs. 12083 to Rs. 313331. According to monthly income and expenditure gaps, it shows that households were able to save around 20 percent of their monthly income. However, savings were diverted according to estate, rural and urban sectors indicating a higher income inequality among the sectors. Except for 2002, the base year for estimates, the difference between nominal and real income values have widened during the respective periods. Nevertheless, both nominal and real household income has increased indicating a significant improvement in monthly mean and median household incomes during three respective periods (table 4).

TABLE 4: MONTHLY HOUSEHOLD INCOME AND EXPENDITURE (2002-2010)

Monthly HH Income	2002 (Rs/Month)	2006/07(Rs/Month)	2009/10 (Rs/Month)
Nominal median income	8482	16735	23746
Real Median income	8482	11120	11159
Nominal mean income	12803	26286	36451
Real mean income	12803	17645	17129
Mean HH Expenditure	12803	22952	31331

Source: Department of Census & statistics, (2008)

4.1.4 HOUSEHOLD FOOD EXPENDITURE

Access to food and drink is measured by food ratio, which indicates the value of food expenditure as the percentage value of total expenditure. It measures both in terms of nominal and real values. The table 5 indicates nominal and real values of food expenditure in Sri Lanka. Thus nominal mean food expenditure in 2010 was Rs. 13,267 and it accounts for 42 percent of total expenditure. The real mean food expenditure in 2010 is Rs. 14,723 and it accounts for 32 percent of total income.

Though the value of food expenditure in Sri Lanka is higher than the developed nations, the real value of food expenditure as a % of total expenditure has declined from 50% in 2002 to 32 % in 2009/10. Since the demand elasticity for essential food items is high, food ratio also remains somewhat high. It also shows that real mean monthly food expenditure is higher than nominal food expenditure values (Table 5). According to Consumer Finance Survey conducted by the Department of Census and statistics in 2006, 26 percent of food expenditure of low income households has spent for cereals.

TABLE 5: VARIATION OF NOMINAL AND REAL MEAN FOOD VALUES (2002-2009/10)

Item	2002	2006/07	2009/10
Nominal mean monthly food expenditure	5488	3641	13267
Nominal mean nonfood expenditure	7299	14317	18064
Value of food expenditure as a % of total expenditure	44.5	37.6	42
Real mean monthly food expenditure	13147	15250	14723
Real mean nonfood expenditure	13147	22252	31331
Value of food expenditure as a % of total expenditure	50	40	32

Source: Department of Census & Statistics (2010)

4.1.5 FOOD ACCESS AND POVERTY LEVEL

Poverty line, which demarcates the minimum food requirement for surviving people is used as a sufficient indicator to measure access to food. According to Department of Census and Statistics in Sri Lanka (2002), poverty was defined basically on three main criterions.

- (1) Households belonging to lowest four per capita expenditure deciles.
- (2) Households which spend more than 50 percent of their household expenditure on food.
- (3) Households for which average caloric consumption is between 2475 and 2750 kilocalories per adult equivalent per day.

Once the households satisfy simultaneously the above conditions (1), (2) and (3) are isolated, for those households, average per adult equivalent food expenditure per month is calculated. This value is referred as Minimum Required Adult Equivalent Food Expenditure (MRAEFE). Then considering all the households, poor households were defined as the households which spend more than 50 percent of expenditure on foods and the adult's equivalent food expenditure is below MRAEFE. According to Household income and expenditure surveys conducted by the Department of Census and Statistics in 2001/2002 and 2009/2010 years, monthly value of MRAEFE was equivalent to Rs. 1294 in 2002 and it has increased Rs. 3808 in 2013 (Table 6).

TABLE 6: VARIATION OF NOMINAL POVERTY LINE

Sri Lanka	2002	2004	2005	2006	2007	2008	2010	2013
Nominal Poverty line	1294	1628	1817	2066	2427	2845	3208	3808

Source: Department of Census & Statistics (2010)

Similarly. Household income and expenditure surveys conducted by the Department of Census and Statistics in 1990/91, 1995/96, 2001/2002 and 2009/2010 years highlights the percentage of poor households that based on the official poverty line has gradually decreased over the years. Table 7 shows change in Head count index (HCI) or the percentage distribution of population below the poverty line according to urban, rural and estate sectors.

