Agricultural Innovation Systems in India – an Analysis

DST PROJECT: DST/NSTMIS/05/128/2010-11

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Preface

Indian agriculture has been facing innumerable problems from different angles. Although we are happy on attaining the status of self-sufficiency in food grain production (257.44 MT in 2012-13), it cannot be sustained as it is directly related to the ever increasing population. In order to be self sufficient in our food production, we need to be always innovative, vigilant and work persistently under continuously changing climatic, economic, policy and social conditions. Innovations need to be brought in different sectors viz., research, policy framework and institutional structure and adjustment to improve the agricultural productivity and to enhance the economic status of the farming community. The researchers in both public and private sectors have contributed enormously in shaping Indian agriculture through developing high yielding varieties, yield enhancing and resource conserving production and protection technologies. Similarly, changes in policy environment to help the farming community through the supply of good quality planting material of high yielding varieties, inputs, marketing and credit facilities are also part of this development. Further, institutions involved in agricultural development also played a major role in achieving the present status of production in our country. Besides all these contributions, there had been stagnation in overall production of food grains during last two decades (from 1990 onwards) except 2011-12 and 2012-13. The reasons could be many ranging from changing climatic conditions, social problems like fragmented land holdings and unavailability of labour for farming operations, decreased soil fertility, urbanization, lack of adoption of new technologies, poor marketing network and structures, lack of region specific technologies, poor policy regulations, poor agronomical practices, poor mechanization, switching over to cultivation of commercial crops etc. Even though, there are changes in food habits by shifting towards animal protein and enhancement in intake of fruits and vegetables, majority of Indian population still depends upon the two major cereals viz., rice and wheat and it takes minimum two to three decades to bring up a major shift in food composition. Hence, we need to depend on these two food grains for our self sufficiency in food production.

A study sponsored by Department of Science and Technology, Government of India on "Agricultural Innovation Systems in India – An Analysis", with focus on rice and wheat sectors in major food grain producing states of India was taken up during 2011-2014. In the present study, we tried to find out the reasons for the stagnation / deceleration in food grain production. As a part of our investigation we surveyed six districts of four major food grain producing states (Andhra Pradesh, Haryana, Karnataka and Punjab) and collected information from all the stakeholders including farmers, extension specialists, state department of agriculture, researchers and heads of major agricultural institutions. This study revealed several facts about production situations, problems faced by farmers in different production situations, pests and diseases, deficiencies in policy regarding credit facilities, marketing, input supply, infrastructure availability etc.

A Local Project Advisory Committee (LPAC) was constituted by identifying many distinguished individuals from industry and academics. The DST approved the project proposal vide Ref. No. DST/NSTMIS/05/128/2010-11. Details of project were as follows: Principal Investigator: Dr. P. K. Shetty; Total approved cost: Rs. 36.00 lakhs; Duration of the project: 24 months. The project was initiated in March, 2011. The DST had approved the extension of the project till February 2014 at no additional cost basis. The project team had several interaction meetings with LPAC members during the project period. The project team carried out a detailed study in 4 States, covering 6 districts and 30 villages. The study revealed many interesting facts, which are discussed in length in the executive summary and also elsewhere in the report. In general, it is observed that the area under major food crops (Rice and Wheat) has not changed much but with a slight decrease of around 5 to 7%. Paddy and wheat farmers are satisfied with the improvements in research front but are unhappy with certain policies of the government because of which they are facing problems of labour availability, enhanced wages and problems of marketing. From the survey details, through the analysis of secondary data and from the feedback acquired from experts of concerned fields the measures have been suggested for further enhancement of our status in food grain production by bringing innovations in research, policy framework as well as institutional dynamics. This study will help to develop a policy document on suggestions for enhancing food grain production in India and similar work can also be carried out in different sectors like oilseeds, pulses, vegetables, fruits, animal husbandry etc. for enhancing their production. The views expressed in the report are of the investigating team and not necessarily of the Department of Science and Technology, Government of India, not of the National Institute of Advanced Studies, Bangalore.

Acknowledgement

I wish to place on record my sincere appreciation to the Department of Science & Technology (DST), Government of India for sponsoring the project entitled "Agricultural Innovation Systems in India – An analysis". The idea of this project had evolved upon in-depth discussion with Dr Parveen Arora Sc-'G' / Adviser,NSTMIS, DST, Government of India and I am grateful for his valuable suggestions and necessary assistance throughout the project period. My special thanks to Dr. V.S. Ramamurthy, Director, National Institute of Advanced Studies, Bangalore, for his support and encouragement in undertaking this project.

I am grateful to the farmers, agricultural labourers, extension workers, researchers, policy makers and others in different agro-ecological regions in the country for sharing valuable information. My special thanks to members of Local Project Advisory Committee - Dr. M.V. Srinivasa Gowda, Formerly: Visiting Professor, SBM Chair, University of Mysore; AICTE Member, Senate of Jadavpur University Kolkata and Professor and University Head, Dept. of Agriculture Economics, University of Agricultural Sciences, Bangalore; Dr.M.R.Hegde, Head, RMCU, Indian Institute of Horticulture Research, Hessaraghatta, Bangalore, Dr. T.Venkatesan, Principal Scientist, National Bureau of Agriculturally Important Insects, Bangalore; Dr. S.K. Jalali, Principal Scientist, National Bureau of Agriculturally Important Insects, Bangalore and Dr. Nayeemulla Khan, Professor, St. Joseph College, Bangalore for their support and valuable suggestions. I sincerely thank all the distinguished experts for their valuable contributions to the report made through various meetings/conferences organized by the National Institute of Advanced Studies. I am also thankful to the research team, colleagues and staff of NIAS for their wholehearted support and cooperation in carrying out the study.

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Abbreviations

ACRP	Agro Climatic Regional Planning
AD	Anno Domini
AEZ	Agricultural Economic Zone
AgGDP	Agricultural GDP
AICRP	All India Co-ordinated Research Project
Anon	Anonymous
AOA	Agreement on Agriculture
ATMA	Agricultural Technology Management Agency
BGREI	Bringing Green Revolution to Eastern India
BOLT	Build-Own-Lease-Transfer
BOO	Build-Own-Operate
BOOT	Build-Own-Operate-Transfer
CABA	Cab Abstracts
CADP	Command Area Development Programme
CAP	Cover and Plinth
CII	Confederation of Indian Industry
CIMMYT	International Maize and Wheat Improvement Centre
CRRI	Central Rice Research Institute
DASP	Diversified Agricultural Support Project
DCPS	De-Centralized Procurement Scheme
DVD	Digital Video Disc
et al.,	And others (authors)
etc	Etcetera
EMVP	Estimated Marginal Value Product
FAO	Food and Agricultural Organisation
FCI	Food Corporation of India
FCO	Fertilizer Control Order
FICCI	Federation of Indian Chamber of Commerce and Industry
Fig	Figure
FFSs	Farmer's Field Schools
GAP	Good Agricultural Practices
GATT	General Agreement on Trade and Tariff
GDP	Gross Domestic Product
GM	Genetically Modified
GOI	Government of India
GR	Green Revolution
ha	Hectare
HRD	Human Resource Development
HYVs	High-yielding varieties
IAAP	Intensive Agricultural Area Programme
IADP	Intensive Agricultural District Programme
IARI	Indian Agricultural Research Institute
ICAR	Indian Council of Agricultural Research
ICDP	Intensive Cereal Development Programme
ICTs	Information and Communication Tools
i.e.,	That is
IFPRI	International Food Policy Research Institute
IPM	Integrated Pest Management
IRR	Internal Rate of Return

ISOPOM	Integrated Scheme on Oilseeds, Pulses, Oil palm and Maize
ITC	Imperial Tobacco Company
KCC	Kissan Credit Card
Kg	Kilograms
Kg/ha	kilograms per hectare
Mt/ha	Million tonnes per hectare
KVK	Krishi Vigyan Kendra
LPAC	Local Programme Advisory Committee
MAGIC	Multiparent Advanced Generation Inter Cross
MEP	Minimum Export Price
Mha	Million hectares
MIRR	Marginal Internal Rate of Return
ml	Milli litre
M & M	Major and Minor
MSP	Minimum Support Price
MSSRF	MS Swaminathan Research Foundation
MT	Million tonnes
MOU	Memorandum Of Understanding
MW	Mega Watts
NABARD	National Bank for Agriculture and Rural Development
NARI	Natural Agricultural Resource Index
NAIP	National Agricultural Innovation Project
NATP	National Agricultural Technology Project
NBS	Nutrient Based Subsidy
NFSM	National Food Security Mission
NGOs	Non Government Organization
NMMI	National Mission on Micro Irrigation
NPK	Nitrogen Phosphorus and Potash
NPS	New Pricing Policy Scheme
NSP	National Seed Programme
NUE	Nutrient Use Efficiency
NWRC	National Water Resource Council
OECD	Organization for Economic Co-operation and Development
PDS	Public Distribution System
PHL	Post Harvest Loss
PHM	Post Harvest Management
PIM	Participatory Irrigation Management
PMT	Per Metric Tonne
PPV&FR	Protection of Plant Varieties and Farmers' Rights
RBI	Reserve bank of India
R&D	Research and Development
RKVY	Rashtriya Krishi Vikas Yojana
RPS	Retention Price Scheme
RRB	Regional Rural Bank
RWCS	Rice wheat cropping systems
SAU	State Agricultural University
SEZ	Special Economic Zone
SHG	Self Help Groups
SIA	Survey of Indian Agriculture
SMS	Short Message Service
SRDP	Special Rice Development Programme
TE	Triennium Ending
TFP	Total Factor Productivity
T &V	Training and Visit
TMM	Technology Mission on Maize
TNAU	Tamil Nadu Agricultural University
TRIPS	Trade Related Aspects of Intellectual Property Rights
UAS	University of Agricultural Sciences
UP	Uttar Pradesh
URAA	Uruguay Round Agreement on Agriculture
WTO	World Trade Organization
WUAs	Water User Associations
WUE	Water Use Efficiency

Executive Summary

During the last one hundred years, Indian agriculture has undergone a series of strides. Today, National Food Security is the agenda of India's development plan. Green revolution has brought a sea of change in India's food security status by changing its 'hand to mouth' position to self sufficiency and to even a food exporting nation since middle of last decade. This transformation can be attributed to three major factors: a) Green revolution technologies combined with government support in terms of establishing fertilizer factories, irrigation projects, agricultural universities, marketing network and extension facilities. b) Market support through provision of minimum support price (MSP) and c) Government support through provision of subsidized inputs such as high yielding variety seeds, fertilizers, pesticides etc. However, if we critically analyse the food grain production during last two decades, there is not much progress and we experience a plateauing in the yields of two major cereals, wheat and rice. The reasons could be umpteen and we are unable to pinpoint the exact ones. Further, the reasons for this stagnation are variable under different production situations. For example, in Punjab and Haryana which are considered as Green Revolution states, the production situation is entirely different. Here, the annual compound growth rate of food grains production (5.76%) and productivity (8.24%) is the highest in 1970s i.e., during the period of green revolution and from then onwards it started declining. The highest compound growth rate in 1970s was mainly because of intensive adoption of high yielding varieties, government support policies, availability of irrigation and use of fertilizers and pesticides. But in other parts of the country, the maximum compound growth rate in production and productivity could be observed in 1980s.

The reasons for the decline in production after 1970s in Punjab and Haryana could be over exploitation of the fertile lands with the use of higher doses of fertilizers and pesticides, irrigation water and continuous cropping of rice and wheat which resulted in resurgence of pests. But situation is different in many other parts of the country. In eastern states viz., Bihar, Assam and West Bengal the soils are fertile. The Government is focusing more on these states through "Bringing Green Revolution to Eastern India" programme and allocating Rs.1000 crores during 2013-14 budget. Now, we need to understand the location specific problems and find out the solutions according to the requirement. The other reasons for decline in the food grain production during the last two decades are crop diversification with emphasis on commercial crops like cotton and sugarcane due to liberalization, changing food habits of consumers towards more fruits, vegetables and animal protein, climatic variability, no major breakthrough in research, fragmented land holdings etc. The demand for food grains in 2050 being estimated at 494 million tones (high demand scenario), there is a need to focus on increasing production through application of various innovations. Adding to this, the passing of Food Security bill by Government of India Cabinet on 19th March 2013 creates a demand of

62 million tons of food grains. All these factors warrant for development and application of innovations in different sectors of agriculture viz., research, policy and institutional reforms.

Suggestions: The problems of declined production of food grains during last two decades are diverse in different states and regions. Hence a location specific strategy needs to be evolved to retort them efficiently. In general, research needs to be geared towards innovative techniques to develop C_4 rice, multiple stress resistant varieties, super rice hybrids and also wheat hybrids. This would be possible through utilization of latest knowledge on biotechnology, genomics etc. In Punjab and Haryana focus needs to be diverted on diversification of crops in order to improve the soil condition as well as ground water condition. Research needs to be focused on development of alternate crop planning strategies with the development of suitable varieties and technologies for inter and sequential cropping. Similarly, in Eastern states there is possibility to enhance area under food grains but with a right mix of other suitable crops. Boro rice can be popularized by providing irrigation facilities through government policies. In Southern states like Andhra Pradesh and Karnataka, the area under rice has almost stagnated and in recent years it started declining in few locations. By bringing changes in quality parameters of hybrid rice, it is possible to enhance its acceptance by the farmers. The soil degradation can be avoided through application of fertilizers and pesticides judiciously. Bhoochetana programme being implemented in Karnataka could enhance production from the degraded soils through correction of micro nutrient deficiencies, use of quality biofertilizers and application of minimal required quantities of fertilizers. Nutrient based fertilizer subsidy appears to be a good step in avoiding soil degradation. Irrigated area can be increased through proper management of irrigation water by avoiding wastage and application losses. This can be achieved through formation of Water User Associations (WUAs) who can manage the water use more efficiently by proper planning and budgeting. The success story of Andhra Pradesh in this front is an example to emulate. Non availability of labour for agriculture operations is another important problem. This can be tackled by mutual sharing and making some modifications to MNREGS (Mahatma Gandhi National Rural Employment Guarantee Scheme) like linking agricultural operations in this scheme and incentivizing the people who work for agriculture etc. The Self Help Group Model of Dharmasthala in Karnataka could succeed in solving labour problem to some extent through compulsory sharing among members. By implementing suitable policies to provide the farmers with better support price and bringing changes in rural employment generation schemes either by integrating them with agricultural activities or by incentivizing the people working for agricultural activities with additional provision of subsidized food grains, it is possible to improve food security in India.

Chapter 1
Introduction

Agriculture is one of the major employment sectors in India, accounting for about 52% of the employment and about 70 per cent of the population depends on agriculture for its livelihood. In recent years, the growth rate of agricultural output and the share of agriculture sector in the economy are declining. The GDP of agriculture including allied sectors of forestry and fishery declined from 37% in 1983 to 25% in 2000 and around 14.6 % in 2009 to 14.1 % in 2011-12. The performance of agriculture, particularly in case of wheat, coarse cereals, pulses and oilseeds has decelerated during the last decade. In this scenario, there is a need towards continuous innovation in the agriculture sector. Envisaged growth rate in agriculture can be achieved by developing and adopting various combinations of knowledge from different sectors such as innovation in research, institutional reforms and policy.

Agricultural growth essentially aims at poverty reduction. Research has shown that for every one per cent increase in agricultural growth, rural poverty falls by 1.83%. Appropriate science based technology is a key driver of agricultural growth. Agricultural development requires knowledge management and dissemination in key areas such as technology, socio-economic research to study institutional constraints, policies and organizational efficiency.

It is important to mention here that India's food security primarily depends on rice and wheat cropping system and that contributed to 104.32 million tonnes of rice and 93.9 million tonnes of wheat out of 257.44 million tonnes of total food grains in 2011-12. But in recent years the rice and wheat cropping system has been showing signs of fatigue, and the growth is stagnated due to several problems leading to unsustainability. Interestingly, China has 30 million hectares under paddy cultivation and it produces 200 million tonnes of rice per year, whereas India has 45 million hectares but the produce is only close to 100 million tonnes of rice. If we look into per hectare productivity in rice cultivation, one hectare of land yields 6.6 tonnes of rice in China and 3.3 tonnes in India.

The purpose of the present study was primarily to identify the factors responsible for deceleration in growth of agricultural production especially food grain production that too of major cereals such as rice and wheat. The study also covered the innovations that took place in rice and wheat sectors under research, policy front and institutional dynamics. It also focused in identifying the major factors affecting the reach of innovations in agricultural production systems in different agro ecological zones in India. The emphasis was on larger issues while analyzing the decline in growth of agricultural sector such as the role of public and private R & D in knowledge generation and transmission, local and regional policies, role of government and other institutions in assimilation of the innovations by various stakeholders including farmers, pest and disease problems, problems of extension mechanism etc.

In the present study, field investigations were carried out in certain selected districts to find out the reasons for deceleration in food grain production, the rate of adoption of modern technologies, the impact of input and output pricing policies, the research gaps and improvements that are required to counter the problems of food grain production. The data collected from various secondary sources was analyzed to find out the reasons for plateauing/ decline in food grain production and what are the plausible solutions to overcome these problems. This study would definitely help in guiding the researchers to reorient their research programmes for enhancing food grain production in the country. This would also help policy makers to formulate sound policies which can help in enhancing farmers' profitability through creation of right policy environment in terms of subsidies and other welfare programmes, while safeguarding the natural resources from further degradation. For extension personnel, this study would be of enormous help to identify the lacuna in dissemination of technologies, the type of modern tools or interventions required to enhance the reach of modern knowledge and the type of institutional changes required in the field of agriculture.

The objectives of the project were:

a) To study the research, policy framework and institutional dynamics that shaped agricultural innovation system in India.

b) To identify the factors affecting the reach of agricultural innovations in Indian agricultural systems including socio-economic and ecological factors especially in rice and wheat sectors.

Chapter 2
Methodology

Primary field investigation

Under this project a survey was conducted in Punjab, Haryana, Karnataka and Andhra Pradesh which are the major food grain producing states of our country. In the selected districts a field investigation was carried out in different agro ecological zones and the primary data was collected as per a set of designed questionnaire for specific themes and from various stakeholders of rice and wheat cropping system.

Table1. Selected areas for field investigation

State	Districts	Agro-ecological regions	Crops
Andhra Pradesh	East Godavari	Moist semi arid dry sub humid eco sub region	Paddy
	Khammam	Hot dry semi arid eco sub region	Paddy
Haryana	Hissar	Semi arid eco region	Wheat
Karnataka	Mandya	Hot semi arid region	Paddy
	Bellary	Hot arid eco region	Paddy
Punjab	Roopnagar	Hot semi arid (dry)	Wheat

Field investigation: In the field investigation in different districts of India, we collected information on new technologies adopted, which includes high yielding varieties, accessibility of technologies, yield obtained, pest management strategies followed, emerging/reemerging pests and diseases, nutrient management, water management, socio economic conditions, data on type of innovations that resulted in crop improvement, yield improvement in rice and wheat crops and cropping systems, problems faced by the farmers in rice and wheat production, and their expectations from government welfare schemes, farmers' view on price and subsidy policies, participation of youth in agriculture, marketing and storage facilities available etc.

Database on Rice and Wheat production systems

Information was collected on varieties and technologies developed, problems faced in rice and wheat cultivation, innovations in research that enhanced rice and wheat production in the country, present status of research on hybrids and high yielding varieties, scenario of pest and diseases etc., from major rice and wheat research institutions in India including Indian Agricultural Research Institute, New Delhi, Directorate of Wheat Research, Karnal, Directorate of Rice Research, Hyderabad, Punjab Agricultural University, Ludhiana and Hissar Agricultural University, Hissar.

Visit to Krishi Vigyan Kendras (KVKs) and District Agricultural Advisory and Transfer of Technology Centre (DAATT)

Visits were made to KVKs and DAATT centres in different districts of Punjab, Haryana, Karnataka and Andhra Pradesh. The field investigations were carried out to get information on available technologies, rate of adoption by the farmers, problems in adoption, what improvements are required in the existing technologies etc. Data was collected on cropping pattern, irrigation availability, fertilizer use, farmers' perspective on modern technologies and mechanization.

Visit to State Department of Agriculture offices, farmers and other stake holders

In addition to KVKs and DAATT centres, the project team also visited various state department of agriculture offices, farmers, mill owners and godowns. While visiting farmers, the project team could witness rice and wheat crops grown under different production situations and collect information on problems faced by the farmers in different districts and their experiences with these crops.

Knowledge generation and collection of secondary source data

The overall knowledge on production trends in agricultural innovation systems are analyzed through secondary databases collected through published information available in peer reviewed journals, newspapers, reports, government documents and books. The project team also collected data through interactions with local NGOs, stakeholders and agricultural experts from the selected region. Secondary data was also collected from science and technology institutes, universities, institutes of higher learning and government offices.

National / International Seminars/ Conferences

The project team has interacted with several distinguished scientists, policy makers and other stake holders to obtain relevant information for the project. The team also organized a one day National Seminar on "The present situation and prospects of rice production in India" on August 3, 2012, and a National Workshop on "Innovations in Agricultural Policies/ Schemes/ Programmes in India" on August 10, 2012 at NIAS, Bangalore. Further an International Conference on "Increasing Agricultural Productivity and Sustainability in India – The Future We Want" was organized on 8th and 9th of January, 2013, in which distinguished National/ international experts of various sectors of agriculture took part.

Chapter 3
Trends in Agricultural Production in India

In India, agriculture is the principal means of livelihood for over 52% of its population. Agriculture also provides raw material for many industries and it accounts for about 10 per cent of the total export earnings. To meet demand of growing population, India needs to increase the production of food grains to 350 million tonnes by 2030 (Vision 2030, Indian Institute of Soil Science) and hence the production of food grains needs to be increased at the rate of 5.5 million tonnes annually from now onwards. Decelerated and unstable growth rates and the recent intensification of agrarian crisis in several parts of the country, pose a threat not only to national food security, but also to its economic well-being. Further, the estimates on food grain demand during coming years warrant a thorough analysis of production situation.

Table 1: All India: Temporal Change in Area (thousand hectares) Composition of Crop Groups, 1966/67 to 1996/97

Sl. No.	Crops	TE* 1966/67	TE 1976/77	TE 1986/87	TE 1996/97	2010-11
1	*Rice*	35728	38625	41154	42978	42863
2	*Wheat*	17930	16018	15995	25548	29069
3	*Coarse Cereals*	39610	46741	46711	31788	
4	*All Cereals*	93268	101384	103860	100314	100363
5	*All Pulses*	22905	23154	23437	23373	26408
6	*All Foodgrains*	116172	124537	127297	123686	126771
7	*All oilseeds*	16848	17988	20071	27837	27224
8	*Fibres*	9383	8403	8618	9716	
9	*Spices*	950	1326	1695	1904	
10	*Fruits & Vegetables*	1120	1480	1913	2382	
11	*Other Field Crops*	4544	5665	5828	5486	
12	*Plantation Crops*	489	677	840	691	
13	*All Non-Cereals*	56238	58691	62402	71389	
14	*All Crops*	149506	160075	166262	171703	
15	*Sugar cane*	2580	2841	2960	4061	4885
16	*Cotton*	8054	7266	7288	8678	
17	*Potato*	460	610	841	1162	1863

*TE- Terminal Estimate

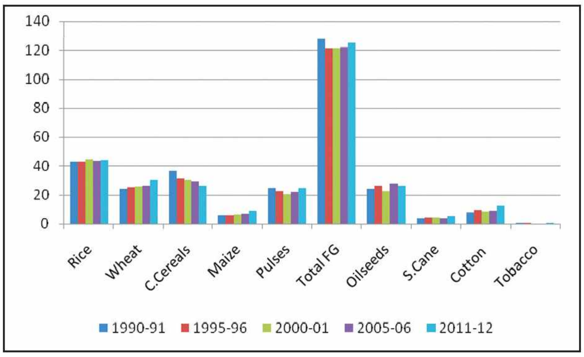


Figure 1: Area under different crops in last two decades

Source: Directorate of Economics & Statistics, Department of Agriculture & Cooperation

I. Food grain Production

Decadal analysis: The production of food grains increased from a mere 50 million tonnes during 1950-51 to about 242 million tonnes by the end of first decade of this century. The increase in productivity of total food grains is greater during the decade ending 1990-91 and it is followed by the decade ending 2010-11 (Figure 2). If we look at the decennial averages of area, production and average yield of total food grains, the area increased up to the decade 1981-90 and from there it started declining. The increase in area was more during 1961-70 and it was less during 1971-80 and 1981-90. From 1990-2000, the average area under food grains started declining as compared to that of the previous decade which could be due to more diversification of agriculture towards commercial crops. The total production as well as productivity of food grains witnessed an increasing trend until the decade 1991-2000 and showed a decreasing rate in the last decade (Table 2). The increase in area, production and productivity of total food grains during the last 60 years had been 29, 375 and 268 per cent respectively, compared to its values in the year 1950.

Similarly, the trend in area, production and yield of food grains in the first year of each decade is depicted in the following figure (Figure 2) which indicates that the area under food grains has started declining since last two decades. But the production is increasing because of improvement in average yields.

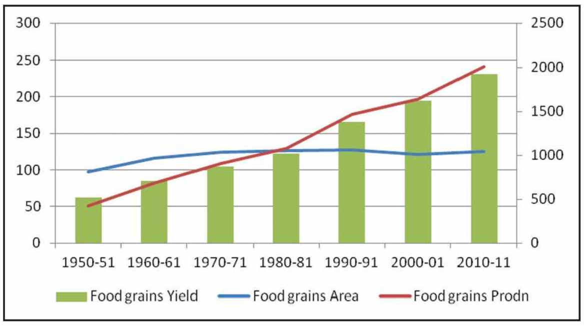


Figure 2: Area (Mha), Production (MT) and productivity (kg/ha) of food grains in the first year of every decade

Some interesting observations could be made from the analysis on annual growth rates in area, production and yield of seven major crops. The growth rates were estimated for three decades viz. 1980-81 to 1989-90, 1990-91

Table 2: Rice, Wheat and total food grain production situation in India (as decadal averages)

Crop		1951-60	1961-70	1971-80	1981-90	1991-00	2001-10
All food grains	Area (Mha)	107.51	118.20	124.81	126.81	123.62	121.31
	Production(MT)	65.47	85.00	111.53	146.55	188.55	211.22
	Yield (kg/ha)	606	718	893	1156	1521	1740
Rice	Area (Mha)	31.58	35.86	38.64	40.65	43.22	43.31
	Production(MT)	26.29	35.86	44.76	59.78	80.1	89.56
	Yield (kg/ha)	829	999	1156	1467	1852	2066
Wheat	Area (Mha)	11.46	14.01	20.11	23.30	25.55	26.86
	Production(MT)	8.36	13.30	27.78	44.76	64.21	73.68
	Yield (kg/ha)	728	937	1376	1917	2495	2741

to 1999-2000 and 2000-01 to 2010-11(Table 3). Rice had shown a declining trend in growth rates in area and production, especially during 2000 to 2010 against 1980's, though a marginal increase in growth rate of yield was observed in 2000 to 2010. Wheat, the second major crop had also shown declining trend in growth rates in area, production and yield during 2000 to 2010 compared to 1980's. However, maize had shown increasing trend in area, production and yield since 1980's. Much progress in production of pulses could be seen, as the area under pulses had increased from 22.46 million ha in 1980-81 to 26.28 million ha in 2010-11.

