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2nd Green Revolution

Growth Engine for Transformation

THE ASSOCIATED CHAMBERS OF COMMERCE AND INDUSTRY OF INDIA

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Second Green Revolution

"Growth Engine for Transformation"

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सत्यमेव जयते

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भारत सरकार
MINISTER OF AGRICULTURE &
FOOD PROCESSING INDUSTRIES
GOVERNMENT OF INDIA

8, June, 2011

MESSAGE

It is a matter of great privilege and honour to be associated with prestigious programs like the Global Summit on Green Revolution II: Growth Engine for Transformation. I appreciate the initiative of ASSOCHAM as the subject is well chosen and taken up.

Food Processing & Agriculture sector holds immense potential to spearhead Green Revolution not only in India but also on a global scale to contribute in world food security. The Global Summit on Green Revolution II will promote the business opportunities especially in the field of food processing and agriculture. On a bigger note this Conclave will pave exploring possibilities for investments in agriculture sector for sustainable living and better livelihoods of rural population in India. This event is a step to synergise collaborative efforts among the stakeholders to deliberate on the issues for developing greater linkages from the grass root level to national and international markets.

I am sure that the deliberations and suggestions will receive due consideration from concerned authorities and will prove beneficial in framing conducive policies.

I wish the Summit a great success.

(SHARAD PAWAR)

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PREFACE

The first Green Revolution in the 1960s characterized by the use of high-yielding varieties and more intensive farming techniques transformed the agricultural landscape in the developing world in that era. It played a key role in preventing mass starvation and hunger deaths in developing countries in the face of a growing population and an increasing food demand. However, its non-sustainable nature coupled with its limited scope and subsequent impact on the ecosystem, have led to a quest for a more sustainable and greener alternative.

Events that transpired over the past forty years have placed the agricultural system that feeds the human race in critical decline. Food consumption has outstripped production causing an imbalance. Experts believe that the problem could worsen as governments curtail grain exports to increase their own stockpiles. Rising food costs have prompted political unrests across the globe. The challenge of climate change looms large over agriculture. Productivity has fallen with new varieties and innovations unable to make impacts in the face of declining and degraded natural resources. Farming communities, majority of which are composed of small and marginal farmers, are getting poor returns for their produce at a time when cost of cultivation has gone up drastically. Also, the supply chain infrastructure in many countries has declined. It is estimated that countries across the globe have probably spent at least $1 trillion on food imports in 2010, with the poorest paying as much as 20 percent more than in 2009.

According to the World Bank, 44 million people have been forced into extreme poverty by food inflation since June. As per the Nomura Food Vulnerability Index which comprises 80 rich and poor nations, among those suffering most from costly food are 25 countries which include India, China, Philippines, Bangladesh, Nigeria, Kenya and Vietnam.

Whether it is climate change and the shrinking farm-holding area that will make it difficult to feed 9 billion people by the year 2050, or the rising cultivation costs and low value for farmer produce that makes agriculture unprofitable and hence unattractive to rural youth, innovative modalities become crucial to reverse this perfect storm, a confluence of the factors mentioned above.

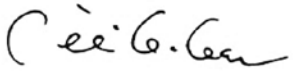
The next Green Revolution or the Evergreen Revolution (as Dr Swaminathan calls it) will have to bring about food and nutritional security to the billions in the country but without further damaging the fragile ecosystem. Its long-term success will depend on a strong convergence strategy that brings together civil society and the public and private sectors through mutually beneficial partnerships that ultimately advances the agricultural sector.

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) conducts agricultural research for development in Asia and sub-Saharan Africa with a wide array of global partners, impacting on the semi-arid or dryland tropics where over 644 million poorest of the poor dwell. ICRISAT and its partners help empower these poor people to overcome poverty, hunger and a degraded environment through better agriculture.

The Institute has adopted Inclusive Market-Oriented Development (IMOD) as its guiding principle to empower smallholder farmers to grow their way out of poverty. IMOD is a dynamic progression from subsistence towards market-oriented agriculture. It starts by increasing the production of staple food crops, converting deficits into surpluses that are sold into markets. This inclusive strategy will enable the poor, particularly women and the youth, to participate, rather than be sidelined, in the development process. We are confident that IMOD as a strategy will play a vital role in the path toward a second Green revolution.

The development of innovative products, processes and concepts by entrepreneurs and private players and their integration into existing agricultural systems is the pathway to true inclusive agricultural growth. An environmentally sustainable agricultural growth is a prerequisite for economic development in general and rural development in particular.

We appreciate ASSOCHAM's initiative in taking up the issue of a second Green Revolution to transform rural livelihoods and in involving our Institute as a Knowledge Partner to produce this study. I am sure this document will serve as a useful resource material for stakeholders in the agricultural sector.



William D. Dar
Director General
ICRISAT

MESSAGE

It gives me immense pleasure to associate with the Chamber's prestigious program "3rd Global Summit on Green Revolution II: Growth Engine for Transformation". The recommendations of the first two Global Meets were greatly appreciated and many of them have been accepted.

In 1968, the birth of the Green Revolution was announced by Indira Gandhi by issuance of a special stamp titled 'the wheat revolution'. The Green Revolution was meant to denote that the pathway for the advance of food production is increase in productivity per hectare, not area expansion. Since then India has witnessed a second Green Revolution and the steps taken by government in the field of technology, training, techno-infrastructure and trade are truly commendable.

This Global Summit will promote partnership & business opportunities especially in the field of agriculture sector. Agriculture and allied sectors have a potential to spearhead revolution not only in India but also at global scale. On a bigger note this Global Summit will pave way for exploring possibilities of investments in agriculture, to increase trade and strengthen global food security. This event is a step to synergize collaborative efforts among the stakeholders to deliberate on the issues for developing greater linkages to national and international markets & to deliberate on how to share the science and technology resources as well as services for enabling healthy growth in agriculture.

I'm sure that this Global Summit will achieve its desired objectives and has relevance to all the participants both directly and indirectly.

(Dilip Modi)
President
ASSOCHAM

MESSAGE

With the advent of First Green Revolution in India during 1960's, India achieved food security for it's masses. The Second Green Revolution which began in recent past needs to carry momentum through current decade. It marks the beginning of a paradigm shift from measuring agricultural progress from merely growth rates in production to measuring the wellbeing of farmers in terms of real improvement in their net income. Success of current revolution will create a foundation for prosperous India by 2020.

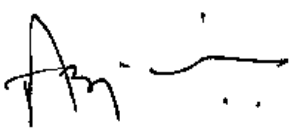
Today, major challenge before us is how to ensure sustainability of this ongoing technology based revolution while managing to keep agriculture remunerative even for small holders. We are a large agriculture power in terms of lot of quantitative achievements. However, we need to score on quality, efficiency, productivity and value addition.

There are many immediate issues we need to address such as mechanization of agriculture, use of Bio-technology, Efficient irrigation, Controlled agriculture through Green houses, over use of wrong fertilizers, deteriorating quality of soil, market linkages and so on.

I would like to congratulate ASSOCHAM for convening this summit on Green Revolution-II and for its commitment to achieve food security for nation and better future for farmers.

I wish ASSOCHAM a great success in attaining its objectives of inclusive growth and sustainable development through aggressive promotion of Green Revolution.

Jai Kissan !



Anil B Jain
Chairman
ASSOCHAM-National Council on Agriculture & Food Security

ACKNOWLEDGEMENT

This Global Summit have significance and importance not only for farmers but also to all the stakeholders of Agriculture & Allied sector as it is focused on the most important strata of Indian economy and society at large. The technological innovations & Business opportunities are the frontiers that can be harbored to strengthen industries from these sectors.

I extend my heartiest thanks to ICRISAT for bringing out a very informative study. I specially acknowledge the efforts put in by Dr. William Dar, Director General, ICRISAT and his team headed by Dr. K.K. Sharma, CEO-Agribusiness and Innovation Program for overall development of the background paper.

ASSOCHAM extends earnest gratitude to Ministry of Food Processing Industries, Ministry of Earth Sciences, Ministry of Agriculture, Ministry of Water Resources, Ministry of MSME and Government departments like NABARD for their support in making this programme a grand success. We also extend our genuine thanks to our State Partner Government of Andhra Pradesh for their sincere support.

This programme would not be the same without the due support from the top Industries like Jain Irrigation Systems and MONSANTO India as well as our Print Media & Online Media Partners.

Last but not least, the hard work put in by my colleague Dr. O. S. Tyagi, Director and his team members Mr. Nakul Lakhe, Mr. Waseem Khan and Mr. Nitesh Sinha is commendable.

I not only wish the Global Meet a great success but also assure that ASSOCHAM shall continue to organize such programs for larger public benefits with great degree of excellence.

(D.S. Rawat)
Secretary General
ASSOCHAM

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The Green Revolution

CHAPTER 1

In crisis, there is hope.

The transformation of the Indian agricultural scenario that started in the late 1960s and which was termed as the *Green Revolution* by Dr William Gaud of USAID (owing to the phenomenal growth in agriculture) is indeed a prime example of hope hidden in a crisis.

India after its Independence from the British Empire was always vulnerable to a food crisis. The spectre of the Great Bengal famine of 1943, in which an estimated four million people died of hunger still persisted with the country. The population was growing at a high rate while the growth in food production was inadequate to meet the consumption needs of the population. The urgency of the situation can be noted when Jawaharlal Nehru said, *'Everything else can wait, but not agriculture.'*

With the initiation of the Five year plans in 1951, a focused approach was made in improving the productivity of the agricultural sector. The steps initiated included land reforms, expansion of farming areas, establishment of fertilizer and pesticide factories, strengthening of cooperative credit institutions, construction of large multi-purpose irrigation-cum-power projects along with community development and national extension programs. State agricultural universities and Central research institutions were also started for developing agro-technologies to enhance the production for the agricultural sector. An Integrated Agricultural Development Program (IADP) was initiated in 1960 to enhance the productivity in irrigated areas. The aim was to introduce good seeds along with a package of agronomic practices, which can help optimize the benefit from irrigation water. In order to encourage the farmers to adopt better technology, incentive price policy was adopted in 1964 and the Agricultural Price Commission was setup to advise the Government on the fixation of support prices of agricultural crops.

However, even with these investments in the sector, food shortages continued and India had to import food to feed its starving millions. Productivity was stagnant even though more land was brought under agriculture. Unfortunately under the IADP, it was found that the package of practices promoted had one important missing ingredient, namely varieties which can respond well to good irrigation and soil fertility management. India was virtually living in a ship-to-mouth mode. Tragedy struck again with back-to-back famines in the mid 1960s. The world helped, and especially the United States of America under its PL-480 program which touched a peak of 10 million tonnes in 1966.

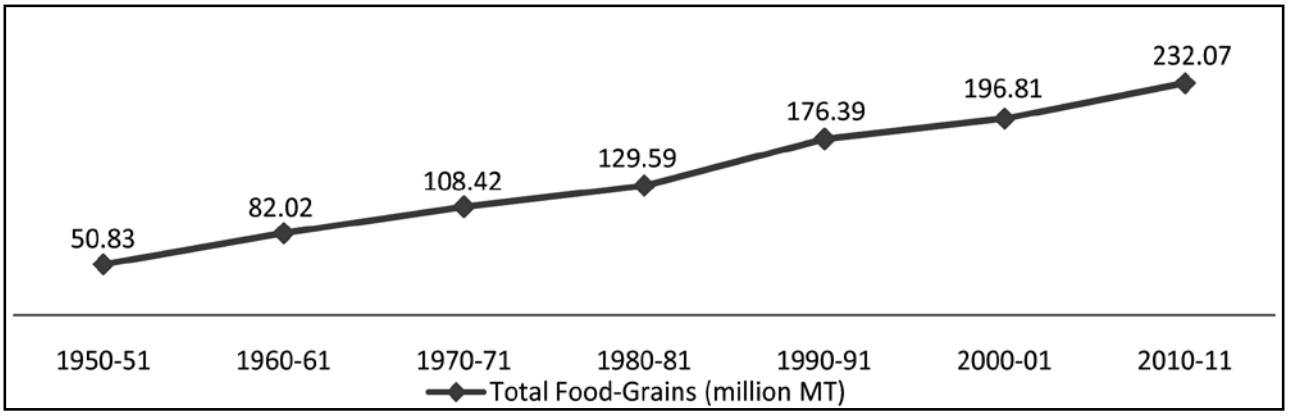
The scenario changed with the launching of the High Yielding Varieties (HYV) program in food grains in 1966. Aided by a comprehensive plan and successful engagement of the political and research fields, the new agricultural technology slowly and steadily transformed the agricultural landscape of the country. During the year, the Government of India imported 18,000 tonnes of seed of the Mexican semi-dwarf varieties of wheat, *Lerma Roja* 64A and Sonora 64. This was the start of the revolution in the agricultural sector and resulted in the country becoming self-sustainable in food grains and later to a net exporter. Similar successful attempt was made in rice varieties also as these are the two major cereals contributing about 75 percent of the food grain production of the country and together provide livelihood support to our massive population and thus, have a significant impact on the national food security.

Apart from importing of seeds, the agricultural scientific community also came up with HYV seeds that were developed in India. The Green Revolution thus had four ingredients for its success: **technology**, which gave a quantum jump in yield; **services**, like irrigation and electricity; **marketing**, through a public policy and the PDS that helped in getting the farm produce to the lowest tier of the society, and lastly, **farmers** zeal to take up this revolution.

1.1 Outcomes

Wheat production that was stagnant at six million tonnes jumped to 17 million tonnes by 1968. The same was seen in rice and other coarse food grains. As depicted in graph 1, the food grain production has been growing steadily and has quadrupled from 50.8 million tonnes in 1950-51 to 232.07 million tonnes in 2010-11 (based on second advance estimates released by the Ministry of Agriculture). Among cereals, the production of wheat recorded major growth when compared to rice and coarse cereals. As per the advanced estimates released for 2010-11, rice production increased more than four times from 20.5 million tonnes in 1950-51 to 94.01 million tonnes in 2010-11 while the production of wheat touched more than 14 times during the same period.

Graph 1: Food grain production (1950-2010)



Source: Reserve Bank of India; Economic Survey Report, 2010-11

The Green Revolution helped in generating self-confidence among the agricultural community. The agricultural research, education and extension segment was reorganized and strengthened along with setting up of institutions for providing assured marketing opportunities and remunerative prices to the farmers. New HYV of cereals and other crops were developed at these research stations and introduced to the newer and existing fields, which has led to India achieving the premier position in production and area for various crops. Anticipatory research to avoid potential environmental problems was strengthened and a wide variety of high yielding strains possessing resistance or tolerance to the principal disease causing organisms were developed. Such awareness led to intensified efforts in varietal diversification and developing tolerance to biotic and abiotic stresses.

The gains of the revolution were consolidated during the Sixth Five Year Plan period (1980-85) when for the first time agricultural growth rate exceeded the general economic growth rate, largely because of the priority accorded to irrigation. The Sixth Five Year Plan also illustrated the benefits arising from farmer-centric priorities in investment and emphasis placed on bridging the gap between scientific know-how and field level do-how.

The use of HYV seeds grew from seven percent to 22 percent within the first 10 years of the revolution. It has now reached more than 70 percent and between 1967-68 and 1996-97, the area under HYV program increased from 6.07 million ha to 76 million ha. It also helped in popularizing double-cropping in existing farmlands as the new varieties were able to grow under irrigated conditions and had shorter duration, which contributed to increased production. The per capita availability of food grain has increased by nearly one and half times. As can be seen from the table given below, the food grain production has improved to such an extent that we are now carrying three times (60 million tonnes in June 2010) of the prescribed limit to be kept as buffer stock.

Table 1: Food grain production vs buffer stock (1950-2000)

Year	1950	1960	1970	1980	1990	2000
Food grain production (MT)*	50.83	82.02	108.42	129.59	176.39	196.81
Food grain import (MT)*	4.8	10	7.5	0.8	0.3	-
Buffer stock (MT)*	-	2	-	15.5	20.8	40
Population (Bn)	0.36	0.40	0.55	0.68	0.85	1.02

*Source: Ministry of Agriculture, Govt. of India; *-Million Tonnes (MT)*

The changes in productivity had a great social impact on the farming community. With increased production, income from the farms improved and with greater money to spend, new needs for farm inputs, milling, processing and marketing services occurred and spurred the local economy to growth.

The transformation of the agricultural sector thus had a multiplier effect on other sectors of the economy. Since the new varieties responded well to chemical fertilizers and pesticides and needed water, the manufacturing industry grew and generated employment opportunities and helped in improving the GDP of the country. The dams which were used to help in bringing more land under cultivation were used for generating hydro-electric power that in turn, boosted industrialization across the country. With increased purchasing capacity, there were changes in the consumption pattern and resulted in a diversified diet. Food prices also came down due to the large production and the Public Distribution System (PDS) that helped in distributing the agricultural produce, especially the food grains at very low prices to the rural population living below the poverty line. This helped in reducing poverty in the rural community.

1.2 Limitations

Yet for all its benefits, the Green Revolution had its set of limitations and drawbacks:

- The transformation initiated in the late 1960s focused primarily on rice and wheat and bringing out new varieties in these two crops while other coarse cereals and pulses, rich in nutritional value, was not accorded much attention. This led to malnutrition, especially among the bottom tier of the society.
- The focus area of the revolution was in the northern part of the country, especially Punjab where there was plenty of water and fertile lands. The farmers of Punjab still produce 40 percent of the wheat and 26 percent of the rice produced in the country. Though this is highly commendable as they are sustaining the public distribution system and justified at that time since the country was facing yet another shortage in food, the revolution was not replicated throughout the country. The north-east and eastern parts of the country were fully left out and still are in economically backward category.
- One of the widespread criticisms of the revolution was that only the rich farmers could access the new seeds and technologies and reap the benefits from it. This has led to concentration of wealth among few, while majority of farmers who had small and marginal land could not get the facilities.
- The use of pesticides and chemicals along with the introduction of HYV seeds in more than 70 percent of the agricultural land has led to a drastic reduction in the ecosystem. Natural defense mechanisms like predators and beneficial insects and soil fertility levels have gone down. The large water requirement for the growth of these new varieties has led to reduction in the water table across the lands. Irrigation practices have led to salt build-up in the fields and rendered it uncultivable. There has been a loss in bio-diversity of the crops due to cultivation of few major varieties in food grains that led to loss of local varieties of rice and other crops.