TABLE 7: HEAD COUNT RATIO AND PERCENTAGE OF POOR HOUSEHOLDS BASED ON OFFICIAL POVERTY LINE

Country/Sector	1990/91	1995/96	2002	2006/07	2009/10
All country	26.1	28.8	22.7	15.2	8.9
Urban	16.3	14.0	7.9	6.7	-
Rural	29.4	20.9	24.7	15.7	-
Estate	20.5	38.0	24.3	22.0	-

Source: Department of Census & Statistics (2008), Central Bank of Sri Lanka

$$HCI = \frac{\text{No of poor people in the population}}{\text{Total population}} \times 100$$

4.1.6 FOOD USE

It is vital to know the nutritional adequacy of basic food requirements that includes calories, protein, energy fats etc. So the nutritional value of food is a combine effect of food basket that includes grains, meat, fish, milk, vegetables, fruits and other vitamins. The table 8 shows average monthly per capita availability of nutrition per day for 2007-2013 period. Accordingly kilo calorie and protein gram requirements per day have increased over the period and fat gram requirements has decreased slightly.

TABLE 8: PER CAPITA AVAILABILITY OF NUTRITION PER DAY, 2007-2013

Year	Kilo Calories per day	Protein Gram per day	Fat Gram per day
2007	2367.7	59.6	48.9
2008	2539.5	61.3	43.8
2009	2437.1	61.1	46.2
2010	2688.3	67.0	46.0
2011	2581.2	66.1	46.3
2012	2632.8	66.8	46.4
2013	2756.7	68.5	47.7

Source: Statistical Abstracts (2013), Department of Census & Statistics

Statistical analysis in relation to food security, particularly with respect in food availability, accessibility and affordability has showed that food insecurity in Sri Lanka is low compared to many developing countries. Though the risk and uncertainty is still existed in the process of food supply, technological advancement programs were greatly influenced to minimize the risk by enhancing production and productivity of domestic food production.

4.2 INNOVATION, TECHNOLOGY ADVANCEMENT AND FOOD SECURITY

Innovation is a process of inventing or discoveries. Though invention and discoveries are the result of creative process, which is often difficult to predict and plan, meaning of these two concepts is slightly different from each other according to its origins. Thus, discover refers to what before existed, which we unknown; and invention refers to what did not before exist. Accordingly, some innovations are technology based while other innovations such as new product or service are facilitated by technology. It also categorized as product innovation and process innovation. Product innovation increases net revenue sufficiently to yield a positive rate of return on Research and Development (R&D) while Process innovation can lower a firm's production costs by improving internal production techniques.

On the other hand, the term of technology refers increasing production efficiency through knowledge, skills and creativeness. Thus technological innovation is defined as adoption of new technology enabling more revenue to be obtained from given total resources (Hill, 1977). The increase in revenue may be obtained either from increased physical output, improved quality or combination of both. Whatever, its source, the result of technological innovation must be to increase revenue or decrease the production cost (ibid). The technological innovations in agriculture are practiced mainly through three methods i.e. mechanical innovations, biological innovations and chemical innovations.

In line with technology development programs implemented in Sri Lanka, particularly in view of agricultural and food production, it has been adopted many technological development programs since 1960s for the purpose of increasing domestic food production. Like many other developing countries, Sri Lanka also adopted biological, mechanical and chemical technologies in this regard. It includes introducing high yielding varieties, chemical fertilizer and farm machineries. Basically It aimed at preventing the diminishing returns that inherited in small scale subsistence farming through new technology, which known as dynamic disequilibrium (Ellis, F 1992). Thus our discussion is focused on reviewing how mechanical, biological and chemical innovations were effective in increasing production and productivity of domestic food products.

MECHANICAL INNOVATIONS

Mechanical innovation is referred in using new farm machineries for reducing burden and cost of existing farming system. Thus Sri Lanka has introduced various farm machineries time to time with a view to overcoming labour shortage and high labour cost. Thus, Tractors (2w) and (4w), seeders, harvesters and combine harvesters were introduced time to time for the sake of increasing production efficiency of paddy other food crops.