In the case of oilseeds also there is a positive growth in area, production and subsequently yield. Cotton showed a mixed trend over the years, as in 1980's it witnessed a negative growth in area and in 1990's there was negative growth in yield despite a marginal increase in area. However with the introduction of GM technology, the trends were reversed during periods 2000-01 to 2010-11 with as high as 13.80 per cent growth in production and 10.91 per cent growth in yield of cotton. Sugarcane showed an unstable trend as the area under sugarcane declined during 1990's as against 1980's and later recovered during 2000-01 to 2010-11. But no substantial increase in growth in production and yield could be observed.

The above growth rates of the principal crops over the years could lead to some important conclusions. Yield gain is the reason behind any increase in production rather than expansion in cultivated area. Food security could be achieved mainly because of Green Revolution technologies and no major technological breakthrough could be achieved afterwards (Planning Commission, 2011).

II Rice Production

In case of rice, the decadal average shows an increasing trend in area during the first four decades but at declining rate, whereas in the fifth decade there was an increase of 2.56 million ha and in the last decade there was a negligible increase in rice area (0.1 m ha). In general, production and productivity of rice showed increasing trend but at ascending rate upto 5th decade of our analysis and at descending rate during the last decade (Table 3). On the whole, the increase in area, production and productivity of rice over last six decades had been 38, 363 and 235 per cent respectively (Figure 3).

Similar to total food grains, rice production also followed a similar trend with stagnated area but with improvement in production and productivity at decadal intervals.

Table 3. Compound Growth Rates (%) of seven major crops in last three decades

Crop	1980-81 to 1989-90			1990-91 to 1999-2000			2000-01 to 2010-11		
	A	P	Y	A	P	Y	A	P	Y
Rice	0.41	3.62	3.19	0.68	2.02	1.34	-0.10	1.51	1.61
Wheat	0.46	3.57	3.10	1.72	3.57	1.83	1.28	2.16	0.87
Maize	-0.20	1.89	2.09	0.94	3.28	2.32	2.81	5.65	2.77
Total Pulses	-0.09	1.52	1.61	-0.60	0.59	0.93	1.62	3.35	1.90
Nine Oilseeds	2.47	5.36	2.49	0.17	1.42	1.42	2.13	5.16	3.01
Cotton	-1.25	2.80	4.10	2.71	2.29	-0.41	2.60	13.80	10.91
Sugarcane	1.44	2.70	1.24	-0.07	2.73	1.05	1.12	1.64	0.52

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation.

A - Area, P - Production, Y – Yield

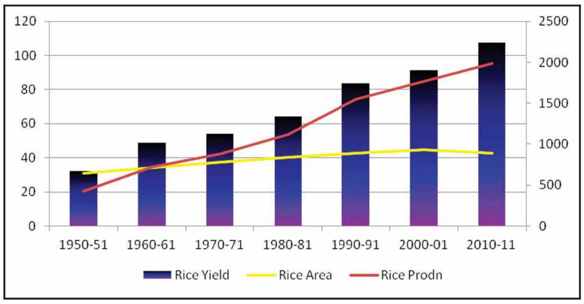


Figure 3: Area (Mha), Production (MT) and productivity (kg/ha) of Rice in the first year of every decade

The year 2011-12 was a landmark year for agriculture in general and for rice production in particular with the country crossing the magical mark of 100 million tonnes for the first time and as per final estimates; rice production is around 105.41 million tones.

State wise analysis

As per the statistics of 2009-10(Table 4), West Bengal contributed the major share of about 16 per cent of the total production of rice in the country with an area of about 13 per cent. However, the state's average yield is about 2547 kg/ha as against the national average of 2125 kg/ha and 4010 kg/ha already realized in Punjab. Out of 16 rice producing states, only 7 states had achieved yield more than the national average and 9 states had shown a yield performance of less than national average.

III. Wheat Production

The current analysis showed that area under wheat increased significantlyduring third decade (1971-80), which could be attributed to green revolution during the previous decade which facilitated availability of seeds of high yielding wheat varieties. In general, wheat area had shown an increasing trend over the past 60 years. The production and productivity of wheat also showed a positive growth during this period with an increasing rate during first five decades and followed by a decelerating rate during the last decade.

In case of wheat, the rate of increase in

Table 4: State wise share in Area, Production and Yield of Rice (2009-10)

State	Area %	Rank	State	Production %	Rank	State	Yield (kg/ha)
West Bengal	13.43	1	West Bengal	16.10	1	Punjab	4010
Punjab	12.37	2	U.P	12.61	2	Tamil Nadu	3070
U.P	10.41	3	Orissa	12.13	3	A.P	3062
A.P	8.76	4	Chhattisgarh	11.83	4	Haryana	3008
Orissa	8.21	5	A.P	7.76	5	Kerala	2557
Tamil Nadu	7.67	6	Bihar	6.36	6	West Bengal	2547
Assam	6.68	7	Punjab	4.87	7	Karnataka	2482
Chhattisgarh	5.95	8	Assam	4.61	8	U.P	2084
Karnataka	4.40	9	Tamil Nadu	4.14	9	Gujarat	1903
Haryana	4.18	10	Others	4.07	10	Assam	1737
Bihar	3.55	11	Karnataka	4.04	11	Orissa	1585
Others	3.51	12	Maharashtra	2.45	12	Jharkhand	1546
Maharashtra	3.45	13	M.P	1.73	13	Maharashtra	1485
Jharkhand	2.87	14	Haryana	1.45	14	Bihar	1120
Gujarat	2.37	15	Jharkhand	1.41	15	Chhattisgarh	1120
M.P	1.62	16	Gujarat	0.67	16	M.P	872
Kerala	0.56	17	Kerala	3.77	17	Others	-
All India	**100**		**All India**	**100**		**All India**	**2125**

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation.

production and productivity is more spectacular up to the first decade of the present century but again the increase in area is showing diminishing trend (Figure 4).

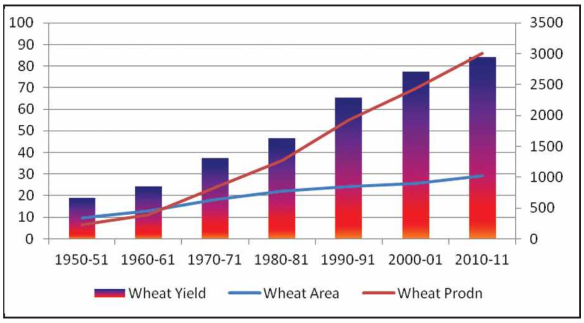


Figure 4: Area (Mha), Production (MT) and productivity (kg/ha) of Wheat in the first year of every decade

Statewise analysis

Uttar Pradesh ranked first in area and production occupying about 34 per cent of the total area under wheat in the country contributing 34 per cent of the total wheat produced in the country with an average productivity of 3002 kg/ha, a marginal increased level of productivity compared to the national average of 2907 kg/ha(Table 5).

Wheat crop has exhibited a vigorous growth trend since the onset of the Green Revolution in 1968. In 2001 Indian farmers harvested nearly 74 million tonnes of wheat, while the wheat harvest at the time of our Independence was only 6 million tonnes. Much of the increase in wheat production has come from productivity improvement.

IV. Annual growth rate

The area under wheat has increased significantly during the period 1966 to 1977 and after that an oscillating trend is observed in both wheat as well as total food grain area (Figure 5).

Similar to area, an enormous increase in annual growth rate of production and productivity of wheat is observed during 1967 to 1972 and in rice it is during 1975 to 1990 (Figure 6).

Improvement in yield of wheat and rice is more during green revolution period and continued to increase up to 1990 but then has been consistent during the last 20 years. This indicates that after green revolution, no major advancement in yield could be achieved in these two major crops.

Table 5. State wise share in Area, Production and Yield of Wheat (2009-10)

State	Area %	Rank	State	Production %	Rank	State	Yield (Kg/ha)
U. P	33.97	1	U. P	34.06	1	Punjab	4462
M.P	15.03	2	Punjab	18.77	2	Haryana	4390
Punjab	12.38	3	Haryana	12.99	3	Rajasthan	3175
Haryana	8.76	4	M.P	10.41	4	U.P	3002
Rajasthan	8.41	5	Rajasthan	9.28	5	West Bengal	2490
Bihar	7.71	6	Bihar	5.66	6	Gujarat	2377
Maharashtra	3.80	7	Gujarat	2.91	7	Bihar	2043
Gujarat	3.09	8	Maharashtra	2.15	8	Uttarakhand	2003
Uttarakhand	1.39	9	West Bengal	1.05	9	J& K	1735
H. P	1.24	10	Uttarakhand	1.05	10	M.P	1723
West Bengal	1.11	11	H.P	0.40	11	Jharkhand	1541
J.& K	1.02	12	J & K	0.36	12	H.P	1520
Karnataka	0.99	13	Karnataka	0.31	13	Maharashtra	1483
Others	0.56	14	Jharkhand	0.21	14	Assam	1090
Jharkhand	0.35	15	Assam	0.08	15	Karnataka	918
Assam	0.21	16	Others	0.31	16	Others	-
All India	**100**		**All India**	**100**		**All India**	**2907**

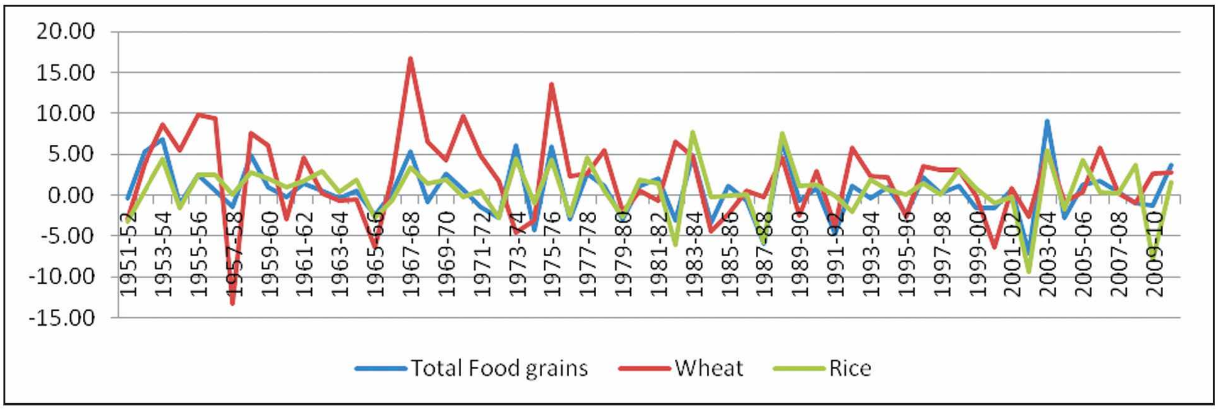


Figure 5: Per cent increase (annual) in area of Wheat, Rice and Total Food grains during the last 60 years

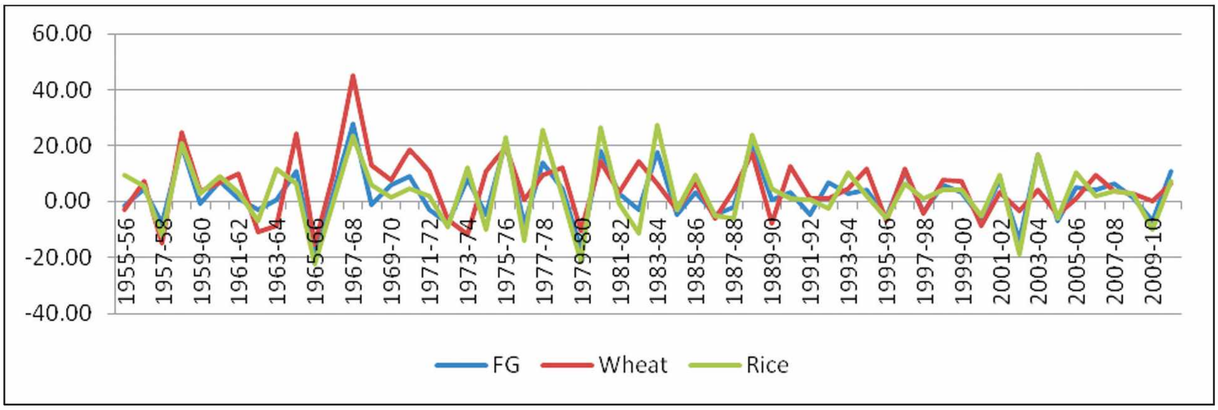


Figure 6: Per cent increase (annual) in Production of Wheat, Rice and Total Food grains during the last 60 years

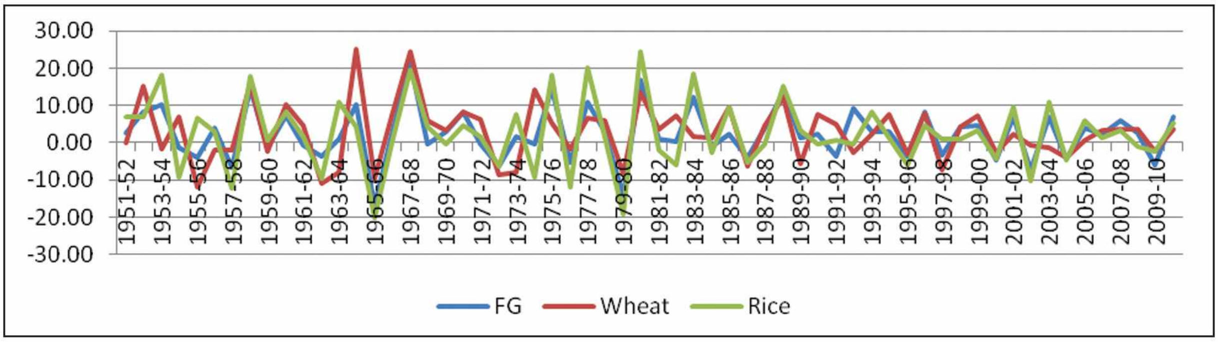


Figure 7: Per cent increase (annual) in Productivity of Wheat, Rice and Total Food grains during the last 60 years

V. Contribution of Agriculture to GDP

Agriculture makes the highest contribution to India's GDP. It has been seen in the last few years that the contribution of the agriculture sector in National GDP has been declining, but it is still the biggest contributor. The total production of food grain was 212 million tonnes in 2001-2002 and the next year it declined to 174.2 million tonnes. The growth Rate of the Agriculture Sector in India GDP grew at the rate of 1.7% each year between 2001-02 and 2003-04. From 19 per cent in 2004-05, the percentage share of agriculture & allied sectors in GDP dropped to 18.3 per cent in 2005-06 and then to 17.4 per cent in 2006-07. It further dropped to 16.8 per cent in 2007-08 and 15.8 per cent in 2008-09 before reaching 14.5 per cent in 2010-11. Share of agriculture and allied sectors to Gross Domestic Production (GDP) declined further to 13.9 per cent in 2011-12 from 14.5 per cent in 2010-11. The decline is on account of comparatively higher growth in GDP of non-agriculture sectors. And a number of factors such as literacy, insufficient finance, inadequate marketing of agricultural products etc. could be the reasons for this decline in the share of agricultural GDP. The other reasons for the decline in agriculture share to GDP are decrease in size of average land holding, level or non adoption of modern technologies such as high yielding varieties, balanced nutrition and good agricultural practices like appropriate planting time, timely weeding and harvesting. Insufficient irrigation facilities and injudicious management and unpredictable rainfall are also some of the reasons for this decline.

VI. Supply and Demand Scenario

An elaborative study conducted by Mittal (2008) concluded that an increase in demand for food is seen with low yield growths especially in cereals and any surplus in cereal production in the country is likely to diminish in the years to come. The deficit however, is projected to increase over the years particularly on the food items. This is a challenge as well as an opportunity. Providing ample opportunities to domestic producers might increase the income, generate more employment and involve more number of additional stakeholders through handling, value addition, processing and marketing.

It is estimated that by 2030, at least 150 million tonnes of milled rice is required to meet the food demands of growing population as against present level of 105 million tones.

Table 6: Shift in cropping pattern in India

	1970-71	1980-81	1990-91	2000-01	2009-10
Rice	23.02	23.18	23.00	23.82	22.01
Wheat	10.42	12.98	13.04	14.28	14.87
Coarse cereals	28.48	24.25	20.48	16.17	14.51
Total cereals	61.93	60.41	56.53	54.27	51.39
Total Pulses	13.5	13.23	12.94	11.49	12.47
Total Food grains	75.54	73.67	69.47	65.32	63.86
Total Oilseeds	9.85	10.11	12.51	12.96	14.86
Groundnut	4.42	4.14	4.64	3.68	2.92
Cotton	4.70	4.27	4.08	4.70	5.22
Jute	0.42	0.51	0.39	0.45	0.43
Total fibres	5.41	5.08	4.64	5.27	5.74
Sugarcane	1.62	1.62	1.90	2.23	2.39
Tobacco	0.27	0.25	0.22	0.21	0.25
Condiments and Spices	1.04	1.23	1.32	1.52	1.70
Potatoes	0.31	0.43	0.51	0.69	0.82
Onions	-	0.14	0.17	0.24	0.33
Total Fruits and Vegetables	2.24	2.77	3.57	4.35	5.40
Fodder Crops	4.15	4.50	4.59	4.55	
Total Non-Food grains	19.39	20.13	23.60	25.44	
Gross Cropped area	100.00	100.00	100.00	100.00	100.00

VII. Shift in cropping pattern

Although the gross cropped area has not changed much, there is a change in area under each crop during last 60 years especially after reforms are introduced (Table 6). The area under rice almost remained constant (22 to 23% of GCA) but wheat area increased from 10.4% to 14.81 % between 1970-71 to 2009-10. However the increase was only 0.83% during the last 20 years. A significant reduction in total cereals (10% in 40 years and 5% in 20 years), total food grains (12% in 40 years and 6% in last 20 years) is observed. Though the area under oilseeds is showing increasing trend, Groundnut area has come down drastically especially during the last twenty years. Cotton area improved substantially during the last twenty years along with other fibre crops. Area under sugarcane also has increased during last thirty years. Area under potato, spices and onions is showing a steady state of growth during the last four decades. A substantial increase in area under fruits and vegetables is observed during the last forty years. This indicates that there is a solid shift in area under cultivation from cereals to other commercial crops viz., cotton, sugarcane, fruits and vegetables, spices and condiments.

References:

Hazra, C. R (2001)Crop Diversification in India.FAO,Rome.

Surabhi Mittal,(2008) Demand-Supply Trends and Projections of Food in India, Working Paper No. 209, Indian Council For Research On International Economic Relations.

Vision 2030, (2011), Indian Institute of Soil Science, Bhopal.

Chapter 4

Factors Responsible for Deceleration in Food Grain Production

Critical factors for stagnation of food grain yield after mid 90s

1. Technological and environmental problems

a. **Exhaustion due to intensive practices of Green Revolution:** Enhancement in crop-yields during the Green revolution was possible mainly due to significant increase in the use of high yielding varieties, fertilizers and application of pesticides. However, excessive and imbalanced/inappropriate use of fertilizers led to pollution of groundwater, depletion of land resources and multiple nutrient deficiencies such as Zn, Fe, Mn and B increased. Pesticides consumption, which was 2000 tons in 1950-51 increased significantly and finally levelled off at 70,000 tons in 1990. This led to a shift in the spectrum of pathogens, accompanied by an increase in the infestation by pests and pathogens. Monoculture as against multi-cropping also favoured the growth and resurgence of pests.

Intensive farming and use of natural resources in a non-sustainable manner led to decline in soil health specifically. Organic content of the soil decreased. Eroding biology of the soil reduced the efficiency of fertilizers (Gadgil *et al*, 1999). In 1970s, 1 kg of fertilizer was sufficient for the production of 50 kg of grains. However, the same quantity of fertilizer in 2007/08 yielded 5-fold less amount of food grains (Benbi and Brar, 2009). Long-term experiments in Indo- Gangetic plains have shown that degradation of soil fertility has led to decline in yields of rice and stagnation in wheat production even with the application of N, P, and K fertilizers, and the use of modern intensive farming (Nambiar, 1994; Sinha *et al.*, 1998; Grace *et al.*, 2003). Intensive tillage and burning of crop residues has resulted in depletion of soil organic carbon and reduced productivity. Declined soil organic carbon is directly responsible for the decreased nutrient and water holding capacity thereby adversely affecting the fertility and structural stability of soil (Joshi *et al.*, 2000; Grace *et al.*, 2003).

b. **Salinity and waterlogging**: Intensive irrigation in areas with poor drainage led to a rise in the water table and consequently in the semi-arid and arid zones this led to salinity buildup, while in the humid zone to waterlogging. Poor irrigation system design and management and poor water pricing are major factors leading to salinity problems. In India, nearly 4.5 million hectares are affected by salinization and 6 million hectares by waterlogging (Dogra, 1986). Bastiaanssen *et al.*, (1998) estimated that in Sirsa Circle, Haryana, water tables were rising at 0.5 m per year, adding 1.8 t/ ha/ year of salt to the soil profile each year.

c. **Poor adoption of modern agricultural technology**: The Indian farmers being poor and less credit worthy are unable to adopt modern technologies which require high investment. Farming in such a situation is complex, diverse and risk prone. The Indian farmer receives just 10 to 23 percent of the price the Indian consumer pays for exactly the same produce, the difference going to post harvest losses, inefficiencies and middlemen traders. Farmers in developed economies of Europe and the United States, in contrast, receive 64 to 81 percent of the price the local consumer pays for exactly the same produce in their supermarkets. (bharatrashtra.com 2013)

In general, adoption rate of modern techniques is very low and it varies with the ecological conditions under which the crop is grown. Rate of adoption is comparatively better in irrigated agriculture than the rainfed agriculture. Due to the scarcity of ecosystem-specific improved varieties, the rate of adoption of modern varieties has been moderately low, and thereby led to low productivity (Barah, 2005). More than 55 per cent of the total number of modern varieties is targeted for irrigated areas, while the same is 27 per cent in rainfed lowland and 19 per cent for rainfed upland.

d. **Post harvest losses due to inefficient supply chains**: A third of all the food that is produced is lost due to inefficient supply chains. Yield losses can be caused due to poor pre- and post-production handling. Post-production losses range from 10% to 30% of the harvestable yield. Losses are more serious in the wet-season harvests due to the lack of drying facilities. Resource-poor farmers tend to deploy labor-intensive practices like hand harvesting, sun drying, manual threshing, wind winnowing, and inappropriate storage, thus contributing greatly to grain losses. Training of farmers and access to credit to introduce more efficient technologies to handle threshing, drying, storage, and milling at the village level are important for reducing post-production losses.

e. **Dependence on rainfall**: Indian agriculture is a gamble as it is highly dependent on monsoon. At present, only 55% of the gross cropped area is under irrigation because of inadequate irrigation sources, though the potential of irrigation is far ahead (140 M ha). Rainfall deficiency causing early drought situation affects vegetative development of rice crop, while submergence and floods due to high rainfall, damage the rice crop in the later period. In the eastern states, damage from flash floods is also severe (Barah, 2005).

f. **Climate Change:** Some studies by the Indian Agricultural Research Institute, New Delhi, indicated the possibility of loss of 4-5 million tonnes in wheat production with every rise of 1° C temperature throughout the growing period even after considering carbon fertilization, but no other adaptation benefits (Aggarwal *et al.*, 2010). In the IGP, rice yields during the last three decades are declining; partly due to the gradual change in weather conditions in the last two decades (Aggarwal, 2008). Extreme weather conditions, such as floods, droughts, heat and cold waves, flashfloods, cyclones and hail storms, are direct hazards to crops. More subtle fluctuations in weather during critical phases of crop development can also have a substantial impact on yields (Kumar *et al.*, 2004).

2. Socio economic problems:

i) Land (size, and tenure, topography, soil fertility/health, salinity, organic matter, waterlogging and drainage, depletion of groundwater, land market); (ii) Labour (seasonality of labour use, skill, training, family vs. hired labour, labor control and wage rate, gender issues); (iii) Capital (availability and use of seed, fertilizer, pesticides, credit availability, quality and timeliness, and farm machinery); (iv) Management (skill, education, awareness, extension, and adoption and modification of practices); and (v) Marketing and infrastructure (location, transportation, storage, processing, and market information) (Pingali, 1999) are some of the important socio economic problems contributing to reduction in overall productivity of food grains.

Small Farm holding size

The average size of the farms is very small which in turn has resulted in low productivity. Smallholders in agriculture constitute more than 80% of total farming households, 50% of rural households and 36% of total households in India. The growth in rural population is the main factor underlying an increase in number of holdings in India. It is interesting to point out that since 1970-71, both the number of landholdings and rural population increased exactly at the same rate (1.76%). Per hectare value of crop output was Rs 25,173 at holdings below 0.4 ha and Rs 18,921 at holdings of size 0.4 ha to 1 ha. As the farm size increased towards 2 ha, productivity declined to less than Rs 17,000 per hectare. In large farms (4 ha to 10 ha) the value of aggregate crop production declined to Rs 13,500 per hectare. Farmers operating on landholdings above 10 ha (the very large size category) were found to have very low productivity (Rs 7,722) which was about half of the productivity at large holdings and less than one-third of the productivity in the bottom farm size category. Agriculture productivity in marginal and smallholdings was found to be much higher than the average productivity for all size categories. The above results indicate the inverse relationship between farm size and land productivity. Per capita output is low on smallholdings despite higher productivity due to lower per capita availability of land.

Whether the size of farm land really affects the productivity?

The average size of land holdings is very small (less than 2 hectares) and is subject to fragmentation due to land ceiling acts, and in some cases, family disputes. Such small holdings are often over-manned, resulting in disguised unemployment and low productivity of labour. Some reports claim smallholder farming may not be because of poor productivity, since the productivity is higher in China and many developing economies even though China smallholder farmers constitute over 97 percent of its farming population. Chinese smallholder farmer is able to rent his land to larger farmers, China's organized retail and extensive Chinese highways are able to provide the incentive and infrastructure necessary to its farmers for sharp increases in farm productivity.

Table 7: Average farm size, productivity, annual agriculture growth rate and per capita daily income in China and India

Particular	China	India
Average farm size	0.6	1.21
Productivity/ha Kg 2008		
Paddy	6,556	3,370
Wheat	4,762	2,802
Average annual agriculture growth rate (%):		
1990-2009	4.1	3.2
2000-09	4.4	2.9
Poverty based on $1 per capita daily income based on PPP 2005 (%):		
1981	84.0	59.8
2005	15.9	41.6

Sources: (1) FAOSTAT. (2) World Development Indicators 2010, World Bank. (3) Selected Indicators of Food and Agricultural Development in the Asia Pacific Region, 1995-2005, RAP Publication 2006/16, FAO RAP, Bangkok.

Table 8: Changes in Share of Smallholders in Number and Area of Operational Holdings at All India Level (%)

Year	Share in No of Landholdings			Share in Operational Area		
	Marginal (< 1 ha)	Small (1-2 ha)	Subtotal (< 2 ha)	Marginal (< 1 ha)	Small (1-2 ha)	Subtotal (< 2 ha)
1970-71	51	19	70	9	12	21
2005-06	65	19	83	21	21	42

Source: Agricultural Census 2000-01 and 2005-06, Department of Agriculture and Cooperation, GOI.

During the 1960s and 1970s there was an intense debate on the observed inverse relationship between farm size and per hectare agricultural productivity in India. It was subsequently argued that the higher productivity of smallholdings would disappear with the adoption of superior technology, modernization and growth in general. However, close to half a century later, National Sample Survey data from the initial years of the 21st century showed that smallholding in Indian agriculture still exhibit a higher productivity than large holdings. These smallholdings however show lower per capita productivity and the incidence of poverty is widespread. Strategies for Indian agriculture and smallholding households should include reducing the inequality in land distribution and promoting off-farm work in the rural areas itself. The strategy of improving the crop land-man ratio by facilitating migration from rural India has not worked and will not work. The lives of smallholding families can be improved only by building on their higher per acre agricultural productivity and income by promoting off-farm rural employment.