★★★

Need for the Second Green Revolution

CHAPTER 2

"The green revolution that made the nation self-sufficient in food grains has run its course. Its outcomes need to be boosted; a second green revolution that maximises productivity and generates income and employment opportunities for the rural population is needed."

- Mrs. Pratibha Patil, the President of India
at a national conference on "Rural Prosperity through Better Agriculture"

The demand for a second, sustainable and evergreen revolution is being increasingly heard in the scientific and political spectrum. The decline in productivity though at seemingly high levels of production is an issue of large concern. Again, this increase in production has been at the cost of land degradation and other environment problems in agricultural areas, caused by the imbalanced use of agrochemicals, unplanned land use and decreasing land holding sizes, improper use of irrigation water, and improper and inappropriate agricultural practices. A weak agricultural development, paired with a rapid population growth and decline in the per capita availability of food that leads to make the country increasingly vulnerable to food insecurity and dependent on food imports. Compounding problems further is that the sector, which has only 2.3 percent of the world's total land area, has to ensure the food security for 17.5 percent of the world's population amidst declining natural resources, erratic monsoons, climate change crisis, energy crisis, loss of bio-diversity, weak extension machinery, rising input costs, inadequate storage infrastructure and high post harvest losses, all of which ultimately pulls down the returns to the farmer-producer. The situation of agriculture turned adverse during post-WTO period that covered all the sub-sectors of agriculture. The growth rates in output of all crops decelerated from 2.93 percent to 1.57 percent that is lower than the growth rate of population. The livestock declined from 4.21 percent to 3.40 percent. The fisheries declined from 7.48 percent to 3.25 percent. At the same time, other sectors, especially services sector and the economy have grown considerably making India an emerging superpower in the global arena. Such gains will be hard to sustain unless the primary sector of the country, on which majority of the population depends for its livelihood and which is the raw materials source to the industry, improves in terms of productivity and returns to the farmer producer.

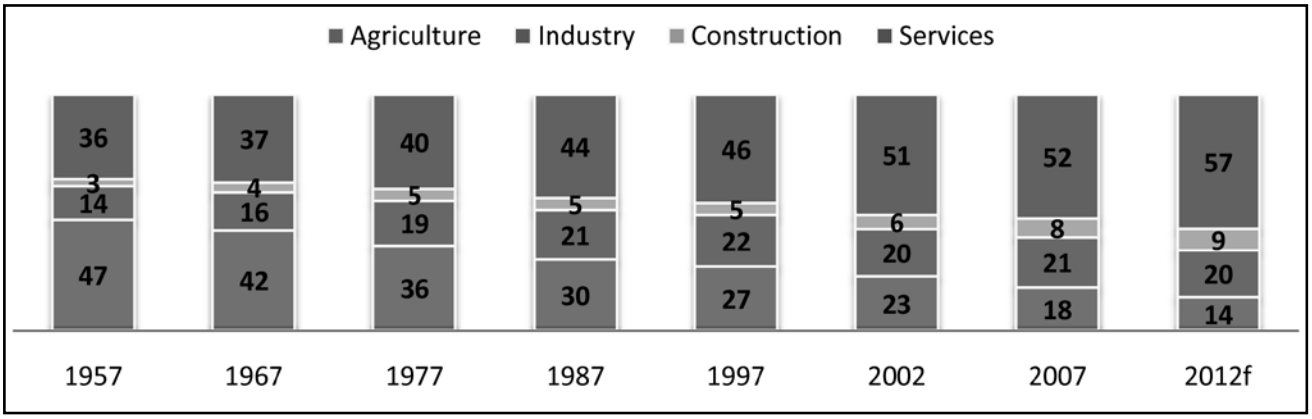
Agriculture production is a biological process, agriculture is diminishing returns activity because land is ultimately a fixed factor of production, and the demand for agricultural commodities is income inelastic. These characteristics make agriculture different to other sectors. Therefore, a

separate policy for agricultural development is a must. The section will highlight the need for having another green revolution for improving the agricultural sector in the country.

2.1 Key economic indicators of agricultural sector

The agricultural sector is vital for ensuring the food and nutritional security of the country. With over 58 percent of the population of the country dependent on the sector as the principal source of their livelihood, the sector assumes greater importance in the Indian economy. The GDP of India has increased nearly ten-fold, with its growth accelerating above five percent from the 1980s, to seven percent for the last decade and to over eight percent during the last half decade. While poverty reduction has accelerated somewhat since the early 1990s, the change in the rate of decline was not statistically significant; because of population growth, the rate of decline in the number of poor people has only been at the rate of 0.3 percent (Datt and Ravallion, 2009).Indian agriculture performed best during the 1980s when the Green Revolution was generalized across most of agriculture, and agriculture output (but not GDP) grew at nearly four percent. Since then the growth rates have varied between 2-3 percent. Agricultural growth measured by GDP has grown at just over three percent in the last five years. This is more evident from the sector-wise contribution to overall GDP as given in graph 2. While other sectors have grown, the contribution from agricultural sector has gone down. The agriculture share of GDP in the economy declined from 41.7 percent in the early 1960s to 14.6 in 2009, a decline of over 60 percent.

Graph 2: Contribution to GDP by all Sectors (1957-2007)



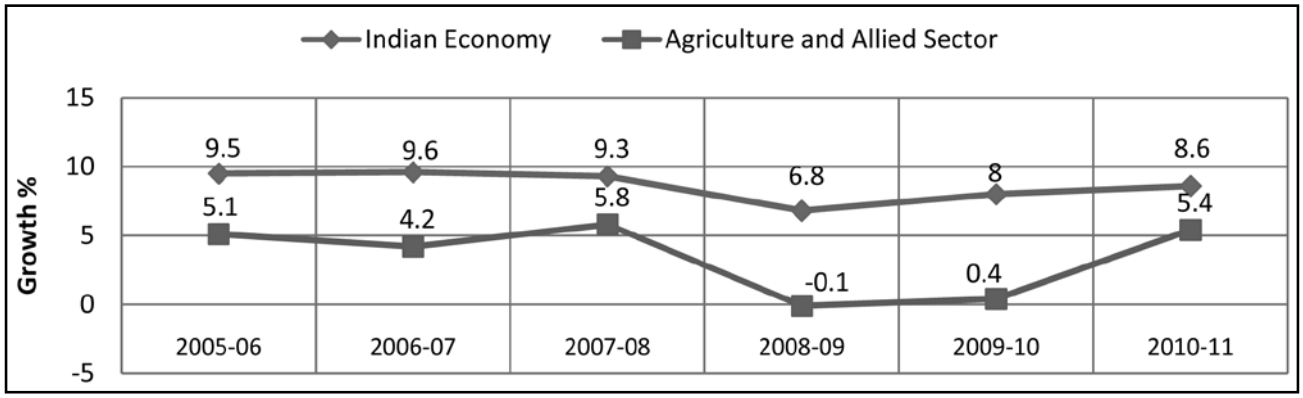
Source: Reproduced based on data presented in Financial Chronicle, August 31, 2009

In the last three years to 2009, productivity in the non-agricultural sector was US$2817, while it was only US$672 in agriculture. The overall GDP grew by 8.62 percent on average during 2004-05 to 2010-11 while the agricultural sector grew only by 3.42 percent during the same period. However, a proportionate decline in the workforce engaged with the sector has not been seen. Another issue is that while agricultural GDP has quadrupled during the past sixty years, the

GDP per agricultural worker is around '2000 per month, an increase of only 75% higher in real terms. This reveals the trend in the income level in the workforce engaged in different sectors and also indicates the lack of non-farm employment opportunities which can absorb the surplus labour in the farm sector and equipping those in agriculture to access opportunities. Thus, new technologies and employment opportunities are needed to increase agricultural income so as to boost the growth.

Though the decreasing contribution may be justified as an expected outcome due to changes in the economy and increasing growth from other sectors, the growth rate of the agricultural sector per se is hovering in the range of 4-5 percent which is lower than the growth of the economy pegged at 9 percent (graph 3). Another concern would be that the production growth rate has gone below the population growth rate that could again lead the country to a situation of high demand but severe shortage for food grains.

Graph 3: Growth of Indian economy vs agricultural sector (2005-2010)

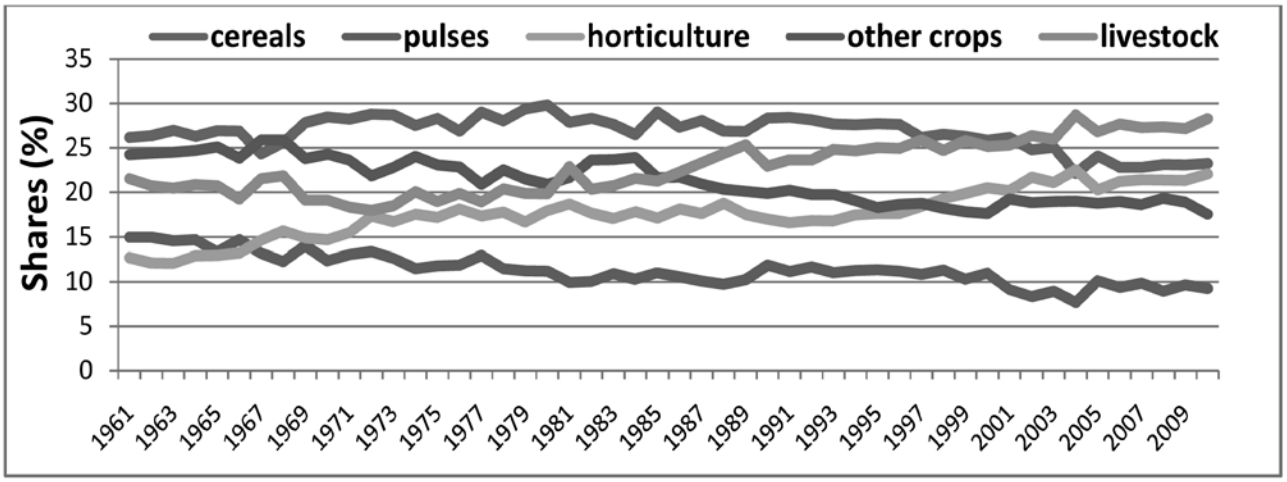


Source: Graph based on data from CSO, Ministry of Statistics and Implementation Program, GoI

In terms of sectoral composition, out of a total share of 14.6 per cent of the GDP in 2009-10 for agriculture and allied sectors, agriculture alone accounted for 12.3 per cent followed by forestry and logging at 1.5 per cent and fisheries at 0.8 per cent. The sectoral composition of production in agriculture has changed very slowly over time (graph 4). Within the crop sector, cereals have declined by only 3.5 percent to 23.1 percent of agricultural value added. The disappointing performance of oilseeds and pulses is reflected in a decline in their share of value added from 14.8 percent to 9.4 percent. All other crops (that include sugar, cotton, plantation crops, spices and other industrial inputs) have also declined in importance, from 24.4 percent to 18.6 percent. Horticulture, on the other hand, has compensated for all the other declines by increasing its share by 9.1 percent, to 21.5 percent, a higher absolute increase in their share than even livestock products. Horticulture production has increased from 170.8 million tons in 2004-05 to 214.7 million tons in 2008-09, i.e. by 26 percent over the five years. As a consequence, per capita availability of fruits and vegetables increased from 391 grams per day to 466 gram per day. On

the other hand, India is not able to keep pace with growth in demand. Demand is growing by about 6 million tons while supply is growing by only 3.5 million tons per year.

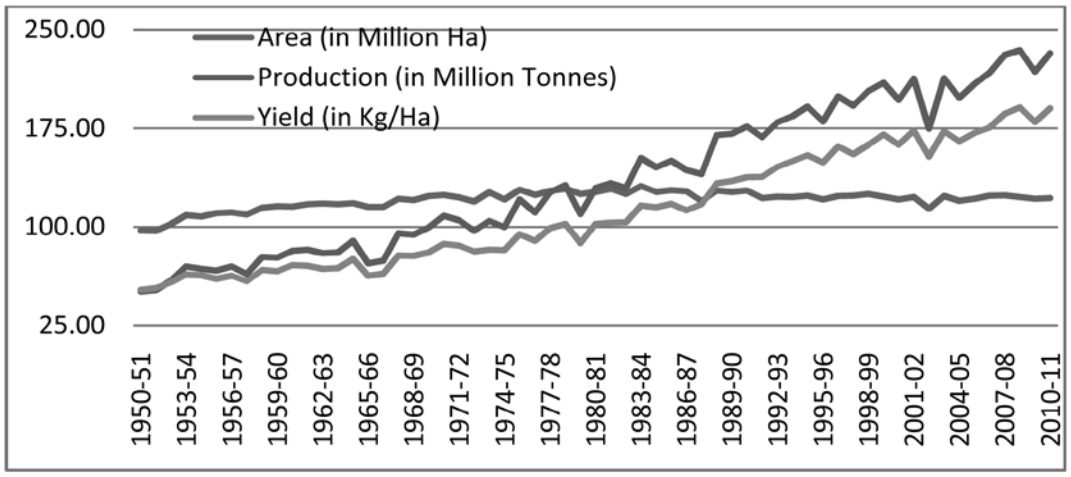
Graph 4: Changing composition of agriculture in India (1961-2009)



Source: Ministry of Agriculture, Govt. of India

As mentioned earlier, the concern for food availability in the developing countries such as India, stems from food production, particularly that of food grains, which are considered to be of paramount significance for household food and nutritional security. The food grains comprising mainly of cereals and pulses are staple foods and there are no perfect substitutes for them. Importantly, food grains are also the cheapest source of energy compared to other foods and are indispensable for the food security of low income classes.

Graph 5: Productivity vs area and production of food grains (1951-2010)



Source: Ministry of Agriculture, Govt. of India

From graph 5, it can be seen that apart from quantum jump in production during the 1970s and achieving high growth rate of 3.5 percent in the 1980s, the growth in food grains has been

erratic. Food grains, especially rice and wheat, are the two major cereals contributing about 78 percent of the food grain production of the country and together provide livelihood support to our massive population, and therefore, have a significant impact on the national food security.

Of late, food grain production has failed to keep pace with population growth, due to stagnating and tapering yields and acreage under predominant food grain crops. It is estimated that by 2020, the Indian population will touch 1.4 billion and to support that population and meet the demands due to increasing income, the agricultural sector has to grow by 4 percent every year. It is also to be noted that the agricultural decline is occurring at a time when the international prices of food grains are going up steeply, partly due to use of grains for ethanol production which can be later used for bio-fuel production. This can also defer the food grains meant for consumption being diverted to industrial purposes and threaten food security of the country.

2.2 Cropping pattern

Out of the total reporting area of 305.67 mn ha, the net area sown in India is only 46 percent (140.86 mn ha) as per provisional data for 2007-08. This was 41 percent in 1950-51. During the same period, the area under non-agricultural use has increased from 9.36 million ha to 25.92 million ha while barren and uncultivable land came down from 38.16 million ha to 17.29 million ha. Both the cultivable waste land and fallow lands have also decreased during this period although 4.4 percent of the total reporting area is available as a cultivable waste land and 4.8 percent of total reporting area is fallow land. This indicates that there is scope to increase the net sown area by at least 5 to 10 percent by improving both cultivable waste land and fallow. The gross sown area that was 131.89 million ha in 1950-51 that increased to 195.83 million ha in 2007-08 (41 percent growth) indicating that through intensive cropping aided with better eco-friendly agro-technologies , the net area sown can be further increased, thereby leading to an increase in production.

In terms of the cropping pattern (the proportion of area under different crops at a particular period of time), it can be noticed that the area under non-food crops as a proportion of the total cropped area is increasing but food grains still dominate the scene (Table 2). The area under food grains that was 77 percent in 1950-51, came down to 66 percent by 2000-01 while the area under non-food crops increased to 34.17 percent.

Table 2: Changes in cropping pattern (1950-2000)

Crops	1950-51	1960-61	1970-71	1980-81	1990-91	2000-01
Rice	23.5	22.3	22.6	23.3	23	24.03
Wheat	7.6	8.5	11	12.8	12.9	13.84
Coarse Cereals	29.9	29.4	27.8	24.6	19.6	16.55
Total Cereals	61.1	60.2	61.4	60.8	55.5	54.43

Total Pulses	15.6	15.5	14	13.2	13.5	11.4
Total Food grains	76.7	75.7	75.4	73.9	68.9	65.83
Sugarcane	1.3	1.6	1.6	1.7	2.1	2.49
Spices	0.9	1	1.1	1.2	1.3	1.5
Fruits & Vegetables	1.7	1.9	2	1.7	3.6	4.39
Total Oilseeds	8.3	8.3	8.9	9.1	13.5	13.56
Total Fibres	5.1	5.7	5.5	5.3	4.7	5.22
Tobacco	0.3	0.3	0.2	0.3	0.2	0.16

Source: Agricultural Statistics at a Glance, 2008

The change in the pattern indicates a change from subsistence cropping to commercial cropping, which is mainly influenced by the prevailing price in market and profitability per hectare. It is noted here that while the area under rice and wheat cultivation has more or less been maintained/ increased, it is the area under coarse cereals and pulses that has gone down that does not augur well for the nutritional security of the country, nor in ensuring food security to the bottom of the pyramid. The area under oilseeds went up due to a change in the agricultural policy that was adopted by the Government of India in the late 1980s, while the change in the area under fruits and vegetables shows the market forces at play.