TABLE 9: EFFECT OF FARM MECHANIZATION FOR HARVESTING PADDY

Machine/Activity	Rs/Acre
By using Tractor	
Harvesting by labor (350*8)	2800.00
Threshing cost for tractor	1000.00
Cost For labor (350*6)	2100.00
Fanning by tractor (Rs/hour)	350.00
Other (Foods/ tea for labors)	1600.00
Total	7850.00
By using Combine Thresher	
Harvesting by labor (350*8)	2800.00
Threshing by machine	2700.00
Other (Foods/ tea for labors)	1000.00
Total	6500.00
By using Combine Harvester	
Harvesting by combined harvester	6500.00
Helper	350.00
Drying and fanning	2100.00
Total	8950.00

Source: The Study on Recent Trend of Labor Market, (HARTI, 2007)

Use of farm machines had a greater impact on reducing the number of labour units and the cost (HARTI, 2007). Table 9 highlights how tractors, combine thresher and combine harvesters were effective in reducing required number of labours units and the cost. It shows that use of combine harvester was more efficient and economical in harvesting paddy. Thus farm mechanization for paddy cultivation has greatly influenced to reduce labour cost of paddy production by 10 percent (ibid).

BIOLOGICAL INNOVATIONS

Biological innovations are referred to breeding and using higher yielding seed varieties and strains of livestock. Sri Lanka introduced high yielding varieties and protection technologies since late 1960s. The Department of Agriculture (DOA) is responsible for technology development and diffusion it at farm level. Thus several research centers have established under direct supervision of the DA. Accordingly, 05 Rice/Paddy Research Centers were established at Batalagoda (BG), Bombuwala (BM), Ambalantota(AT), Mahailuppallama(MI) and Labuduwa (LD) areas in view of developing suitable varieties required to different climatic conditions. At the same time, Mahailuppallama, Gannoruwa, Wanathawilluwa, and Angunakolapelassa centers were established conducting R & D for other food crops such as vegetables, fruits and tubers. Table 10 displays innovative technology advances applied on diffusing of new varieties of paddy and other food crops.

TABLE 10: NEW PADDY AND OFC VARIETIES DEVELOPED BY THE DOA

Crop	VARIETIES RELEASED BEFORE 1990	VARIETIES RELEASED AFTER 1990
Paddy	BG 11-11, BG 3-5, LD 66, MI 273, BG 34-6, BG 34-8, BG 90-2, BW 78, BG 94-1, BW 100, BG 94-2, AT 16, BG 276-5 BG 400-1, BG 379-2, BG 407, BG 745, BG 38, BG 380, BW 266-7, BW 267-3, BW 2272-6B; BG 450, BW 451, BW 400, BG 350, BW 351, BG 300, BG 301, BW 302	BW 452, BG 403, BW 453, AT 401, AT 402, BG 352, AT 353, AT 354, LD 355, BG 304, AT 303, LD 356; BG 357, AT 405 BG 305, BG 358, BG 359, BG 360
Chili	MI -1 150-180 MI- 2 120-150	KA- 2 115-150 Arunalu 105-150
Maize	Badhra 115-130	Ruwan 105-155, Aruna 90-110, Mutu 110-115
Finger Millet	MI-302 115-130	Ravi 90-100
Pigeon pea	MI-10 Semi perennial	Prasada 120-135
Green gram	MI-4 75-80	Harsha 55-60
Green gram	Type 77 75-80	No
Cowpea	MI-5 90-100 MI-1 90-100 MI-35 70-80	Wijaya 60-70 Waruni 60-70 Dhawala 60-70
Black gram	MI-1 90-100	No
Soybean	PB-1 80-95 Improved Pelican 95-105 Boissier 90-100	PM 13 90-95 PM 25 95-100
Groundnut	MI-1 90-100 No.45 90-100 X-14 90-100	Tissa 90-100 Walawe 120-135 Indii 110-115
Sesame	MI-1 (Black seed) 90-100 MI-3 (White seed) 90-100	Uma 85-90 Mali 75-80
Cotton	HC-101 Semi perennial	No
Total	20	18

Source: Annual Reports, Department of Agriculture

These technology improvements are included in introducing old high yielding varieties as well as new high yielding short-term varieties that suitable for any climatic condition of the country. OFC varieties are famous as new improved high yielding varieties that suitable for commercial cultivation.