Marginal and smallholders make better use of inputs as revealed by the lower fertilizer imbalance index. Crop intensity, which is the main source of growth in agriculture in India, was found to be the highest in marginal holdings and it declined with an increase in farm size. The inverse relationship between farm size and productivity based on the aggregate of all crops has been quite pronounced in the recent years. Advances in technology and the scale factor in production did not dilute the superior performance of lower size holdings. Various theories about disappearing advantages of marginal and small farmers and efficiency gains of large sized farmers with economic development are not found to be operating in Asian countries like India. Farm size on consideration like non-viability of smallholders will adversely affect productivity and growth of Indian agriculture. The recent evidence on farm size and productivity provides strong support in reducing land inequality and lowering agricultural land ceiling limits to improve productivity and growth of Indian agriculture. Tiny holdings below 0.8 ha do not generate enough income to keep a farm family out of poverty despite high productivity. Nearly three-fourths of small farmers in India fall under poverty if they do not get income from non-farm sources. Raising income of such farmers, by relocating a sizeable chunk outside agriculture and thus raising the size of holdings had not worked in India and other major Asian countries. Another strong factor against this option is that an increase in the size of landholdings involves lower productivity. Serious steps should be taken to create employment avenues for smallholders outside agriculture, but within the countryside so that the workforce in small farms gets work and income from rural non-farm activities without leaving the farms. This seems to be the only way to achieve higher productivity and to sustain agricultural growth together with augmenting the income of smallholders for improved livelihood.

There are contradictory findings that smaller size of land holdings results in reduced productivity and vice versa. The experience of China also offers some interesting lessons for India's policy towards smallholders. Tiny size of holding did not constrain the attainment of high level of productivity and growth of agriculture sector (Table 7). Second, unlike developed countries in the west, the farming population in Asia has a strong preference to hold agricultural land. It is thus imperative to look for ways and means to improve productivity and livelihood of smallholders without worrying too much about the size of holdings per se.

Reddy and Sen (2004) reported that in Bihar, factors like farm size, farmer's education, extension contacts, and experience in production and percentage of good farm land reduce the technical inefficiency in wheat production while fragmentation of farm land and age of farmer influence it positively.

3. Policy and institutional issues

a. **Opening up of Indian economy:** In early 1990s Indian economy was opened out to the world and liberalization/ globalization became an important development strategy of the government. A visible effect of this strategy was that the crop pattern shifted from food-grains to high-value crops such as oil-seeds, sugarcane, cotton, fruit and vegetables. Primary reason for this trend was high demand for fruit and vegetables, introduction of BT cotton and protection of domestic oilseed industry from imports. Thus the relative importance of food-grains declined and demand shifted to high-value crops, due to their higher profitability (Sharma, 2011).

b. **Lack of timely availability of credit:** Farm credits have significantly increased over years. However, due to urban sectors being the prime focus of scheduled commercial banks, their outreach in rural areas is limited. This has resulted in lower deployment of Credit in agriculture. Long-term credit is essential for creation of rural agri-business infrastructure like warehouses, storages, etc. Lower growth in long-term credit in agriculture as compared to short-term credit is a cause of concern, since it is linked to decline in agriculture productivity in general and food-grains in particular. Also, a decline in the number of small loans suggests that small farmers are bearing the burden of credit crunch in agriculture (Sharma, 2009).

c. **Subsidy policy:** Due to vote bank politics and sometimes because of over enthusiasm to help the farmers, the subsidy policy initiated on fertilizers and free electricity resulted in imbalanced use of fertilizers and over exploitation of aquifers resulting in declined productivity and toxicity of soils. Subsidy to urea created an imbalanced use as farmers apply excess of urea (N) but do not care about the application of P, K and other secondary and micro nutrients. This deteriorated the soil nutrient balance and resulted in reduced yields.

References:

Aggarwal, P.K. and Sivakumar, M.V.K. (2010). Global Climate Change and Food Security in South Asia: An Adaptation and Mitigation Framework. pp. 253-275.

Aggarwal, P.K. 2008. Global climate change and Indian agriculture: impacts, adaptation and mitigation. *Indian J. Agric. Sci.* 78: pp. 911-919.

Agricultural Census 2000-01 and 2005-06, Department of Agriculture and Cooperation, GOI

Barah BC, Pandey S. 2005. Rainfed rice production systems in eastern India: an on-farm diagnosis and policy alternatives. *Indian J. Agric. Econ.* 60(1).

Benbi D. K.and M.S. Brar. (2009) Evaluation of Soil Fertility and Nutrient Balances under Intensive Agriculture. *Proceedings IPI-OUAT-IPNI International Symposium.*

Bharatrashtra.com, 2013. Available from: <http://bharatrashtra.com/2013/10/current-situtation-of-indian-agriculture/> [7 January 2014]

Directorate of Economics & Statistics, (2013). Department of Agriculture & Cooperation.

Gadgil S, Abrol Y.P and Seshagiri Rao P.R.(1999). On growth and fluctuation of Indian food-grainproduction. *Curr. Sci.*76: 548-556.

Grace, P.R., Jain, M.C., Harrington, L., Philip Robertson, G., (2003). The long-term Sustainability of tropical and sub-tropical rice and wheat systems: an environmental perspective.

Improving the Productivity and Sustainability of Rice – Wheat Systems: Issues and Impacts, ASA Special publication 65, Madison, USA

Joshi, P.K., Asokan, M., Datta, K.K., Kumar, P., (2000). Socio-economic constraints to legumes production in rice-wheat cropping systems of India. ICRISAT, Patancheru, India, pp. 176 – 184.

Kumar K. K, Kumar K. R, Ashrit R. G., Deshpande N. R. and Hansen J. W (2004), Climate impactso n Indian agriculture. *Int. J. Climatol.* 24, pp. 1375–1393.

Nambiar K. K. (1994), Soil fertility and crop productivity under long-term fertilizer use in India. Indian Council of Agricultural Research, New Delhi, pp 234 – 67.

Pingali, P. L., Rajaram, S. R., (1999). World Wheat Facts and Trends 1998/99 CIMMYT Institute, Mexico, DF.

Reddy, A.R., C. Sen and R.R. Mishra, (2004). Inefficiency in rice production: Sone Command Area of Bihar. Productivity, 44: 683-687. Selected Indicators of Food and Agricultural Development in the Asia Pacific Region, 1995-2005, RAP Publication 2006/16, FAO RAP, Bangkok.

Sharma, Madhu (2009) Agricultural Credit in India: Status, Problems and Future Strategies. Oil & Food Journal, Vol. 4, No. 11, pp 48-50.

Sinha, S.K., Singh, G.B., Rai, M. (1998), Decline in Crop Productivity in Haryana and Punjab: Myth or Reality? Indian Council of Agricultural Research, New Delhi, India.

Vijay Paul Sharma and Dinesh Jain, (2011), High-Value Agriculture in India: Past Trends and Future Prospects, Indian Institute of Management,Ahmedabad.World Development Indicators 2010, World Bank.

Chapter 5
Innovations in Research in Indian Agriculture

1. **Green Revolution technologies:** Development of semi-dwarf varieties in Wheat and Rice combined with improved farming practices and policies to support these initiatives have contributed to a very great extent in shaping the Indian agriculture. This made the country self sufficient in food grain production. The food grain production has increased from a mere 50.82 million tons in 1950-51 to 257.44 million tons in 2012-13.

2. **Release of photoperiod insensitive varieties of rice and wheat:** This helped to extend the cultivation of these crops to non-traditional areas thereby expanding their area under cultivation. The release of photo periodically insensitive cultivars of rice and wheat made timely sowing and harvesting of both crops possible in rice-wheat cropping systems. The dominant characteristic of that system is the repeated transition from the anaerobic conditions for rice to aerobic conditions for wheat. This has great impact on the soil physical properties, as well as on the chemical reactions of indigenous and exogenous nutrients in the soil (Timsina and Connor, 2001) and on the overall production.

3. **Hybrid Rice Technology:** In light of the remarkable success of the Chinese in this field, ICAR initiated a goal oriented project in December, 1989 to develop and utilize hybrid rice in Indian Agriculture. Till now 59 hybrids have been released, 35 from public sector and 24 from private sector. During the year 2011, hybrids were cultivated in an area of 2.0 million ha. It is expected that during the next five years hybrids will cover about 3 - 5 million hectares. By cultivation of hybrids, farmers are obtaining an additional yield advantage of 1-2 t/ha, the additional net profit being in the range of Rs. 3,000 – 5,000 per ha. In hybrid rice seed production, seed yields of around 2.0 t/ha are obtained with a net profit of Rs. 25,000 to Rs. 30,000/- per ha for the seed growers.

4. **Gene pyramiding for biotic and abiotic stress resistance in Basmati rice :** This has revolutionized the rice production and resulted in export of basmati rice. Successful pyramiding of genes for biotic (bacterial blight, blast and brown plant hopper) and abiotic (salt tolerance and phosphorus uptake) stresses in Basmati rice is likely to revolutionize the rice production in India. Indian Agricultural Research Institute (IARI) has successfully carried out pyramiding of genes there by realising resistance to biotic (bacterial blight, blast and brown plant hopper) and abiotic (salt tolerance, and phosphorus uptake) stresses in Basmati back ground (Singh *et al.*, 2011). In 2011, three drought-tolerant rice varieties bred by IRRI in partnership with the Nepal Agricultural Research Council were released *viz.*, Sookha Dhan- 1, 2 and 3, which have shown a yield advantage of 0.8–1.0 ton per hectare over

current varieties under severe drought. Golden Rice enriched with high levels of pro-vitamin A, holds promise overcoming malnutrition in rice.

5. **Resource conserving technologies**

a) **Zero tillage or reduced tillage**: Zero tillage or reduced tillage is a promising technological innovation which is successfully used in rice – wheat production system in the Indo - Gangetic plains (IGP) in India. Zero tillage of wheat after rice generates significant benefits at the farm level, both in terms of significant yield gains (6-10 %) and cost savings (5-10%, particularly tillage savings).

b) **System of Rice and Wheat Intensification** Through SRI both in rice and wheat, it is possible to save both irrigation water and also seed. This helps in increasing the irrigable area and thereby production. Tamil Nadu is far advanced by adopting SRI principles in 20% of the rice area. In addition to this, germplasm conservation, interactive kiosks for different crops, quality planting material, natural resource management through resource characterization, crop diversification, farming system technologies, development of farm machinary etc. are also the contributors.

I. Innovations in Rice Sector

In India, rice is cultivated in 44 million hectares, which contributes to almost 30% of total food crop and 43 % to the total food security of the country among the food grains. Rice generates an income of about 3 lakh crores, that is about 35 to 40 % of GDP with production of 130 to 135 MT. Currently, the import-export balance in agriculture looks positive, due to the basmati rice export which contributes about 12,000 crores. The number of rice varieties released in the country has reached around 1000 from the post independence situation of 400 varieties due to the efforts of various research institutes in the country (Viraktamath, 2012). The following are the important innovations that took place in rice crop which shaped Indian agriculture towards its present position of self sustainability. A critical analysis of the factors contributing for the increase in rice production suggest that area expansion and extension of area under irrigation contributed to the extent of 8.3 and 15 per cent respectively while remaining 76.7 per cent has come from varieties, fertilizer inputs and adoption of improved crop and pest management practices.

1. Development of Semi-dwarf high yielding varieties

Due to the development of high yielding varieties through introduction of dwarfing gene *sd-1*conferring short stature, from a Chinese variety, Dee-geowoo-gen, rice area, production and productivity increased by 21, 125 and 86 per cent respectively during a period of 30 years starting from 1970's. India not only became self sufficient in rice but also started exporting rice – both the scented basmatis and non-basmatis. The first high yielding variety in rice, Jaya was released by India in 1968. The first generation HYVs were semi-tall, profuse tillering, photo-insensitive, fertilizer responsive, non-lodging with a yield potential of 4 t/ha. These varieties ushered in the green revolution in the country. During the next three decades, over 580 varieties were developed and released for various rice ecologies. Their yield potential ranged between 1.5 to 7.5 t/ha with a duration of 75 to 185 days. The key to this success was the selection of the genotypes with rapid vegetative vigor at the earlier growth stages. This helped farmers to grow two rice crops during the year in areas where good irrigation facilities existed, or introduce a non-rice crop in the rice-based system depending on the resources available. Improved scented varieties like Pusa Basmati, Sugandhmati, Yamini etc. have enhanced rice exports. While 2.2 million tons of basmati rice worth 10,580 crores is exported from the country during 2010-11, even non-basmati type varieties are exported to the tune of 3.0 to 5.0 million tons worth another 4,000 crores rupees in foreign exchange.

Early rice variety *Vandana* for escaping cyclone in coastal areas: The early maturing variety vandana developed by CRRI, Cuttack matures within 90 days and it can be grown successfully in coastal areas where occurrence of cyclones is a regular phenomena. This can be harvested before the cyclonic prone period of September to November. Many of the farmers in coastal districts of Odisha are adopting this variety.

2. Genome Sequencing

Along with these innovations in breeding, in 2002 the draft sequence of indica (Yu *et al.*, 2002), and japonica subspecies of rice (Goff *et al.*, 2002) were sequenced and assembled. *Oryza sativa* L. ssp. *indica* genome is of 466 megabases in size, with an estimated 46,022 to 55,615 genes, while the *Oryza sativa* L. ssp. *japonica* genome is of 420-megabases with 32,000 to 50,000 genes. The results of sequencing rice are providing the foundation for future the improvement in rice improvement.

Rice being the first crop that was completely sequenced, the sequencing of rice genome and decoding of map-based rice genome is a significant milestone in plant genomics. More than eighteen thousand simple sequence repeats (SSRs) are identified in rice which can act as a potential source of markers that would help tremendously in molecular breeding. Cereals comparative genomics has revealed an extensive synteny and gene homology between rice and the other cereal genomes, and has helped unravel major events in genome evolution of cereals and millets (Tyagi, 2007). Presently the research scientist all over the world are eager to use the tools and resources available after the sequencing of rice genome, and one of the successful use of these resources results in cloning the gene which help rice plant to grow in phosphorus-starvation(Gamuyao *et al.*, 2012). But the challenges for the future lie in the understanding of regulatory networks during plant development and response to biotic/abiotic factors, as well as in deploying the knowledge gained to support breeding.

3. Hybrid Rice Technology

Convinced by the potential of hybrid rice technology to enhance productivity and production of rice, in light of the remarkable success of the Chinese in this field, Indian Council of Agricultural Research (ICAR) initiated a goal oriented project in December, 1989 to develop and utilize hybrid rice in Indian Agriculture. First set of hybrids were developed and released in 1994. Till now 59 hybrids have been released, 35 from public sector and 24 from private sector. The hybrid rice seed production and cultivation packages have been developed and optimized. During the year 2011, hybrids were cultivated in an area of 2.0 million ha. It is expected that during the next five years hybrids will cover about 3 - 5 million hectares. The popular hybrids being cultivated in the country are PA6444, PHB-71, Pusa RH 10, KRH-2, Sahyadri, Rajlaxmi, DRRH3 etc. Unlike in China, in India, private industry is very proactive in hybrid rice research and also seed production. More than 20 private seed companies are actively involved in hybrid rice research, varietal development and also seed production. Over 95 percent of the hybrid rice seed in the country is produced by the private sector.

By cultivation of hybrids, there is an additional yield advantage of 1-2 t/ha, and the additional net profit is in the range of Rs. 3,000 –

5,000 per ha. In hybrid rice seed production, seed yields of around 2.0 t/ha are obtained with a net profit of Rs. 25,000 to Rs. 30,000/- per ha for the seed growers.

At present hybrids are cultivated in Uttar Pradesh, Chattisgarh, Jharkhand, Bihar, Haryana and Punjab. Some of the major constraints to further expansion of hybrid rice are lack of matching grain quality, lack of resistance to major pests and diseases and higher seed cost. Research efforts to overcome these constraints are underway. Recently released hybrids like DRRH-3, 2T P 11 and JK 3333 have excellent cooking quality (DRRH-3, the first rice hybrid with MS grain type). It is expected that hybrid rice will play a major role along with the New Plant Type (NPT) varieties, in raising the productivity and production of rice in the coming decades.

> According to Dr. Mahadevappa, Agricultural Scientist, if hybrid rice and SRI method of paddy cultivation are adopted, there is ample scope to make tangible progress in improving the production in all the riparian states of south India by reducing the pressure on water demand and the dispute for water will gradually fade way in the country

Hybrids did not make much head way in South India because of the preference for medium slender grain type with premium quality similar to BPT5204. The existing hybrids are long grained and sticky type. Hence a new hybrid was developed by DRR, Hyderabad with medium slender grains having premium quality similar to BPT 5204 and matures 10 days earlier to it. This is expected to increase the hybrid rice cultivation in southern states like Andhra Pradesh, Karnataka, Tamil Nadu, Pondicherry and Maharashtra where very limited area is under hybrid rice at present.

4. System of Rice Intensification (SRI)

The system of rice intensification is an organic technique for increasing the yield of paddy. It was developed in Madagascar in 1983 by Henri de Laulanié, a French Jesuit. Norman Uphoff, Director of International Institute for Food, Agriculture and Development at Cornell University, New York, helped to spread SRI across the globe in the 1990s. Instead of planting three-week-old rice seedlings in clumps of three or four in waterlogged fields, as rice farmers around the world traditionally do, the farmers carefully nurture only half as many seeds, and then transplant the young plants into fields, one by one, when much younger. Additionally, they space them at 25cm intervals in a grid pattern, keep the soil much drier and carefully weed around the plants to allow air to their roots. The premise that "less is more" was taught by Rajiv Kumar, a young Bihar state government extension worker who had been trained in turn by Anil Verma of a small Indian NGO called PRAN (Preservation and Proliferation of Rural Resources and Nature), which has introduced the SRI method to hundreds of villages in the past three years (Vidal, 2013).

- There are four main SRI principles: early and healthy transplant; reduced plant density; improved, organic soil conditions; and reduced and controlled water application.
- Seedlings are transplanted when they are eight to twelve days old
- The roots are carefully protected to minimise 'transplanting shock'
- To avoid root competition and to encourage faster growth, seedlings are planted 25cm apart in a square grid pattern
- Soil is enriched with organic matter. Some farmers use urea to achieve balanced fertilisation

- Ten days after transplanting, a rotary hoe is used every seven to ten days. It keeps weeds under control, provides superficial tillage, aerates soil, prunes roots of the crop and removes water patches in the field (Dnyanesh Jathar, 2014).

SRI is increasingly recognized in India as an innovative practice that increases productivity in a sustainable way, and is gaining acceptance by farmers, especially marginal and resource poor. Under the conditions of dwindling water resources and climate change, SRI offers a sustainable solution for efficiently utilizing each drop of water more efficiently.

Kenyan team studies SRI project in Villupuram, Tamil Nadu (Adapted from The Hindu report)

SRI is not a fixed package of technical specifications, but a system of production with four main components, *viz.*, soil fertility management, planting method, weed control and water (irrigation) management. Several field practices have been developed around these components. SRI requires almost no standing water for the rice to grow and also increases the yield. With this method of rice cultivation women were benefitted as it reduced the labour requirement as well as drudgery. The field trials of Directorate of Rice Research, Hyderabad proved that grain yield recorded under SRI was significantly higher compared to NT at 53% of the locations, while it was similar to that under ICM at 33% of locations involved. Higher grain yield under SRI was recorded in diverse soil types, with wide range of soil pH (6-8) and different regions which could be associated with increased number of panicles per unit area, biomass and panicle weight. However, the cultivars used had significant interaction with method of cultivation at 28% of the locations. Rice hybrids responded better than varieties.

In India alone due to efforts of the WWF-ICRISAT project and many other national partners, it is estimated that about 600,000 farmers are growing rice with all or most of the recommended SRI crop management practices in about 1 million ha distributed across 300 districts of the country. This is probably the most rapid uptake of new agricultural practices seen in this country. It sets a great example of a partnership between farmers, civil society, government agencies and international organizations working together, learning from each other and pooling together the competitive strengths (ICRISAT). SRI cultivation is reported to improve the yields by 30 to 80 per cent and save water up to 40% than the traditional method of cultivation. It also helps in saving of seed requirement

A farmer named Sumant Kumar of Darveshpura in Bihar's Nalanda district got a bumper harvest of 22 tonnes per hectare using SRI, which was more than the world record of 19.4 tonnes by the agricultural scientist, Yuan Longping of China who is known as the father of hybrid rice. Yet another farmer named Surendra Prasad from Sarilchak in Nalanda has set a national record for wheat production with a yield of 12.6 tonnes per hectare by adopting SRI for wheat. (Dnyanesh Jathar, 2014).

However, there are mixed responses from different states on SRI performance. Bihar had shown good improvement in yields and in Tamil Nadu also it is very suitable for seed production. Presently almost 20 per cent of rice area is under SRI method of cultivation in Tamil Nadu. A round table discussion was held by National Consortium of SRI (NCS) on up scaling of SRI cultivation in XII plan during January, 2012 and it was decided that it would be included in the XII plan in some form and it is a part of NFSM.

5. Pest Management

The widespread use of semi dwarf varieties of rice and nitrogen fertilizers and the increased use of insecticides have changed the status of pests from low to high economic importance in rice production. Integrated pest management (IPM) is the most effective method for controlling pests while improving productivity and caring for the environment (Kenmore, 2003).

Evidences indicate that pests cause 25 percent loss in rice, 5-10 percent in wheat, 30 percent in pulses, 35 percent in oilseeds, 20 percent in sugarcane and 50 percent in cotton (Dhaliwal and Arora, 1996).

The pest problems are more severe in irrigated rice ecosystems. Among different rice systems, rice-rice-rice harbor more insect pests than rice-wheat or rice-maize systems. A study carried out by Rockfeller foundation reveals that seven out of 20 major challenges in rice production are insect pest and diseases. Among the biotic stresses insect pests cause about 10-15% yield losses. The average yield losses in rice have been estimated to vary between 21-51 per cent. Yellow stem borer, brown planthopper and gall midge were the key pests in rice causing 25-30%, 10-70% and 15-60% yield losses, respectively. At National level, stem borers accounted for 30% of the losses than planthoppers (20%), gall midge (15%), leaf folder (10%) and other pests (25%).

The composition of pests and diseases infesting rice crop may vary in different regions. For instance, in the north-western states (Punjab and Haryana), stem borer, leaf folder and white backed planthopper among insect pests, and bacterial leaf blight among diseases are the important pests. While in the coastal Andhra Pradesh, stem borer, gall midge and brown planthopper are major insect pests. Leaf folder and whitebacked planthopper are relatively less important. In Assam, stem borer among insect pests and bacterial leaf blight and blast among diseases are of major concern. In upland and rainfed rice areas, some other insect problems like termites, root aphid and gundhi bug are of major concern in addition to stem borer and leaf folder. Blast is a major disease problem in upland and hilly areas. This pest identification is a first step in developing location-specific IPM programmes. Once the pest has been identified, the immediate step is the selection of a variety with desired traits such as resistance, grain quality, etc. This should be followed by sowing and planting at an appropriate time (Pasalu *et al.*, 2004).

The different components of IPM are

a) Resistant crop varieties

A number of resistant varieties, with single or multiple resistance to insect pests, mites and nematodes, are commercially available in rice. These varieties have high yield potential and possess desired agronomical characteristics. This is the cheapest and most safest method of pest control.

b) Good Agronomic Practices (GAPs)

Adoption of some good agronomic practices can also help in keeping some of the pest problems at abeyance. Timely planting, proper water management and sanitation, proper spacing and balanced fertilization contribute to better pest control.

c) Biological Control

Release of egg parasite, *Trichogramma japonicum* and *T.chilonis* is really an effective approach to decrease the Yellow stem borer or Leaf folder incidence in rice. It is also observed that use of a very high count of *Trichoderma viridae* and a few bacterial antagonists are effective against fungal pests.

d) Chemical Control

This is one of the quickest and, sometimes, the only solution for the sudden outbreak of pests, specially insect pests. But it is not an environmentally safe practice when used alone. Adoption of IPM can help in better control of rice pests along with minimal environmental pollution.

e) Botanicals for control of Rice blast

By spraying of aqueous extract of Bael leaf @ 25 g/litre of water and steamed aqueous extract of Tulsi leaf @ 25 g/litre of water at 10 days interval, the blast disease of rice was successfully and effectively controlled in farmers' field. The rice crop had registered, an 80% to 85% recovery as compared to 45% recovery in ediphenphos (Hinosan) sprayed field.

6. Diversified Farming

The Green Revolution technologies had been highly explorative and exploited natural resources to a very great extent. This warranted development of integrated farming system to improve the productivity and sustainability by the integration of different components. Among the various farming system options in rice ecologies, rice - fish farming has great potential particularly in eastern India in view of the resources, food habits and other socio-economic conditions. Rice-fish diversified farming system with the integration of compatible components, such as improved varieties of rice, fish, prawn, pulses, oilseeds, horticultural crops, agroforestry, mushroom, poultry, duckery, goatery, floriculture, apiculture etc. can increase the farm productivity, besides farm employment over traditional rice farming.

a) Rice-fish culture

In India, though six million hectares are under rice cultivation, only 0.03 per cent of this is now used for rice-fish culture. This type of fish culture has several advantages such as (a) economical utilization of land, (b) little extra labour, (c) savings on labour cost towards weeding and supplemental feeding, (d) enhanced rice yield, and (e) additional income and diversified harvest such as fish and rice from water, and onion, bean, and sweet potato through cultivation on bunds. Considering these, it is imperative to expand fish culture in the rice fields of our country. The paddy fields retain water for 3-8 months in a year. The culture of fish in paddy fields, which remain flooded even after paddy harvest, serves an off-season occupation and additional income to the farmer. This system needs modification of rice fields, digging peripheral trenches, construction of dykes, pond refuge, sowing improved varieties of rice, manuring, stocking of fish at 10,000/ha and finally feeding of stocked fish with rice-bran and oilcakes at 2-3% of body weight.

This method of farming has the following advantages:

- Fish increases rice yield by 5 to 15 per cent, which is chiefly due to the indirect organic fertilization through the fish excrement and also the control of unwanted filamentous algae which may otherwise compete for the nutrients.
- Tilapia and common carp control the unwanted aquatic weeds which may

otherwise reduce the rice yield up to 50 per cent.

- Insect pests of rice like stem borers are controlled by fish feeding on them like murrels and catfish.
- Fish feed on the aquatic intermediate hosts such as malaria causing mosquito larvae, thereby controlling water-borne diseases of human beings.
- Rice fields may also serve as fish nurseries to grow fry into fingerlings. The fingerlings, if and when produced in large quantities may either be sold or stocked in production ponds for obtaining better fish yield under composite fish culture.

Coastal saline soil extends from the main sea coast to a few or even 50 km at places interior to the main land. The ground water table under these soils is generally present at a shallow depth and contains high amount of soluble salts. These salts accumulate on the surface of the soil due to capillary rise of saline groundwater during dry periods of the year rendering the soil highly saline. Almost the entire area of the rain fed coastal saline soil is mono cropped in nature. The major agricultural crop of kharif is rice, grown during monsoon period when soil salinity is low. During the rest of the year, the land usually remains fallow due to high salt content of the soil.