It is also imperative to look at the regional performance, since the national averages will mask over the inefficiency and gaps in production at the state level. The regional disparity exists owing to the availability of fertile lands and water bodies. The landscape consists of drylands, irrigated lands and lands that depend on the monsoons for water. Production also varies accordingly, with states like Punjab and Haryana, with its fertile lands and rivers showing high productivity, while the BIMARU states show low figures. The next green revolution will need to plan out interventions based on the existing local factors and evolve the agricultural systems by fully utilizing the local environment and local systems of production on a common supporting framework.

2.3 Consumption pattern

As per the National Sample Survey 64th round, the monthly per capita consumption pattern of principal food items during 1993-94 to 2007-08 (given in table 3) shows major consumption features of rural and urban households:

- The per capita consumption of cereals is significantly higher in the rural households than in the urban, mainly due to higher consumption of rice by the rural households.
- The per capita consumption of meat/fish/eggs and fruits/vegetables is higher for the urban households due to affordability and want for diverse food basket.

- Consumption of pulses is decreasing that maybe due to their non-availability.
- From the point of view of food security, there is a shift within the food group from cereals to non-cereal food items in both rural and urban areas.

Table 3: Monthly per capita consumption (1993-2004)

Items	Rural				Urban			
	1993-94	2004-05	2007-08	% change (1993-05)	1993-94	2004-05	2007-08	% change (1993-05)
Rice	6.79	6.38	6.36	-6.0	5.13	4.71	4.75	-8.2
Wheat	4.32	4.19	4.19	-3.0	4.44	4.36	4.51	-1.8
All cereals	**13.4**	**12.12**	**11.67**	**-9.6**	**10.6**	**9.94**	**9.68**	**-6.2**
Pulses	0.76	0.71	-	-6.6	0.86	0.82	-	-4.7
Chicken (kg)	0.02	0.05	-	150.0	0.03	0.09	-	200.0
Edible oil	0.37	0.48	-	29.7	0.56	0.66	-	17.9
Milk (lts.)	3.94	3.87	-	-1.8	4.89	5.11	-	4.5
Eggs (nos)	0.64	1.01	-	57.8	1.48	1.72	-	16.2
Fish (kg)	0.18	0.20	-	11.1	0.20	0.21	-	5.0

Source: NSS 64th Round, Report No. 530, Ministry of Statistics and Program Implementation

There is a general decline in per capita consumption of cereals and increase in non-cereal food items, both in rural (9.6 percent) and urban areas (6.2 percent) during 1993-94 to 2004-05. Within cereals, it was observed that consumption of rice decreased by 6.0 percent in the rural areas and by 8.2 percent in the urban areas in 2004-05 over 1993-94. During the same period, the decline of wheat consumption in rural areas was by 3.0 percent whereas in urban areas, it declined by about 2 percent. The per capita consumption of pulses (as an important source of protein) also experienced a decline, both in rural and urban areas during 1993-94 to 2004-05.

The consumption of non-cereal food items such as milk, chicken, fish, eggs and fruits and vegetables exhibited an increase in 2004-05 over 1993-94. The above changes in the nature and quantity of food consumption have nutritional implications for the country's population. The reduction in cereals and food grain consumption indicates a shift in requirement of calories from cereals and food grain products to non-grain products such as meat, fish, eggs, fruits and vegetables.

The changes in the consumption pattern have been reflected in the monthly expenditure (Table 4). While there has been a reduction in the expenditure on food, it can be seen that the rural households spends much greater share of their food expenditure outlay on cereals as compared to

their counterparts in urban areas. The expenditure on cereals came down to 18 percent (against 41 percent) in rural areas during the period of 1972 to 2004, while the decline in urban areas was from 23 percent to 10 percent. This trend repeats also for the pulses. However, the budget share of non-cereal items such as fish/meat/egg, edible oil, beverages and fruits and vegetables, either increased or remained more or less the same in both the areas.

Table 4: Changes in expenditure on major food groups (1972-2004)

(in %)	Rural					Urban				
Sector	**1972-73**	**1987-88**	**1993-94**	**1999-2000**	**2004-05**	**1972-73**	**1987-88**	**1993-94**	**1999-2000**	**2004-05**
All food	72.9	64	63.2	59.4	55	64.5	56.4	54.7	48.1	42.5
Cereals	40.6	26.3	24.2	22.2	18	23.3	15	14	12.4	10.1
Pulses	4.3	4	3.8	3.8	3.1	3.4	3.4	3	2.8	2.1
Milk & milk products	7.3	8.6	9.5	8.8	8.5	9.3	9.5	9.8	8.7	7.9
Edible oil	3.5	5	4.4	3.7	4.6	4.9	5.3	4.4	3.1	3.5
Egg, Fish & Meat	2.5	3.3	3.3	3.3	3.3	3.3	3.6	3.4	3.1	2.7
Vegetables	3.6	5.2	6	6.2	6.1	4.4	5.3	5.5	5.1	4.5
Fruits	1.1	1.6	1.7	1.7	1.9	2	2.5	2.7	2.4	2.2
Sugar	3.8	2.9	3.1	2.4	2.4	3.6	2.4	2.4	1.6	1.5
Beverages	2.4	3.9	4.2	4.2	4.5	7.6	6.8	7.2	6.4	6.2

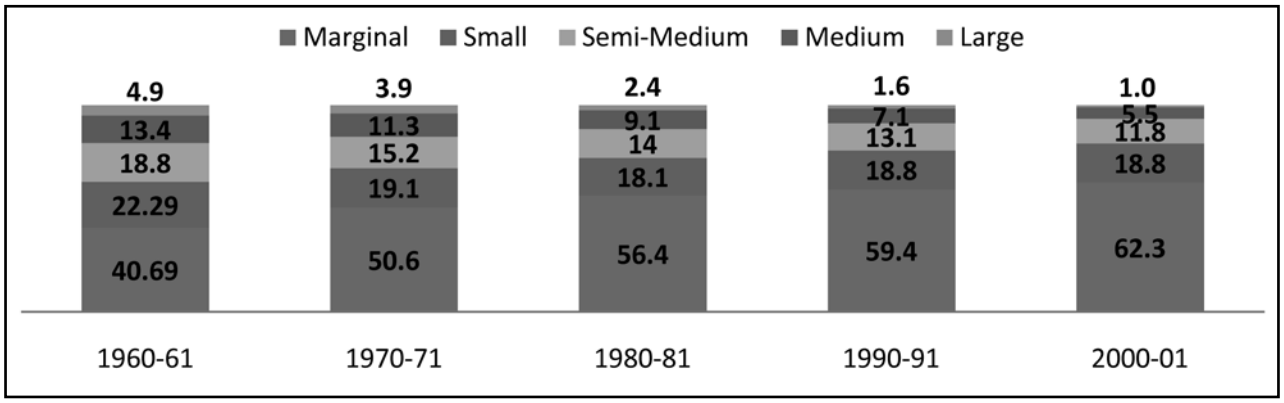
Source: NSS 61st Round, Report, Ministry of Statistics and Program Implementation

This shift in budget share indicates that the composition of nutritional intake in India is fast changing and that the non-cereal foods are increasing their share of the daily nutritional intake, thereby indicating that there is a lot of demand for that category, while production is very much limited.

2.4 Land holding pattern and degradation

One of the characteristics of Indian agriculture is that it is dominated by small and marginal farm holdings. Over the years, the size of the land holding has been reducing which can lead to potential economic loss to the farmer, not to mention the lower productivity. The following graph gives a clear picture of the land holding pattern in the country between 1960 and 2000.

Graph 6: Land holding pattern (1960-61 to 2000-01)



Source: Ministry of Agriculture, Govt. of India

Of the available cropping area, marginal (<1 ha) and small (1-2 ha) farmers dominate the landscape which has increased in the given period mainly due to the reduction in holding sizes in the medium (4-10 ha) and large (>10 ha) categories. The average size of the land holding has declined to 1.32 ha in 2000-01from 1.41 ha in 1995-96; it was 2.30 ha in 1970-71. However, in terms of area operated upon, there was a reduction of 2.4 percent that is a cause for concern. If this trend continues, the average size of land holding in India would be mere 0.68 ha in 2020, and would be further reduced to a low of 0.32 ha in 2030. This is a very complex and serious problem that can threaten the food production scenario.

The average size of landholding contracting at a time when the share of agriculture in GDP is going down, coupled with increasing fragmented cropping areas and large number of small and marginal farmers will have a detrimental impact for the sector. Due to the small land sizes, the farmer has to generate adequate marketable surplus (MS) in order to generate income from the farm and avoid agrarian distress. Under current conditions, both inherent to the bio-diversity and the external conditions like climate change and, land degradation, it is now becoming difficult to generate better productivity and thereby, adequate MS especially from food grain crops. Farmers are now shifting to crops that are considered high value like spices, plantation crops and exotic vegetables to overcome the situations. However, without adequate infrastructure and improved technological advancements, this endeavour at most times, ends up with farmers being forced into agrarian debt.

There is thus a general lack of interest among the farming community, especially the rural youth, in engaging with agriculture as a livelihood option, most of whom are migrating to the cities in search of a better standard of living. In fact, a survey by the National Sample Survey Organisation states that 45 percent of the farmers, if given a choice, would not continue with farming.

With the economy on the rise and the social fabric of the country undergoing a sea-change, more land is required to support the population and the industries and services sectors. Due to low

returns from the farming sector, many farmers have been forced to sell off their lands to settle their debts. Thus, more and more agricultural land will get fragmented and sold-off to the real estate sector which can bring down the net available area for cultivation, and put more stress on the existing farming lands to produce more to maintain status quo. This will adversely affect the fertility of the soil and destroy the ecosystem that is already becoming a key constraint in augmenting agricultural production.

Available estimates reveal that nearly 120.72 million ha of land in the country is degraded due to soil erosion and about 8.4 million ha has soil salinity and water-logging problems. Besides, huge quantities of nutrients are lost during crop production cycle. Annually, India is losing nearly 0.8 million tonnes of nitrogen, 1.8 million tonnes of phosphorus and 26.3 million tonnes of potassium. Problems are further aggravated by imbalanced application of nutrients and excessive mining of micronutrients, leading to deficiency of macro- and micronutrients in the soils.

Similarly, the water-table is lowering steeply in most of the irrigated areas, and water quality is also deteriorating, due to leaching of salts and other pollutants. For example, in the heartland of Punjab and Haryana, were the first Green Revolution was successfully implemented, the water table has decreased drastically. The annual water draft in Punjab is 31 BCM that is more than net annual groundwater availability of 21 BCM. Of the 138 blocks in the state, 103 blocks are designated as overexploited and five of them are critical. In Haryana, the annual water draft is 9 BCM against net availability of 8.6 BCM. For the country as a whole, 226 blocks have been declared critical and 839 over exploited[1]. The future of agriculture in the country needs to ensure that the water use efficiency improves considerably to meet the demand and negate the effects of chemical fertilizers and pesticides on the environment.

2.5 Technology diffusion

The technology diffusion mechanism for the agricultural sector in the country is through the National Agricultural Research Systems (NARS) of the Indian Council of Agricultural Research (ICAR). Well-developed, funded, and staffed agricultural research programs are crucial if farmers are to be more productive and prosperous in the future. With public sector investments decreasing since 1990s (Table 5), the quality of extension service has been very poor and often non-existent. According to a Planning Commission review, the low productivity since the 1990s has been due to weakened support systems and more importantly, due to a non-responsive agricultural research, broken down extension and inadequate seed production, distribution and regulation. The involvement of the private sector research in the agricultural sector has concentrated on few crops and emerging areas of biotechnology and seed industry where the profit levels are high. The drawback of the current system is, that it benefits only a handful of large farmers while the

[1] *Agricultural Innovations and Market Reforms for Food and Nutrition Security, Assocham, 2010*

majority consisting of the small and marginal farmers are not able to benefit from the new agro-technologies. Together, this is a total breakdown in the agro-technological support systems for the farmers.

Table 5: Growth rate of public expenditure in Research & Extension (1960-2005)

Period	Growth rate of Public Expenditure in	
	Research & Education	Extension & Training
1960	6.5	10.7
1970	9.5	-0.1
1980	6.3	7
1990-2005	4.8	2

Source: Balakrishnan, Golait and Kumar (2008)
Note: For Extension and Training, figure for 1980 is for 1980-84

The technology system has not been able to make any new breakthrough in agriculture since the Green Revolution (Economic Survey Report, 2010). With the farming landscape is changing to include more number of fragmented landholdings comprised of small and marginal farmers, technological advancements are urgently required that are specially suited to the new conditions.

2.6 Subsidies and Investment in Agricultural R&D

It is a matter of concern that since the late 1980s there has been a decline in the public investments made in the agricultural sector, while there has been an increase in the input subsidies-on fertilizers, power and irrigation. As a result the gap between investments and subsidies has widened to such an extent that subsidies amount to five to six times that of the public investment in agriculture. This has had a negative impact on the growth in the sector. The fiscal crisis of 1991 that led to the liberalization of the economy also led to a scenario of lesser investment in agriculture by the Government. Agriculture being a state subject, each state government decreased their investment in the sector due to paucity of funds. A complimentary increase in the private investments has not been fully able to compensate the loss from falling public investment. Without adequate public investment, it has not been possible to improve the infrastructural requirements in irrigation and other facilities that helped in boosting productivity in the 1980s. This in-turn led to lower yields and productivity from the sector. As can be seen from Table 6, Gross Capital Formation (GCF) in agriculture as a share of agricultural GDP, began to decline from the early 1980s and continued to decline in the 1990s. In the 2000s, the share began to rise, settling at 12.5 per cent of the agricultural GDP in 2006-07. Public investment as a share of agricultural GDP, began to decline from the early 1980s and continued to decline in the

1990s up to 2004-05 and showed a moderate improvement since then; in 2006-07, the share was 3.7 per cent, which was still considerably lower than the share for the early-1980s.

Table 6: GCF in agriculture as share of GDP from agriculture (1980-2007)

Period	GCF in agriculture as a share of agricultural GDP		
	Public sector	Private sector	Total GCF
1980-81 to 1984-85	5.0	5.5	10.5
1985-86 to 1989-90	3.5	5.2	8.7
1990-91 to 1994-95	2.4	5.9	8.4
1995-96 to 1999-00	2.0	5.9	7.9
2000-01	1.8	7.8	9.6
2001-02	2.0	9.1	11.1
2002-03	2.0	9.8	11.8
2003-04	2.1	8.0	10.2
2004-05	2.8	8.3	11.1
2005-06	3.2	8.5	11.7
2006-07	3.7	8.9	12.5

Source: Ministry of Agriculture, Govt of India

Private investment in agriculture by farmers and the private sector after stagnating in the 1980s rose moderately in the 1990s and more rapidly in the 2000s. While the rise in private investment in the 1990s was insufficient to compensate for the fall in public investment, the rise of total investment in the 2000s was aided significantly by the growth in private investment.

There has also been a drastic reduction in the public sector R&D investment that resulted in technology, extension and production fatigues. India has one of the most complex and largest agricultural research systems in the world. A proactive approach by the Government in 1966 towards the sector, aided with an active scientific community and donors could launch a successful campaign to meet the food requirements in the country, thereby making the country self-sufficient in not only food grains, but also a leading producer for other crops. However, the recent trend of increasing subsidies has had an adverse impact on R&D sector as they compete with limited funds that are available for public investment.

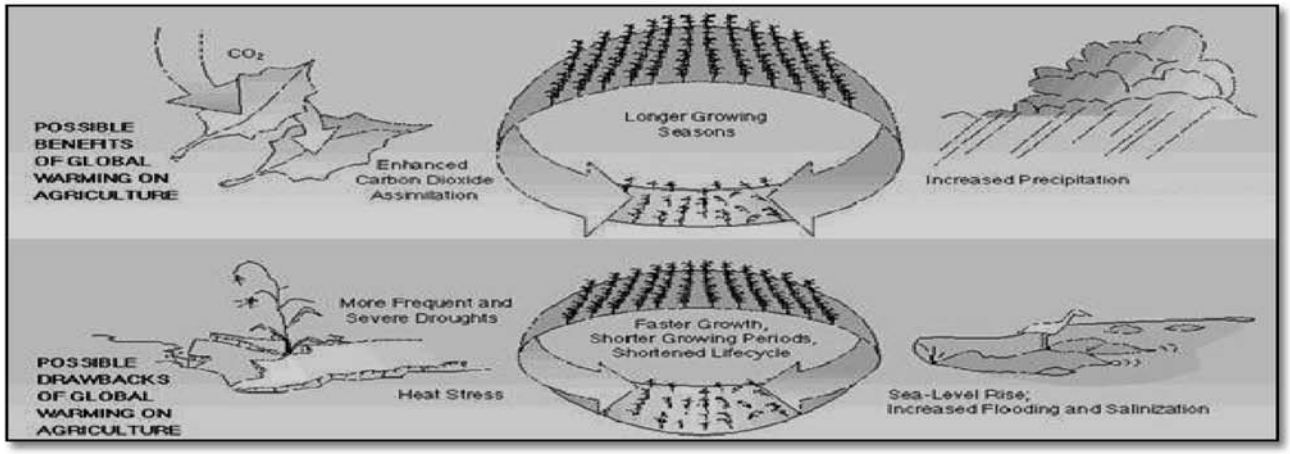
Research done by the International Food Policy Research Institute (IFPRI) in many countries, and recently in Africa shows that investments in R&D have the highest impact on agricultural growth per million rupee invested. The rates of return have been as high as 60 percent in research and over 50 percent in extension. India currently invests only 0.5 percent of its agricultural GDP in R&D. It is 0.7 percent in other developing countries, while China invests close to 1 percent

and it is two to three percent in the developed countries. This shows that the Government has been under-investing in the sector that can offer high social returns, besides scope for diverting incremental outlays to priority areas in research.

2.7 Climate changes

The Inter-Governmental Panel on Climate Change (IPCC) has projected that by the end of this century, global earth temperature is likely to increase by 1.8o to 4.0°C. This would lead to more frequent hot extremes, floods, droughts, cyclones, and recession of glaciers, not to mention the loss in agricultural revenue. Some of the possible effects of climate change are indicated in figure 1. Dynamics of pests and diseases would be significantly altered. The productivity of crops will be affected and the projected increase in these events will result in greater instability in food production and will threaten the livelihood security of the farmer.