CHEMICAL INNOVATIONS

Chemical innovation is referred in using chemical fertilizer and herbicide and pesticide for controlling pests and diseases more efficient manner. Once introduced biological and mechanical innovations for domestic agriculture, use of chemical fertilizer and agro chemicals were also followed as a package of new technological advancement. Today fertilizer application becomes the main variable factor of increasing paddy production and almost all paddy farmers are relied on chemical fertilizer application despite its' increased prices (Henegedara, 2006). Hence the government of Sri Lanka granted 90 percent fertilizer subsidy for paddy farmers in order to protect them from high cost of production that lead to reduce returns of paddy cultivation. Though the high reliance on chemical inputs created negative externalities on causing diseases and environmental problems, still using chemicals regards as the important factor of increasing domestic rice production.

The above technological advancement programs implemented in Sri Lanka had a positive impact on increasing domestic food production (Soyza and Silva, 2007). Thus the total production of rice, the staple food has increased from 1357, 000Mt in 1973 to 3846, 000Mt in 2012 and subsequently domestic self-sufficient ratio of paddy/rice has increased from 0.73 to 0.95 during the consecutive period (Table2). Similarly, average output per Hectare has increased from 2929 in 1980 to 4353 in 2012 (HARTI, 2008). The main factors influenced for increasing paddy production are associated with biological and chemical innovations relating to use of chemical fertilizer and high yielding varieties (Central Bank of Sri Lanka, 2012). It also revealed that biological innovations had a positive impact on increasing the productivity of other field crops grown in Sri Lanka leading to reduce the amount of imports of said crops (HARTI, 2008).

Self-sufficiency in staple food (rice) is a sufficient measure to indicate the outcome of technological advancement of any country. It measured by using midyear population, per capita consumption, rice requirements for consumption and seed paddy and the extent sown as main proxies. Thus Table 3 shows that self-sufficiency ratio of paddy has reached to 100 percent of the domestic rice requirement though it fluctuates slightly time to time due to climatic factors. Time series data shows that the self-sufficiency ratio has increased during the 1973 - 1985 period and decreased after 1986. But, it had been increased after 2000 fulfilling more than 100 percent of domestic food requirements. However assurance of remaining in 100 percent self-sufficiency ratio is still a challenge since its high volatility in fluctuation of production due to frequent climatic changes in Sri Lanka as a typical monsoon country.

The technological advancement in agriculture development has impacted negatively on domestic labour use indicating a labour displacement or decline in labour absorption to paddy cultivation. Subsequently, rural unemployment and outgoing migration has increased (HARTI, 2010). The Table 11 shows gravity of labour displacement as use of farm machineries in paddy production. The labour absorption for paddy while increasing the labour productivity. So the labour displacements in agriculture has badly affected for food affordability and domestic food insecurity. The Table 11 also highlights the variation of labour use according to irrigated and rain fed farming areas, reflecting that labour productivity is high in irrigated areas where farm mechanization is high than in the rain fed farming areas where relatively low farm mechanization existed.

TABLE 11: VARIATION OF LABOR REQUIREMENTS AND LABOR ABSORPTION IN PADDY FARMING SECTOR

Type of Farming	District	1990/91 Maha	1990/91 Maha	2007/08 Maha
Irrigated farming	Anuradhapura	43	37	32
	Kalawewa	43	39	19
	Hambantota	57	41	31
	Polonnaruwa	41	45	33
	Kurunegala	53	35	31
Rain fed Farming	Kandy	103	50	37
	Kalutara	49	43	31

Source: Cost of production of paddy Cultivation, Department Of Agriculture (2006)

Once technological conversion in agriculture has increased, farmer's reliance on imported inputs such as chemical fertilizer, machineries and agro chemicals were increased and subsequently cost of cultivation were also increased tremendously over the years. However output prices were not increased sufficiently and thereby terms of trade in relation to agricultural crops, consumer goods and industrial goods were decreased (Statistical Abstracts, Department of Census and Statistics). Thus relative prices of milk food, urea and wheat have increased with a greater variation than the variation of farm gate prices of food commodities. Technological advancement practices in Sri Lanka was based mainly on imported inputs leading to increase cost of production and to decrease farm income. However this effect would be negligible when increased the total factor productivity (Henegedara, 2006).