The kharif paddy varieties widely used in such areas are Mahsuri, Sadamota, Kalomota, Talmugur, Damodar, Dasal, Getu, Nona-patnai, Jaya, Ratna, Pankaj, Patnai-23, Luni, Cuttackdhandi, Pokkali, Vytilla, Bilikagga, CSR-4, CSR-6, Matla, Hamilton, Palman 579, BKN, RP-6, FR-46B, Arya, etc. Paddy cum brackish water fish/ shrimp culture in paddy fields aims at utilizing the summer fallow period of the coastal saline soil through a short-term brackish water aquaculture without affecting the subsequent kharif paddy crop. This type of activity provides the farmers with a substantial subsidiary income during the fallow season.

In West Bengal, where the salinity is either low or lowered by fresh water discharge diluting the tidal water, the cultivation of fish is undertaken in paddy fields. In pokkali fields of Kerala, summer fallow months are utilized for brackish water aquaculture. The production of fish in such culture varies from 300 to 1000 kg/ha. The brackish water shrimp culture is introduced in a big way in such areas as the remuneration is very high. The species commonly cultured are *Penaeus monodon, Penaeus indicus, Metapenaeus dobsonii* and *Metapenaeus monoceros*.

Success story of Rice-Fish farming in Orissa

Shri Sunakar Mishra of Mahisara village under Dharmasala block and Jajpur district in Orissa has developed 35 acres large rice-fish farm following the technology developed at CRRI, Cuttack. The farmer got a net income of Rs 16 lakh from rice-fish-prawn and other crops. Shri Mishra grows CRRI semi-deepwater rice varieties (Varshadhan, Durga) along with around 3 lakhs juveniles of fresh water prawn (*Macrobrachium rosenbergii*) and 2 lakhs of fingerlings (Catla, *Catla catla* and Rohu, *Labeo rohita*). Vegetables (bitter gourd, okra, ridge gourd), tuber crops and pulse (pigeon pea) are grown on the bunds around.

A study conducted by Mangala (2008) in Dharwad district of Karnataka on impact of BAIF introduced integrated farming system (IFS) programme resulting in significant changes in the overall socio-economic status of BAIF beneficiaries. The IFS practices were agriculture + horticulture + dairy (3.57%), agriculture + horticulture + dairy + forage crops (7.86%), agriculture + horticulture + forestry + dairy + forage crops (5.00%), agriculture + horticulture +forestry + dairy + vermicompost (62.14%), agriculture + horticulture + forestry + dairy + vermicompost + forage corps (21.43%). Major contribution of higher income by adopting the combination of agriculture + horticulture + forestry + dairy + vermicompost + forage corps (average Rs. 38,000/annum) followed by agriculture + horticulture + forestry + dairy + vermicompost (average Rs. 35,000/annum).

II. Innovations in Wheat Sector

Wheat (*Triticum* spp.) is the second most important winter cereal in India after rice. Bread wheat contributes approximately 95% to total production while another 4% comes from durum wheat and Dicoccum share in wheat production remains only 1%. Wheat crop contributes substantially to the national food security by providing more than 50% of the calories to the people who mainly depend on it.

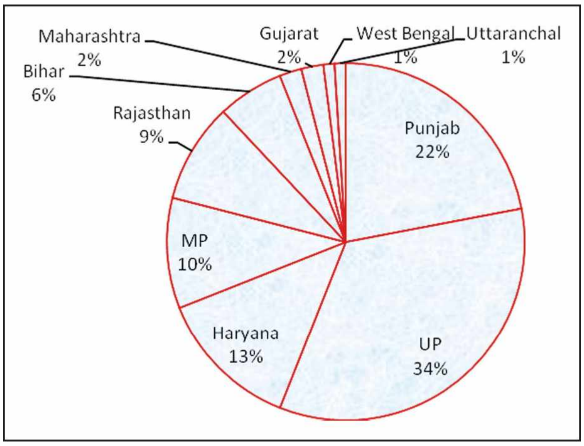


Figure 8: Per cent share of wheat production in different states (2009)

About 94% of the wheat is produced in six North Indian states viz., Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, Rajasthan and Bihar. Among them Uttar Pradesh with 1/3rd production is the highest producer of wheat followed by Punjab (22%) and Haryana (13%). Higher productivity is seen in Punjab and Haryana(Figure 8).

1. Semi-dwarf Varieties

Development of high yielding semi dwarf varieties by introducing the dwarfing gene Norin-10 has revolutionized the wheat production in India during 1960s and the momentum continued even upto early 80s. So far, about 399 wheat varieties have been developed, comprising bread wheat (335), durum (54), dicocccum (5) and triticale (5), for cultivation under different wheat growing zones. The wheat production has increased almost 9 fold from 10 million tones in 1960s to 105 million tones in 2011-12.

The Green Revolution breakthrough came in March, 1961, when a few dwarf spring wheat strains possessing the Norin-10 dwarfing genes, developed by Norman E.Borlaug in Mexico, were grown in the fields of Indian Agricultural Research Institute. They were dwarf with long panicles. In 1964, a National Demonstration Programme was started in farmers' fields both to verify the results obtained in research plots and to introduce semi-dwarf varieties for improving the productivity of wheat. Small farmers, with the help of scientists, could harvest over 5 tonnes of wheat per hectare. Consequently, the demand for seeds began and the area under high yielding varieties of wheat rose from 4 ha in 1963-64 to over 4 million ha in 1971-72 because, in 1966, C. Subramaniam, the then Minister for Food and Agriculture, decided to import 18,000 tonnes seed of the Mexican semi-dwarf varieties, Lerma Rojo 64A and Sonora 64. This was followed by the release of Kalyan Sona and Sonalika, selected from the advanced generation material received from Mexico. Further, hybridization between Mexican strains and Indian varieties resulted in many high yielding and rust resistant strains in different parts of the country.

Aneuploid stocks

Wheat is a hexaploid. Through nulli-tetrasomic (Sears, 1966), ditelosomic (Sears and

Sears, 1978), and deletion lines (Endo and Gill, 1996) the mapping of markers to the specific chromosome of A, B, D genome, or to arm and sub-arm of different chromosomes has become possible (aneuploid stocks). This is a significant innovation in wheat breeding which helped in developing cytogenetically based physical maps of the wheat homologous groups, and information on the physical positions of genes controlling phenotypic traits and many aspects of wheat chromosome structure and function (Endo and Gill, 1996).

2. Resource Conservation Technologies

a) Zero Tillage

Resource conserving technology (RCT) i.e zero tillage or reduced tillage is promising technological innovations which are successfully used in rice – wheat production system in the Indo - Gangetic plains (IGP) in India. Zero tillage (ZT) of wheat after rice generates significant benefits at the farm level, both in terms of significant yield gains (6-10 %) and cost savings (5-10%) particularly tillage savings.

Zero tillage wheat is particularly appropriate for rice–wheat systems in the IGP by allowing earlier wheat planting, helping control the weed *Phalaris minor*, reducing production costs and saving water. ZT wheat after rice generates substantial benefits at the farm level through the combination of a yield effect (a 5–7 % yield increase, particularly due to more timely planting of wheat) and a cost savings effect. The combined effect of a yield increase with a cost saving implies that returns to ZT adoption are pretty robust (Erenstein and Laxmi, 2008).

Zero tillage was found successful in Ramba village, Karnal district of Haryana. During 2007-08, the average wheat yield in a farm was 6.0 ton per ha using zero tillage which is at par with conventional practices. Wheat was sold as seed @ Rs 11200 per ton to seed growing companies. The operational expenditure was Rs 10000 per ha. Therefore the net profit was Rs 5,72,00 per ha. Without compromising on wheat yield, the farmer saves at least Rs 2500 to 2900 on account of ploughing. A minimum saving of Rs 2,50,000 is simply due to adoption of zero tillage technology.

b) Bed Planting

The practice of growing rice, the major water-using crop in rice-wheat systems, on narrow raised beds was introduced only very recently in the Indo-Gangetic Plains (IGP) to reduce water use, conserve rainwater and improve system productivity.

In bed planting systems, wheat or other crops are planted on the raised beds in ridge-furrow system. Recent work shows that system of raised bed planting of crops may be particularly advantageous in areas where groundwater levels are falling and herbicide-resistant weeds are becoming a problem. In furrow irrigated raised bed system (FIRB), management of irrigation water is improved. On an average it uses, 30% less water than flat bed methods and improves crop yields by more than 20%. FIRB planting saves 30% to 50% wheat seed compared to flat bed planting. Yield potential is enhanced through improved nutrient-water interactions and less lodging. Yield of rice transplanted on FIRB is comparable with traditional rice culture with as much as 25%-50% saving in irrigation water. Compaction of soil is limited only to the furrows used as tramlines (tractor tracks) (Connor *et al.*, 2002).

3. Intercropping in Bed Planting

Bed planting has been found successful specially in regard to water savings, mechanical weed management possibilities, fertilizer placement and bolder grain production. But, farmers did not adopt this technology in a larger extent as there are certain problems like hindrance by previous crops stubbles to bed planter, termite problem on top of the dry beds and problem in adjusting seeding depth. In bed planting of wheat, 35-40 cm wide beds with interfurrow spacing of 70 cm were formed with the help of a bed planter, fitted with seed-cum-fertilizer mechanism. Wheat is sown in 2 or 3 rows per bed with lower seed rate in bed planting. The results indicate an increase of 5.5% in wheat yield due to bed planting. However, farmers did not take up this technology readily, as it is costly. But, bed planting is an agronomic intervention where intercrop is sown on beds. When wheat is grown as intercrop with sugarcane, it worked out very well and resulted in increased yields of both the crops as it accommodated timely planting for wheat (within October to first week of November) and longer growth time for sugarcane crop. The yield of wheat raised on beds was on par with the yield obtained in case of sole crop of wheat. Simultaneously, an increase in the yield to the extent of 222 q ha-1 was recorded in case of sugarcane. This is a paradigm shift in the way sugarcane and wheat can be grown together with no yield penalty to wheat or sugarcane.

4. Integrated Pest Management Strategies

Through concerted research efforts in the form of protection technologies, a check has been kept on the management of various pests and diseases. As a result of this, no outbreak of any diseases or pests has been witnessed during the last three and a half decades. Significant breakthrough in resource management research has led to the development of a number of resource conservation technologies, like zero tillage, that have increased the sustainability and profitability of wheat based cropping systems.

References:

Arora, R. and Dhaliwal, G.S. (1996) Agroecological changes and insect pest problems in Indian agriculture. *Indian J. Ecol*. 21(2) pp.109-122.

Connor D.J., Raj K. Gupta, Peter R. Hobbs and K.D. Sayre. 2002. http :/ /www .knowledgebank. irri. org/ckb/PDFs/croppingsystem/conservation/ bed%20planting%20in% 20rice-wheat %20 systems.pdf

Dnyanesh Jathar, 2014, Rice and shine. Available from <http://week.manoramaonline.com/cgibin/ MMOnline.dll/portal/ep/theWeekContent.do? programId=1073755754&contentId=15873238>, accessed on January 10, 2014

Endo T. Rand Gill B. S, 1996, The Deletion Stocks of Common Wheat, *Journal of Heredity*,Vol.87, pp. 295-307

Erenstein, O., and V. Laxmi. (2008). Zero tillage impacts in india's rice-wheat systems: A review.*Soil and Tillage Research* 100 (1–2): 1–14.

Goff, S.A, *et al*, (2002) A Draft Sequence of the Rice Genome (Oryza sativa L. ssp. japonica).*Science* Vol. 296, 5565 pp. 92-100.

Jun Yu *et al*, (2002), A Draft Sequence of the Rice Genome (*Oryza sativa* L. ssp. indica) *Science* Vol. 296 no. 5565 pp. 79-92.

Mangala (2008) impact of integrated farming system on socio-economic status of bharatiya agroindustries foundation (baif) beneficiary farmers. M.Sc. (Ag) Thesis submitted to UAS, Dharwad

Pasalu I.C., B. Mishra, N.V. Krishnaiah and Gururaj Katti1 2004. Integrated Pest Management in Rice in India: Status and Prospects Proceedings (11) of Integrated Pest Management in Indian Agriculture. *Edited by*Pratap S. Birthal, O. P. Sharma pp: 25-50

Rico Gamuyao *et al*, (2012) The protein kinase Pstol1 from traditional rice confers tolerance of phosphorus deficiency. *Nature* Vol. 488, pp.535–539.

Sears ER, 1966.Nullisomic-tetrasomic combinations in hexaploid wheat. In: Chromosome manipulation and plant genetics (Lewis DR. ed).London: Oliver and Boyd; 29-47.

Sears ER and Sears LMS, 1978.The Telocentric chromosomes of common wheat.Proceedings ofthe Fifth International Wheat Genetics Symposium, NewDelhi, India, 23-28 February 1978 (Ramanujam S, ed). New Delhi, India: Indian Society of Genetics and Plant Breeding, IARI; pp. 389-407.

Singh, K, S. Gopalakrishnan, V. P. Singh, K. V. Prabhu, T. Mohapatra1, N. K. Singh, T. R. Sharma1, M. Nagarajan, K. K. Vinod, Devinder Singh, U. D. Singh, Subhash Chander, S. S. Atwal, Rakesh Seth, Vikas K. Singh, Ranjith K. Ellur, Atul Singh, Deepti Anand, Apurva Khanna, Sheel Yadav, Nitika Goel, Ashutosh Singh, Asif B. Shikari, Anita Singh and Balram Marathi (2011). Marker assisted selection: a paradigm shift in Basmati breeding *Indian J.Genet.*, 71(2): 1-9.

Timsina, J., Connor, D.J., 2001. Productivity and management of rice –Wheat cropping systems:issues and challenges. *Field Crops Res.* 69, 93 – 132.

Vidal, John, 2013, India's Rice Revolution. Available from: <http://www.theguardian.com/global-development/2013/feb/16/india-rice-farmers-revolution >

Chapter 6
Innovations in Policy Framework

India had no concrete agricultural policy till 1999. At the beginning, agricultural policies were aimed at distribution of food through various government schemes and then they were focused on agricultural production and consequently on resource management. Once India attained the status of self sufficiency in food production, then the focus of policies was shifted towards pricing, market, insurance, liberalization etc. Among the different policies, Land Reform policy (1948), goal oriented production policy and price policy are very important. Land reform policy was successful in West Bengal, Karnataka, Maharashtra and Andhra Pradesh where land was distributed to land less. But, the poor farmers were unable to cultivate the crops in these lands as they were lacking in investment for purchase of seeds and inputs. Seed policies were started in 1960s and consequently National Seed Corporation was started by Government of India. National Seed Policy was introduced in 2002. It is a fact that the seed replacement in our country is only 12% as against the recommended level of 30%. Apart from this, Water Users Co-operative Society established to control irrigation water supply was a successful step in most of the areas. Insecticides Act of 1968 and Fertilizer control order, subsidy policy on fertilizers which has been changed recently to Nutrient based subsidy, credit policy etc also contributed enormously to Indian agriculture. National Insurance Policy 2000, Food Safety and Standards Act 2006, Tariff Policy of 1995 are also other important policies. Establishment of NABARD is an important innovation in credit policies of our country. Kisan Credit card is another welcome step. Indian economy remained closed until 1990s and it was opened with economic reforms in 1991. The economic reforms include liberalization, privatization and globalization. The Exim Policy has undergone a sea change in 1992, where restrictions on agricultural trade flow were removed except for the export of cereals, pulses and edible oil and import of onions.

Impact of Land Reforms: In 1949 states were given liberty to form their own land reform legislations as per their convenience. In general there were four types of land reforms viz., 1.Tenancy reforms 2.Reforms to abolish intermediaries 3. Reforms on land ceilings and 4. Consolidation of disparate land holdings. Among these four, tenancy reforms and abolition of intermediaries have had a strong link with reduction of poverty in different states. Land reforms also benefitted agricultural labourers by raising the wages. From analysis of data pertaining to the period 1958 to 1992 Timothy and Burgess (1999) felt that policies aimed at partial reforms concentrating on improving agricultural production would further benefit to reduce the poverty and enhance the agricultural wages.

Impact of Economic Reforms

Table 9: Growth in area under food grains in India

Crops	Area (Million hectares)				CGR		
	Pre ER	Post ER	Over all	% change	Pre ER	Post ER	Over all
Total food grains	126.29 (2.35)	122.29 (2.00)	124.29 (2.25)	-3.17	-0.02	-0.06	-0.14
Rice	40.44 (2.43)	43.39 (2.92)	41.91 (3.89)	7.28	0.50	0.09	0.30
Wheat	22.56 (4.41)	26.50 (2.88)	24.53 (3.70)	17.46	1.01	0.60	0.80
Maize	5.85 (2.12)	6.88 (3.62)	6.37 (7.10)	17.75	-0.40	2.12	0.90
Total Pulses	23.16 (3.83)	22.42 (4.25)	22.79 (4.16)	-3.20	0.02	0.01	-0.11
Total oilseeds	19.27 (6.70)	25.50 (7.11)	22.39 (8.69)	32.33	2.22	0.18	1.41
Cotton	7.54 (5.92)	8.68 (7.43)	8.11 (7.71)	15.12	-0.20	0.90	0.60
Sugarcane	3.08 (6.45)	4.18 (8.45)	3.65 (7.13)	35.71	1.41	1.21	1.51

Figures in the parenthesis indicate the respective coefficient of variation around the trend

Pre Economic Reforms (1974-75 to 1991-1992), Post Economic Reforms (1992-93 to 2009-10) Overall (1974-75 to 2009-10)

Table 10: Growth in production of food grains in India

Crops	Production (Million tonnes)				CGR		
	Pre ER	Post ER	Over all	% change	Pre ER	Post ER	Over all
Total food grains	139.46 (6.42)	202.55 (5.24)	171.01 (6.21)	31.15	2.02	1.21	2.02
Rice	56.99 (8.15)	85.77 (6.33)	71.38 (8.07)	33.56	3.36	1.11	2.33
Wheat	41.08 (5.25)	70.14 (5.35)	55.61 (6.78)	41.43	4.50	1.51	3.05
Maize	7.14 (12.37)	12.94 (9.69)	10.04 (15.11)	44.81	2.12	4.19	3.25
Total Pulses	11.95 (10.20)	13.51 (8.20)	12.73 (9.07)	13.05	1.01	0.50	0.70
Total oilseeds	12.26 (14.94)	23.02 (13.49)	17.64 (15.15)	87.77	4.29	1.41	3.46
Cotton	7.71 (13.79)	14.86 (23.77)	11.34 (26.89)	92.74	2.22	4.71	3.36
Sugarcane	176.06 (8.52)	281.84 (10.81)	231.12 (11.34)	60.08	3.05	1.11	2.43

Figures in the parenthesis indicate the respective coefficient of variation around the trend

Pre Economic Reforms (1974-75 to 1991-1992), Post Economic Reforms (1992-93 to 2009-10) Overall (1974-75 to 2009-10)

The average area under food grain (Table 9) during the pre reforms period was 126.29 million hectare whereas the same during the post reforms period was 122.29 million hectare. Thus, there was a reduction in the area under food grains. The area under rice and wheat which are the two major cereals of the country recorded a positive growth. The rate of growth in area under these two crops was however slightly less during the post reforms period when compared to that in pre reforms period. The area under food grains decelerated at a mild annual rate of -0.02 per cent.

It was interesting to note the rate of deceleration was slightly more during post reforms period. Maize was another cereal which registered a substantial positive growth during the post reforms period. The annual rate of growth in pulse production during post reforms period was less by about half of that during pre reforms period and average area under oil seeds and cotton during post reforms period was higher compared to that of pre reform period.

The production of the rice was increased at an annual growth rate of 3.36 per cent and wheat at 4.50 percent during pre reforms period, while rice production increased at annual rate of 1.11 percent and wheat at 1.51 per cent during post reforms period (Table 10). However, the growth rate in food grains production was much higher during pre reforms period as compared to that of post reforms period. The annual rate of growth in pulse and oilseed production during post reforms period had decelerated but a substantial increase in the average annual production of cotton was observed in post reform period compared to pre reform period.

The productivity of rice and wheat as given in Table 11, grew at around 3 per cent per annum during pre reforms period while, the productivity growth was around only one per cent during post reforms period. Thus the growth in the food grain production in the country was a result of the growth in productivity. In fact the area under food grains has registered a negative growth. The productivity of cotton has improved during the post reforms period and the annual growth rate was 3.67 per cent whereas the pulse and oilseed productivity increased at a slight level.

Shift in Cropping pattern over decades in Indian Agriculture

- **Net Sown area** is the total area sown with crops in a country. Area sown more than once is counted once only.
- **Gross sown area** is the area sown more than once in an agricultural year plus net sown area.
- **Main food grain crops**: rice, wheat and maize

Table 11: Growth in productivity of food grains in India

Crops	Productivity (Kg/ha)				CGR		
	Pre ER	Post ER	Over all	% change	Pre ER	Post ER	Over all
Total food grains	1103.92 (4.99)	1655.77 (3.74)	1379.85 (5.15)	49.99	3.05	1.21	2.22
Rice	1402.20 (6.72)	1975.12 (4.30)	1688.66 (6.15)	40.86	2.74	1.01	1.92
Wheat	1804.12 (4.11)	2641.72 (3.54)	2222.92 (5.90)	46.43	3.36	0.80	2.12
Maize	1220.50 (11.00)	1863.15 (7.11)	1541.83 (8.77)	52.65	2.12	1.92	2.22
Total Pulses	514.83 (7.53)	601.90 (5.48)	558.37 (6.59)	14.47	1.01	0.30	0.80
Total oilseeds	626.33 (9.61)	899.53 (9.39)	762.93 (9.69)	43.62	2.02	1.29	1.92
Cotton	174.00 (10.92)	287.50 (21.75)	231.92 (21.71)	65.23	2.53	3.67	2.63
Sugarcane	56906.24 (3.80)	67379.28 (4.75)	62397.28 (6.16)	18.40	1.51	-0.10	0.80

Figures in the parenthesis indicate the respective coefficient of variation around the trend
Pre Economic Reforms (1974-75 to 1991-1992), Post Economic Reforms (1992-93 to 2009-10) Overall (1974-75 to 2009-10)

- **Coarse cereals**: Jowar, Ragi, Bajra, Save, Harka, Barnyard Millet, Barley, Oats, Rye
- **Total cereals** : Main food grains + Coarse cereals
- **Total food grains**: Main food grain crops + coarse cereals + pulses
- **Commercial crops**: Oilseeds, Cotton, Sugarcane, Jute and Mesta, Horticulture crops
- **Non-Food crops**: oil seeds, fibres, sugarcane, cotton, fodder crops etc.

In last 40 years cropping pattern in India had undergone a significant change due to the increased population and growing demand for food. This has put agricultural land into stress condition resulting in crop intensification and substitution of food crops to commercial crops or non-food grain crops. This may lead to imbalance in agricultural sustainability and also can cause threat to food security.

Although the net cropped area has not changed much, there is change in area under each crop during last 40 years especially after economic reforms were introduced. Rice and wheat are the staple food for majority of the population in India, where area under rice crop remains constant. In case of wheat during last 40 years 4.5% increase in wheat area is observed. In the past, coarse cereals extensively contributed towards total food grain area when compared to rice and wheat crop. In the recent decades coarse cereals are less preferred and used, has lead to drastic decrease in its area by 14%. Due to decline in area under coarse cereals, it has affected area under total cereal production which include wheat, rice, maize and other coarse cereals that has significantly affected the total area under food grain crop/ has lead to threat to food security in country(Table 12).

In addition, decreased production of food grains due to shift in focus of farmers towards

Table 12 : Percentage (%) shift in cropping pattern over decades in Indian Agriculture

Crops	1970-71	1980-81	1990-91	2000-01	2008-09	2009-10
Rice	23.02	23.18	23.00	23.8	23.1	22.0
Wheat	10.42	12.98	13.04	14.23	14.3	14.9
Coarse cereals	28.48	24.25	20.48	16.2	-	14.5
Total cereals	61.93	60.41	56.53	54.3	51.6	51.4
Total Pulses	13.5	13.23	12.94	11.5	12.2	12.5
Total Food grains	75.54	73.67	69.47	65.3	63.8	63.9
Total Oilseeds	9.85	10.11	12.51	13.0	15.2	14.9
Groundnut	4.42	4.14	4.64	3.7	3.2	3.0
Cotton	4.70	4.27	4.08	4.7	4.8	5.2
Jute	0.42	0.51	0.39	0.4	0.4	0.4
Total fibres	5.41	5.08	4.64	5.3	5.3	5.8
Sugarcane	1.62	1.62	1.90	2.2	2.5	2.4
Tobacco	0.27	0.25	0.22	0.2	0.2	0.3
Condiments and Spices	1.04	1.23	1.32	1.5	1.6	1.7
Potatoes	0.31	0.43	0.51	0.7	-	0.8
Onions	-	0.14	0.17	0.2	-	0.3
Total Fruits &Vegetables	2.24	2.77	3.57	4.3	5.2	5.4
Fodder Crops	4.15	4.50	4.59	4.5	4.4	3.9
Total Non-Food grains	19.39	20.13	23.60	25.4	26.8	26.6
Total Gross Cropped Area (Mha)	**1970-71**	**1980-81**	**1990-91**	**2000-01**	**2008-09**	**2009-10**
	165.8	172.6	185.7	185.3	195.4	192.2
Net Cropped Area (Mha)	140.3	140	143	141.3	141.3	140.3
Total area under Food grain cultivation	124.3	126.7	127.8	121	122.8	121.1

commercial crops has resulted to major shift in area under food grain sector, to be replaced with commercial crops such as oilseeds, sugarcane, cotton, fruits & vegetables etc.

Interestingly, the food habits of consumers in India during 1990s onwards underwent a significant change; the per capita consumption of cereals declined, while that of high value commodities/ commercial crops increased considerably. As we know, India initiated economic reforms in 1991. Since then, a number of policy initiatives have been undertaken to liberalize markets and improve agriculture industry linkages. Some of the above developments played a role in inducing shift in cropping pattern from food crops to commercial crops.

In addition, introduction of certain programmes/ schemes in the high value food commodities especially oilseeds and horticulture may have influenced shift in cropping pattern. These programmes such as The National Horticulture Board of 1984, National Horticulture Mission of 2005, Technology Mission on Oilseeds of 1986 etc were initiated to boost production, disseminate information, provide technical know-how and services, exports etc to these sectors.

Cotton area improved substantially due to widespread cultivation of Bt cotton, the major reason for the rise in production of cotton. It was found that productivity and profit from Bt cotton cultivation was substantially higher than the conventional hybrid cotton varieties (Naik *et al.*, 2005).

In general, a) slowly picking up momentum in favor of high value food commodities to augment income, b) the nature of shift in cropping pattern differs across regions due to wide heterogeneity in agro-climatic and socio-economic environments.

Thus the continuous shift/change in cropping pattern from food grain crops to non-food grain crops, may lead to imbalance in cropping pattern which can affect sustainable development and can cause threat to food security.