Figure 1: Possible changes in agriculture due to climate change



Source: Scientific American, March, 1994.

Climate change alters temperature and precipitation patterns that directly affects crop production and has indirect effects through changes in the availability of irrigation water and evapo-transpiration potential. The drought in 2009 is a recent example of how climate changes can affect the agricultural production in India and threaten its food security. Table 7 shows the effect of climate change on yield of important cereal crops under different climate change models.

Table 7: Effect of climate change on important cereals

Crops	No climate change (Kg/ha)		With Climate change (%)		
	2000	2050	Hadley	NCAR	CSIRO
Maize	1869	2384	-1	-5	-4
Millet	801	1685	0	-3	-3
Rice	2070	3151	-10	-20	-11

Sorghum	799	1407	0	-3	-2
Wheat	2503	6432	-50	-56	-50
Other grains	1721	3399	-5	-4	-4

Source: ADB 2009; CSIRO = Commonwealth Scientific and Industrial Research Organization, NCAR = National Center for Atmospheric Research

Producing enough food for increased demand against changing climate scenario is a challenging task for agricultural research. The heat sensitive irrigated crops like rice and wheat will lose the productivity potential unless drought and heat tolerant variety are not adopted by the farmers to reduce the risk of climate change. Wheat and rice are very much affect by climate change in India when compare to other dryland cereals like maize, millet and sorghum. The dryland cereal crops have a very good potential in the changing climate with increased temperature and reduced rainfall.

2.8 Food insecurity

As per the currently available estimates, there are ample stocks of food grains in the central pool. Currently, the grain stocks are touching a record 60 million tonnes, more than double the buffer norms of around 22-25 million tonnes set by the Government. The central pool stock of wheat as on July 1, 2010 was 33.58 million tonne and rice was 24.26 million tonne. In spite of this, the food grain stock at many of the warehouses are rotting and not being dispatched to the poor and needy. With yet another bumper yield expected for *kharif* of 2011, the situation will worsen if the distribution channels are not improved. Compounding the issue of food security is that of nutritional security. Despite impressive accomplishments in producing food grains, even after over 60 years of independence, India has the dubious distinction of having one of the highest prevalence (over 50 percent) of under-nutrition in the world[2]. Nearly half of the population suffers from chronic mal-nutrition. The most vulnerable sections of the society are children, women and the elderly, especially among the lower income groups. Estimates show that:

- About 40 percent of the undernourished children in the world are in India, although India accounts for less than 20 per cent of the children in the world.
- There has been declining calorie consumption, especially in the bottom 30 percent of the population, which may be due to poor access/purchasing capacity.
- Over 50 percent of preschool children and 30 percent adults are undernourished.
- Over 70 percent of women and children suffer from anaemia.
- Every third child is born with low birth weight, and may have impaired mental and physical development and immunity.

[2] *Indian National Science Academy (2009), 'Nutrition security for India–Issues and way forward'.*

- Almost 60 percent of deaths due to major infectious diseases are caused by coexistence of mal-nutrition.
- Over 10 percent Indians are overweight or obese, the incidence being almost 20 percent in urban areas.

2.9 Agricultural value chain

The value chain starts from the farmer and ends with the consumer. Processing, storage, transport, marketing and retailing services add value to the produce. A typical value chain consists of the following levels:

The traditional value chain in the country has about four to six levels between farmer and the consumer; fruits and vegetables would have more since the production level/volumes being traded at lower levels will be very low. This is much more than the supply chain in developed countries. A CII-McKinsey report indicates that while it is common to have up to six intermediaries in the fruit and vegetables chain in India, there is just the wholesaler and retailer in the US supply chain. Similarly, there are at least two intermediaries between the wheat farmer and the flour mill in India when compared to just one in the U.S. The length of the marketing chain stems partly from the need to consolidate supplies. Such assembly happens at the village and district level as the supplies find their way to the wholesale markets. Linking each of the levels are the various modes of transport.

The length of the supply chain has its own effect on a perishable commodity like agriculture. Not only does the cost gets added onto the produce, the loss arising due to handling and processing and poor post-harvest infrastructure is as high as 25-30 percent. As a result the farmer's share in the consumers rupee goes down as it is diverted to meeting the expenses of the intermediaries.

The inefficiency of the supply chain further exacerbated by poor storage infrastructure has led to a grim situation: on the one hand, the farmers produce record food grains, on the other hand, the food grains collected from the farm lands are left to rot in the storage units. Hence, costs of the basket of essential food items has increased by 30 percent to as high as 200 percent (the recent onion crisis) leading to food shortage crisis. In India, people spend more than twice the proportion of their income on food than UK residents - paying the equivalent of £10 for a litre of milk and £6 for a kilo of rice[3]. This is occurring at a time when there has not been much change in the income level, leading to lower purchasing capacity, thereby resulting in low levels of per capita calorie consumption and declining/stagnating consumption levels. Better infrastructure

[3] *Growing a better future (2011), Oxfam*

and supply chains aided with proper processing units would help in taming the inflationary prices. It is, therefore, imperative that the supply chain is improved so as to enhance the shelf-life of the product while adding value to the produce so that the excess stocks can be exported to other countries and help in realizing better prices. The Government's response has been to increase production and initiate technological and financial recourse in the sector.

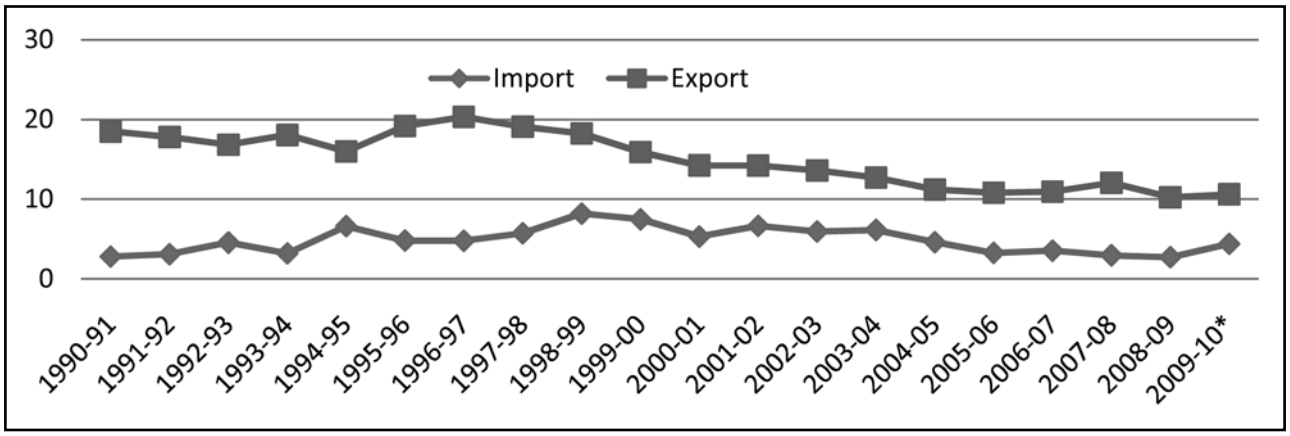
With the opening of the economy in 1991 and advent of globalization and the IT revolution, India is no more insulated from the shocks occurring in the world economy. The integration of the domestic and international markets led to an influx of agri-commodities into our market that led to lowering of prices. At the same time, since the cost of cultivation increased, the Government had to shield the farmers from this imparity through high subsidies. The volatility of prices in international markets was also seen in highly imperfect and monopolized market environment of our country. Even though IT has transformed the economy of the country, it has so far not helped in improving the agricultural landscape and removing the information asymmetry and lack of price discovery in the sector. Due to the volatilities in the external markets, uncertainties in cultivation increased and misleading price signals on specific crops was also noticed, leading to adoption of economically unviable and ecologically unsuitable cropping patterns (box 1). The uncertainties extended to the sub-sectors also.

Box 1: Volatility in Pricing and Market Information

The rapid adoption of vanilla crop in upland Kerala was due to the increasing prices for vanilla at a time when prices of all the other major crops grown in the region were falling. The domestic price of vanilla which in 1995-96 was '2,000 per kg touched '8,000 per kg in 2001-02. During 2002-04, the domestic price shot up to '15,000 per kg. The rise in the prices was due to a fall in production of processed vanilla due to a cyclone in Madagascar. Once the production resumed and increased in Madagascar by June 2004, the vanilla prices fell sharply to '1,618 per kg in January 2005. Many farmers, who had replaced their coffee plantations with vanilla, were left helpless as a switch-back to coffee would have involved another gestation period of at least 3 years.

One advantage that was expected to be generated through the economic liberalization was that the agricultural sector would be revitalized by the prospect of exports of agricultural produces, and that farmer producers will be able to generate better returns. However, this has not been the case so far (graph 7). In fact, since the economy opened up in 1990, the percent contribution of the agricultural sector to the national export has been declining (by 25 percent as of 2009-10 against 2001), more prominent since the post-WTO reforms of 1996. At the same time, the imports have been steady during the same period.

Graph 7: Export-Import Scenario in Agricultural Sector (1990-2009)



Source: Agricultural Statistics at a Glance, Ministry of Agriculture;-figures for 2009-10 are projected*

The reasons for these trends could be that the national export (which has been growing) has increased proportionately or that the exports are not meeting the requirements- in terms of quality, processing, product of the targeted market. This will have a backward effect on the farmer who will plan for cultivating high value crops to earn better foreign exchange. Without adequate technical and scientific backstopping, infrastructural facilities and a volatile price market, this is a considerable risk that the farmer will be undertaking.

Although, the imports have been low during the period, it has led to lowering of the prices of many agricultural commodities. It has also led to dampening the productivity of certain crops like soya bean that was promoted widely under the Technology Mission in the late 1980s. As mentioned earlier in this section, this led to an increase in the area under cultivation of soyabean only for it to be stagnant with the import of soya bean, thereby also lowering the price of the produce in the local market.

★★★

Pathways to the Evergreen Revolution

CHAPTER 3

With over 17.5 percent of the world's population sustained by a meager 2.5 percent of the total global land, Indian agriculture has come a long way since the Green Revolution of the late 1960s. The evolutionary changes brought about by it helped the country in warding-off the specter of famines and ensuring the food security of the nation. It transformed the country from a begging bowl to a net exporter of food grains. Even now our buffer stock of grains is much more than the prescribed limits.

The opening of the economy and the trade liberalization regime change brought about new challenges and opportunities for the country. The focus shifted from agriculture to more technologically intensive and services sectors that have helped the country to achieve the status of an emerging superpower along with China. However, the complexities and the sheer magnitude of dependence on the agricultural sector by the economy and the population have led to a situation where another revolution is urgently needed so as to sustain our livelihoods and boost the productivity of the sector. While the first revolution focused on production, the next green revolution should focus on improving productivity by utilizing the advancements in technology, from the limited asset of lands and decreasing natural resources without harming the ecology. In a nutshell, the next big thing in Indian agriculture should be an evergreen, sustainable revolution. It should not be evolutionary but a carefully planned activity.

It should protect the gains made in the first revolution, spreading across the country especially in the rainfed areas where the agricultural production can be increased. Unlike the first revolution, the next effort will have to incorporate both the public and private sectors along with the civil societies to realize the benefits of the revolution.

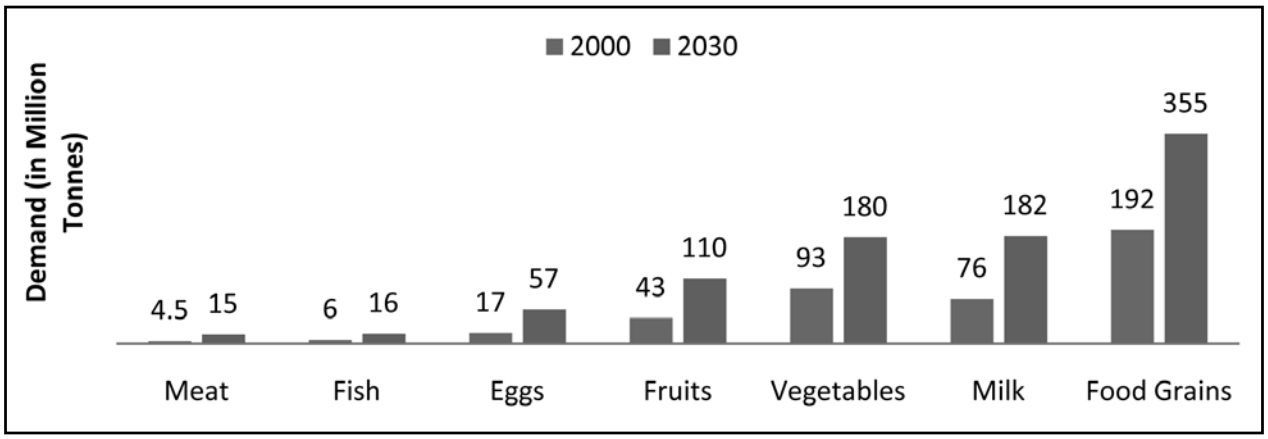
The section provides an overview of the how the second green revolution will have to include different stake-holders and sectors of the economy to ensure impact and success. Market-orientation resulting in linking the farmers to the markets should be considered. Most importantly, value-addition linked to entrepreneurship development will drive the second green revolution where the food processing industry should play a major role. Focus needs to be shifted towards other crops and coarse cereals that have more relevance in today's scenario of climate change, and changing consumer demands for food products delivering "health beyond nutrition". Post-harvest management and related infrastructure, such as warehousing, terminal markets, food parks etc., to enhance the value chain of farm produce and infrastructure for promoting research and development are key to success of the second green revolution. Entrepreneur development through business incubation and the role of business incubators is an important component

that will have to be considered. Last but not the least, the role of the government in terms of appropriate polices and incentives in prompting and integrating all the key players shall decide the path to success for the second green revolution, and bring about the desired prosperity across all segments of the society. In summary, the second green revolution needs to be based on an "inclusive and market oriented" approach.

3.1 Food and Nutritional Security

The demand for food and processed commodities is increasing due to growing population and rising per capita income. Chand (2009) estimates an annual growth in per capita income by more than seven percent and population growth of 1.2 percent. There are projections that demand for food grains would increase from 192 million tonnes in 2000 to 345 million tonnes in 2030 (graph 8). Hence, in the next 20 years, production of food grains needs to be increased at the rate of 5.5 million tonnes annually. In fact, the demand for high-value commodities (such as horticulture, dairy, livestock and fish) is increasing faster than food grains, and its demand is expected to increase by more than 100 percent from 2000 to 2030.

Graph 8: Projected food production demand at 2030 vis-a-vis 2000



Source: ICAR Vision 2030

India presents an interesting scenario: both GDP and food grain production in the country have risen faster than the growth in population over the last 50 years which would mean that there should be no cause for food security. But malnutrition, poverty and hunger exist in the country. According to FAO statistics, it is worse than those experienced in sub-Saharan Africa. A primary reason attributed to this anomaly is the failed distribution system and pathetic post harvest infrastructure that has led to grains rotting and not available to the poor and needy. The cropping pattern also needs to undergo a transformation. Over the past sixty years, with the advent of the Green Revolution, the country has had a fixation with production of wheat and rice, while neglecting other coarse cereals (that form the staple food of the bottom of the pyramid) and pulses (both rich in proteins and minerals).

The next Green Revolution should, therefore, focus on ensuring food and nutritional security to the Indian populace especially the below poverty line (BPL) population which constitutes around 28 percent of the Indian population. There is a need to ensure collaboration between nutrition scientists and agriculture scientists to ensure nutritionally-oriented cropping pattern and production technologies.

- **Food and nutritional security**

Optimal nutrition is crucial to health and human development. India faces several major health problems arising from nutrient deficiency, including chronic energy deficiency, kwashiorkor, marasmus and micronutrient deficiencies such as goitre, beriberi, Vitamin-A deficiency and anaemia. While the country has taken up several initiatives to improve nutritional status of the population during the last five decades, several challenges remain. In the last five decades, the mortality rate has come down by 50 percent and the fertility rate by 40 percent, while the reduction in mal-nutrition is only 20 percent. Around half of the pre-school children suffer from under-nutrition. Micronutrient deficiencies are widespread; more than half the women and children are anaemic; reduction in Vitamin-A deficiency and iodine deficiency disorders (IDD) is sub-optimal. Under-nutrition associated with HIV/AIDS will soon emerge as a public health problem.

According to the Planning Commission report, India needs to produce an extra five million tonnes of food grains annually and increase the production of livestock, fish and horticultural products to meet all the nutritional needs of the growing population. It is a formidable challenge given the shrinking arable land and farm size, low productivity, growing regional disparities in productivity and depletion of the natural resource base. In addition, appropriate steps have to be taken to minimise the potential adverse consequences of globalisation on domestic production, employment and price stability of food commodities.

India needs an agricultural growth rate of 4.0 to 4.5 per cent to reduce poverty and food insecurity significantly (Rao and Radhakrishna, 1997). This cannot be achieved single-handedly by the public sector alone, given the large scale infrastructure required and considering that private players have already forayed into fisheries, horticulture and dairy. Private sector can be encouraged to invest in limiting post-harvest losses and ensuring quality of produce by establishing supply chains, cold storages and ware houses where required.

Private sector is a key partner in advancing the nutrition and food security goals. Following are some key considerations for the involvement of private sector:

- Engaging the private sector in planning and execution of nutrition and food security initiatives can increase the success rate. Private sector should be involved systematically and early in developing strategies and plans to address nutrition and food security issues.

- High levels of trust and transparency will be required for successful public-private partnerships.
- Private sector's contribution to food security and nutrition needs to be well documented with case studies and best practice models.