5. DISCUSSION

Hypothetical phenomenon assumed that adoption of innovative technologies had influenced in increasing food production and food security in Sri Lanka was statistically proved implying that availability of rice and other food crops had been increased. However food availability itself is not sufficient enough to satisfy that required to fulfill other components i. e, food access and affordability. So it seems that the tendency for food insecurity is slightly there with respect in food access and food use. The factors influenced in this regard are discussed in this section by focusing on implications and the issues to be addressed by policy makers.

1. Though the R&D and innovations were effective in increasing productivity of total rice production, overall production pattern was always fluctuated over the years due to climatic changes. Therefore still around 5-10 percent of total rice requirements of the nation has to be fulfilled by imports. Due to continued crop failures in two consecutive seasons in 2012/13 Maha and 2013/14 Maha, the present level of rice production is not adequate to fulfill domestic food requirements and hence reliance on rice imports were increased. Consequently food insecurity in terms of food availability, food access and affordability has increased in the recent past mainly due to climate changes.
2. The recent trend in high reliance on food imports in Sri Lanka open eyes of policy makers on two important factors. First it indicates the comparative disadvantage for producing some food items such as millets, moon bean, potatoes and even rice. Secondly it shows how accomplish foreign exchange that required for imports. Though both of these issues are two sides of the same coin, it is important for macroeconomic stability of the country. So if the country doesn't have comparative advantage for rice compared to major producing countries, then alternative measures to be followed with respect in increasing the production efficiency by cutting the production costs.
3. Some technological methods followed for increasing food crops had made negative externalities such as labour displacements, environmental pollution and health hazards etc. For instance, it was found that kidney troubles in dry zone areas in Sri Lanka were happened mainly due to polluted water from extensive use of agro chemicals. When the negative externalities are high in a country it will affect the social cost particularly for economic sustainability.
4. Data in relation to head count ratio and poverty line indicate that food accessibility in rural and estate sectors are rather vulnerable than in urban areas despite the fact that national poverty line has decreased 8 percent in 2013. The vulnerability has occurred mainly due to disparities in land ownership, vicious circle of poverty in remote areas and institutional barriers existed in marketing and extension. Tendency for having spatial poverty and seasonal poverty is high due to uncertainty in climatic factors and marketing.
5. The global food production and supply has exceeded the global demand resulting decline in world food prices (Somaratne, 2011). Though global climate changes has threatened change in world food production time to time (Ekanayake, 2011), increase in global food production is a crucial factor in determining the comparative advantage in producing food crops among major producing countries. Regional integration through trade blocks has created trade restrictions rather than free and fair trade (Cherunilam, 2008, 216).

6. CONCLUSION

According to three main criterion of food security such as food availability, food access and food use, the country has adequately fulfilled the requirements of maintaining food security. Thus food availability was assured both in terms of local production and free imports. Food access, which measured by household income, expenditure and food values, indicates that about 40 percent of total income is spent on food and beverages in spite of wider disparities among urban and rural sectors. When considered the food use in terms of poverty line, food ratio and head count ratio (HCR), people living below the poverty line become 8.6 in 2012 indicating food insecurity is low. But the food availability or the food use does not assured the malnutrition level and other food deficiencies in some segments of the society who live somewhat vulnerable position in rural and estate sectors. Though the nominal food values has increased due to the inflationary effects in the recent past, real values of household income and expenditure on food are rather higher because non traded items are used by people in rural sector.

Though the Technological innovations developed through mechanical, biological and chemical innovations has effectively contributed to increase the domestic food supply, particularly achieving more than 90 percent of self-sufficiency in rice production, its impacts on declining food insecurity is yet to be increased by improving food access and food use.

Therefore, attention of policy makers should be focused on the comprehensive policy framework based on clear ends and means along with millennium development goals and global challenges. The policy recommendations should also necessarily be based on the implications discussed in section four.

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