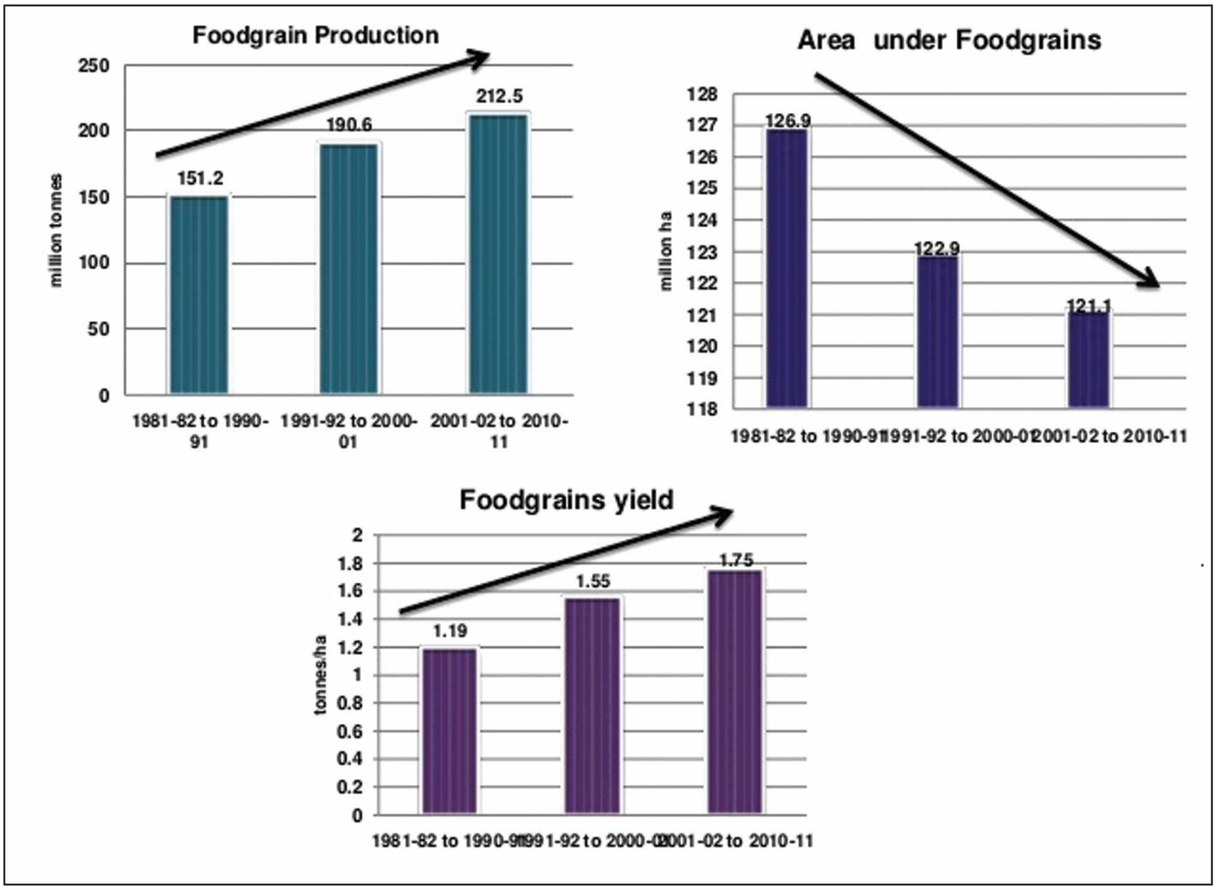
From figure 9 it is clear that the shifting in cropping pattern has affected the food grain cultivation area, where about 5.8 m ha of land is diverted to non-food grain area in a span of three decades. It can also be observed that though the area under food grains is declining but the production and productivity is not being affected. Thus it creates more pressure on available agricultural land, minimal scope for land expansion, excessive dependence on fertilizers and pesticides, creating negative impact on soil health and fertility.

Table 13: Trends in per capita direct consumption of cereals and pulses as food, kg/year

Commodity	1973-74	1983	1993-94	2004-05	2011-12#	2020-21#
Rice	79.98	76.87	79.92	73.77	70.53	66.83
Wheat	44.91	55.30	54.55	53.46	52.24	50.62
Coarse cereals	48.86	37.76	19.77	12.62	9.80	7.57
Total cereals	173.76	169.94	154.24	139.86	134.58	125.01
Pulses	-	-	9.56	8.99	9.01	9.37
Food grains	-	-	163.80	148.85	141.59	134.39

From the above table we can observe that per capita consumption of rice has declined from 79.98 kgs/year during 1973-74 to 70.53 kg/year during 2011-12. Similarly wheat consumption has gradually decreased and increased over a period of time. But coarse cereal uptake has shown a very sharp decline in consumption levels from 48.86 kg/year in 1973-74 to 9.80 kg/year during 2011-12. total pulses intake has remained constant.

Figure 9: Trend of area, production and productivity of food grains in India



Source: www.Indiastat.com

During Green Revolution era, public policies relating to input and output pricing and special assistance to small and marginal farmers were given much attention. In addition to this, minimum support prices were announced and implemented. However, a large proportion of the increase in food grain production during Green Revolution occurred in the 10 per cent of districts with adequate local infrastructure. Minimum support price policy is not successful in many of the states as it is not complemented with procurement policies. Food procurement started in 1971 when 21 MT of food grains were fixed as buffer stock.

Some special programmes were also announced by the government for improving the agricultural production in the country. They are : High Yielding Varieties programme

- ✓ Establishment of FCI and Agricultural Prices Commission (APC) – To have control over imports, to procure food grains for PDS and bufferstock and to fix MSP
- ✓ Trade liberalization in 1990s and trade policies played an important role in pricing of commodities
- ✓ Construction of irrigation dams
- ✓ Emphasis on agriculture in five year plans are also responsible for food production enhancement.
- ✓ Targeted Programmes
- ✓ Besides the NFSM (2007), other targeted programs like Integrated Cereals Development Program(ICDP), the National Agriculture Development Program(NADP), Rashtriya Krishi Vikas Yojana (RKVY), and special program to Bring the Green

Revolution to Eastern India are being implemented by the government of India through the state governments.

Green Revolution

There are three phases in GR policies in India (Fan, Gulati and Dalafi 2008)

1. Policies for modernizing and intensifying agriculture (1966-72)

By using improved seeds, multiple cropping methods, modern fertilizers and pesticides etc., it was focused to improve the yields of different crops mainly rice and wheat. During this period, 18000 tonnes of wheat seeds were imported from CIMMYT and sown in Punjab, Haryana and UP. ICAR was reorganized to co-ordinate the research activities of different organizations at state level, doing commodity based research etc. in 1965-66. Apart from this, farmers were trained in various activities through extension services. For supply of seeds of high yielding varieties, National Seed Corporation Limited, to monitor and control the prices of food grains Agricultural Prices Commission and for procuring and storing of food grains Food Corporation of India and Central Warehousing Corporation were set up. For diffusing the technologies, IADP (Intensive Agricultural District Program) was initiated and later on it was modified as Intensive Agricultural Area Program (IAAP).

2. Policies for developing HYVs and use inputs (1973-80)

During this period, emphasis was given to develop new varieties including hybrid rice and input subsidies were introduced. The quantum of subsidies was raised substantially and it reached 4% of agricultural GDP by mid 80s and to 8.7 per cent by the end of 90s.

3. Policies and schemes for region specific development (1980 onwards)

More attention was paid to minimize the regional differences in food grain production systems through ACRP (Agro-climatic Regional Planning) approach in 1988. The country is divided in to 15 agro-climatic zones and region specific developmental plans were formulated which were continued in 9th and 10th plans. Further, under coarse cereal development, ICDP-Coarse Cereals was launched, transport subsidy was provided for maize seeds (1986-87) and TMM (Technology Mission on Maize) was launched in 1995-96. Apart from these, Minikit Demonstration Program of wheat, rice and maize was also launched. A centrally sponsored Integrated Scheme on Oilseeds, Pulses, Oil Palm and Maize (ISOPOM) was initiated in 2004-05 and it is being implemented in 15 states.

All these policies were essential and boosted the agricultural production in general and food grain production in particular. However, emphasis on usage of inputs through provision of subsidies has led to unsustainable production and over exploitation of soil and water resources especially in GR states which are the main source of food procurement in the country. The water resources are over exploited in these states. Now, policies are required to bring these areas to normalcy by developing strategies for diversification and emphasizing on other food items such as horticulture, dairying, poultry farming and integrated system of farming.

> In the budget 2013, an allotment of 500 crore rupees for the development of GR states is a welcome step in this direction and this may be utilized for developing technologies for conservation natural resources and avoiding further degradation of factors of production.

National Food Security Mission (NFSM)

A set of policy measures were initiated to stimulate growth in rice, wheat and pulses to enhance the food grain production under NFSM in 2007. This is a centrally sponsored scheme but execution lies with state and district agencies. At present this scheme is operational in 312 districts in 17 states. Under this, Bihar has got largest number of NFSM-rice districts.

Rashtriya Krishi Vikas Yojana (RKVY)

This is a centrally assisted scheme aiming at integrated development of food grains viz., coarse cereals, minor millets and pulses, mechanization, soil health and productivity, horticulture sector, marketing, development of rainfed farming etc. The other two components of RKVY are - a special initiative for pulses and oilseeds development in selected villages in rainfed areas and a scheme to bridge the yield gap in the eastern region (Ministry of Finance 2010).

There are mixed responses on the performance of these schemes. In UP, non-NFSM districts seem to have registered slower production and productivity growth compared to NFSM districts in 2007-08 and 2008-09 over the previous year (Government of UP, 2010). According to the Government of Bihar (2010), the coverage of Boro rice in 2008/09 showed a 94 percent increase over the previous year and in Maharashtra, there has been a steady increase in seed replacement rate and better productivity growth in NSFM districts for rice and wheat in 2008-09 were reported (Government of Maharashtra 2010).

Input Policies

1. Seed policies

There were no organized policies for seeds during early years of independence in India. National Seed Corporation (NSC) was set up in 1963 to take care of production, storage and distribution of quality seed of HYVs in the country. But, certification was not included in this. With the Seed Act passed in 1966, the certification has been streamlined and with Seeds Order coming into force in 1983 the marketing of seeds is rationalized. Licensing was made compulsory by bringing the seeds under Essential Commodities Act of 1955. Seed production increased enormously with the intervention of government through research centres of ICAR and agricultural universities and also private sector companies. With the recommendations of a review committee on seeds, National Seed Programme (NSP) was launched in 1976 with the support of World Bank. The NSP provided infrastructural support for seed production and also concessional loans to private sector to encourage their participation in seed production. This has brought rich dividends and enhanced the production capacity to greater heights. Further, the policies like New Policy on seed development of 1988, New Industrial Policy (1991) which allowed foreign investors to invest in Indian Seed industry have supported to grow the seed industry and seed marketing in India. With the TRIPS agreement of 1994, the intellectual property rights of seed sector came into lime light. In consequence, PPV&FR (Protection of Plant Varieties and Farmers' Rights Act) came into existence in 2001 and PPV&FR authority was established in 2005. The National Seed Policy was drawn up in 2002 and the Seed Bill was formulated in 2004 and it is modified in 2010 to keep up the provisions of seed policy.

2. Irrigation Policies

Water management is a state subject and the following are some of the developments in water management in India. In independent India, canal irrigation was the major method for developing irrigation sources. Providing and maintaining the canals is the major challenge in this system. The canal system has got deteriorated due to poor maintenance, siltation and lack of enough funds. This has widened the gap between the potential of irrigation and its utilization. In 1970, a Model Bill was introduced for ground water development and the second irrigation commission report was submitted in 1972 to address the problem of gap between potential for irrigation created and utilized. The Command Area Development Program (CADP) was initiated in 1974 for centrally sponsored M&M projects and National Water Resource Council (NWRC) was formed in 1980 which has brought out the National Policy on water in 1987. For regulation of ground water, two revised model bills were introduced in 1992 and 1996. In 1993, Vaidyanathan committee submitted its report. In 1997, at the state level, PIM (Participatory Irrigation Management) was launched for the first time with Andhra Farmers Management of Irrigations Systems Act and in 2002 the Revised National Policy on water was brought out by NWRC (Ganga Sreedhar *et al.*, 2012). In 2004-05, the mandate of CADP was extended to other areas and it was linked up with PIM. Now PIM is functional in many states viz., MP, Rajasthan, TN etc. In PIM water user associations (WUAs) are formed and the administration and distribution of water is looked after by them.

Then came the ground water utilization through tube wells which was well supported by government through subsidies on credit and electricity. But these subsidies have resulted in unprecedented tapping of ground water resources and over exploitation in most of the locations especially in fertile green revolution states of Punjab and Haryana. Although the canal irrigation is not performing well since last two decades, this is good in recharging the groundwater resources. In India, the canal and ground water irrigation contributes to 42 and 46 per cent of total irrigation potential respectively (Ganga Sreedhar *et al.*, 2012). As per the GOI (2002) report, the recharge potential of canal irrigation is about 21%.

Although there are model bills prepared and revised twice, the bill awaits to be passed. In the absence of protection by law all these bills remain only as policy documents for guidance. India needs a strict water policy for avoiding further exploitation of ground water especially in over exploited areas and also by shifting the rice cultivation from north – western states to Eastern states by modifying the food grain procurement policy to these states. Emphasis should also be given on water use regulations and conjunctive use of water. The subsidies on irrigation in the form of electricity and credit needs to be revisited and modified in the interest of restricting ground water over exploitation.

3. Fertilizer policies

Fertilizer use has increased considerably since GR and the pricing policy has played an important role in it. With the passing of FCO (Fertilizer Control Order, 1957), to control the prices of fertilizers and to control their distribution, the area under fertilizer use has increased enormously. By 2001, 91% of irrigated and 60% of rainfed area of rice, wheat and maize had been supplied with fertilizers (Ganga Sreedhar *et al.*, 2012).

The subsidy on fertilizers played an important role in increasing fertilizer use in the country. Initially, recommendations of the Tariff Commission, the chief account officer of the Ministry of Finance and the Fertilizer Association of India were the basis for deciding the quantum of subsidy. With the unusual enhancement in oil prices in 1973, the urea prices also increased and the farmgate price which is fixed by government had been doubled. Consequently the usage of fertilizer came down. To look into these matters, a committee was set up and RPS (Retention Price Scheme) came into existence in 1977. This scheme was not aiming at improving cost efficiency. As a result the subsidy burden increased enormously.

The amount of subsidy for fertilizer in India is given in Table 14 and input sunsidies given to agriculture is depicted in Figure 10.

Table 14: Amount of subsidy on fertilizers in India

Year	Subsidy in billion Rs.
1980-81	1.7
1997-98	83.5
2001-02	126.9
2002-03	110.6
2006-07	280.2
2007-08	433.2
2008-09	994.9
2009-10	640.3
2010-11	528.4
2011-12	658.37
2012-13	659.7

The fertilizer policy review committee (1997) recommended to abolish the RPS for urea and deregulate the fertilizer industry. To reduce the fertilizer subsidy, an Expenditure Reforms Commission was set up which recommended a scheme for decontrol the urea sector. In 2002, the New Pricing Policy Scheme (NPS) came into existence and it was aimed at increasing the efficiency of production units. The aim of all fertilizer pricing policies was to reduce the burden on subsidy. But this has led to some secondary problems of serious implications such as imbalanced use of fertilizers, unhealthier nutrient interactions in the soil and thereby soil deterioration. The soil health is greatly affected by imbalanced application of major nutrients especially NPK. The ideal ratio estimated for our conditions is 4:2:1 of NPK. But the application of NPK was in the ratio of 7.2:1.8:1 in 1960-61, 10:2.9:1 in 1996-97 and 5.5:2.1:1 in 2007-08 (Ganga Shreedhar *et al.*, 2012).

A nutrient based subsidy (NBS) was introduced in 2010 for improving the application ratio of NPK fertilizers and this scheme is applicable to 17 fertilizer products (excluding urea). The per Kg NBS rates of fertilizer nutrients namely Nitrogen (N), Phosphate (P), Potash (K) and Sulphur (S) for the financial year 2012-13 had been at Rs. 24, Rs. 21.804, Rs. 24 and Rs. 1.677 respectively. Accordingly, the subsidy on Di-Ammonium Phosphate (DAP) and Muriate of Potash (MOP) would be Rs. 14350 PMT and Rs. 14440 PMT, respectively. The per Metric Tonne subsidy on other P&K fertilizes covered under the Nutrient Based Subsidy Policy shall be as per the nutrient content in that grade (http://pib.nic.in/newsite/erelease.aspx?relid=80639). Total amount of subsidy paid during 2008-11 on imported fertilizers is shown in Table 15 and installed capacity of fertilizer manufacturing units is detailed in Table 16.

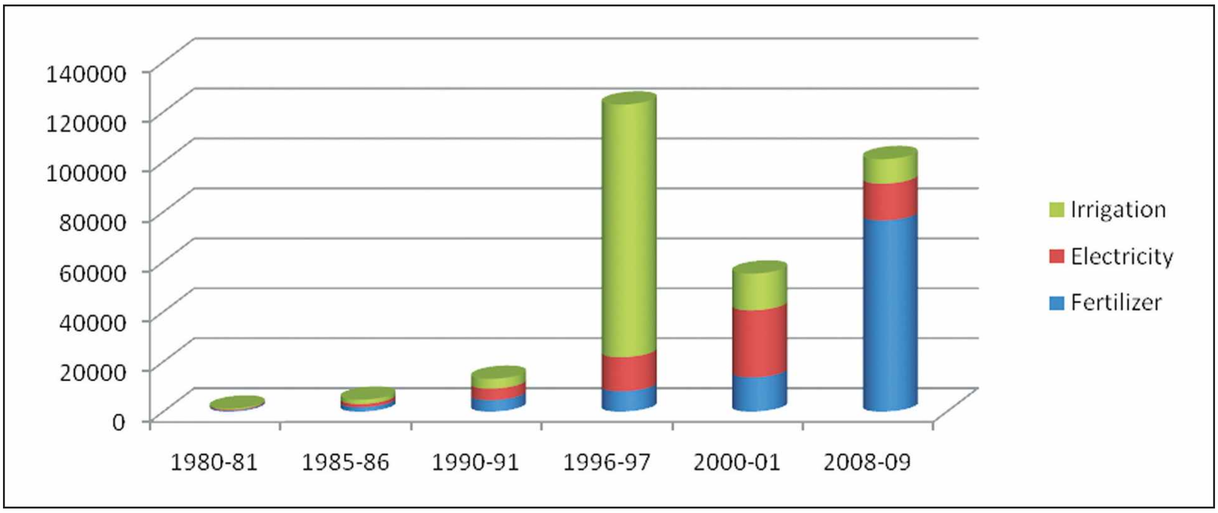


Figure 10: Input subsidies for agriculture in India

Nutrient Based Subsidy Scheme has been implemented with the expectation that it will promote balanced fertilization of soil, which will lead to increased agricultural productivity and consequently better returns to the farmers. The decontrolled scenario is also expected to promote competition leading to efficiencies in production and import. In the long run, the policy is expected to stabilise demand and supply situation and also contain the subsidy outgo (Parliament question dt 22.2.2013 http://fert.nic.in/node/1221 accessed on 11.3.2013)

Table 15: Total amount of subsidy paid during last three years on imported fertilizers:

Year	Imported P&K fertilizers	Import of Urea (Gross)
2008-09	32597.50	12971.38
2009-10	23452.06	6999.63
2010-11	20850.00	9255.95

The details of the type and quantity of fertilizer imported during the last three years are:

Year	Quantity (LMT)				
	Urea	DAP	MAP	TSP	NPK
2008-09	56.67	61.92	2.67	1.73	--
2009-10	52.10	58.89	1.93	0.87	--
2010-11	66.10	74.11	1.88		

(Source: PIB, 2012 http://pib.nic.in/newsite/erelease.aspx?relid =82006) (Rupees in Crores)

Table 16: Installed capacity of fertilizer manufacturing units as on 31.3.2010

S.No		Capacity (Lakh MT)		Percentage share	
		N	P	N	P
1	Public Sector	34.98	4.33	29.0	7.65
2	Cooperative Sector	31.69	17.13	26.27	30.27
3	Private Sector	53.94	35.13	44.73	62.08
4	Total	120.61	56.59	100.00	100.00

Source: Ministry of fertilizers) (Source: PIB, 2012 http://pib.nic.in/newsite/erelease.aspx?relid=82006) (Rupees in Crores)

4. Farm Mechanization

In India, use of farm machinery started way back in 1889 when modern ploughs, corn grinders and chaff cutters were introduced in the Cawnpore Experimental farm in UP. The steam tractors were introduced in Punjab in 1914 (J Singh, 2005). Manufacturing of tractors started in 1961and now India is the largest producer of tractors in the world (Jain 2006). As per the 2008 report of FICCI (Federation of Indian Chambers of Commerce and Industry) the use of threshers, harvesters, reapers and land levelers increased by 20, 5, 300 and 35 percent respectively between 1994 and 2006. In spite of all these advancements the level of mechanization in terms of farm power availability is still low in India (Table 17). And there are large disparities between different regions in terms of level of mechanization. The rate of mechanization is faster in GR states (Punjab, Haryana and western UP) and it is very slow in north eastern states.

Table 17: Total on-farm power availability both from animate and mechanical sources (Kilowatts per ha)

India	1.5 (in 2005-06)
South Korea	7 (in 1996-97)
Japan	14 (in 1996-97)
United States	6 (in 1996-97)

(Source: G Singh, 2005)

Under National Agricultural Policy (2000), GOI aims at improving the competitiveness of agricultural commodities in international markets by lowering the production costs. Some of the schemes for the promotion of mechanization are mentioned below.

Under central sector schemes for Promotion and Strengthening of Agricultural Mechanization through Training, Testing and Demonstration (since 2004-05) is under operation. At state level, subsidies are provided for purchase of farm machinery. Support is also provided for custom hiring and manufacture of implements through various development corporations. Besides all these, there are several problems in achieving the goals of farm mechanization viz., lack of adequate facilities for servicing and maintenance, inadequate access to credit for purchasing machinery by small and marginal farmers, lack of well suited technology for small sized farms and uneven availability of machinery in different regions of the country.

In future, these problems need to be tackled by supplying farm machinery evenly in all the regions and by making it available to small and marginal farmers through various supportive measures like custom hiring and providing concessional loans for their purchase. Research also needs to be strengthened to develop machineries which are suitable for small holdings and affordable to small farmers.

Output Policies

1) Output Pricing Policy

Government has brought out Minimum Support Price (MSP) Policy in order to protect the interests of both producers and consumers and also to encourage the adoption of modern technologies by farmers. Initially, MSP was different from that of procurement price of the government but from 1970 onwards both became same. From the beginning, wheat and rice received good support in MSP and this has resulted in increased area under these crops.

Table 18: Minimum support price for Wheat and Paddy (Rs)

S.No.	Year	Wheat	Paddy
1	2001-02	610	530
2	2002-03	620	550
3	2003-04	630	550
4	2004-05	630	560
5	2005-06	640	570
6	2006-07	700	620
7	2007-08	850	745
8	2008-09	1000	900
9	2009-10	1080	1000
10	2010-11	1100	1000
11	2011-12 (RE)	1170	1080
12	2012-13 (BE)	1285	1250

Source: FCI, 2012

The difference in MSP and prices in international markets greatly influence the food grain procurement and stock position in India. If international prices are higher, there will not be any stock and vice versa.

Generally MSP is fixed based on Cost of Production (CoP) criteria and also demand-supply situation and trends, changes in input prices, effect on cost of living intercrop parity, international economic situation etc.

Table 19: Food grain procurement (lakh tones)

S.No.	Year	Wheat	Paddy	Coarse cereals	Total	Rice	Wheat
1	2001-02	221.28	206.3	3.15	430.73	23.7	28.3
2	2002-03	164.22	190.26	0.60	355.08	22.9	28.9
3	2003-04	228.28	158.01	6.51	392.80	25.8	21.9
4	2004-05	246.83	167.96	8.27	423.06	29.7	24.5
5	2005-06	276.56	147.85	11.5	435.91	30.1	21.3
6	2006-07	251.07	92.26	0.0	343.33	26.9	12.2
7	2007-08	287.36	111.28	2.04	400.68	29.7	14.2
8	2008-09	341.04	226.89	2.03	569.96	34.4	28.1
9	2009-10	314.57	253.82	13.76	582.15	35.3	31.4
10	2010-11	341.98	225.14	4.07	571.19	35.9	26.2
11	2011-12 (RE)	344.64	283.35	1.28	622.56	33.1	33.7
12	2012-13 (BE)	-	380.23	0.36	365.95	-	-

Source: GOI, 2012 and FCI, 2012

During the last two years input prices especially that of fertilizers have increased exorbitantly due to price volatility in international markets. But, from the farmers' point of view, the MSP of rice has not been enhanced to commensurate with these input prices. Announcement of MSP well in advance is also being demanded by the farmers.

Food grain procurement and stocking policies

The Food Corporation of India (FCI) is responsible for procurement, storage, distribution and sale of food grains(Table 19). Initially, the procurement share was too high from green revolution states and it caused lot of burden on transportation. To avoid this, a De-Centralized Procurement Scheme (DCPS) was introduced in 1997-98. But still the situation has not changed much. There are certain policies to maintain stocks for feeding the Public Distribution System and to meet the demands of emergency situations. The norms to maintain buffer stock changes every quarter. In most of the occasions the actual stock position is highly deviant from that of the norm fixed for any particular quarter.

Table20: Buffer stock and actual stock norm of foodgrains (1980-2010)

Quarter/Year	Buffer stock norm (in tonnes)	Actual stock (tonnes)
1.1.1980	16.7	-
1991	17.9	-
1999-00	-	-
July 2002	24.3	63
July 2010	-	57.8

Food grains are stored by FCI, Central Warehousing Corporation and 17 State Warehousing Corporations (Table 20). There are three methods of storage 1.Silos 2.Godowns and 3.CAP (Cover And Plinth). The storage in CAP method is not safe and there are many reports of rotting of food grains due to longer storage under CAP. The storage charges in FCI are comparatively higher than that of private players. Even then FCI runs in loss because of inefficient cost management. Due to different trade controls like licensing, levy etc., imposed by government, private sector is not able to play any major role in grain markets. A Model Act on Agricultural Produce and Marketing (Development and Regulations) Act was formulated in 2003 to promote agricultural markets in the private and cooperative sectors, contract farming, market fee rationalization etc. Now, only few private companies are participating in the grain markets viz., PepsiCo Foods in rice, Britannia, Cargill and ITC in wheat etc.

On International trade also there are many restrictions especially for food grains. Actually, after signing of Uruguay Round Agreement on Agriculture (URAA) under GATT (now WTO) in 1994 only India has liberalized its agricultural trade policy.

Import Policy

Under this the participating countries should have tariff barriers with ceiling tariff bindings and also quantitative restrictions. Lot of improvements took place in this policy: the quantitative restrictions have been phased out, general import licensing system was removed and in 2001 many tariff lines were removed (Pursell *et al.*, 2007).

Export Policy

Earlier, there were many price and quantitative restrictions for most of the agricultural commodities. With the signing of URAA in 1994, India lifted the Minimum Export Price (MEP) of rice allowed the export of non durum wheat. And also Agricultural Export Zones (AEZs) were set up, credit lines for export are opened and export quotas were eliminated barring some items like onion, paddy etc.