Private sector activities that can improve food security and nutrition could include:

- Investing in research and development that leads to new products, practices, and other innovations that enhance the food system.
- Building economies of scale, marketing (including social marketing) and communications to promote positive nutrition messages.
- Sharing expertise in supply chain logistics, distribution channels.
- Supporting the development of strategic infrastructure: ports, roads, storage etc.
- Raising global standards, including standards for product quality and food safety.
- Sharing perspectives, experiences and, technical expertise.
- Investing in farmer, especially smallholder, education and training, and promoting free trade to ensure open access to markets.
- Creating distribution channels for the delivery of fortified and other high-quality foods.
- Responding to gaps and priorities identified by NGOs, governments, and others.
- Conducting market assessments that lead to price discovery.
- Developing risk management tools.
- Convening individuals and organizations to find common ground or to advance shared objectives.
- Making capital investments and providing other forms of financial support.

3.2 Environmental Sustainability

India is witness to the ramifications of agricultural practices unmindful of environmental concerns. A state like Punjab, where intensive irrigation and fertilisers were used during the first green revolution is facing the challenge of lands degraded due to water logging, salinity, and excess presence of fertilisers and pesticides. The agriculture patterns adopted in the past decades have harmed the environment and exacerbated poverty and food insecurity among rural people, even as agriculture has met national food needs and contributed to export earnings. In order to ensure that this trend is reversed and agriculture contributes to economic prosperity along with environmental sustainability, the second green revolution needs to pay special attention in dealing with the climate change, fertiliser and pesticide application and its impacts.

Climate change has already taken its toll on agriculture through unexpected floods and draughts. The (IPCC) Third Assessment Report (2001) concluded that the poorest countries would be

hardest hit, with reductions in crop yields in most tropical and sub-tropical regions due to decreased water availability, and new or changed insect pest incidence. It has projected that by the end of this century, global temperature is likely to increase by 1.8° to 4.0°C that could lead to frequent extremes of temperatures, floods, droughts, cyclones, and recession of glaciers. The projected increase in these events will result in greater instability in food production, thereby threatening the livelihood security of the farmer.

Producing enough food for increased demand against the background of changing climate scenario is thus a challenging task for agricultural research. One of the major reasons for the stagnated production of foodgrains in India is weather aberrations. During the severe drought years of 1972, 1979, 1987, 2002 and 2009, the *kharif* foodgrains production was adversely affected to a considerable extent, while the drought in 2009 is a recent example of how climate variability can threaten food security in India.

Agriculture is the process of using natural resources like soil, water, air and sunlight to produce a consumable product (e.g., food, fuel and fiber), while maintaining sufficient resources for the future generations. Agricultural production systems in future need to be sufficiently flexible to respond to climate variability and change, declining natural resources, uncertainties in global markets and to changing political and population demands. The next revolution faces a formidable challenge in anticipating the impact of climate change on agriculture and adapting its interventions accordingly (e.g., using less water intensive crops). Coping with climate change is coping with biotic and abiotic stresses. Adaptation strategies based on crop and cropping system based approaches like selection of suitable climate change tolerant varieties, crop rotations, intercropping, integrated pest management and agroforestry have a great role to play in sustainable rainfed agriculture. These strategies need to be linked through resource conservation and management measures like rainwater harvesting and recycling, *in situ* moisture conservation, efficient use of irrigation water, zero tillage in irrigated areas, enhancing energy efficiency in agriculture and conservation agriculture.

- **Designing interventions with adaptive capacity**

➢ The second green revolution needs to identify production systems most resilient to climate variability, i.e., the ability to adjust to or recover from negative impacts and take advantage of positive impacts of the current climate variability. This includes two strategies:

  - *Increased diversification:* including activities that are less sensitive to drought and/or temperature stresses and activities that take full advantage of beneficial climate conditions, and
  - *Escaping sensitive growth stages:* establishing crop practices that avoid the concentration of sensitive growth stages in the same period of the year (e.g., different season lengths, sowing dates, etc.).

- Another pathway for increasing resilience is by eliminating the climate-related factor that is most limiting to crop productivity (e.g., introducing irrigation in water-limited summer crops).

To enhance productivity in the sector, the dryland and rainfed areas need to be brought under the intervention of aggressive farming activities during the next revolution. Since water is the main limiting factor in pursuing such activities in these areas, watershed management is now an accepted strategy for the development of rainfed agriculture. Watershed approach has many components that help both in adaptation and mitigation (Box 2).

Box 2: Consortium Model for Integrated Watershed Management

Watershed, a land unit to manage water resources is also a logical planning unit for sustainable resource management. Conventional watershed approaches in the past focused only on soil and water conservation measures. An innovative model with a consortium of institutions was developed by ICRISAT for project implementation and technical backstopping following the Integrated Genetic and Natural Resource Management (IGNRM) approach. This consortium was composed of non-governmental organizations, national and state / province governments, agricultural universities, national research institutions, advanced research institutions and farmers' groups. The model is targeted to deliver tangible benefits equitably amongst community members, improving community participation from the initial stages up to monitoring and evaluation for achieving sustainable development, and water management is used as an entry point for improving the livelihoods of the people through empowerment and knowledge sharing. ICRISAT facilitated the formation of consortium, undertook strategic research in interdisciplinary mode and took lead in capacity building of stakeholders.

Integrated Watershed Management (IWM) comprises of improved land and water management, integrated nutrient management including application of micronutrients, improved varieties and integrated pest and disease management and substantial productivity gains and economic returns have been obtained by farmers. Widespread deficiency (among 80-100% of fields) in micro and secondary nutrients (zinc, boron and sulfur) has been observed in the farmers' fields in the Indian States of Andhra Pradesh, Gujarat, Rajasthan and Karnataka. Application of micronutrients resulted in a 20-80% increase in yield of several crops, which further increased by 70-120% when micronutrients were applied with adequate amounts of nitrogen and phosphorus. Watersheds have improved groundwater, reduced runoff and soil loss. Use of locally available organic manures like farm yard manure, *pongamia* and *neem* cake, vermicompost generated through recycling of left-over residues, green leaf manures like *Gliricidia* raised on the field bunds in the watersheds in conjunction with inorganic supplement the nutrient requirement of the

crops. Application of these organic manures resulted in improvement in soil physical properties like water holding capacity, soil structure and thereby increased the rainwater and nutrient use efficiency.

Since the climate change is likely to enhance the frequency of occurrence of droughts, basic goal of watershed management is to improve livelihood security by mitigating the negative effects of climatic variability while protecting or enhancing the sustainability of the environment and the agricultural resource base (Box 3). Integrated Watershed Management has been identified as the engine for sustainable agricultural production even in the projected climate change scenarios.

Box 3: IWM for Reducing Impacts of Drought

At Kothapally, Ranga Reddy District, Andhra Pradesh, crop and household incomes were generally higher in 2001 than in the drought year 2002. In the normal year 2001, crop incomes constituted about 36% and 44% of household income in Adarsha watershed and in the non-project villages, respectively. In the drought year 2002, crop income for the non-project village declined by 80% while it declined by only a third in the project village. Hence, the contribution of crop income to household incomes in the non-project villages declined to a mere 12% while it remained unchanged at about 36% in the project villages. This was largely compensated by increased migration and off-farm employment in the non-project villages, where the share of off-farm income increased from about 50% in 2001 to almost 75% in 2002. This shows how IWM has contributed to stability of crop income in the watershed despite the serious drought conditions in 2002.

Climate change is now considered as one of the greatest challenges facing humanity that impacts agriculture in many ways. Future research is aimed at improving resilience of agricultural systems to climate variability and change through developing crop varieties that emit reduced greenhouse gases and with resistance to abiotic and biotic stresses.

Strategies aimed at increased agricultural production, greenhouse gas reduction and increased ecosystem services also need to consider a balance between crop intensification and extensification. High intense rainfall leads to excessive removal of fertile surface soil. Soil degradation by depletion of nutrients and soil organic carbon pools is further worsened by extractive farming practices.

Appropriate organic amendments need to be developed for subsistence rainfed farmers for improving soil macro and micro-nutrients and water-holding capacities. Projected climate change is likely to bring changes in the dynamics of crop pests and diseases. Integrated pest and disease management strategies are to be improved further such that socially sustainable management practices can be promoted and practiced widely.

Weather climate services play a crucial role in climate change assessment and developing suitable adaptation strategies for climate resilient agriculture leading to the Second Green Revolution. Adaptation research which is more region and location specific, while national level efforts are required to come up with cost effective mitigation options, new policy initiatives and cooperation.

In order to mitigate the emissions from agriculture, the measures to be adopted may include:

- Energy conservation and efficient production.
- Increasing fertiliser use efficiency.
- Creating and targeting laws and regulations pertaining to climate mitigation measures.
- Intensifying ecological/ organic agriculture in highly intensive production areas.
- Enhancing development and transfer of new eco-based technologies.

3.3 Technology Approach

3.3.1 ICT and Agriculture

Farming is an important part of Indian economy and it involves a wide range of stakeholders, of whom the small holder farmers are the largest group. Information sharing on new production processes with the farmers was prominent in the 'sixties which was the key to the success of the Green Revolution. Agricultural extension, the process of enabling farmers and experts to exchange information with each other, has been institutionalized by now to a high degree and is assessed to be not as effective as it had been a generation back. The advent of digital, technology-mediated information and knowledge management was thought to offer significant new opportunities for Indian farming as a whole. These hopes led to the launching of a host of initiatives in different parts of India, which has emerged as the host of the largest number of rural development projects where contemporary information and communication technology play a pivotal role. While analyzing the outputs of such initiatives, many studies have pointed out that farming is not a priority concern of most of them. On the other hand, we can notice a non-complimentary strand of ICT in agriculture projects operated by a number of institutions with ICT resources playing a key role in some of them.

Almost two decades later, the original hope remains unfulfilled. The availability of digital content in relation to the farming sector is small when compared to equally important development sectors such as public health. This has considerably limited the opportunities for various stakeholders to build viable online services on production, marketing and meteorology for farmers and other stakeholders.

What we now have is a collection of project activities that are fragmented in their overall understanding and approaches. What we need is an approach that can bring together the two strands, namely, of ICT in rural development and ICT in agriculture. Such an effort, however,

needs a new IT architecture to be built for aggregation of content and to make services available in multiple modes. Two groups of projects in India, namely, the Agropedia and the KISSAN-Kerala, have built large prototypes and human capacities using unprecedented innovations in web technology areas and have been able to link these up with different modes of delivery including mobile telephony. With their advent, a wider range of solutions to the challenge of developing a novel architecture for information services for farming in India are now feasible and need to be researched upon.

Given that countries that offered models for extension in farming in an earlier generation do not require innovations for mass outreach for prosperity through farming, India needs to build solutions, processes and structures of its own so that the advantages accruing from its export-oriented IT sector can flow to the benefit of its farmers. There is a task to be accomplished, contrary to the prevalent understanding in the leadership of farm education, research and extension sector that all the ICT solutions needed are available.

Technology will drive the future growth in Indian agriculture. In order to push the frontiers of productivity, generation and harnessing of state-of the-art agricultural technology becomes inevitable. India currently uses technology of the first green revolution era which is seed-fertiliser intensive. Plant breeding techniques have been extensively used in agriculture to develop high yielding varieties for drastic improvement in production. Similarly crop improvement technologies, crop protection technologies and machinery-based technologies are used. The common technology outreach mechanism used still continues to be agricultural extension services of agriculture departments and universities. Recently many states have also introduced IT based outreach mechanisms. The private sector has a vital role in filling up the void of the extension services. Using the technologies developed at the research stations and other agro-research companies, the sector can become the bridge that connects the farmers with the knowledge bodies and the market.

While it is widely agreed that technological innovation is the engine of modern agricultural productivity improvements; however it is important to ensure that socio-economic and environmental impact of technology are not detrimental to sustainable agricultural/economic development. There is an urgent need for evaluation of current agricultural technologies of the country for the externalities generated by them. In view of this understanding, the next revolution must focus on developing sustainable technologies that are consistent with the preservation of the environment and promote the socio-economic well-being of both current and future generation.

3.3.2 Markets and Farmers centric Agricultural Technology Development

Improved agricultural technology – seeds, soil husbandry, crop management practices, pest and disease control, water management, food processing and new methods of technology

transfer- is a key driver for agriculture. Although, major investments have been made to support technology development and transfer, impacts have only been partial. Lessons from across Africa and Asia show that the effectiveness of agricultural technology generation and dissemination institutions depends crucially on their relevance and responsiveness to farmers' and markets' needs. ICRISAT advocates an inclusive market oriented development in a systems perspective focusing in increased incomes, stakeholders' inclusiveness and sustainable resource utilization and management in agriculture technology management where in the farmers and market preference for the technology is critical. To achieve this, new approaches – along with new technology options and new players, particularly the private sector and harnessing the synergies among partners is the key.

Market requirements and farmers' preferences are highly dynamic. The level of knowledge, financial health, cultural changes in farmers and consumer play a crucial role in orienting the technology development. For example, minor millets were close to extinction in the consumer's food basket in most countries till recently. However, with increased awareness on nutritional and health benefits of millets, more and more consumers are shifting towards millet consumption, or at least adding millets in to their food baskets. This calls for a push for millet production for which an appropriate millet production technology development is a prerequisite. Similarly, climate change poses major challenges for crop production with predicted increase in temperatures and increased rainfall variability. Forage cultivation is an important option, particularly for agriculturally most difficult areas considering the ability of forages to withstand various biotic and abiotic production constraints and the new market potential for fodder with rising demand for dairy and meat products in most of the developing countries. Therefore, climate change and markets will drive the technology development in the years to come.

Components of market driven technology development

Making agricultural technology generation and dissemination relevant to the needs of farmers – particularly the poorest and those in complex, risk-prone environments – is a huge challenge. Over the past two decades, shifts have begun away from technology transfer approaches towards more people-centered research and development. Participatory varietal selection (PVS) involves farmers in the process of choosing and testing new crop varieties as per their choices. Extension systems are being transformed, moving from top-down instruction towards farmer-to-farmer exchange and joint learning. The use of new information technologies is expanding, allowing information sharing between farmers. As a result, farmers are increasingly being seen as partners in the innovation process, rather than merely recipients of national and international research and extension. However, the present efforts are not sufficient and genuine empowerment of farmers is needed to ensure their meaningful participation in setting priorities for agricultural technology development.

How to make the market/farmer come first?

To accomplish this we need to make certain in the way we do things in agricultural technology development as follows:

- **Moving beyond the farm**

This requires taking an innovation systems perspective. Empowering farmers to become active players in an increasingly globalized system, means-moving beyond the traditional focus on farmers and technologies to farmer relations with other actors through the markets. Participatory approaches are being used to: diagnose market chain challenges and opportunities, and facilitate change in market systems. New platforms for interaction between farmers, farmer groups and businesses are being created. However, there are winners and losers in this model: the challenge is in sharing potential benefits more widely among marginalized farmers. This means going beyond participatory diagnosis to addressing political, institutional and organizational change – changing the rules of the game to benefit the lowest segment of farming strata.

- **Organizing research and development**

Mostly, the standard technology transfer models are challenged in fundamental ways. The separation of basic centralized research from adaptive decentralized research is seen as inappropriate; whilst farmers - as users of technology and research – need to be involved throughout the research system as collaborators. Notable successes include:

- *Participatory varietal selection* – where farmers are involved in the early stages of research when objectives are set (priority setting), and decentralized breeding programs enable varietal selection with farmers in diverse local environments
- *Farmer Field Schools* – innovative programs in Integrated Pest and Disease Management improved understanding of innovation systems and factors influencing scaling up from the point of view of farmers, field practitioners and institutions. However, often farmer participation is an add-on to old style approaches, with the real research decision-makers unaccountable to users. This requires serious attention to the 'politics of demand' - where farmer organizations can play a key role.

- **Working with farmers' organizations**

Farmers are seldom involved in governance of research organizations, particularly in budget allocation and setting priorities for R&D – apart from often token consultations. Farmer organizations have a critical role to play in voicing demand for technology research and development. This call for a paradigm shift in the way farmers' organizations is involved in prioritizing the technology development to meet their requirements.

3.3.3 New technologies in agriculture

Since the days, some 10,000 years ago, when humans first began to save the seeds of one plant variety and discard those of another, they favored the ones that produced the plumpest grains, the earliest maturities, the highest yields. They also selected hardy specimens, varieties that could withstand the heat and the cold and all the blights that cursed and killed their crops. They were farmers, but they were also seed scientists, consciously transforming wild grasses into harvestable grains.

With an advent of modern biotechnological tools, his trend of innovation has become easier, by adopting integrated strategies that include breeding for resistance, the judicious use of biological, crop management and chemical control methods. With the growing population and ever-growing challenges of agriculture, the increasing productivity and income per unit of the scarce natural resources is possible only through understanding, integrating and deploying new advancements in science and technology in agricultural production. To address the emerging environmental challenges, it is projected to have the potential to provide large emerging agriculture centered economies in the developing countries (Romig et al., 2007). For a developing economy like ours, it therefore, becomes essential to use the well-established technology platforms by creating newer biotechnology and nanotechnology based solutions and industries. Emerging technologies can create competitive advantage and commercial success for farmers and agricultural industries as well as benefit rural communities (Sastry, 2009). Mapping research themes to specific sectors in the agricultural value chain will enable a rational assessment of the potential applications of biotechnology, genetics and nanotechnology in the agri-food sector by identifying and prioritizing research needs across the agricultural value chain, and assessing the societal implications of these emerging technologies.

Various high-yielding crop varieties released till date have contributed substantially to improving agricultural productivity. However, new biotechnological innovations have the potential to provide solutions by giving a make-over to the existing cultivated varieties. Availability of genome sequences of more and more crops, investigation of the alteration at transcriptomic, proteomic and metabolomic level, whole genome transcriptome sequencing, and RNA sequencing, are some essential biotechnological tools which can be exploited for crop improvement and enhanced production. Genetically engineered or "Biotech" crops have a great potential to bring about the second green revolution. India is currently working on 111 transgenic crop varieties of various vegetables, fruits, spices, cereals, bamboo etc. Several transgenic crops like brinjal, cabbage, castor, cauliflower, corn, groundnut, okra, potato, rice and tomato are under different field trials stages and moving ahead in the pipeline towards commercialization. Similarly, with the use of emerging technologies like bio-prospecting of novel genes from stress tolerant plants as well as other organisms and allele mining would help to combat the changing global climate. Such developments will help extend the crops to fallow lands, increase productivity and income, and

enhance sustainability of agriculture in some of the most deprived regions. Development of diagnostics and vaccines for animal diseases, technology development for fish breeding, advances made in identifying beneficial microbial and fungal populations, popularization of vermi-compost technology, development and dissemination of technology in a wide variety of agricultural and allied disciplines etc., are some of the other achievements in the area of biotechnology.

Similarly, among the recent advancements in science and technology, nanotechnology (NT) is fast emerging as the new science and technology platform for the next wave of development and transformation of agri-food systems (Roco, 2003; Kuzma and Verhage, 2006; Scrinis and Lyons, 2007), as well as to improve the conditions of the poor (Juma, et al., 2005). The need to maintain technological parity with global competitors is indeed a critical strategic issue for the agricultural and rural sectors in India. Some examples include development of electrochemically functionalized single-walled carbon nanotubes (SWNTs) and metal oxide nano-wires and nano-tubes for gases such as ammonia, nitrogen oxides, hydrogen sulfide, sulfur dioxide and volatile organics that would help to monitor agricultural pollutants, as well as to assess their impact on ecological health and in increase of crop productivity and reducing land burden (Mulchandani, 2009). Similarly, In Brazil Embrapa has developed nano-structured materials for toxin detection and water decontamination (Neto, 2009). This kind of initiatives can be looked upon as a guideline for strategic implementation in rural India.

UN survey on potential applications of nanotechnology in developing countries have identified agricultural productivity enhancement as second most critical area of application for attaining the Millennium Development Goals (MDGs) while energy conservation and storage was ranked first and water treatment as the third area needing focus. Nanotechnology can revolutionize agriculture and food systems security, disease treatment delivery system, new tools of pathogen detection, protection of environment and education of the public and future agricultural forces (Scott and Chen, 2003). It is essential that nanotechnology be extended across the entire agricultural value chain to increase agricultural productivities, product quality, consumer acceptance and resource use efficiencies (Kalpana Sastry et al., 2007). Development of smart sensors and smart delivery systems will help the agricultural industry combat viruses and other crop pathogens. Ongoing research in nanotechnology potentially promises availability of nano-structured catalysts that will increase the efficiency of pesticides and herbicides, allowing lower doses to be used for farm operations. Similarly, through the use of alternative (renewable) energy supplies, and filters or catalysts to reduce pollution and clean up existing pollutants, nanotechnology protects the environment indirectly.

Needless to point out that these emerging technologies need to be well complemented with a revolution in information technology, GPRS or remote sensing system which will become a key strategic resource, enabling farmers to better tailor their crops and management to their particular locales and conditions, extracting the most efficient use of the endowment they have

at hand. These technologies, undoubtedly have a potential to enhance agricultural productivity and food security. A strategic, complementary and powerful partnership between scientific researchers, Government and private enterprises is a timely approach towards the Second Green Revolution.

3.4 Consumer Demand, Value addition and Research

The Second Green Revolution needs to be inclusive. It needs to address the changing consumer aspirations, the emerging needs of the society, empower the farmers, and leverage upon the strengths of the available pool of talented young population, especially women, with entrepreneurial drive to bring in a self-sustaining economy linking agriculture with the markets.

The foundation of such a self-sustaining model has already been laid by the former President of India, Dr. APJ Abdul Kalam who proposed the revolutionary concept of PURA (Provision of Urban Amenities in Rural Areas). Indeed, this visionary concept has already chartered the path for the successful evolution and implementation of the "second green revolution" in India. In the words of Dr. Kalam "During the last few decades, we have achieved success in many areas. One of the primary accomplishments was the first green revolution. In parallel, India has made significant progress in many areas like space, IT, bio-technology, food processing, and banking. We have the challenge to bring out the second green revolution by doubling our food output, with the constraints of less land, less water and less manpower. The PURA Mission should focus on increasing agricultural productivity and value addition to agro-products and nurturing and promoting horticulture……"[4]

The new strategic plan to 2020 of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) reiterates its commitment to harnessing complementary and purposeful partnerships, through Inclusive Market-Oriented Development or IMOD[5]. IMOD serves as a dynamic progression from subsistence towards market-oriented agriculture. This pathway reduces poverty, since the markets create demand for a wider diversity of high-value foodstuffs and agro-industrial products. This stimulates agro-enterprises that raise rural incomes and create opportunities beyond agriculture. Smallholder farm families have to be empowered and assisted along this development pathway to lead them from pessimism to prosperity. A similar approach also needs to form the essence of the second green revolution.

[4] *"Abdul Kalam stresses on PURA mission". Daily News And Analysis (DNA), 6th February 2010 (URL of the article: http://www.dnaindia.com/india/report_abdul-kalam-stresses-on-pura-mission_1344075-all. Last accessed on 26th May 2011)*

[5] *"Strategic Plan to 2020 Inclusive Market Oriented Development for Smallhoder Farmers in Tropical Drylands", International Crops Research Institute for the Semi Arid Tropics (ICRISAT), 2011 (URL of the article: http://www.icrisat.org/newsroom/latest-news/one-pager/sp2020/sp-2020.htm. Last accessed on 26th May 2011)*

Thus, favourable policies that promote networking of farmer and farmers groups with different stakeholders in the value-chain, especially the private sector food processing industry, entrepreneurs and organisations that promote entrepreneurship development are the need of the hour. Important role of the food processing industry and value addition, entrepreneurs and entrepreneurship development activities and key infrastructure and policies will be required to drive the second green revolution.

3.4.1 Role of the food industry in the second green revolution

- **Changing consumers demands and the new age food processing industry**

In recent years, consumers have become more health conscious. This has led to demand for food crops and food products that can be consumed as a part of their daily diet. There is also the need in India, to address malnutrition and other deficiency diseases. In addition, very high rates of mortality occur due to coronary heart-diseases (CHDs) cancer and diabetes – all related to diet. Nutritional security, is thus a key issue which encompasses agriculture as well as the food processing industry. Health concerns are attributed to poor nutrition in low income segments of the population, whereas the affluent strata of the society need to address health issues that emerge from changing lifestyles and food habits. The neutraceutical industry is also growing as consumers demand for more healthy food products, which can take care of their health needs and prevent severe health conditions. It is clearly evident that the changing demands and habits of the consumers will be driving the growth of a new age food industry in India. The second green revolution needs to ensure that the farmers be part of the new age food industry. In addition to designer neutraceutical food products, the trend is also to obtain nourishment as well as prevention of chronic diseases through staple diet. Thus, keeping this in mind, the second green revolution should also focus on not just high yielding varieties of crops but also on varieties, which in addition to being high yielding and having insect and pest resistance, are also sources of micronutrients, antioxidants, bioactives etc., thereby having the potential to deliver "health beyond basic nutrition" to the consumers. Farmers growing these crops will be an integral part of the value chain of the emerging neutraceutical industry, and hence also reap the economic benefits associated with the neutraceutical industry.

- **Value addition**

The growth in the food industry can result in demand for more agricultural produce, both for fresh consumption as well as for convertion into different value-added food products. According to the Vision 2015[6], for the food processing India, of the Ministry of Food Processing (MOFPI) Government of India plans to treble the size of the food processing industry. The basis of this

[6] *"VISION 2015: Vision, Strategy and Action Plan for Food Processing Industries in India" Volume I. Ministry of Food Processing Government of India, 2005. (URL of the document: http://mofpi.nic.in/images/volume1.pdf. Last accessed on 26th May 2011)*

vision is the vast potential of the Indian agriculture.

Box 4: MOFPI Vision 2015

To realize the vast potential of Indian agriculture by trebling the size of processed food sector so as to enhance farmer income, generate employment opportunities, provide choice to consumers at affordable price and contribute to overall national growth by increasing:

- *the level of processing of perishables from 6 percent to 20 percent*
- *value addition from 20 percent to 35 percent*
- *share in global food trade from 1.5 percent to 3 percent*

This Vision 2015 (box 4) of MOFPI for the food processing industry can only be achieved by establishing a seamless linkage of the farming community with various stakeholders in the food processing industry. The second green revolution, in fact can be the backbone of a successful new generation food industry. In order to leverage on the opportunity to benefit the farmers by linking to the new age food industry, the farmers need to explore ways of value addition at the farm level by minimising post-harvest losses, equip themselves with improved post-harvest management technologies and practices, beside inculcating the entrepreneurial spirit in order to explore new business opportunities based on developing niche value-added products from their farm produce.

- **Nutri-cereals: an important component**

The focus of the first green revolution was wheat and rice, but the second green revolution needs to be inclusive with respect to the other crops with its objective to deliver "health beyond basic nutrition" to the consumers. The consumer demand for "health beyond basic nutrition" has shifted the focus to coarse cereals. There is also renewed interest for millets and sorghum in the present context of climate change, as they have the ability to grow under high temperature and drought conditions. Recently, the Government of India has announced an allocation of '300 crores in 2011-12 under Rashtriya Krishi Vikas Yojana for the promotion of millets as Nutri-cereals. A scheme on "Initiative for Nutrition Security through Intensive Millets Promotion (INSIMP) has been formulated to operationalize the announcement. The scheme aims to demonstrate the improved production and post-harvest technologies in an integrated manner with visible impact to catalyze increased production of millets in the country. Besides increasing production of millets, the Scheme through processing and value addition techniques is expected to generate consumer demand for millet based food products. The Scheme will be implemented from Kharif 2011[7]. Similar policies and schemes that promote both basic agricultural research as well as entrepreneurship around these coarse cereals should also be considered as part of the second green revolution.

[7] *Initiative for Nutritional Security through Intensive Millets Promotion (INSIMP) Operational Guidelines, Department of Agriculture and Cooperation, Minsitry of Agriculture, Government of India, 2011 (URL of the document: http://agricoop.nic.in/INSIMP.pdf. Last accessed on 26th May 2011)*

- **The new age food industry demand safe produce**

The demand for safe food needs to be implemented right from the farm level. Adoption of integrated food safety management systems is an important aspect that should be considered when framing the policies that will form the basis of the second green revolution. Identification and implementing ways of producing crops without indiscriminate use of pesticides and crops free of mycotoxins will go a long way in providing a new dimension to the second green revolution. However, the farmers will need support from the private sector food industry to understand and implement the industry requirements in order to deliver safe produce. India has already consolidated the laws relating to food safety under The Food Safety and Standards Act, 2006, whereby the Food Safety and Standards Authority of India (FSSAI) has already been established is responsible for formulating science based food standards and regulates the manufacture, import, processing, distribution, and sale of food[8].

3.4.2 Key support mechanisms

Value-addition coupled with entrepreneurial development activities must be an integral part of the "second green revolution". To integrate value-addition and entrepreneurship with the core agricultural sector, it is essential to identify the intervention points at each stage of the value chain and suggest suitable interventions to promote appropriate value addition, develop infrastructure and identify appropriate market opportunities through agro enterprise development. The following key areas need to be addressed:

- **Post-harvest and supply chain management**

One of the major problems that the Indian farmers are facing is the poor returns on their produce, owing to the highly inefficient supply chain, presence of intermediaries, low level of processing (2-15%) and huge post-harvest losses (20-30% in perishables). Storage and warehousing facilities is one of the key requirements that need to be addressed as part of the "second green revolution". With government incentive allowing 100 percent deduction for tax purposes[9] on the investment in warehousing for storing agricultural produce, efforts need to be made in engaging the private sector to invest in warehousing facilities, especially for promoting the coarse cereals and perishable produce.

Another important area which can initiate forward engagement of the farmers and buyers for production and supply of farm produce, thereby resulting in assured returns to the farmers and quality produce to the buyer is contract farming. Presently contract farming has been adopted by private sector for crops of commercial value. However, efforts need to be made to initiate contract farming into other crops such as sorghum and millets, demands for which are already growing in

[8] *Food Safety and Standards Authority of India (FSSAI), (URL: http://fssai.gov.in/)*
[9] *An Appetite for Growth: Opportunities in the Indian Food Industry, Ernest & Young, 2009.*

the food industry, and for which there is no organised market at present. The fruits and vegetable sector, which account for higher wastages in the traditional value chain can, tremendously benefit from contract farming. While the Government of India has been actively encouraging contract farming endeavours, the National Agricultural Policy envisages that 'private sector participation will be encouraged through contract farming and land leasing arrangements to allow accelerated technology transfer capital inflow and assured market for crop production.'

- **Development of terminal markets**

Terminal markets where the farmers can assemble and sell their produce to the end consumer, or to the processor, or the produce can be packed for export, or even stored for disposal at a future date needs to be developed. Again this approach needs to include all crops, and not just wheat and rice. The farmers and farmer associations need to be integrated into a model where the terminal markets are linked to the collection centres that can be developed close to the farms. It is worth mentioning here that the Government of India is looking to promote terminal markets, as a means of integrating domestic produce with retail chains. There are plans to set up such markets in eight cities across five states, at a cost of US$ 131 million.[10]

3.4.3 Research and Development and related Infrastructure for value addition

In the previous sections, it has been highlighted that the market value of farm produce can be enhanced through the development and promotion of value-added products based on proper scientific research and development. Presently, the private sector companies are leading this effort. Government research institutes and universities are more focused on developing basic technologies, but there is a need to develop technologies that are market-oriented and address specific needs of the farmers and entrepreneurs. The latest initiative of the Government of India in setting up the "National Institute of Food Technology Entrepreneurship & Management (NIFTEM)"[11] is a step in the right direction to address this important issue.

The NutriPlus Knowledge Program, an initiative of the Agribusiness and Innovation Platform (AIP) of ICRISAT (Box 5) is another such initiative which provides access to research and development infrastructure and facilities for entrepreneurs and farmers, especially to promote value

Box 5: NutriPlus Knowledge Program

Vision: *"Growth through Value addition" for the small holder farmers of the semi arid tropics.*

Mission: *Value addition and post harvest management in Agri food sector through innovative processing and product development for a prosperous food secure and resilient drylands.*

[10] *"High-tech agri markets coming soon". Agriculture & Industry Survey. February 1 2006. (URL of the article: http://www.agricultureinformation.com/mag/2006/02/high-tech-agri-markets-coming-soon/. Last accessed on 26th May 2011)*

[11] *National Institute of Food Technology Entrepreneurship & Management (NIFTEM). Ministry of Food Processing, Government of India.(URL of the article: http://mofpi.nic.in/content_printpage.aspx?categoryid=795. Last accessed on 26th May 2011)*

addition and food safety for entrepreneurship development based on the crops of the semi-arid tropics.

An important initiative taken by the Government of India to promote the food processing industry are the Food parks[12]. The government is considering investing US$ 22.97 million in at least 10 mega food parks in the country, besides working towards offering 100 percent foreign direct investment and income tax benefits in the sector. The second green revolution needs to leverage on such initiatives and also work towards identifying ways to promote these initiatives among the farmers and entrepreneurs.

3.5 Entrepreneurship in Agriculture

According to Joseph A. Schumpeter, entrepreneurship employs "*the gale of creative destruction*" that will replace in whole or in part, inferior innovations across the market space and industries while creating new business models at the same time. The dynamism generated through innovations and new combinations of existing means of production leads to changes in the status quo. This fosters conditions that will result in increasing employment opportunities (predominantly for skilled labour), creation of more wealth, application of new technology, changes in lifestyle, and thereby support growth of the economy.

Indian agricultural sector is full of challenges and opportunities. Agribusiness is one of the solutions to meet the challenges of the sector especially that of falling returns and lack of interest in the rural youth to take up farming as a vocation. In the next revolution, agriculture and its allied sectors should be promoted as a business opportunity; one that will be provide attractive remuneration to the farmer producer which will be supported by certain programs/entities to meet the risks involved. Agribusiness will also enable a climate of innovations in the sector that can help in not only refining the agro-technologies in the research stations but also evaluating new local technologies that can be scaled-up. There are lot of avenues in the agricultural and allied sectors for agribusiness start-ups and private sector players to operate like seed business, farm ventures like contract farming, organic farming, bio-parks, processing sectors, agro-biotechnology, supply chain management etc. In this section, we look at how these concepts can be applied in the Indian agricultural system and how to overcome the challenges.

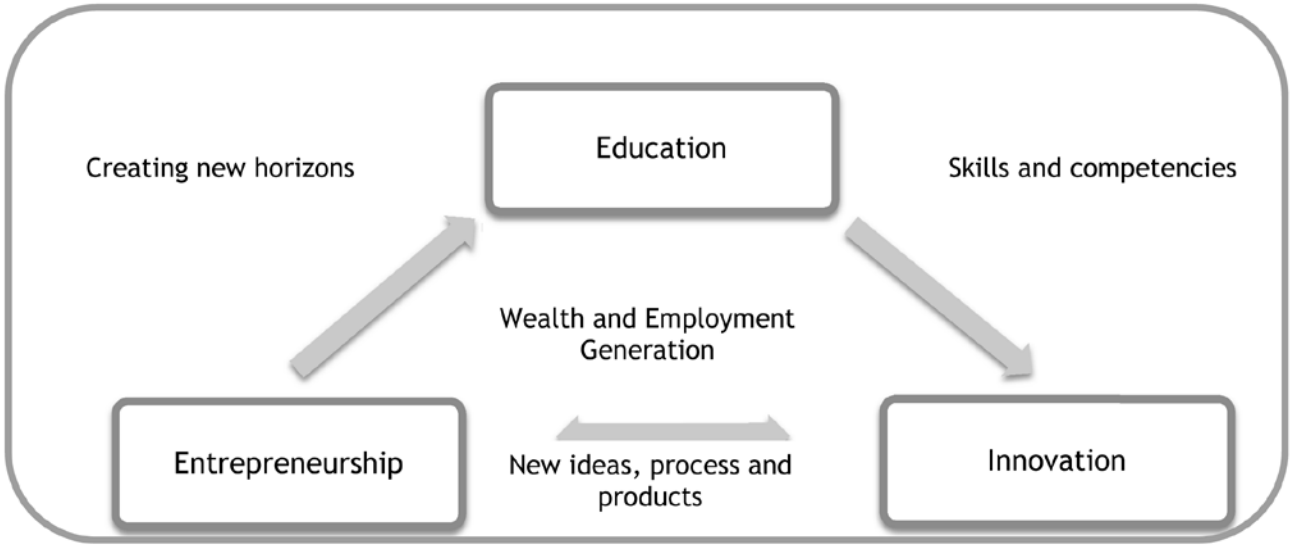
- **Agribusiness as a vocation**

Agribusiness provides an opportunity for thousands of agricultural graduates who pass out from the State Agricultural Universities (SAUs) in the country with an opportunity to start an own venture. While entrepreneurship culture would help in creation of wealth from knowledge, innovation on the other hand would result in new markets being discovered that promotes

[12] *Food Processing. India Brand Equity Foundation, March 28th 2011. (URL of the article: http://www.ibef.org/artdisplay.aspx?art_id=28463&cat_id=114&page=2)*

entrepreneurship. A dynamic entrepreneurial environment supported by a vibrant and supporting academia linked to innovation will definitely help in making agribusiness a livelihood option for many (Figure 2).