Table 21: Exports of Wheat and Rice

	Rice	Wheat
1994	1	86.6(in 000 t)
1995	5	
1996		1.1
2003		4

Source: Ministry of Commerce and Industry, 2010

However, the outcome of Agreement on Agriculture (AoA) has not been as beneficial to India as was expected due to external and internal factors. Numerous distortions and market access barriers in the developed countries have adversely affected Indian agriculture exports. On the domestic front, vast opportunities to harness agricultural potential still remain to be tapped for achieving higher agricultural growth (Seminar on "Prospects of India's Agriculture Exports : 2025 Pressure on Agri commodity prices likely to stay' dt. 6.6.2011). The data on export of wheat and rice from India is given in Table 21 and 22

Table 22: Exports in Lakh tonnes

Item	2007-08	2008-09	2009-10
Basmati Rice	11.83	15.56	20.16
Non-Basmati Rice	52.86	9.31	1.39
Wheat	0.002	0.01	0.0002
Pulses	1.64	1.36	1.00
Other cereals	32.28	40.00	29.04
Total value (US Million $)	13191.92	13808.48	12118.56

Futures Trading

Futures trading for rice and wheat was allowed with the notification issued by the government in 2003. Three commodity exchanges viz.,

1. National Multi-Commodity Exchange (NMCE), Ahmedabad
2. Mumbai Multi Commodity Exchange (MCE), Mumbai) and
3. National Commodity and Derivative Exchange (NCDEX), Mumbai were recognized for this. Due to shortage in domestic supplies and stocks of wheat and rice were prohibited from futures trading in 2006-07. Wheat trading was reintroduced in May 2009.

Food Wastage

Lot of food grains get wasted due to unexpected rains during harvesting, and also during transportation and storage.

Rice and Wheat Sectors

Initially the focus of the Green Revolution policy package was on the two main cereals, rice and wheat. Roughly, three phases can be identified during the course of the "Green Revolution" policies (Fan *et al.*, 2008). In the first phase (1966–1972) the policy focus was on modernizing and intensifying agriculture to raise yields through the use of improved seeds, multicropping methods, modern fertilizer and pesticides, and so on. In the second phase (1973–1980), more investment went into developing new seed varieties, including efforts at developing hybrid rice, and Green Revolution technology spread to more areas (TE 1999/00; Gulati and Narayanan, 2003). The last phase is from 1980s onward, when India became food secure and successfully managed the 1987 drought. During this phase the government started paying more attention to the growing regional divide in food grain systems.

In 1988, the Agro-Climatic Regional Planning Approach (ACRP) was initiated by the Planning Commission to formulate a macro-level strategy for the 15 broad agroclimatic zones. This "Regionally Differentiated Strategy" continued to be emphasized in the ninth and tenth Plans. In 2007, the government launched a National Food Security Mission (NFSM) (http://nfsm.gov.in/) to address food security concerns due to the slowdown in the growth of food grain production in the last decade (2000). The NFSM aimed to increase the country's wheat, rice, and pulse production by 8, 10 and 2 million tons respectively by the end of the 11^{th} Five Year Plan (2011/12) to ensure food security. The NFSM seeks to bridge the yield gap through promotion and dissemination of improved technologies like seed, integrated nutrient management, integrated pest management and resource conservation technologies-particularly in the western and central states. Besides the NFSM, other targeted programs like Integrated Cereals Development Program, the National Agriculture Development Program (Rashtriya Krishi Vikas Yojana, RKVY), Integrated Cereal Development Programme (ICDP) and Special Program to bring the Green Revolution to Eastern India are being implemented by the government of India through the state governments. The government of India formulated a minimum support price (MSP) for rice and wheat on the basis of recommendations by the Commission for Agricultural Costs and Prices (CACP) Government agencies like the Food Corporation of India (FCI) and various state marketing agencies have the mandate to procure wheat at the MSP for central government stocks. Subsequently, the government allocates rice and wheat for distribution through the public distribution system and welfare schemes at a subsidized price. In years of surplus procurement and stocks, the government sells rice and wheat in the open market to the private trade at market prices. The government policies relating to the MSP for essential agricultural crops and the price for the Public Distribution System (PDS) supply serve the twin objectives of providing remunerative prices to farmers and affordable prices to poor consumers. Additionally, the Government of India, with the support of state governments, has undertaken various rice-specific development schemes like the Special Rice Development Program (SRDP), NFSM, Promotion of Hybrid Rice, etc. In November 2011, India announced major reforms in organized retail. These reforms would include logistics and retail of agricultural produce. The reform announcement led to major political controversy. The reforms were placed on hold by the Indian government in December 2011.

References:

Basavaraja,H; Sachinkumar T.N and. Mahajanashetti, S. B (2013), Impact of Economic Reforms on Production and Productivity, *Innovations in Agricultural Policy*, edited by Shetty P.K., Sreenivasa Gowda M. V. pp. 71-84.

Fan, S., Gulati A., and Dalafi. S. (2008). Reforms and Development in China and India. In The Dragon and the Elephant, edited by S. Fan and A. Gulati. New Delhi: Oxford University Press.

Fan, Shenggen, Hazell, Peter and Thorat, Sukhadeo (1999) *Linkages between Government Spending, Growth and Poverty in Rural India*. Research Report 110. International Food Policy Research Institute, Washington, DC, USA.

FCI (2012a), —*Progressive Procurement of Rice during Kharif Marketing Season and Wheat during Rabi marketing Season 2012-13 (as on 12/07/2012)*, Food Corporation of India, New Delhi.

Ganga Shreedhar, Neelmani Gupta, Hemant Pullabhotla, A. Ganesh-Kumar and Ashok Gulati.(2012); A Review of Input and Output Policies for Cereals Production in India, IFPRI Discussion Paper 01159.

Government of Bihar. 2010. Implementation Status of National Food Security Mission in Bihar. Accessed March 4 2010. http://nfsm.gov.in/.

GoI (2012a), —*Foodgrains Bulletin May 2012 and earlier Issues* Department of Food & Public Distribution, Ministry of Consumer Affairs, Food and Public Distribution, Govt. of India, May 2012.

Government of Maharashtra. 2010. National Food Security Mission in Maharashtra. http://nsfm.gov.in.

Government of Uttar Pradesh. 2010. National Food Security Mission in Uttar Pradesh. http://nfsm.gov.in.

http://pib.nic.in/newsite/erelease.aspx?relid=80639

http://pib.nic.in/newsite/erelease.aspx?relid=82006

Jain, R. C. (2006). Tractor Industry in India—Present and Future. Accessed November 10, 2013. www.unapcaem.org/Activities percent20Files/A0611/P-In.pdf.

Ministry of Finance, 2010 Parliament question dt 22.2.2013 http://fert.nic.in/node/1221 accessed on 11.3.2013

Pursell, G., Gulati A, and Gupta K. (2007). Distortions to Agricultural Incentives in India. Washington, DC: World Bank. Seminar on "Prospects of India's Agriculture Exports : 2025 Pressure on Agri commodity prices likely to stay' dt. 6.6.2011

Singh, G. 2005. Agricultural Machinery Industry in India (Manufacturing, Marketing and Mechanization Promotion). In *Status of Farm Mechanization in India*, edited by K. Tyagi, H. Bathla, and S. Sharma. New Delhi: Indian Agriculture Statistics Research Institute.

Timothy Besley and Robin Burgess 1999. http://econ.lse.ac.uk/~rburgess/wp/lfjuly99.pdf Accessed on 28.2.2013.

Chapter 7
Innovations in Institutional Dynamics

Institutional Developments

a. Research & Development institutions

Establishment of ICAR (1929) and several State Agricultural Universities (1960s) and All India Coordinated Crop Improvement Projects (AICRP) along with Private organizations are the real contributors of R&D in agriculture.

b. Agrarian and Credit institutions

Land and tenancy reforms in Karnataka (Land Reform Act 1974 and Amendment 1979) and West Bengal ('Operation *barga*'), respectively, have contributed significantly to agricultural development. The tenancy reforms also improved tenants' access to new technology, modern inputs and institutional credit.

Agricultural Credit

Due to the vagaries of monsoon and differences in economic condition of farmer groups, there used to always be a need for external credit support in India. Initially, the colonial government started to provide credit to farmers during drought years. To provide credit support to the farmers, Co-operative Societies act was passed in 1904. Even in Reserve bank of India (RBI) some provisions were made for farm credit. After nationalization of commercial banks, agriculture was given much importance for credit support through policies formulated during green revolution. With the setting up of National Bank for Agriculture and Rural Development (NABARD) the credit requirement for agriculture was thoroughly met as it was also coordinating the micro finance activities. The economic reforms of 1991 brought out some changes like deregulated rates of interest in commercial banks, RRBs and cooperatives, recapitalization of few RRBs, introducing Kissan Credit Cards (KCC), enhanced capital contribution to NABARD etc (Mohan, 2006). With the reforms in banking sector, the share of rural banks increased to 58.2% in 1990 from a mere 17.6% in 1969 (Satish, 2007). But due to poor funding most of the units became inefficient and so the number decreased to 44.5 per cent in 2005-06. The NSSO (2003) data shows that only 27 per cent of farm families received bank credit and 22 per cent loans are from private lenders and the rest of them had not taken any loan (Planning Commission, 2008).

Microfinance to Self Help Groups

Microcredit was initiated with NABARD as SHG-bank linkage program in the year 1992. As it was a big success in almost all the southern states, now it is being implemented all over the country. Apart from governmental support, some non governmental agencies are also involved in this micro financing program.

Employment and infrastructure development

Improved institutional and credit support and increased rural employment opportunities, including those through creating agriculture-based rural agro-processing and agro- industries, improved rural infrastructures, including access to information, and effective markets, farm to market roads and related infrastructure also contributed in shaping agricultural innovation system in India.

Linking of Self-Help Groups (SHGs) with commercial financial institutions through NGOs has reduced the transaction cost. This institutional innovation has made significant impact in terms of empowering the rural poor, particularly the women. This is more successful in southern India and needs to be extended to other parts of the country.

A number of international agencies played important roles in the development of the public agricultural R&E system in India. Notable among these were the Rockefeller Foundation, which provided support to AICRPs (Lele and Goldsmith 1989), and the U.S. Agency for International Development, which played an active role in the establishment of the SAUs and the training of staff through partnerships with U.S. land-grant universities. The World Bank has provided considerable resources to agricultural research since 1980. The initial phase of this support emphasized the development of research infrastructure and human resources, while recent support has focused on strategic research areas, priority research themes, and institutional reforms.

Private-Sector Development

Initially, a few private companies dealing with agricultural inputs (pesticides, fertilizers, and machinery, for example) invested modestly in product development, although there was little effort to establish in-house research capacity. The situation changed in the 1980s with the growing availability of trained scientists, rapid expansion of markets for agricultural inputs and processed foods, and liberalized policies to support private-sector development. The private sector now supplies half of all certified seed, half of all fertilizer, and most of the pesticide and farm machinery. Private investment in research currently the focus is on hybrid seeds, biotechnology, pesticides, fertilizer, machinery, animal health, poultry, and food processing. The government has provided strong incentives in the form of tax exemptions on research expenditures and venture capital, and liberal policies on import of research equipment to encourage participation of the private sector in research. The most significant development has occurred in the seed sector after the implementation of a new seed policy in 1988, which allowed the importation of seed materials, as well as majority ownership of seed companies by foreign companies (from 1991). A number of foreign seed companies entered the market, and several local seed companies have established considerable research capacity (Pray, Ramaswami, and Kelley 2001). Some local companies collaborate with overseas companies for access to proprietary tools and technologies. Private hybrids now account for a significant share of the market for sorghum, maize, and cotton (Singh, Pal, and Morris 1995; Pray, Ramaswami, and Kelley 2001), and companies with some foreign ownership account for about one-third of this market (Pray and Basant 2001). Developments in biotechnology have further strengthened these trends. With implications for innovation that are not yet clear, the Indian government recently approved the Protection of Plant Varieties and Farmers Rights Act (2001) to provide intellectual property protection to plant breeders. At the same time, the act emphasizes farmers' rights to save, exchange, and sell unbranded seed of a protected variety. India has also amended the Patent Act (1970) to make it compatible with WTO agreements. A third set of amendments enshrined in the Patents (Amendment) Act (2005) grants process and product patents in all fields of technology. These are likely to stimulate research in the biotechnology and plant and animal health sectors. Participation of private nonprofit organizations in agricultural research has also increased. There are now a few private foundations, as well as NGOs, actively engaged in agricultural research. In particular, the M. S. Swaminathan Research Foundation and Mahyco Research Foundation have developed considerable research capacity with a national presence and are working in close collaboration with the ICAR/SAU system. In addition, many small, regional, and local NGOs are engaged in agricultural research, such as those managing some ICAR-sponsored KVKs.

Extension

Extension was considered as an important part in agricultural development since the introduction of IADP and from the time of green revolution. In 1970s the Training and Visit (T&V) system was introduced which was more technology-input driven rather than supply. Agriculture being state subject, most of the extension activities used to be undertaken by state departments of agriculture and also by ICAR, SAUs and Farmer Field Schools (FFSs).The private sector entered the extension services only in 1990s (ex; e-Choupal of ITC). Some NGOs and farmer based institutions also started working as extension agencies (Glendenning and Babu, 2010). Some public-private partnerships were also established.

Diversified Agricultural Support Project (DASP) (1998-2004): This project was aimed at enhancing the agricultural productivity through intensive and diversified development of agriculture.

National Agricultural Technology Project (NATP) (1999-2005): This project aimed at reorganizing the ICAR, improving the research project effectiveness, enhancing the ability to respond to farmers' technological needs and sustaining the system with accountability.

Agricultural Technology Management Agency (ATMA): It was initiated on pilot basis in 1998 and spread to all parts of the country in 2007. ATMA acts as a platform to coordinate the extension programmes of district from different sources. This seems to be an efficient program. However, Adhiguru *et al.*, (2009) reported that only 4.8 and 12.4 per cent of small and large farmers respectively have got access to public extension workers.

Developing other desired Institutional Support System

1. Encouraging Public-Private Partnership in research and infrastructure development

Private organizations are highly successful in biotechnological research and their partnership in infrastructure development such as construction of godowns / warehouses need to be encouraged. This can be done by undertaking case studies in various countries and developing models and tools to encourage Public-Private partnership in agricultural research, infrastructure development such as roads, marketing facilities, storage facilities etc.

2. Corporatization of agriculture

Co-operative movement which was in vogue in 1950s and 60s had failed. But by making the farmers as share holders according to the extent of land in their possession, it is possible to enhance the profit as they can enjoy both bonus as well as wages for their contribution.

a. Make farmers share holders

Farming can run on business lines by following corporate principles. The right solution for this issue is to organize the farmers and make them equal partners in agricultural value chain. Once the farmers form corporatized entity, it will empower them to aim for higher profits and will also make them aware of the best market trends. It is a great movement towards institutionalizing the farmers. Such institutions promoted by farmers can set up its own grading units, packaging units and provide such services on a fee based model to all its farmer members. Such entity can use spot exchange platform to sell produce of their farmer members to all domestic buyers and consumers through spot exchange network. Gradually, these companies can develop their own brand to market such produce directly in overseas markets. Hence, the cost of intermediation will go down and farmers will be able to fetch the maximum pie out of price paid by the consumer or by the overseas buyer. This is the ideal model to protect and promote the interests of Indian farmers.

Any commodity market is a network of spot and futures market, warehousing agencies, assayers, credit providers and financing. Thus, what is needed is an integrated development of warehousing facilities and a sound negotiable warehousing receipt system. The government has taken a number of measures to create a single common market for agricultural commodities. The Warehousing Regulatory Development Authority has been set up with a mandate for orderly growth of the warehousing infrastructure and developing a sound negotiable warehousing receipt system. The Ministry of Agriculture has formulated a model law on agricultural marketing which provides for establishment of private markets, direct purchase centres and promotion of public private partnership in the management and development of agricultural markets in the country.

b. Crop associations are successful in Maharashtra

Maharashtra farmers and government has exhibited a unique trend of forming and successfully operating crop based organizations e.g. MAHA GRAPE, MAHA MANGO, MAHA BANANA, MAHANAR (Pomegranate), Floriculture association, etc. This associations/ co T operatives work for upliftment of their farmers and crops. These groups act on the needs and demands of farmers and also develop joint infrastructure for the same. They also formed Self Help Groups (SHG) which would look after post harvest handling, marketing and primary processing. They also run Agri business centre. All these co-operative, SHG and associations work smoothly and benefit the farmers in numerous ways. They have played a key role in improvement of farmer status to help them to reach the current level (CII, 2012).

The solution to this issue lies in promoting institutionalized farmers' aggregators, who can aggregate the stock on behalf of small and marginal farmers and use futures exchanges to hedge their price risk to sell such produce, if the price offered on spot exchange or futures exchange is higher than price offered by local traders. Besides, the aggregator will be able to hedge the price risk on futures exchange on behalf of the farmers. FMC is making efforts through the National Exchanges to develop a model of "aggregation", so that various agencies, viz. Cooperatives, Farmers' Associations, State Marketing Federations, Non-Government Organizations and Banks would be able to act as aggregators and take consolidated positions on behalf of groups of farmers to facilitate their hedging operation and transfer the benefit of futures trading to them. However, there is little development on this front and not many institutional aggregators have come up. A lot more effort and initiative from the exchanges and other stakeholders in agricultural marketing chain are required. The commodity exchanges should initiate the process for developing farmer aggregator models. The cooperatives, marketing federations, NGOs, Banks and other organization having requisite domain knowledge and experience have to come forward and act as an interface and facilitator between the farmers and the futures market.

Credit support is very essential for farmers to take up farming operations. Our government has tried to give possible support through various institutions like commercial banks, Regional Rural Banks, Cooperatives and NABARD. Even then, credit support is yet to reach a sizeable population of farmers especially small and marginal. For making credit available to all the farmers, lot more needs to be done in an innovative way.

This objective can be met out by modernizing the credit institutions through latest technological advancements in telecommunications, information technology tools etc. But this needs a network of players who can provide banking facilities in combination with farming technology, market information and guidance. So, for this the traditional banking institutions would not be enough and they need to work with other players which include technology providers (IT companies), insurance companies, retailers in the village, extension specialists etc. in coordination. This may result in increased efficiency of credit support initiatives and larger portion of needy farmers would get benefit from such a network.

References:

Adhiguru P, Birthal P S and Ganesh Kumar B (2009). Strengthening Pluralistic Agricultural Information Delivery Systems in India. *Agricultural Economics Research Review* 22 (1) pp. 71-79.

CII 2012. http://mycii.in/KmResourceApplication/E000000924.5980.Maharashtra%20

Planning Commission. (2008). Eleventh Five Year Plan (2007–12): Volume 3. New Delhi: Government of India.

Satish, P. (2007). Agricultural Credit in the Post-Reform Era: A Target of Systematic Policy Coarctation. *Economic and Political Weekly*. Vol. 42; 2567–2575.

Pray, C. E., and Basant R. (2001). India.In: Private Investments in Agricultural Research and International Technology Transfer in Asia, edited by C. E. Pray and K. O. Fuglie, 32–55. ERS Agricultural Economics Report No. 805. Washington, DC: Economic Research Service, US Department of Agriculture.

Singh, RP, Suresh Pal and Morris M (1995). Maize Research, Development and Seed Production in India: Contributions of the Public and Private Sectors. Economics working paper 95-3, Mexico, D.F.: CIMMYT.

Progressive%20Agriculture%20-%20A%20New%20Horizon.pdf Accessed on 24.1.2013

Chapter 8
Factors affecting reach of agricultural innovations

I. Reasons for Non-adoption of Technologies

The following are some of the reasons for non adoption of technologies by farmers.

a. Farmers do not believe in new technologies because it is new to them.
b. They worry of low yield
c. Lower education level
d. Old age of farmers: Old aged farmers do not believe in new technology and only believe their own experience and age old practices.
e. Large Farmers feel that if the yield loss due to new technologies is significant, the amount of loss will be greater. Farmers usually overestimate the yield loss caused by insects rather than the actual loss.

In a study conducted in Madhya Pradesh, the paddy farmers are surveyed for level of adoption of different recommended technologies and found that Nursery practices and plant population recorded the lowest rate of adoption. Most of the problems in rice production for export were due to technological constraints. Non-availability of suitable high yielding varieties was the most important constraint reported by 63.33 per cent of the respondents. High yielding variety seeds were reportedly not available in time in local markets and Block level agricultural office (Singh and Varshney, 2010). Heavy weed growth and pest and disease incidence caused a lot of waste. In addition, lack of knowledge, non-availability of weed control chemicals and equipment, high cost of inputs, lack of trained labour were the main reason for non adoption of recommended Integrated Crop Management technologies.

The most important socio-economic constraint was poor infrastructures as perceived by 78% of the farmers studied. They face problems such as poor road for transportation and non-availability of transporting facilities to move the produce from their fields to the markets and home. There was the lack of other advanced facilities for storage, processing, drying, etc. Some farmers revealed that they still used traditional tools and method for rice harvesting. High cost of labour was expressed as a constraint by 72.50 per cent of the respondents as the agricultural labourers were demanding higher wages irrespective of nature of work. Non-availability of trained labour on time was also considered as a constraint by 54.17 per cent of the respondents. Most of the respondents reported that the available farm labourers were not properly trained since most of the cultivation practices in rice farming right from sowing to post harvest require special skills. High cost of inputs, lack of subsidy for inputs and lack of support price acted as other serious hindrances for them.

II. Are there efficient knowledge transmission and dissemination in these agro ecosystems? If no, what are the inhibiting factors?

It has been reported that people's involvement in the decision making process, plan conduction, evaluation and sharing of their developmental plans are the important factors.

There are no efficient knowledge transmission and dissemination mechanisms at present because the agricultural education institutions work in academic isolation. But for effective knowledge transmission they should transform into dynamic promoters of change and become active contributors to agricultural and rural development through innovative research, teaching and extension.

The reasons for failure of extension programmes are

1. Lack of commitment and professionalism
2. Lack of meaningful objectives and goals
3. Failure to develop and implement strategies
4. Excessive reliance on experience
5. Lack of organizational support
6. Resistance to change

III. The relationship between selected socio-economic traits of farmers such as age, education, land holding size and level of income on the one hand and the reach/adoption of technological innovations in rice and wheat to the farmer's field

Older people and women with low hierarchy have a lower participation rate. One of the important factors affecting this is that participation rate is more with higher level of education than lower one (Roussel, 2000). There was a positive and significant relationship between farmers memberships in clubs, rate of low property lands, rate of listening to radio's educational programs, propensity to the region's agriculture advancement, being elected as premier farmer and access to agricultural inputs with the rate of participation (Bastami, 2000). Type of Farmers: Innovators/Laggards, higher education level, income, family size, credit availability, value system and beliefs are positively related to adoption whereas, low education level, old age, small farm size are negatively related to adoption of new technologies.

Extension Policy Framework: Reforms in Public Extension

1. Public extension should be cleaner, better qualified, more professional
2. Farmer-to-Farmer extension: Subject Matter Specialists (SMS) up to Block level, below that operate through Para-professionals linked to 'Farmers' Groups
3. Role of Village Level Extension Functionaries / as Farm Advisor / Mitra Kisan (Service provider)
4. Public Extension Functionaries to be organized in innovative, restructured institutional arrangements

IV. Biosecurity measures required in restructuring the R & WCS in the country

As per estimates without management control losses upto 44–54 percent in wheat and 64–80 percent in rice will be caused by invasive alien species and even with controls, losses average upto 28 percent in wheat, 37 percent in rice at pre-harvest stage (Oerke, 2006).

Invasive alien species, already being a threat to the rice-wheat cropping system in India are grouped into weeds, insect-mite and other arthropod species, pathogens, nematodes and rodents (Normile, 2010).

Khuspe *et al.*, (1982) and Nandpuri *et al.*, (1986) estimated 42% weeds in India are alien and total cost associated with them is about US$ 37.8. Weeds are responsible for 30% loss in potential crop production (Singh, 1996) which is worth about US$ 90 billion per year in reduced crop yields. *Parthenium hystrophorus* a noxious weed native to Northeast Mexico, probably introduced in India along with wheat grains under PL 480 scheme and spread alarmingly like a wild blaze to almost all the states in India and established as a naturalized weed (Kapoor, 2012). *Lantana* *camara*, a major weed shrub in India introduced from Australia as an ornamental plant covered about 4% of India's land area.). In recent years, five new species of Invasive Alien weeds viz. Giant Ragweed (*Ambrosia trifida*), Spiny Burr Grass (*Cenchrus tribuloides*), Hound's Tongue (*Cynoglossum officinale*), Horsenettle (*Solanum carolinense*) and European field Pansy (*Viola arvensis*) have known to entered India along with wheat imported by government of India in 2006-07 (Pandey *et al.*, 2009).Details of the important introduced alien plant pathogens to India are given in Table 23.

Sujay *et al.*, (2010) reports in past ten years, at least six species of insect and mites have invaded India affecting agricultural, horticultural and forest production. Arthropods as a group reduce potential crop production by 18.7% (Oerke *et al.*, 1994). Approximately 30% of the insect and mite crop-pest species in India are alien species (David and Kumaraswami, 1975; Lal, 1990). In India approximately 74% of the major plant pathogens are considered alien species (Singh, 1985). Rice Blast (*Magnaporthe oryzae*) and rust diseases caused by the fungus *Puccinia graminis,* are the major diseases.

Table 23: Some of historically introduced alien plant pathogens in India

Pathogen/(Disease)	Host	Origin	Year of introduction
Urocystis tritici (Flag smut)	Wheat	Australia	1906
Magnaporthe grisae (Blast)	Rice	SE Asia	1918
Helminthosporium oryzae (Leaf spot)	Rice	Japan	1919
Xanthomonas campestris pv. Oryzae (Bacterial blight)	Rice	Japan	1951

(Singh and Kaur, 2002)

Biosecurity of rice-wheat cropping systems against these Invasive Alien Species is quite challenging as in a system pests of two different crops have to be tackled and there are chances that pests of one crop may shift to another. For example, rice pink stem borer, *Sesamia inferens*, and shoot fly, *Antherigona oryzae*, originally attacked only rice, can now attack both crops and are considered general threats in India (Nagarajan, 1989). Green leaf hopper (*Nephotettix nigropictus*) and dark-headed stem borer (*Chilo suppressalis*) posing threats to rice-wheat systems in Nepal (Gyawali *et al.*, 1997) may shift to India if proper biosecurity measures are not taken. Yellow rust emerged in early 1990s with epidemics in North Africa, Middle East and Asia, and in early 2000s stem rust resistance was broken by Ug99 race lineages, that emerged from East Africa and spread north and eastward are major threats posed by the pathogens (Hodson, 2011).

Presently, no systematic efforts have been made towards survey and surveillance of endemic, exotic, new and emerging pests of rice and wheat in India. Biosecurity in rice-wheat cropping system can be achieved under three components viz., Pre-border actions, Border control and Post-border response strategy. Pre-border incursion management involves design of inter-state/country agreements to promote information disclosure and cooperation. Pre-border regional collaboration is an important means of understanding pest threats and mitigation strategies (FAO, 2007). Understanding pest and its requirements completely prior to attack gives time to take necessary action before its entry. Border control involves movement restrictions and preventative actions which will prevent entry of Invasive Alien Species in countries border. This involve fumigation of importing product, chucking quality certification according to international standards if criteria's are not met importing items should be rejected/stop entering the country. If somehow invasion occurs post border security measures have to be implied immediately. Post-border response strategies involve control spreading, eradication and endemic management of Invasive Alien Species from the vicinity (FAO, 2007). This can be achieved by collaboration of people, farmers, government bodies, research institutes both national and overseas, NGOs etc (FAO, 2007). Post border bio-security response strategy is elaborated process which has to be achieved by educating farmers and people regarding threat and how to fight or prevent attack, bringing changes in cultivation practices use of technologies and integrated knowledge (Timsina and Connor, 2001).