Figure 2: Dynamic entrepreneurial environment



Source: Entrepreneurship, National Knowledge Commission, Government of India

The training and curriculum imparted from SAUs need to be modified to include quality vocational training and skill development which will enthuse such graduates to become entrepreneurs, who can then organise farm cooperatives, agri-clinics, agro-parks etc and help in improving the efficiency and economics of farming. *Earn while you learn and Catch them Young* programs help in inculcating the spirit of entrepreneurship in students. The campus can become the breeding ground for innovations. The support of the faculties and the agricultural knowledge of the University would definitely help the would-be entrepreneurs. Grants, as the Youth-to-Youth Fund provided by Youth Entrepreneurship Facility of Africa, can be provided to the selected agripreneurs to help them in starting their venture. Ethics, transparency and governance should be imparted along with regular courses to inculcate right environment for doing business. Linkages with the agricultural industry, incubation centres, business chambers etc. would tremendously help the students in believing in their start-up and its potential. It will also aid in thinking out of the box and coming up with new ideas for meeting the industry requirements.

However, agribusiness ventures face many difficulties due to the complexities involved in dealing with live systems apart from understanding the knowledge of running an agribusiness venture, motivational and knowledge issues to Government regulations, financial assistance, market development etc. Non-availability of scientific support and skill sets can further derail the venture. To mitigate the problems some steps have already been initiated while some need to be developed.

- **Business Incubators**

Young start-up companies are particularly vulnerable in their early stages. The business environment is generally prone to risks since there are not many options for testing one's idea due to lack of funds and support. Studies show that worldwide close to 66 percent of new start-ups survives after two years of starting while it is 44 percent after four years. OECD study shows that over 70 percent of the start-ups windup their operations by the seventh year.

Business Incubators like the Agri-Business Incubator at ICRISAT (Box 6) provide an attractive framework to entrepreneurs (referred to as incubatee/client in incubator terminology) for dealing with the difficulties faced during start-up stages. Incubators provide the backup that small and new firms encounter by providing numerous business support services that are useful in fostering technological innovation and industrial renewal.[13] They can be viewed as a mechanism to:

- support regional development through job creation, [14]
- create new high tech ventures, technological entrepreneurship, commercialization, and transfer of technology;[15]
- deal with market failures relating to knowledge and other inputs of innovative process.[16]

In general, with incubation support, the closure rate of new star-ups has come down to 15-20 percent among incubator tenants.[17] Although there are over 3500 business incubators across the world, most relate with the ICT and ITES sectors. In fact, there only about 60 incubators in the world that are in the agricultural sector, of which India has 11, making it the country to have the most number of agribusiness incubators.

Box 6: Incubating Success

Agri-Business Incubation (ABI) Program at ICRISAT *was initiated in 2003, as joint venture between ICRISAT and the Department of Science and Technology, Government of India. ABI offers scientific and technical backstopping with state-of-the art infrastructural facilities to the agripreneurs. Apart from the regular services, ABI also provides specialized incubation services like funding innovations and softlanding for foreign agribusiness firms who wish to setup base in India.*

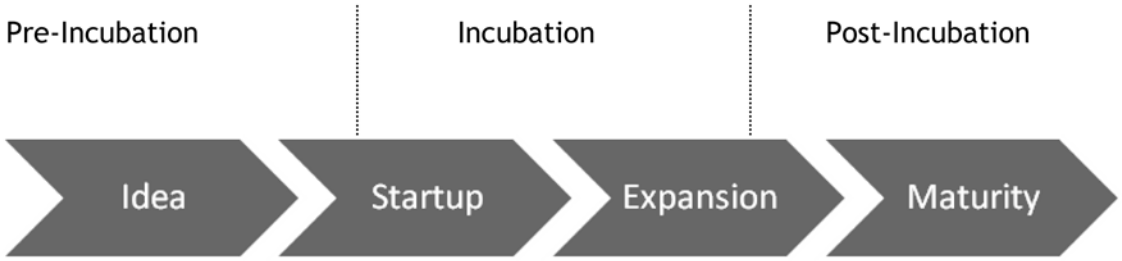
ABI works on five thematic area including: Seed business ventures, Bio-fuels ventures, Farming ventures, Agri-biotechnology ventures and Innovative ventures. So far, ABI has incubated 156 agribusiness ventures, helped in commercializing 44 agrotechnologies and facilitated business development worth US$17.3 million and generated US$6 million. ABI has won many accolades including, the Best National Technology Business Incubator award of GoI (2005) and Best Business Incubator in Asia Pacific of AABI (2007).

[13] *Allen and Rahman 1985; Similor and Gill 1986; Allen and McCluskey 1990; Mian 1996a*
[14] *Allen and Levine 1986; Mian 1997; Thierstein and Wilhelm 2001; Roper 1999*
[15] *Mian 1994, 1997; Phillips 2002; McAdam and McAdam 2008*
[16] *Colombo and Delmastro 2002*
[17] *Bruton 1998; Adegbite 2001; Lalkaka 2002;Abetti 2004*

Business incubators provide the following support for a fledging start-up:

- Scientific and technical backstopping
- Technology transfer from University and Research Institutes
- Business plan and marketing consultancy
- Infrastructural facilities like office space, conference rooms, and communications
- R&D lab space
- Mentoring assistance
- Access to funding agencies
- Training to incubatees
- Promotional support through exhibitions, conventions, workshops etc
- Reduction of operational costs
- Networking with Industry, Research bodies, Commerce chambers etc.
- Assistance in getting clearances from Government regulatory bodies and Licensing bodies
- IPR management

Business incubators also help in generating benefits for the society and its parent institutions, if associated with it. Incubators have evolved over the years since the inception of the first incubator in 1957. The stages in business incubation mirror that of the agri start-up and can be described as given below :[18]



- Agri start-up ventures can be incubated at any of the stages mentioned earlier. Pre-incubation stage can be offered for helping individuals who have an innovative idea. These incubators are usually attached to Universities and Research Institutes and have easy access to scientific and technical support. The risk factor will be high at this stage and can be mitigated by the incubator.
- Incubation stage is where the idea transforms into a plan that can be operationalized. Incubators can help in refining the plan, provide resources and even invest in the company, thereby, financially supporting the start-up. This is the stage where incubation actually happens. The

[18] *Mixed use incubator handbook, infoDev, 2009*

stage will help the incubatee in moving to a more mature stage in the business cycle which is usually for a period of five years.

- Post-incubation stage can be utilized by those agribusiness ventures that are looking for specific support facility. This will also help the incubator in supporting their other incubatees and programs. The risk factor is very low at this stage.

Business incubator networks are spread across the world. Some of the prominent incubator networks are NBIA, AABI, APIN, and *info*Dev (that has a program specifically for agribusiness). India also has its own agribusiness network by way of NIABI that was setup in 2009 (Box 7).

Box 7: Networking with Incubators

The Network of Indian Agri-Business Incubators (NIABI) is a network consisting of ten agribusiness incubators spread across SAUs and Research Institutes under NARS and coordinated by ABI-ICRISAT. The Network, setup to promote agribusiness in the country through technology commercialization and other business incubation facilities, works on a co-business incubation model between its centres. The Network, has so far commercialized 44 agro technologies and generated revenue worth '3 crore.

This provides yet another opportunity for agribusiness entrepreneurs in connecting with other incubatees, research bodies and industries that will help in its success. Through co-business incubation, technology transfer and scientific support can be made within the network that is spread across the country. It can also be used for linking with potential customers that can lead to commercialization of the venture.

- **Funding**

To support the entrepreneurs, the Government has provided lot of support on developing the SME sector, besides directing the financial agencies to provide credit to the sector. However, this has not yet fully benefited the start-ups, partly due to the risk-averse nature of the banking industry and the lack of a proper business plan from the part of the client. Even VCs and similar investors, who have larger funds, have not been funding agribusiness start-ups since their ROI are not as attractive as that of technology-related start-ups and the risks associated with agriculture is very high.

This problem can now be addressed with business incubators standing as collateral. The Ministry of micro, small and medium enterprises has already been offering such support to technology and industrial start-ups through incubators, that has now started offering assistance to agribusiness start-ups as well. Others like DST, TDB and TePP has also started mobilizing funds through this

channel. However, a multilateral funding approach involving Government funding agencies and private firms needs to be adopted for supporting the start-ups and innovators and scaling-up successful ventures. The Government may adopt a professionally managed VC program to help the agripreneurs as is done by the Governments of Singapore and Israel that can be directly targeted to the agri start-ups in the rural sector.

- **Developing skill competency**

The National Skills Authority can help in ensuring that the skill set of the entrepreneur especially the farmers and the next generation entrepreneurs is competent to meet the requirements of the business domain. Since Indian agriculture is primarily in its rural areas, investments should be made to ensure that infrastructure for imparting skills and vocational training are made available at the last mile. This can be adopted at the Block level and can be devised based on the nature of the locality. The skill set imparted should be relevant and in line with the resources and raw materials that are available in that territory. Special focus should be given to imparting required skills to women so as to empower them to take up agriculture based entrepreneurial activities in their locality and to support their livelihood means.

- **Improved support systems**

Clearances and mandatory licensing that are required for setting up of the ventures should be cleared through as quickly as possible, preferably through a single window system. e-Governance and simplified regulatory policies will be a major fillip. Tax sops and other incentives should be extended to the agribusiness sector also. The Government should increase its investment in setting up infrastructure related to the agricultural sector and help in realising a better profit to the farming community.

- **Support of Chambers of Commerce/Industrial Associations/Other Networks[19]**

- Chambers need to take active steps to give prominence to regular entrepreneurial meetings, discussions and networking.
- Chambers need to go beyond mid-size and large companies to reach out to young entrepreneurs.
- Scale up current initiatives on Entrepreneurship; coordinate across associations and networks, and beyond metropolitan cities and top educational institutions.
- Create networks of Entrepreneurship initiatives that are being undertaken across the country.

[19] *Entrepreneurship, National Knowledge Commission, Govt. of India (2008), pg.92*

- Strengthen mentoring programs for upcoming entrepreneurs and actively leverage networks with successful entrepreneurs.
- Provide platforms for discussing entrepreneurial best practices and experiences by holding nationwide workshops.
- Create forums for partnerships with and mentoring by financial institutions.

3.6 Investments and Infrastructure Development

- **Foreign Direct Investment (FDI)**

100 percent foreign direct investment (FDI) is allowed through the automatic route covering horticulture, floriculture, development of seeds, animal husbandry, pisciculture, aqua culture, cultivation of vegetables, mushroom and services related to agro and allied sectors. FDI upto 100 percent with prior government approval is permitted in tea plantation subject to the conditions of divestment of 26 percent equity of the company in favour of an Indian partner / Indian public within a period of five years; and prior approval of the state government concerned in case of any future land use change.

- **Public sector investments**

Public investment is a critical factor to capture capital formation in agriculture and sustain private investment. The status of public investment in agriculture is a matter of key concern. While there has been nominal increase in public investments in agriculture every year, investment in agriculture as a percentage of national GDP has been showing a consistently declining trend as shown earlier.

Although, agriculture being a State subject, public investment in agriculture is the responsibility of the States, many States have neglected investment in infrastructure for agriculture owing to paucity of funds and lack of initiative. The Government needs to increase its investments in the agricultural sector from its present 2-3 percent to atleast 5 percent. This investment can be made on developing infrastructure for storage, processing units, improving connectivity between farm gate and markets to reduce transit time and enhance shelf-life. This will help in promoting public-private partnerships in agriculture, particularly in areas like agricultural research, human resource development, post-harvest management and marketing.

More recently, public investment in agriculture has received a boost from programmes including the Rashtriya Krishi Vikas Yojna, National Food Security Mission, National Horticulture Mission and Extending Green Revolution to the Eastern States.

- **R&D spend on sector**

India's spend on agriculture R&D as a percentage of GDF (Global Development Finance) is 0.34 percent that is lower than that of the Sub-Saharan Africa (0.72 percent) or China (0.4 percent).

This has to improve to eliminate the technology fatigue that has gripped the NARS. The Ministry of Agriculture (MoA) is taking up following major initiatives in R&D[20]:

- National Agricultural Innovation Project (NAIP-ICAR) has been initiated to reform agricultural R&D, strengthen value chain and improve livelihood security in the backward districts of India. NAIP would help to increase agricultural productivity in the country by accelerating collaboration among public research organizations, farmers, the private sector and stakeholders in using agricultural innovations.
- A mega programme on quality seed production has been launched for distribution of the improved varieties developed through R&D to farmers and other stakeholders.
- A network programme on 'climate change' has been launched for better understanding of the changing climate phenomenon and to develop mitigation and adaptation strategies for lowering the impact of climate stress on agricultural production and productivity.
- A new national institute on biotic stress has been set up. It has also been decided to set up a national institute of biotic stress and national institute of agricultural biotechnology.
- Several new programmes on mitigation of greenhouse gases, nano technology, bio-prospecting and allele mining for a biotic stress, translational research in agri-biotechnology, value addition of agricultural produce, quality and safety of products have been initiated in the eleventh plan in a network mode of participation using conventional and molecular approaches to enhance agricultural productivity.

- **Post harvest infrastructure**

➢ **Cold Chain in India**

Twenty five to fourty percent of the agriculture produce is estimated to be lost due to lack of proper cold chain. India needs to invest in the cold chain in order to meet increasing demand of food and to reduce the losses caused by non-existing storage facilities and reefer vans. With 100 percent FDI allowed in the cold chain sector, this provides for the private sector to engage in the sector. As mentioned earlier, food parks are another option. Some examples of other avenues where the private sector can engage with the sector are:

✓ Indian Railways is planning cold chain and warehousing facilities in PPP model for farm produce at 7,000 railway stations.

✓ Cold storage facilities in PPP model for fishing harbour being planned at Rajakamangalam Thurai in Kanyakumari district of Tamil Nadu.

✓ Maharashtra State Agricultural and Marketing Board is planning to establish Terminal Markets in major cities via PPP model.

[20] *MoA(2009), 'Strong R&D base in agriculture,' PIB press release URL at: http://pib.nic.in/newsite/erelease.aspx?relid=50563*

➢ **Food Processing**

The total food production is likely to double in the next ten years and there is an opportunity for large investments in food processing technologies, packaging and equipment. Health foods and health food supplements are other rapidly rising segments of this industry that are gaining vast popularity amongst the health conscious consumers. The most promising sub-sectors include soft drink bottling, confectionery manufacture, aquaculture, grain-milling and grain based products, meat and poultry processing, alcoholic beverages, milk processing, tomato paste, fast-food, ready-to-eat breakfast cereals, food additives, flavours etc. India is one of the world's major food producers but accounts for less than 1.5 per cent of international food trade. This indicates a vast scope for both investors and exporters.

➢ **Marketing Infrastructure**

In addition to direct physical infrastructure required to support the agricultural sector, there is a strong need to supplement it with marketing information / intelligence while addressing various challenges in the supply chain. Even though there has been considerable progress to provide farmers with market information relating to prices, farm inputs and weather forecast, such information in remote rural villages is not easily accessible. There has to be investment in terms of IT hardware and connectivity to the last mile so as to eliminate information asymmetry in agriculture. This will also help in eliminating intermediaries in the supply chain and enable direct marketing with the industries thereby helping the farmer producers realise a better price.Such connectivity with the outside world would also help the farmers in accessing critical information such as weather forecasts that could help them improve the quality of their produce.

• Soft Infrastructure

➢ **Research and Development**

In order to improve farm productivities, continuous introduction and implementation of innovative technologies calls for existence of a strong R&D network. While substantial investment is made in this regard, the efforts have not been rewarding. Krishi Vijnan Kendras (KVK) needs to be revamped to improve upon its mandate of technology validation and transfer between the Research Stations/SAUs to the farmers.

➢ **Extension services**

The private sector can be considered for promoting the extension activities along with their package of services (advisory services) like cultivation operations, fertiliser and pesticide advocacy levels, new crop varieties, credit services in addition to supply of seed input materials. The input companies focus their advisory service mainly on use of their company products while the processing companies focus their services mainly on the crops that they will use as raw

material. In this way, the services become very specialized and perhaps more effective. They use demonstration plots, field days, individual farmer visits, group meetings, large farmer gatherings, exposure visits, website and pamphlets as methods and tools for extension.

- **Human resource development**

Advancement of any industry depends upon the availability of skilled human resource where the agriculture industry is in dire need of highly skilled and trained manpower across different levels to handle various operations. Human resource development needs to cover the entire range from basic infrastructure, education, vocational and technical guidance to professional qualifications.

- **Support infrastructure**

Half of those engaged in agriculture are still illiterate and just 5 percent have completed Higher Secondary education. Incomes and education are of course least among agricultural labourers. Ensuring food security and farmer welfare thus require support systems to extend technology and scale benefits in a sustainable manner to a huge existing workforce in agriculture.

3.7 Enhanced PPP Initiatives

New technologies are critical for enhancing agricultural productivity and reducing poverty in many developing countries. While public-sector investment in research has historically driven technological change in agriculture, recent trends suggest that the public sector's role may not be as significant in the future. There is much optimism about the private sector's capacity to deliver new technologies, even though current levels of private investment in research in developing countries remain low.

The opening of the economy and the post WTO regimes has changed the private sector intervention in the country. This has been further strengthened by changes in the Intellectual Propert Rights (IPR) that led to the protection of biological innovations which has improved the ability of private R&D players to appropriate the returns on their investments. With new innovations and technologies that has been seen to be productive for the sector coming mainly from these private players, access and using of the same depends on the country's ability to stimulate private investment. The private sector also sees developing countries like India and those in Africa as destinations where they use their technology using the farming sector and reap the returns on their investment, in turn providing the farmers with an assured income.

Most private-sector investments in agricultural R&D is distributed across six subsectors:

- basic plant biological research
- plant breeding and the production of seed and planting materials
- agrochemicals, including chemicals for plant protection, fertilizers, and biotechnological applications

- processing, storage, and transport of food
- animal and livestock improvement
- agricultural equipment and machinery.

About one-third of private-sector investment in agricultural R&D globally is directed toward agricultural chemicals, most significantly pesticides (Pray and Fuglie, 2001). Food processing, storage, and transport also provide a significant portion of private-sector investment in agricultural R&D (Pardey and Beintema, 2001).

With the economy growing at 8 percent per year, India has fast emerged as top-destination for private sector agricultural companies for investing their technologies in the agricultural sector and reaping benefits. While the pitfalls from such interventions can lead to exploitation of the Indian agricultural sector, it remains a moot point that the interventions made by the public sector since the Green Revolution has been far and few, leaving many gaps to be filled. It is in this context, that while the public sector makes its contribution in developing the hardware, the private sector can engage with institutions and community on PPP mode to deliver the software, thereby benefitting all parties concerned.

- **Investments in PPP mode in sector**

In order to strengthen the agricultural research programmes in the developing countries, public investment in agricultural research has been increased and committed to form collaboration with private sector as Public-private partnerships to minimize the funding problem, thus partnership is proposed as cost-sharing strategy which encourages the stake holders including local government and private sectors in conducting many agricultural research programmes which will help to resource- poor farmers for good production.

These partnerships serve the interests of resource-poor farmers and vulnerable house-holds of the developing nations, partnerships by constructive means enhances the production of goods, services and technologies which cannot be produced through either of the sectors alone. Public-private partnerships would effectively utilize the limited global resources for development of sustainable agricultural system and good researchers for solving agricultural problems or conflicts.

- **Institutional linkages**

To ensure effective delivery of science-led agricultural research for sustainable food production, Public–Private Partnerships (PPPs) are increasingly being viewed as an effective means for conducting advanced research and transfer of technologies for ensuring food security and enhancing agricultural productivity. PPP mode would effectively utilize the limited global resources for development of sustainable agricultural system and good researchers for solving agricultural problems and as cost-sharing strategy that encourages the stake-holders, including

local government and private sectors in conducting many agricultural research programs which will help resource- poor farmers for good production. PPP mode will also promote innovations that can help in transforming knowledge and technology into an application of social and/or economic relevance through synergy between the public and private sector. PPP also helps partnering Public Institutions to reform their organisational structure and link their research with critical downstream innovation activities thereby bringing about greater impact in their domain of work. PPP mode also provides the participating units with a leverage factor and help in reducing transaction costs and enhancing better delivery.

These partnerships thus serve the interests of resource-poor farmers and vulnerable households of developing nations; a partnership by constructive means enhances the production of goods, services and technologies that cannot be produced through either of the sectors alone.

- **Government support**

Expenditures on agricultural R&D by the indigenous and international Private sectors in developing countries are much lower than in Industrial countries and they are concentrated in few advanced developing countries like Argentina, Brazil, India, and Mexico. During 1970s and 1980s, private sector investments in agricultural R&D in some developing countries increased faster than public sector investments,

In earlier 1960's, the public sector investment in agricultural research for industrial countries was two-third of the global agriculture research; by the end of 1990 the public sector investment in developing countries became more than industrial countries. Now the investments in agriculture research are expressed in terms of percentage of corresponding national GDP.

The industrial country investment is 2 percent of national agricultural GDP, were as developing country investment is 0.5 percent of national agricultural GDP, that is one-fourth of industrial country investment, so the public investment in agriculture research is inadequate to deliver technology and utilize the resources for developing food security, so collaborated agriculture research are required to completely utilize all resources and share funding to make partnership more viable and sustainable for serving pro-poor countries.

- **Technology parks, incubators, SEZs, agricultural export zones**

Science and Technology Park is an organisation managed by specialised professionals, whose main aim is to increase the wealth of its community by promoting the culture of innovation and competitiveness of its associated businesses and knowledge-based institutions. To enable these goals, a Science Park stimulates and manages the exchange of knowledge and technology amongst universities, R&D institutions, companies and markets; it facilitates the creation and growth of innovation-based companies through incubation and spin-off processes; and provides other value-added services together with high quality facilities.

The small business incubator is a flexible method of encouraging the development of new businesses and fostering local economic development. The typical low cost of operating a new business in an incubator facility is conducive to a more rapid growth and maturity into a viable business enterprise. They are particularly valuable for the transfer of high technology and other production and management knowledge to firm. With a view to promoting agricultural exports from the country and remunerative returns to the farming community in a sustained manner, the concept of the agri export zones (AEZ) was initiated. These zones have been set up for end-to-end development for export of specific products from a geographically contiguous area.

- **IPR regime and role in promoting PPP mode**

Agricultural innovation plays a key role in driving long-term agricultural productivity, rural development, and environmental sustainability and therefore innovation needs to be encouraged, supported, and protected. In the present era of technology-driven economy, (IPRs) play a pivotal role in agricultural innovation. IPR has a pull effect on enhancing private sector R&D investment and its protection is necessary to encourage continued investment in research and development, strengthening innovative base in plant science industry, and to protect regulatory data and confidential business information related to crop biotechnology.

In the field of agriculture, a number of product-development partnerships involve complex IP management issues to access and commercialize protected technologies. From both research and industry point of view, IPRs are directly or indirectly linked with agricultural research (access to proprietary enabling technologies, development of IP assets; genomics and bio-informatics, bio-prospecting and access to genetic resources); agricultural trade (patenting, plant variety protection, geographical indications); technology transfer (approval of technology transactions, technology packaging, control of restrictive licenses, remuneration); and traditional knowledge.

❖ **Legal aspect in IPRs**

The global IPR regime in agriculture is changing in the wake of the agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) which provides for international minimum standards relating to the availability, scope and use of intellectual property.

The *Indian Patents Act, 1970* was successively amended in 1999, 2002 and 2005 to make it compliant with the requirements of the TRIPS agreement. The Act provides for grant of patents to protect inventions which meet the criteria of novelty, inventive step and industrial application.

Article 27(3)(b) of the TRIPS Agreement permits WTO Members to exclude from patent protection, plants and animals and essentially biological processes for the production of plants and animals. India opted for sui-generis system of plant variety protection through *Protection of Plant Varieties and Farmers' Rights Act, 2001.* The main objectives of the Act are to stimulate investments for research and development both in the public and the private sectors for the development of new

plant varieties by ensuring appropriate returns on such investments; to facilitate the growth of the seed industry in the country through domestic and foreign investment; and (iii) to recognize the role of farmers as cultivators and conservers and the contribution of traditional, rural and tribal communities to the country's agro-biodiversity.

❖ IPR regime and its impact on Agriculture

The intellectual property regime is expected to contribute in technology development and access to information through providing incentives to inventor of beneficial agricultural innovations. In India, the importance of IPRs is increasing and in coming days, PVP and patenting may be an important tool for encouraging national agricultural research and business. IPRs incentivizes entrepreneurs to keep pushing for new advances in innovation economy. Few issues related to IP regime are discussed below:

❖ Agricultural research

The creation of IPRs in plant varieties developed through classical breeding and the proprietarisation of genetic resources and associated enabling technologies through innovations in patent law have been the vehicles through which private agro-industrial enterprises are assuming a dominant position in Agri-biotechnology market and commercial agricultural research. IP management practices are necessary for developing business strategies to become more innovative and efficient in commercial activities. IP rights are associated with confidence and ease of mind in realization of investment in R&D and source for future funding. IPRs will be a vital techno-legal instrument to make Indian Agriculture more knowledge intensive and competitive.

❖ Technology Transfer

The objectives of the TRIPS Agreement are that protection and enforcement of IPRs should contribute to the promotion of technological innovation and to the transfer and dissemination of technology to the mutual advantage of producers and users of technological knowledge. Changes in both national and international IP frameworks have profoundly affected how innovation reaches to the market and how public and private R&D institutions pursue their work. Technology pooling, technology licensing, technological collaborations are few means of technology transfer. In current business practices, these modes of technology transfer are strongly linked with IPRs that facilitate the free flow of information by sharing the protected know-how critical to the original, patented invention. In turn, this process leads to new innovations and improvements on existing ones.

To conclude, IP is becoming one of the most influential issues in today's knowledge-based society as IPRs are strongly embedded in contemporary business models. Similarly strong IPR policy of a nation affects various issues, such as international trade, legal manifestation of ownership of

breakthrough technologies, foreign direct investment, innovation climates, competition rules, anticompetitive practices and monopolistic behavior. IP is becoming increasingly dominant in the design and execution of basic and applied research, the evaluation of intangible assets, the protection and management of knowledge assets, and to the business strategies of knowledge-based industries and companies.

3.8 Risk mitigation strategy

In India, agricultural risks are aggravated by a variety of factors, ranging from climate variability and change, frequent natural disasters, uncertainties in yields and prices, weak rural infrastructure, imperfect markets and lack of financial services including limited span and design of risk mitigation instruments such as credit and insurance. Without mechanisms to protect themselves against risk, these rural households and agro-enterprises are often unable or unwilling to take advantage of market opportunities. Instead, they follow low-risk/low-return livelihood strategies resulting in low incomes and growth. This not only endangers the farmer's livelihood and incomes but also undermine the viability of the agriculture sector and its potential to become a part of the solution to the problem of endemic poverty of the farmers and the agricultural labor. The criticality of agriculture in the rural transformation and the national economy seen along with its structural characteristics require substantial governmental and financial sector interventions not only to ensure household food and nutritional security of the farming community but also to generate savings and investments and help the farmers to adopt improved in technologies, expand their assets, and thus take advantage of economic opportunities.

In most cases, the solutions are reactive in nature where the government increases the MSP or provide loan waivers after the risks play out to the utmost effect and wreck the livelihoods of farmers. What is therefore needed is a more proactive approach in terms of crop insurance, commodity markets, infrastructure creation etc. to enhance the coping capabilities of farmers with effective coordination between the public and private sector. The poor penetration and development of various risk management tools in the country represent the huge opportunities for the emerging agricultural insurance and commodity markets to pull the producer from out of the poverty trap by insulating him from income shocks and by ensuring that a fair share of the price goes to the producer.

3.8.1 Key agricultural risks

- **Climate and weather risks**

Indian agriculture is highly susceptibility to climate variability and change especially given the rain-fed cultivation methods. The existing vulnerability has been exacerbated by the drastic change in climate resulting in natural disasters as well as frequent floods and droughts. In this scenario, measures like harnessing the technological advances in climate science, remote sensing

technologies, and ICT in developing early warning systems will be crucial. However at individual farmer level, weather insurance would be the most important risk mitigation instrument. The government has already introduced the credit linked National Agricultural Insurance Scheme (NAIS). However, it's penetration has been bogged down by several issues like high administrative expenditure, delays in claim settlement, adverse selection, and non-awareness. The Government may consider the implementation of a single insurance policy that covers all the assets of the farmer.

A large number of private insurance companies have been operating in the Indian Insurance Market since October, 2000, and a few of them have done pioneering work in agricultural insurance mainly by way of introduction of weather insurance products. The issue of private sector involvement in agricultural insurance may be addressed by means of the system of co-insurance in the order the Agricultural Insurance Company Limited (AIC) may be a lead insurer with underwriting capabilities and contacts with multiple agencies and private insurance companies taking shares according to their capability[21]. The agricultural input companies working in the rural areas have excellent distribution networks that connects to the last mile and which can be utilised by the insurance companies to provide their services to that segment. Post offices and Micro-Finance Institutions (MFIs) can also be tapped for this.

Similarly the information regarding technologies and historical data regarding crop yields, climate parameters etc. should be updated and available to all the stake-holders so as to plan effectively and mitigate the crisis due to this risk. An effective coordination and sharing of information between the climate and weather agencies like the Indian Meteorological Department (IMD), Central Water Commission (CWC) and National Centre for Medium Range Weather Forecasting (NCMRWF) and the ministries can be one way of tackling this issue.

- **Financial and credit risk**

The long gestation periods of certain crops result in cash flow problems for the farmers; for expenses during this period, farmers are forced to take credit, often at high interest rates due to the non-availability of credit from formal credit sources. This is one area that has large-scale penetration of private players especially the informal ones. Formal lenders tend to shy away from financing agriculture for a host of reasons including: high cost of service delivery, information asymmetries, lack of branch networks, perceptions of low profitability in agriculture, lack of collateral, high levels of rural poverty, or low levels of farmer education and financial literacy[22]. To encourage formal lenders specifically the private players, the Government needs to adopt following policy measures:

[21] *http://planningcommission.nic.in/aboutus/committee/wrkgrp11/wg11_risk.pdf*

[22] *http://www.ifpri.org/sites/default/files/publications/focus18_10.pdf*

- Developing and implementing institutional innovations—such as credit bureaus, applications of information and communication technology, and delegated agent models of service delivery.
- Agricultural lending cannot be the primary type of lending unless robust risk-transfer techniques (for example, insurance, futures, and securitization) become more commonplace. In place of land, alternative forms of collateral—including warehouse receipts, accounts receivable, equipment, and standing crops or livestock—should be more widely accepted. Improved contract enforcement should be aggressively promoted as well.
- Small and informal institutions engaged in agriculture lending can be provided adequate support and encouragement to grow, consolidate and eventually merge.

- **Marketing/Price risk**

The Minimum Support Price (MSP) aims to support the farmers from adverse price fluctuations. However, evidence shows that MSP has not been very effective in shielding farmers against price volatility. The system should be modified to cover a broader range of crops and MSP should be made attractive by atleast covering the cost of cultivation. Linking with agro-processing units can also help in realising better prices or nullifying the fluctuations.

In this scenario, the emergence of commodity markets has the potential to benefit the farmer through price discovery and to protect him from adverse price fluctuation[23]. An improved participation from the farming community can be made through creating awareness and improving access to the commodity markets. ICT can help in meeting the gap in information and providing connectivity. Options trading should also be promoted since its considered more safer than futures trading. Private players should be encouraged to play an important role in commodity markets. Further APMC laws to be suitably amended, to allow private players to set up e-mandis, would result in competition amongst the existing mandis resulting in better processes, transparency and benefits to farmers. The Government should quickly implement the pending bills on warehousing and the Fowards Markets Commission that will ensure benefits to all the stakeholders. It can also help in setting up of exchange terminals across the country with the support of the private sector.

Yet another mitigation solution can be Contract Farming, which can help in invoking best agricultural practices and techniques for crop production. This will help in engaging the private sector with the farming community, while the Government can act as the Regulator. Through contract farming, agricultural diversification will be made possible thus helping the farmer in getting better value for the produce. Forward and backward linkages should be provided by the

[23] *Through commodity markets, farmers can hedge by taking a position in the futures market and insure against adverse fluctuations in prices in the physical market*

processor, who should also take care of associated costs, technologies and cropping material. Flexible contracts combined with insurance coverage and hedging options can help in making it more attractive.

- **Technology risks**

Advancements in crop technologies should be made accessible to the farming community through effective extension mechanisms. New agro-technologies and improved ones can help in generating better returns to the farmer. The role of ICT is immense in this aspect. Technology advancements in post-harvest segment can go a long way in mitigating risks on the produce and realise better price for the farmer.

- **Policy risks**

Sudden changes in agriculture policies relating to exports, imports, support price fixation, subsidies can significantly alter the profitability of farming activities. Policy risks affect the producers as well as the service providers in the agriculture sector. While farmers have no option but to deal with changing policies and its impacts, uncertainty in agriculture policies might inhibit new players from venturing into the sector. Therefore, it is important to ensure consistency and certainty in agriculture policies at least in the short to medium term.

The Government is also planning to setup a Centre for Risk Management in Agriculture (CRMA) under PPP mode. The CRMA is envisioned to play a catalytic role to promote and deliver integrated risk management services to the farming community.

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Conclusion

CHAPTER 4

The Indian agricultural sector needs to be revitalised to meet the demand of food and nutritional security of a growing population amidst challenging situations. While the first Green Revolution helped in meeting the production demands in the 1960s, the next revolution needs to focus on holistic development of the sector and sustainable in the long run.

The next revolution has to help the small and marginal farmers in sustaining their livelihood. It will need to provide end-to-end services to the farmer, linking him to the market and facilitating access to better technology and other resources. The dairy revolution in the country is a prime example of such an approach. An inclusive market oriented approach can revolutionise the agricultural sector and attract the youth to take up to agriculture as another business venture. An agribusiness development path involving greater productivity growth throughout the entire agribusiness value chain provides for a solid foundation for rapid, inclusive economic growth and poverty reduction. Improving the skill levels of the farmers can help in diversifying and minimising the risk from the sector. This will also foster an ecosystem for innovations from within the community.

The Second Green Revolution should have a convergence strategy, in which the civil society, public and private sector comes together to develop solutions to sustain productivity, provide opportunities for growth of sector and thus boost the economy. The revolution should leverage on the strength of each sector to reform the sector which will help in supporting the livelihood of millions of people engaged in the agricultural domain.

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