Pests changed their status from minor to major and vice versa (Arora and Dhaliwal, 1996; Kumar, 2005; Dhaliwal and Koul, 2010). Insect pests like leaf and plant hopers, leaf folder, gall midge, root weevil and case worm of rice; shoot fly, aphids, brown mite, army worm, pink borer, gram pod borer, wire worms and white grubs of wheat emerged as important pests which were earlier minor pests. Major pests like gujhia weevil prior to green revolution lost importance. Among rice diseases, blast, bacterial leaf blight, sheath blight, brown leaf spot and false smut of rice brown rust, yellow rust, black rust, loose smut, kamal bunt and powdery mildew of wheat were recorded to be the significant ones. After green revolution sheath blight and false smut rice kamal bunt and foliar blights of wheat were more damaging whereas stem rust became relatively less important (Subhash *et al.*, 2003).

We need to reprioritize our research thrusts to protect the RWCS from biological threats through

1. Survey and surveillance of rice and wheat diseases / pests of national and international importance
2. Early detection and diagnostic systems for already known alien pests and pathogens

If these criteria's are met along better agricultural policies, better biosecurity measures and agricultural practices such as crop rotation, balanced use of fertilizers and pesticides will definitely help in safeguarding the rice-wheat cropping system in India.

V. Identification of the critical biotic and abiotic factors/stresses affecting implementation of technological innovations in rice and wheat production

1. Rice - Abiotic constraints

In rainfed rice, moisture stress, cold and heat stress during early and late stages, and low light intensity conditions in the coastal, eastern India and hill regions are important abiotic constraints.

Rice consumes about 2500 – 3000 liters of water/kg grain production. Total water requirement of rice : 200 m3. But, the water availability is declining day by day. Labour shortage, Fragmented land holdings and announcement of minimum support price very late also contributing factors for implementation of innovations. Intensive agriculture is the cause for severe degradation of soil and its quality, nutrient depletion, multi-nutrient deficiencies and toxicities, and declining crop growth rates.

Rice crop is grown under diverse agro ecological conditions and production systems(Table 24). This makes it more vulnerable for poor productivity and net returns.

Table 24: Rice cultivation in different ecoregions

Constraints	States/agro-ecologies
Small and marginal farmers with poor resources to use optimum/ recommended inputs	Mostly Eastern states of India
Erratic rainfall with poor soils	Madhya Pradesh, Odisha and some parts of Uttar Pradesh
Flash floods, water logging due to poor drainage	Assam, West Bengal, North Bihar and Eastern Uttar Pradesh
Use of traditional varieties	Mostly Eastern states
Low and imbalanced use of fertilizers	North-eastern and Eastern states
Delayed and prolong transplanting due to delay in monsoon	Mostly rain fed lowlands
Poor adoption of production technology	Mostly in uplands and lowlands
Saline and alkali soils	West Bengal, Odisha, Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, Maharashtra, Gujarat, Western Uttar Pradesh, Punjab, Haryana etc.

Source:Vision 2020, CRRI

2. Rice – Biotic constraints

Five insect pests *viz.*, rice yellow stem borer, gall midge, brown plant hopper, white backed plant hopper and leaf folder are considered as very important. Other pests are whorl maggot, rice hispa and green leafhopper in wetlands, gundhi bug and climbing cutworm in upland rice and rice thrips, leaf and panicle mites and nematodes in southern region, mealy bug and caseworm in eastern region. Among the rice diseases bacterial leaf blight, blast, rice tungro disease, sheath blight and sheath rot in wet lands, brown spot in uplands have been reported as of economic importance causing substantial crop losses

3. Wheat – Abiotic constraint

The important abiotic stress factors in wheat crop are

1. Adverse climatic conditions
2. Adverse soil conditions/management
3. Improper agronomic practices
4. Inadequate extension services/ transfer of technology

4. Biotic stresses in wheat

Diseases: Rust (Brown, yellow and black), Loose smut, Karnal bunt and foliar blights

Nematodes: Tundu and Molya

Insects: Termites, shoot fly, aphids, cut worms and borers

Weeds: *Chenopodium album*, *Phalaris minor* & *Avena ludoviciana*

VI. Compute/evaluate returns to investment in R & D of new technologies in rice and wheat systems

Many studies have empirically shown the impressive performance of the system, with annual rates of return to investment in research ranging from 35 to 155 percent (Evenson, Pray, and Rosegrant 1999). Studies have shown that irrigation, land reform, infrastructural development, and technical change were the main sources of agricultural growth (Desai 1997; Fan, Hazell, and Thorat 1999). Estimates of total factor productivity (TFP) growth for Indian agriculture since the Green Revolution average 1.5–2.0 percent annually, in line with growth in industrialized countries (Murgai 2001; Pingali and Heisey 2001). In addition, the contribution of TFP to output growth has become more important in recent years. Much of the growth in TFP has been attributed to investment in agricultural research that provided high payoffs (Mruthyunjaya and Ranjitha 1998; Evenson, Pray, and Rosegrant 1999). Details of data on estimated marginal value product and marginal internal rate of returns are given in Table 25 and 26. Marginal internal rate of return to research investment is given in Table 27 and 28.

Table 25: Estimated marginal value product (EMVP) and marginal internal rate of return (MIRR) to investment in rice research in India

State	EMVP (Rs)	MIRR (%)
Andhra Pradesh	17.9	55.2
Assam	28.7	63.3
Karnataka	3.2	31.7
Orissa	9.1	44.8
Punjab	7.8	42.8
Tamil Nadu	22.5	59.0
Uttar Pradesh	50.2	74.0
West Bengal	16.8	54.2

Source: P Kumar and D Jha, 2005

Table 26: Estimated value of the marginal product of research stock and marginal internal rate of return to investment in wheat research in India

Period	EMVP (Rs)	MIRR (%)
1972-75	32.57	65.6
1976-80	32.53	65.5
1981-85	44.61	71.5
1986-90	36.48	67.8
1991-95	25.48	61.1
1972-95	35.35	67.2

Source: S Mittal and P Kumar, 2005

Table 27: Marginal Internal rates of return to research investment (percent) (1978-91)

Measure	Aggregate analysis	Analysis for individual crops	All
Mean	75.4	69.9	71.8
Median	58.5	53.0	57.5
Minimum	46.0	6.0	6.0
Maximum	218.2	174.0	218.2
No. Of studies	10	18	28

Source:Based on information in Alston et al., 2000 and Evenson, Pray and Rosegrant, 1999

Table 28: Return to investments in agricultural research in India

Commodity	Period	Estimated MIRR (%)
Rice (India)	1971-88	60
East		58
North		53
South		33
Wheat	1972-84	51
All commodities	1953-71	40
	1956-65	60
	4966-76	68
	1977-87	75
	1961-87	87-96

VII. Sources of variations in the productivity of rice and wheat across different agro-climatic regions in the country

The main reason for low productivity of rice in India is that rice is grown in the country under various production ecologies mainly grouped as irrigated and rainfed systems. While former is considered most favourable, rainfed system has again a wide range of subsystems like shallow, mid and deep water rainfed lowlands and rainfed uplands. Productivity in these systems vary widely. Based on available figures for 2004-05 the states of Andhra Pradesh, Karnataka, Tamil Nadu, Punjab and Haryana have predominantly irrigated rice and average productivity of these states for 2009-10 is 3.136 t/ha (Rani *et al.* 2010). Total irrigated area in the country, including that in rabi/boro season is about 25 million ha (58%). Likewise states of Uttar Pradesh, Bihar, West Bengal, Orissa, Jharkhand, Chattisgarh and Assam represent predominantly rainfed shallow lowland system that can be considered favorable rainfed ecology. These states have registered an average productivity of 1.658 t/ha. Total area under rainfed lowlands is is about 11.0 million ha. Rainfed uplands which form the least productive system cover about 5 million ha with a productivity of 0.8 t/ha. Rest of the 2 million ha land is deep and semi-deep water with low productivity of 0.5 t/ha (Vision 2030, DRR).

In eastern India 5 Agro-ecological zones of rice cultivation were studied

1. Irrigated kharif
2. Irrigated Rabi
3. Rainfed lowland
4. Upland
5. Deep water rice

Weeds, drought around anthesis, vegetative drought, yellow stem borer, seedling drought, acid soils and bacterial leaf blight are identified as important constraints in different ecologies of rice cultivation.

For wheat crop in Indo-Gangetic plains, Chatrath *et al* (2007) and Joshi *et al* (2007) found that Terminal heat stress, yellow and leaf rust, spot blotch, drought, weed competition, low radiation receipt, salinity as well as a range of variety adaptation, crop production intensification and soil and water sustainability are the most important constraints.

In eastern India, socio-economic constraints were found most important.

- Shortage of quality seeds during sowing time
- High cost of seeds and fertilizers
- The adulteration of fertilizers
- High cost of herbicides
- Non-remunerative prices of wheat
- Higher rates of interest on finance
- Lack of timely easily available credit and
- Lack of funds for the purchase of farm machinery

are all important socio-economic issues (Kumar *et al.* 2007) in wheat cultivation.

VIII. Study the gaps between yield obtained in research farm and farmers field level

Several biotic and abiotic factors and interaction between these various factors contribute to yield variation in farmers' fields. Studies have shown that the year-to-year variations in crop yields are normally associated with fluctuations in climatic conditions, biophysical factors that include soil physical and chemical properties, temperature, precipitation, solar radiation, and human management (Lobell *et al* 2009).

Alterations in soil nutrient status, nutrient deficiencies, soil toxicities, build up of salinity and water logging, water/moisture availability, pest related yield losses and associated consequences of increased use of pesticide. Now, the agriculture sector calls for major reforms, from marketing to investment, Institutional change, especially in water management, new technologies, land markets and creation of efficient value chains.

References:

Arora, R. and Dhaliwal, G.S. (1996) Agroecological changes and insect pest problems in Indian agriculture. *Indian J. Ecol*. 21(2) pp.109-122.

Bastami, H., (2000). Influencing Factors on Farmers' Participation in Research-Extension Projects. Ms.c thesis of Islamic Azad University.

Chatrath, R., Mishra, B., Ortiz Ferrara, G., Singh, S., Joshi, A.,(2007). Challenges to wheat production in South Asia. *Euphytica* 157 (3), 447–456.

Desai, Bhupat M (1997) Agricultural Paradigm: A Synthesis in Bhupat M Desai (ed.), Agricultural Paradigm for the Ninth Plan under New Economic Environment(New Delhi: Oxford and IBH).

Dhaliwal, G.S. and Koul, O. (2010) Quest for Pest Management: From Green Revolution to Gene Revolution. Kalyani Publishers, New Delhi.

Fan Shenggen, P. Hazel, S. Thorat, (1999), —Linkages between Government Spending, Growth, and Poverty in Rural India,Research Report 110, International Food Policy Research Institute, Washington DC.

FAO, (2007), Invasive species: impacts on forests and forestry.

Gyawali, B.K., Ghimire, M.N., Shrestha, K.P., (1997). Entomology studies in the Naldung ricewheat area, 1992/1993-1996/1997.In: Hobbs, P.R., Rajbhandary, N.P. (Eds.), Proceedings of the Rice-Wheat Research End-of-Project Workshop. NARC/CIMMYT/RWC, Kathmandu, Nepal, pp. 39-44.

Hodson D. (2011) Shifting boundaries: challenges for rust monitoring. *Euphytica.*; pp.179:93–104.

Joshi A.K., Ortiz-Ferrara G. , Crossa J. , Singh G. , Sharma R.C., Chand R. , Rajender

Parsad.(2007), Combining superior agronomic performance and terminal heat tolerance with resistance to spot blotch (Bipolaris sorokiniana) of wheat in the warm humid Gangetic Plains of South Asia. *Field Crops Research* 103, pp.53–61.

Kapoor, R.T., (2012). Awareness related survey of an invasive alien weed, *Parthenium hysterophorus* L. in Gautam Budh Nagar district, UttarPradesh, India, *Journal of Agricultural Technology*, Vol. 8(3): pp. 1129-1140

Khuspe, V.S., Subbaiah, R., Mande, J.V., (1982). A Compendium of Indian Weed Science Research (1950–1981). Metropolitan Book Co, New Delhi.

Kumar N, Kulwal PL, Balyan HS, Gupta PK. (2007) QTL mapping for yield and yield contributing traits in two mapping populations of bread wheat. Mol Breeding.; 19(2):163–177.

Lal, O.P., (1990). A survey study of insect and non-insect pests parasitoids and predators from Kullu Valley, Himachal Pradesh. *Indian J. Entomol. Res.* (New Delhi) 14 (2), pp. 99–125.

Lobell, D., G. Bala, A. Mirin, T. Phillips, R. Maxwell, and D. Rotman (2009), Regional differences in the influence of irrigation on climate,*J. Clim.*, 22(8), 2248–2255.

Mruthyunjaya and Kumar, Praduman (2010) *GCARD Regional Review for Asia Pacific: South Asia Report*, presented at Global Conference on Agricultural Research for Development, held in March 2010.

Murgai, Rinku. (2001), The Green Revolution and Productivity Paradox : Evidence from Indian Punjab, *Agriculturual Economics* 25: 2-3 pp. 199-209

Rani, N.S., Prasad, G.S.V., Sailaja, B., Muthuraman, P., Meera, S.N. and Viraktamath,

B.C. 2010. *Rice Almanac India*. Pp.307. Directorate of Rice Research,Hyderabad

Nagarajan, S.,(1989). Plant protection problems in rice-wheat rotation system-a perspective. *Oryza* 26, 329-333

Nandpuri, K.S., Singh, B., Kolar, J.S., Kang, M.S., Chahal, B.S.(1986). Field Problems of Important Crops. Punjab Agricultural University, Ludhiana, India.

Normile D. (2010) Saving forest to save biodiversity. *Science*329: pp.1278–1280.

Oerke, E. C. (2006). Crop losses to pests. *The Journal of Agricultural Science* / Volume 144 / Issue 01, pp 31-43.

Oerke, E. C, Dehne, H. W., SCHO NBECK, F. and WEBER, A.(1994). Crop Production and Crop Protection – Estimated Losses in Major Food and Cash Crops. Amsterdam: Elsevier Science.

Pingali P, Heisey PW (2001) Cereal-crop productivity in developing countries: past trends and future prospects. In: Alston JM, Pardey PG, Taylor M (eds) Agricultural science policy. IFPRI & Johns Hopkins University Press, Washington, DC, USA.

Rani, N.S., Prasad, G.S.V., Sailaja, B., Muthuraman, P., Meera, S.N. and Viraktamath, B.C. 2010. *Rice Almanac India*. Pp.307. Directorate of Rice Research,Hyderabad.

Robert E. Evenson, Carl E. Pray, Mark W. Rosegrant (1999). Agricultural Research and Productivity Growth in India. International Food Policy Research Institute.

Roussel, S., (2000). Factors Influencing Participation in Post-Secondary Education and Training in Australia: department of education, training and youth affairs. REB Report 7/2000 Research & Evaluation Branch.

Singh, C.M., Angras, N.M., Kumar, S., 1996. Weed Management.MD Publications, New Delhi.

Singh P.K and Varshney J.G. (2010) Adoption level and constraints in rice production technology. Indian Res J Ext Edu. 10(1) 91-94.

Singh, R.S., (1985). Diseases of Vegetable Crops. Oxford & IBH Publishers, New Delhi, India.

Sujay YH, Sattagi HN, Patil RK (2010). Invasive alien insects and their impact on agroecosystem. *Karnataka J. Agric Sci.* 23(1): pp. 26-34

Timsina, J., Connor, D.J., 2001. Productivity and management of rice –Wheat cropping systems: issues and challenges. *Field Crops Res.* 69, 93 – 132

Vasanthraj David, B. and T. Kumaraswamy.(1975). Elements of Economic Entomology, Popular Book Depot, Chennai, 536pp.

Vision 2020,CRRI,Cuttack. Vision 2030,DRR, Rajendranagar, Hyderabad

Chapter 9

Future Outlook for Innovations in Research

1. Rice sector

Since last four decades, total area under rice crop is almost constant (23% i.e. 40-42 Mha) out of the total cropped area in India i.e. 141 Mha. The production demand of rice is expected to rise by 60% by 2020 (IFPRI projections) whereas rice demand would rise by 140 MT in 2025. To meet this demand we need to enhance the productivity without damaging the natural resource base.

a. Genetic Engineering (C4 Rice)

In modern high-yielding rice and wheat varieties, the grain mass have reached about 60% of the total biomass above ground at harvest (Evans, 1997). This is the highest among all cereal crops and it may be very difficult to further increase the harvest index. Under this condition, the only possibility is improving the source capacity which includes photosynthesis, by genetic engineering. C4 plants have elevated photosynthetic capacities at warmer temperatures as against C3 plants, and possess 1.3–4 times higher water use efficiency (WUE) and nitrogen use efficiency (NUE) than in C3 plants (Long, 1999; Sage and Pearcy, 2000; Kocacinar *et al.*, 2008; Ghannoum *et al.*, 2011). Installing the C4 mechanism into rice would improve the photosynthetic efficiency as well as improve WUE, NUE and may also possess drought tolerance capacity.

Higher rates of photosynthesis in both wheat and rice may be caused by greater N allocation to Rubisco (Makino *et al.*, 1992) because, Rubisco is the primary CO_2 fixation enzyme, and the amount and kinetic properties of this enzyme strongly affect the photosynthetic rate. An attempt to decrease N allocation to Rubisco may lead to the improvement in photosynthesis per unit of leaf N content as large amounts of N are invested in Rubisco. Makino *et al.*, (1997) proved that antisense *RBCS* rice with theoretically optimal Rubisco content at elevated CO_2 concentrations shows higher rates of photosynthesis only under elevated CO_2 conditions. The oxygenase activity of Rubisco leads to photorespiration and causes substantial loss of energy and reduction in the total turn-over of Rubisco in the mesophyll cells of the rice leaves. In C4 plants, the CO_2 is fixed in the mesophyll cells of the leaf tissue to produce C4 acids and are decarboxylated in the bundle sheath cells. This increases the photosynthetic efficiency.

In 2008, IRRI formed the International C4 Rice Consortium was formed in 2008 at IRRI and is estimated that, it would take 15 years of coordinated research to deliver C4 rice to plant breeders in the developing world. The C4 rice project uses cutting edge science to discover the genes that will supercharge photosynthesis, boost food production and improve the lives of billions of poor people in the developing world. The C4 Rice Consortium at IRRI is a group of multidisciplinary scientists from advanced institutions around the world. Installing the 'C4 mechanism' into rice would improve the photosynthetic efficiency as well as improve Water Use Efficiency (WUE), Nitrogen Use Efficiency (NUE), which helps in inducing more source capacity ie., more grain yield and may also possess drought tolerance capacity. C4 rice, if successfully developed, has the potential of producing 50% more grain yield with less water and nutrient usage and can contribute to the future security in India.

C4 Rice: Rice with a built-in potential of producing upto 50% higher grain yield while using less water and nutrient.

C4 mechanism: It is a biochemical 'supercharger' mechanism which concentrates carbon dioxide inside the leaf, raising the efficiency of photosynthesis. For example, with the same input of water and nitrogen, maize (which uses C4 photosynthesis) can produce twice the biomass and yield of rice (which uses C3 photosynthesis) (Table 29).

Photosynthetic Efficiency: It is the fraction of light energy converted into chemical energy during photosynthesis in plants and algae.

Water Use Efficiency: It is a quantitative measurement of how much biomass or yield is produced over a growing season, normalized with the amount of water used up in the process.

Water use efficiency is defined here as yield of plant product (tonnes of wheat grain, Y) per unit of crop water use (megalitres of water lost by evapotranspiration, ET)

Nutrient Use Efficiency: It is a term used to indicate the ratio between the amount of fertilizer N removed from the field by the crop and the amount of fertilizer N applied.

Table 29 : Yield difference between C3 and C4 plants

C3 plant	C4 plant	Productivity (t/ha)
-	Maize (44 Days after germination)	13.9
Rice (42 days after transplanting)	-	8.3

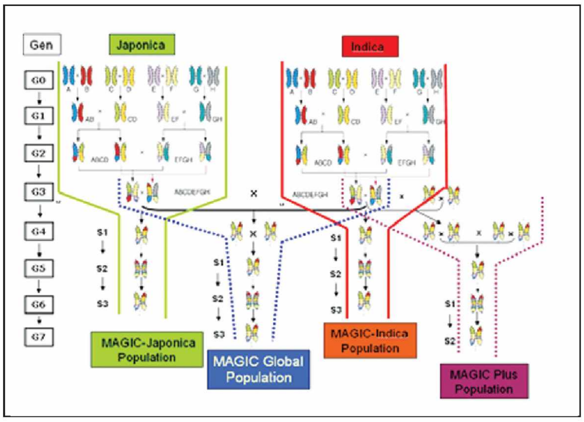
http://www.slideshare.net/CIAT/engineering-c4-rice

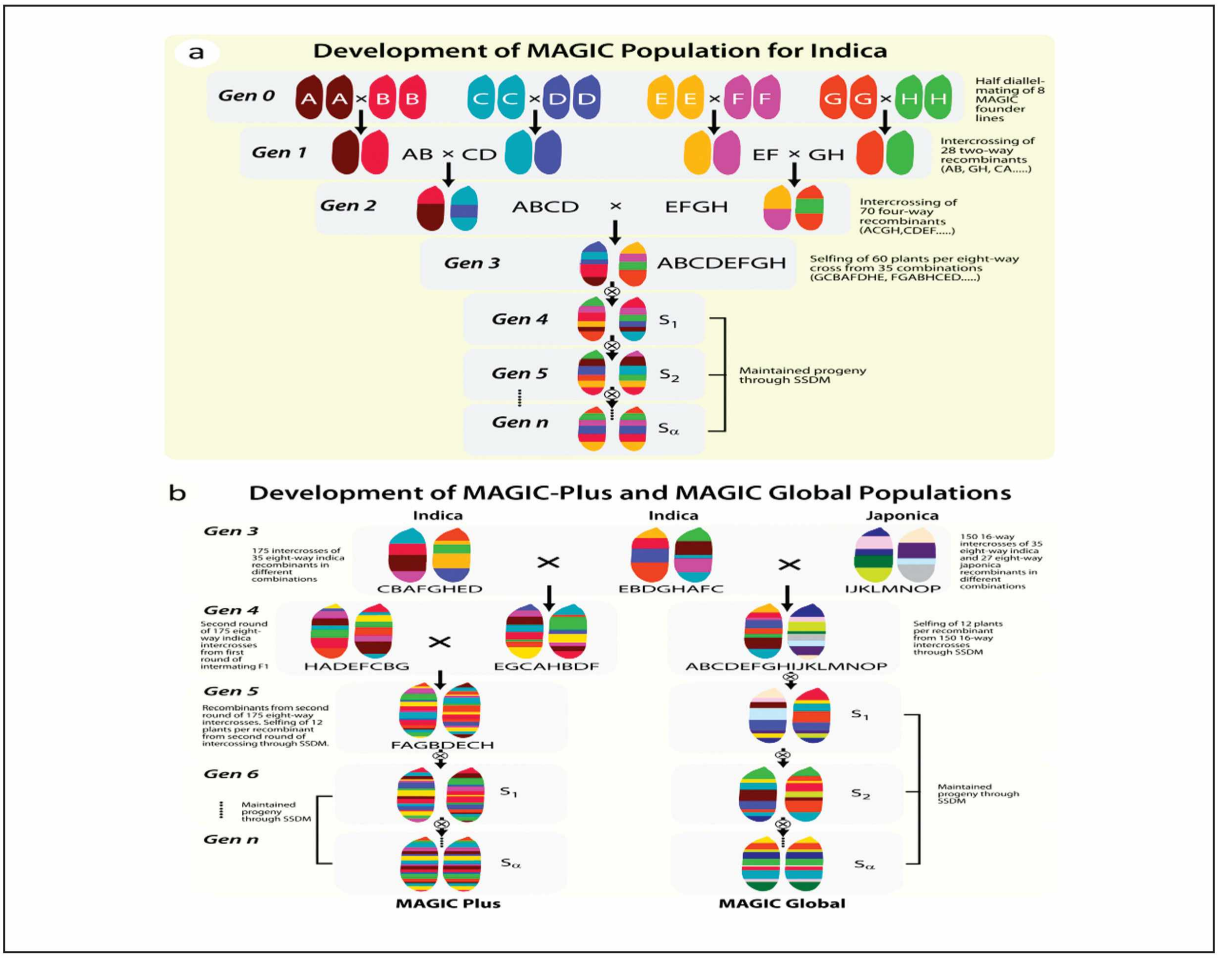
b. MAGIC

MAGIC is Multi-parent Advanced Generation Inter-Cross (MAGIC), a process to breed multiple-stress-proof rice undertaken in IRRI in 2007. The MAGIC procedure involves crossing 'founder lines' best of indica and japonica varieties recommended by breeders due to their tolerance to biotic and abiotic stresses, good plant type, and high yield, among other desired traits. Presently four multi-parent populations have been developed i.e. indica MAGIC, MAGIC plus, japonica MAGIC and Global MAGIC. These MAGIC populations provide a useful germplasm resource with diverse allelic combinations to be exploited by the rice community. These traits can be inserted in new varieties and can breed to develop new varieties that can adapt in various cropping conditions including: blast and bacterial blight resistance, salinity and submergence tolerance, and grain quality. This concept can be used in India situation to develop high yielding multiple stress resistant rice varieties suitable for different agro climatic conditions. The *indica* and *japonica* MAGIC populations will be further crossed to expand genetic diversity and therefore improve adaptation in various cropping conditions across the world, the results of which will be called the MAGIC global population (IRRI-annual report, 2011).

MAGIC Rice: production, characterization, and its use in breeding networks, (Leung 2011).

Crossing scheme for MAGIC populations





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MAGIC: Multi-parent Advanced Generation Inter-Cross

Abiotic factors: The negative impact of non-living factors on the living organisms in a specific environment. E.g.: high winds, extreme temperatures, drought, flood, and other natural disasters, such as tornadoes and wildfires

Biotic factors: stress that occurs as a result of damage done to plants by other living organisms, such as bacteria, viruses, fungi, parasites, beneficial and harmful insects, weeds, and cultivated or native plants.

Allele: It is the alternative form of a gene for a character producing different effects. It is one of a number of alternative forms of the same gene or same genetic locus (generally a group of genes)

Trait: A genetically determined characteristic Similar concept can be used under Indian conditions also to develop high yielding multiple stress resistant rice varieties suitable for different agroclimatic conditions.

c. Aerobic rice

Aerobic rice is an important alternate especially in water constrained areas. Biotechnology through molecular markers, genetic engineering and genomic tools can help in development of aerobic rice. Stress-related genes can be identified with the help of molecular and biotechnological tools and they can be used as probes for selection of tolerant genotypes and for generation of transgenic plants.

In general 90% of the rice is grown under flooded condition in India. Presently due to the climatic variations and prevailing water crisis, International Rice Research Institute (IRRI) developed the "aerobic rice technology" to conserve water and enhance paddy cultivation during 1980s. In aerobic rice systems, wherein the crop is established in nonpuddled, non-flooded fields and rice is grown like an upland crop (wheat and maize) with adequate inputs and supplementary irrigation when rainfall is insufficient. Rice requires soil moisture content of above 70% through-out the season, but it is not mandatory to have fields flooded as some people think. In experiments conducted by Dr. M. Devender Reddy, Acharya N. G. Ranga Agricultural University (ANGRAU) for about 25 years shows that just 7-9 irrigations are required towards 30-40 irrigations in rice cultivation in flooded fields. It is followed with a small reduction in yield compared to transplanted rice but water productivity is much higher at between 30-50%. Fertilizer and pesticide use are almost the same as in transplanted rice, but farmers must follow best practices in weed management, nutrient deficiency and soil preparation to improve rice yield. In 2007 March, India officially released for cultivation its first drought tolerant Aerobic Rice Variety MAS 946-1 followed by MAS 26 (2008) at University of Agricultural Sciences, Bangalore, India.

Water was saved up to 60 % than the conventional irrigation method. Compared to transplanted rice more seeds are wasted in the nursery. Less labour requirement (less than 50% in lowland rice are no puddling, transplanting and less frequent irrigation application) (Bouman et al., 2002). Efficient fertilizer utilization in aerobic rice cultivation was achieved. Less pest / disease incidence were observed. Methane emissions were reduced leading to lower environment pollution. Profuse rooting, High tilling, less lodging, high grain and fodder yield were observed soil structure and quality were retained. Yield difference between aerobic and transplanted rice in various species is given in Table 30 and 31.

Table 30: Grain yield of aerobic rice and transplanted rice within different rice varieties in India

Cultivars	Grain Yield (t/ha)	
	Aerobic	Transplanted
Erramallelu	4.07	4.60
WGL 14	2.14	2.00
Jagtiala sannalu	2.11	1.26
JGL 11470	1.65	3.31
JGL 11727	2.18	2.50
Tella Hamsa	3.70	2.88
IR 64	4.02	2.23
Naveen	4.57	3.92
MTU 1010	4.23	2.42
MTU 1001	3.19	4.11
MTU 1075	1.56	1.75
ARB 21Ax3	2.09	3.86
ARB 17(1)x06	4.48	3.68

Table 31: Grain yield of aerobic, wet seeded and transplanted rice (Erramallelu), Kharif, 1989

Method of establishment	Grain yield (t/ha)
Broadcast sown- Dry seeding	2.88
Line sown-Dry seeding	3.59
Broadcasting sprouted seed- wet seeding	3.29
Transplanting	3.4

RARS, Jagtial, Ann.Rep., 1989

d. P efficient Rice (Phosphorous Efficient Rice)

Phosphorous is one of the major essential nutrients in rice cultivation required during the critical growth periods such as vegetative stage, reproductive stage and tillering stage. Phosphorus is an essential constituent of adenosine triphosphate (ATP), nucleotides, nucleic acids and phospholipids. Phosphorus promotes tillering, root length, plant height, root dry weight and shoot dry weight through tissue P concentrations, P uptake and P-use efficiency. Natural phosphorus reserves are limited, and it is therefore important to develop phosphorus-efficient crops.

Kasalath, a rice variety from India has a set of genes that helps rice grow well in soils low in phosphorus; this was initially discovered by Dr. Matthias Wissuwa from the Japan International Research Center for Agricultural Sciences. Later in collaboration with IRRI has identified a gene called Phosphorus Starvation Tolerance 1 (PSTOL1) helps rice grow a larger, better root system and thereby access more phosphorus.

In field tests in Indonesia and the Philippines, rice with the *PSTOL1* gene produced about 20% more grain than rice without the gene. It is also observed that when grown in phosphorus deficient soils, yield increased by 60%.

In general 60% of the world's rice is grown in phosphorous deficient soils and by the introduction of this phosphorous efficient variety the rice yield can be much more increased, which can induce self sufficiency in food security.

e. Boro rice cultivation to be extended to unutilized areas

Boro rice is commonly known as winter rice. Boro rice is cultivated in waterlogged, low-lying or medium lands with irrigation during November to May. Boro rice has been cultivated traditionally in river basin deltas of Bangladesh and Eastern India including Eastern U.P., Bihar, West Bengal and Assam. In these regions, water accumulates during monsoon months and cannot be drained out in winter months, thus suitable to grow boro rice. This practice is spreading even to those non-traditional areas where irrigation is available. Boro is a winter season, photo-insensitive, transplanted rice cultivated on supplemental irrigation. Due to low temperature and weeds, growth during early vegetative phase of the crop is slow. Therefore, one hand weeding at tillering stage is effective to control weeds in the field. About 1.35 mha of area

Table 32: Efficiency of different systems of rice cultivation in India

Systems of rice cultivation	Transplanted rice	SRI	Aerobic rice
Land preparation	Land should be levelled	Land should be levelled	Not needed
Seed rate	50 kg/ha	5 kg/ha	18 kg/ha
Spacing	15x10 cm	25x25 cm	20x10
Nursery	Nursery should be raised	Nursery should be raised	Direct sowing
Trimming of bunds	Requires constant trimming and plugging holes	Needed	No trimming or plugging is needed
Labour requirement	more	more	less
Intercropping	Not possible	Not possible	Any arable crop is possible
Methane release	Methanogenesis occurs	Less	No occurrence of methanogenesis
Pest and disease incidence	High due to increased moisture accumulation	Low	Low
Cost of cultivation	High	High	Low
Shoot length (cm)	85.8	86.6	71.2
Tillers/sq.m	410	448	375
No. of irrigations	33	27	24
Total water used (m^3/ ha)	16802	14322	9425
% water saving over transplanted rice	-	14.8	43.9
Grain yield	6262	6682	3933

was under boro rice in India during 1991 which raised to 1.60 mha in 1995 and 2.95 mha in 2000. Efficiencies of different systems of rice cultivation in India is detailed in Table 32.

2. Wheat Sector

In wheat, yield is affected by both the grain number and size since single grain weight varies depending on growth conditions (Fisher *et al.*, 1977; Jamieson *et al.*, 1995). Hence the targets for a high yield may be more complicated in wheat than in rice. Some elevated CO_2 experiments show that stimulation of photosynthesis is greater in wheat than in rice (Long *et al.*, 2006a). Productivity of different Indian states is depicted in Figure 11.

For breaking yield barriers in wheat

a. Exploitation of heterosis for developing hybrids

Similar to rice hybrids, there is a possibility to try for the development of hybrids in wheat also to enhance the yield level from the present level of 3.3 tons per ha to about 6 to 7 tons per ha.

b. Broadening of genetics base of varieties

Genetic base of varieties can be improved through pre-breeding, using winter x spring hybridization, synthetics, buitre, Chinese germplasm etc

c. Biotechnological interventions

Through gene pyramiding, marker assisted selection for biotic, abiotic stresses and quality traits, structural and functional genomics there are very good opportunities to break the yield barriers in wheat crop.

d. Enhancing productivity of low productive areas

About 91.5% of the total wheat produced in in India comes from six states viz. Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, Rajasthan and Bihar. By developing regional specific technologies, emphasis can be given to improve the productivity of states having low productivity – UP, MP, Bihar, Gujarat, Rajasthan and eastern parts.

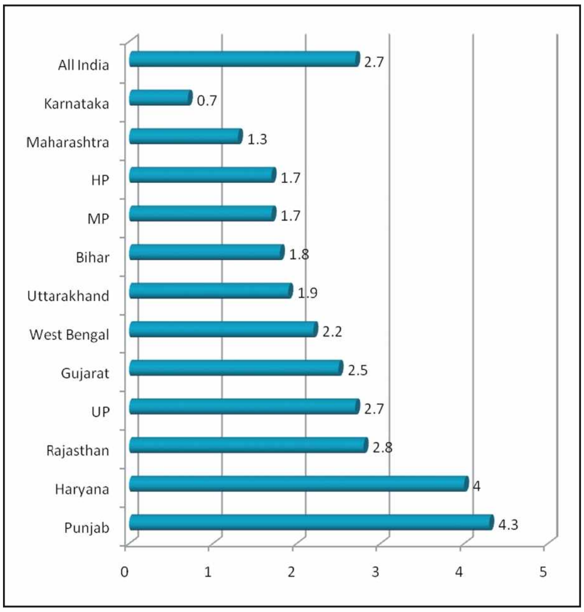

Figure 11: Productivity of wheat in different states (2009)

e. Resource management technologies

Diversification in rice-wheat system, residue management, improved water use efficiency and mechanization can also contribute to improvement in wheat production.

References:

Fisher RA, Aguilar I, Laing DR.(1977) Post-anthesis sink size in a high-yielding dwarf wheat: yield response to grain number. *Aust J Agric Res* 28: 165–175

Ghannoum, O.; Evans, J.R. & von Caemmerer, S (2011). Nitrogen and water use efficiency of C4 plants. In: Raghavendra, A.S. & Sage, R.S. (Eds.) C4 Photosynthesis and Related CO2 Concentrating Mechanisms, Springer Science+Business Media B.V., Dordrecht, The Netherlands, pp.129-146

Hei Leung (2011), Rice genetic diversity platform to excclerat gen discovery and precision breeding. available form [jircaf-d.job.affrc.go.jp]. 21 April 2013.

Jamieson PD,Martin RJ, Francis GS.(1995) Drought influences on grain yield of barley, wheat and maize. *N Z J Crop Hortic Sci* 23: 55–66

Kocacinar F, McKown AD, Sage TL and Sage RF (2008) Photosynthetic pathway influences xylem structure and function in *Flaveria* (Asteraceae). *Plant, Cell and Environment* 31: 1363-1376.

Long SP.(1999) Environmental responses. In Sage RF, Monson RK, eds, C4 Plant Biology. Academic Press, San Diego, pp 215–249.

Makino A, Sakashita H, Hidema J, Mae T, Ojima K, Osmond B (1992) Distinct responses of ribulose-1,5-bisphosphate carboxylase and carbonic anhydrase in wheat leaves to nitrogen nutrition and their possible relationships to C02-transfer resistance. *Plant Phys*- 01100 1737-1743

Makino,A.,Sato,T.,Nakano,H.andMae,T.(1997b) Planta203:390-398

Sage, R.F. and Pearcy, R.W. (2000) The physiological ecology of C4 photosynthesis. Photosynthesis: physiology and metabolism(ed. by R.C. Leegood, T.D. Sharkey and S. Von Caemmerer),pp. 497–532. Kluwer Academic Publishers, The Hague.

Chapter 10

What Needs to be Done in the Area of Policy

1. Enhancing public sector investment in agricultural research

The funding on R&D denotes the capacity to use science in promoting productivity growth to achieve food security and reduce poverty and hunger. It is noted that for agricultural output of every US$ 100, developed countries spend US$ 2.16 on public agricultural R&D, whereas developing countries hardly spend US$ 0.55 (Beintema and Stads, 2008). In the past 35 years there has been a significant increase in public funding for agricultural research and education (R&E) which increased from 37.8 crore in 1971-72 to 4308 crore in 2007-08, an increase of 113-times. A sustained increase in public funding for agricultural R&E could be observed from the early 1980s onwards and it increased from 187.5 crore in 1981-82 to 770.5 crore in 1991-92, 2537 crore in 2001-02 and then to 3681 crore in 2005-06. It further rose to 4308 crore in 2007-08(Table 33).

Funding for research can also be measured in terms of Intensity ratio. Research intensity is measured as research expenditure as percentage of agricultural gross domestic product (AgGDP). India invested $ 0.40 for every $ 100 of agricultural GDP in 2008(Table 25). Thus is less than the amount invested by China ($0.50), Brazil (1.8), Japan (4.75), for every $100 of their agricultural GDP in 2008 and it is also less than the average of $ 0.56 for developing countries in 2000 (Beintema and Stads, 2010). Higher rate of intensity ratio of agricultural R&D by high income countries like Brazil and Australia had triggered the higher growth in agricultural GDP by 1.77 and 12.44 per cent, respectively. Though China and India were the toppers in agricultural R&D investment, the intensity ratio was higher in developed countries like Japan ($4.06) and Australia ($4.57) in 2000 and further increased to $4.75 and $3.56 in 2008. While in China the intensity ratio was $ 0.38 in 2000 and it has improved to $0.5 and for India it was increased from $0.36 to $0.4 per every $100 of Agricultural GDP in the above period.

Table 33: Public agricultural R&D spending and intensity ratio, 2000 and 2008

Country	Spending (billion 2005 PPP prices)		Intensity Ratio ($ per $100 of AgGDP)		AgGDP cgr %	
	2000	2008	2000	2008	1990-00	2001-08
India	1.5	2.3	0.36	0.4	3.85	9.25
Brazil	1.2	1.3	1.86	1.8	-2.33	1.77
China	1.7	3.4	0.38	0.5	5.94	5.55
Australia	0.8	0.6	4.57	3.56	0.004	12.44
Japan	2.6	2.7	4.06	4.75	NA	Na
South Korea	0.6	0.7	1.6	2.3	NA	NA

Source: Suresh pal, *et al* (2012)

Since India's research funding for agricultural research is quite low in comparison with China and Brazil, there is a need to accelerate public as well as private resources. At the same time, it is important to address institutional constraints in the efficient allocation and use of scarce resources. This calls for a three-pronged strategy: mandatory priority assessment and evaluation (concurrent and ex-post) in all institutions and research programs; decentralization of the system for greater autonomy and accountability, and encouraging innovations in research management; and exploiting the synergies of inter institutional collaboration within the public sector and public private sector interface for higher research productivity. India's research intensity ratio, measured as public agricultural R&D spending as a share of agricultural output, continue to be relatively low compared to China and Brazil. In its upcoming 12^{th} FYP, the Indian government seeks to address this deficiency by committing one per cent of agricultural GDP to agricultural R&D.

An aggressive R & D investment strategy is absolutely essential for meeting the demands of present competitive world to have a reasonably good growth in agriculture as well as food security situation. This requires an adequate and continuous investment in agricultural R & D for sustained growth.

In an analysis conducted by Karunakaran (2012) it was found that for every additional one dollar investment in agricultural R&D from the mean level would generate 1.07 per cent increase in agricultural GDP in 10 years and 0.94 per cent growth from the current level of Agricultural GDP could be achieved with in 5 years after investment using current resource endowment. This indicates the importance for agricultural R&D investment for increasing growth rate in agriculture to meet the growing food demand.

The public policies such as investment in research, education and extension, infrastructure, and natural resource management have been the major sources of TFP growth. Increase in agricultural investments, especially in agricultural research, is urgently needed to stimulate growth in TFP. To attain 4 per cent agricultural growth, as targeted by the Planning Commission, at least one-third of this growth must come through technological innovations and remaining two-thirds has to be achieved through additional use of agricultural inputs. To meet these targets, investments on agricultural research need to be doubled by 2015 and tripled by 2020 in relation to the investment level of 2002 (Mruthyunjya and Kumar, 2010).

a. Total Factor Productivity

This is a variable which accounts for effects in total output not caused by traditionally measured inputs. If all inputs are accounted for, then total factor productivity (TFP) can be taken as a measure of an economy's long-term technological change or technological dynamism. Research has been the prime mover of agricultural growth in India. In the post-Green Revolution period, productivity growth was sustained through increased input use. Lately, this has been done through input efficiency-enhancing technical change.

The TFP can be influenced by factors such as research & extension investment, human resources, cropping intensity, balanced use of plant nutrients, infrastructural development, literacy level, climate, etc. The public investment in research has been a significant source of TFP growth in most of the crops. The variables natural resource management and infrastructure have emerged as important sources of TFP growth for most of the crops. Among natural resources, assured irrigation water along with balanced use of fertilizers, have played a significant role in increasing the TFP level. A look at the infrastructural variables has revealed that road density and electricity supply have been the most significant determinants of TFP. This information is of crucial importance for researchers and policymakers in prioritizing the investment decisions (Fan *et al.*, 1999).

It is found that the TFP growth in Indian agriculture was very low in the pre green revolution period and it declined (and even become negative) during the 1970s. However, even during the 1980s the growth rate of TFP in agriculture was relatively higher compared to the earlier period, during the 1990s the TFP growth in Indian agriculture has come down. There is considerable evidence in the literature to argue that the observed decreases in the rate of TFP growth is in large part a consequence of a substantial decrease of investments - notably public-sector investments - in India's agriculture. However, considering the share of TFP in agricultural GDP growth, it is found that the share has increased during the 1980s and 1990s. Since technological progress and technical efficiency are the two key sources of agricultural TFP growth and they declined in recent periods, more government investment in agricultural R& D, technology development, and extension programmes and infrastructure including agricultural credit is required in order to sustain the growth (Saikia, 2009).

b. TFP in Rice and Wheat

Among cereals, wheat experienced the highest growth in TFP during the period 1975-2005. The annual rate of TFP growth was 1.9 per cent for wheat, 1.4 per cent each for maize and barley, 1 per cent for pearl millet, 0.7 per cent for rice and 0.6 per cent for sorghum. More than 50 per cent increase in output of wheat and 24–30 per cent increase in the output of rice, sorghum, pearl millet, barley, chickpea and groundnut was possible through technological change or increase in TFP (Ramesh Chand *et al.*, 2012).

Table 34: Annual growth rate in factor productivity, productivity share in output and real cost of production of crops in India: 1975-2005

Crop	Total Factor Productivity growth	Productivity share in output growth	Growth in real cost of production
Rice	0.67	24.6	-1.01
Wheat	1.92	58.9	-2.28

Source: Ramesh Chand *et al.*, (2012)

Table 35: Direction of sources of TFP growth for Rice and Wheat in India: 1975-2005

Crop	Model 1	Model 2
Rice	Research (+)	Research (+)
	NARI (+)	N:P2O5 ratio (+)
	Infrastructure (+)	Road (+)
	Electricity (-)	
Wheat	Research (+)	Research (+)
	Extension (-)	Extension (-)
	Cropping intensity (+)	
	Road (+)	

Source: Ramesh Chand et al., (2012) (NARI=Natural agricultural resource index)

The public investment in research has been a significant source of TFP growth both rice and wheat crops. Among natural resources, assured irrigation water along with balanced use of fertilizers, have played a significant role in increasing the TFP level. A look at the infrastructural variables has revealed that road density and electricity supply have been the most significant determinants of TFP.

c. Statewise analysis of TFP

Kumar and Mittal (2006) estimate TFP growth across different states for paddy and wheat. They found TFP of paddy has started showing deceleration in Haryana and Punjab but TFP of wheat is still growing in these two Green Revolution states. About 60 per cent of the area under coarse cereals is facing stagnated TFP. Similarly, the productivity gains which occurred for pulses and sugarcane during the early years of Green Revolution, have now exhausted their potential.

Ramesh Chand *et al* (2012) reported that TFP growth in wheat was found positive in all the states, except Himachal Pradesh. In rice, a large number of states have depicted low growth in TFP; only Punjab has shown high TFP growth, while Andhra Pradesh and Tamil Nadu have shown a moderate growth in TFP (Table 36).

Table 36: Trends in total factor productivity growths in various crops in selected states of India: 1975-2005

Crop	Total factor productivity growth category				
	Positive				Negative
	<0.5% (Stagnant growth)	0.5 – 1.0% (Low growth)	1.0-2.0% (Moderate growth)	>2.0% (High growth)	
Rice	Karnataka, Madhya Pradesh, Haryana, Bihar, Odisha, West Bengal	Assam, Karnataka, Uttar Pradesh	Andhra Pradesh, Tamil Nadu	Punjab	
Wheat	Bihar, West Bengal	Madhya Pradesh, Rajasthan	Haryana, Punjab, Gujarat, Uttar Pradesh		Himachal Pradesh

Source: Ramesh Chand *et al.*, (2012)

Statewise analysis of 15 Indian states by Shilpa Chaudhary (2012) revealed that it is a matter of serious concern that efficiency decline is observed in almost fifty percent of the states. This implies huge potential increase in production even with existing technology. Some of these states do not report overall productivity regress only due to the fact that technical progress outweighs the impact of decline in efficiency. The technical stagnation and near-stagnation is observed in most of the states. Demand for food would continue to rise and food supply has to keep pace in order to avoid shortages. This requires production to increase manifold. Since net area under cultivation has almost exhausted, productivity levels have to increase by leaps and bounds. It is necessary to reverse the efficiency decline that is exhibited by many states and achieve a faster and larger scale of diffusion of technical innovations across states.

Table 37: The share of commodities (%) in the total research expenditure in India

Commodities	1965-68	1977-80	1989-92
Wheat	1.46	5.15	1.88
Rice	7.07	5.91	6.08
Maize	1.18	1.60	1.43
Millets	2.79	4.89	4.06

Among cereals, rice occupied the first place followed by wheat(Table29). A state wise distribution of the priorities of a commodity reveals that more than half of the cereal research (52%) was done in the states of Andhra Pradesh, Madhya Pradesh, Maharashtra, Orissa, and Punjab(Table 37 and 38).

Table 38: Region wise investment (in million Rs) in agricultural research as per 1980-81 prices

Region	1965-68	1971-74	1977-80	1983-86	1989-92
Northern	338	630	779	995	1381
Southern	127	340	729	1027	1404
Central	149	292	473	717	958
Western	180	374	601	752	1079
Eastern	126	245	337	429	590
All-India	920	1881	2929	3920	5112

Northern region: States of Haryana, Punjab, Himachal Pradesh, Jammu & Kashmir, and Delhi; Southern region: States of Andhra Pradesh, Karnataka, Kerala, and Tamil Nadu; Central region: States of Uttar Pradesh and Madhya Pradesh; Western region: States of Gujarat, Maharashtra, Rajasthan, and Goa; Eastern region: States of Assam, Bihar, West Bengal, Orissa, and North-eastern states. (Ranjitha, 1996).

To achieve 1 per cent increase in TFP, the investments in research need to be increased by 21.5 per cent for rice, 19.5 per cent for wheat, 19.3 per cent for pearl millet, 13.6 per cent for maize, and 8.7 per cent for sorghum per annum. To achieve 4 per cent growth in agriculture, investments on agricultural research need to be doubled by 2015 and tripled by 2020 in relation to the investment level of 2002 (Mruthyunjaya and Kumar, 2010).

The TFP growth rate has been falling over the years. Such a fall is natural assuming there have been no innovations. Declining productivity trends can be directly associated with ecological consequences of intensive cultivation systems, such as a build-up of salinity and waterlogging, declining soil-nutrient status, increased soil toxicity, and pest build-up. Longer time gains in productivity may be more dependent on sources of technical change, stemming both from research within and outside the agricultural sector, greater input-use efficiency related to increased human capital in agriculture, and possibly, infrastructural development. A constant R&D effort is the most effective way of sustaining productivity growth. The need of the hour is context-based, client-oriented, problem-focussed research in a system perspective to improve its efficiency and efficacy. Till now, qualitative and informed judgements have formed the basis of problem definition. However, more concrete socioeconomic data are required to make a judicious research plan. Sustainability of natural resources should therefore be the major goal of any research.

d. Returns to Investment on Research in Agriculture

The analysis of returns to research investment provides justification for the previous fundings and presents a sound basis for future funding. Analysis has shown that the rate of returns to research investment was higher during 1995-2005 than during 1985-95 in all crops, except wheat and oilseeds. These results have clearly brought out that the future investments on research in agriculture will provide reasonable returns and will lead to agricultural development in the country. During the period 1975-2005, the overall internal rates of return (IRR) to public investment in agricultural research were highest for red gram (57%), followed by sorghum and cotton (39% each), wheat (38%), chickpea (34%), pearl millet (31%), rice (29%), maize (28%), and were lowest for groundnut (18%). It has been estimated that in the absence of contribution of agricultural research, production in the country in 2005-06 would have been lower by 10.4 Mt in wheat and by 6.3 Mt in rice.

e. Contribution of research to agricultural production

Ramesh Chand *et al* (2012) analysed the contribution of research to agricultural production and found that during 1975-76 to 2005-06 the output of paddy increased by 2.32 per cent each year in which 0.32 percentage point growth was due to research in agriculture, which amounts to 0.4228 Mt in terms of quantity which accounts to Rs 241 crore even at minimum support price rates. Similarly, the contribution of research to wheat output during 2005-06 was estimated to be 0.5896 Mt and it is valued at Rs 636.8 crore. Between TE 1975 and TE 2005, the incremental production was of 46 Mt in rice, 44 Mt in wheat, and 8.3 Mt in maize. It has been estimated that in the absence of contribution of agricultural research, production in the country in 2005-06 would have been lower by 10.4 Mt in wheat and by 6.3 Mt in rice. Thus, in the absence of research support, the respective output of rice and wheat would have been 85.5 Mt and 60.9 Mt instead of the actual production of 91.8 Mt and 69.3 Mt in the year 2005-06.

In the same analysis it is observed that the domestic production of wheat in the year 2005-06 was enough to meet 98 per cent of the country's demand. Without contribution of research, self-sufficiency attainment in wheat would have declined to 83.4 per cent. This implies that India would have been forced to import 9.8 Mt of wheat in the absence of research contribution during the past three decades. In rice, India exports about 5 per cent of its domestic production and thus the ratio of production to demand is 105.14 per cent. This ratio declines to 97.9 per cent when incremental output due to research is not counted. Thus, without contribution of research to rice production, India would have been forced to import 1.77 Mt of rice, after wiping out the export of 4 Mt rice. Wheat has enjoyed the highest benefit of technological change during the period 1975-2005 with its annual TFP growth close to 2 per cent. Rice lags far behind wheat and has witnessed annual TFP growth of only 0.67 per cent. Major cereals, namely wheat and paddy have experienced a lower growth in TFP after mid-1990s.

At the state level, the highest growth in TFP in rice production has been experienced in Punjab, followed by Andhra Pradesh during the period 1975-05. The western states of the country including Madhya Pradesh, have benefited a little from the technology and infrastructure-related factors in rice output. Except Himachal Pradesh, all wheat-growing states have benefited from the TFP growth with Gujarat at the top. Agricultural research carried out during past three decades (1975-05) has improved the self sufficiency status in wheat by 15 per cent and in rice by 7 per cent. The growth in food production induced by research has not only reduced the import dependency but has also added to export capacity, amounting to 17 Mt of cereals. In value terms, it comes to more than four-times the annual investment on agricultural research in the country (Ramesh Chand *et al.*, 2012).

f. Rice

The world price of rice is at least three times that of wheat and the total value of rice produced is atleast three times that of wheat. Rice being a high value crop compared with wheat becomes the key to invest in rice research. Since 1965, there has been an impressive growth in productivity of cereals, due to increase in land productivity, more efficient use of inputs, market infrastructure and supportive government policies. There was also a significant investment in research and irrigation. But in recent times there is reduction in rice production and it is attributed to 1) degradation of the land due to intensive cultivation; 2) reducing investment on infrastructure and research and 3) the increasing labor wages. Therefore, further rice productivity growth depends on substantial research investment to shift yield frontier of rice and rice profitability through more efficient use of inputs.

It is clear that despite the respectable national estimate of more than 1% growth in TFP, there has not been much technical change in marginal areas. Deceleration in TFP growth has been observed. Substantial trade in rice can take place from India only if TFP growth is maintained at about 1%, for which increased research investments are needed in several areas.

Three issues should receive high priority in rice research:

1. Greater focus on rice productivity in eastern India, which essentially means rainfed (upland and lowland) rice,
2. Sustainability of irrigated rice production (in the rainy as well as post-rainy season), and
3. Improving input-use efficiency in rice production.

g. Wheat

Wheat yield increased from 1242 kg ha-1 in 1967-71 to 2486 kg ha-1 in 1992-96 with an annual growth rate of 3.1%. Bihar, Haryana, Madhya Pradesh, Punjab, Rajasthan, and Uttar Pradesh are the major wheat-producing states, sharing 94% of the wheat produced. Uttar Pradesh accounts for one-third of the country's area. Nearly 98% of the area is under HYVs and 92% of it is under irrigation. Punjab and Haryana, the other major wheat-growing states, have 42%

and 34% of the gross cropped area respectively. It was observed that in the case of wheat, public research accounted for more than half the TFP growth followed by tubewell irrigation (36%) and rural electrification (6.8%).

> Wheat had shown negative TFP growth in Himachal Pradesh and very low TFP growth in West Bengal and Bihar. Hence emphasis should be given to improve these areas by
>
> 1. Enhancing research funding for these states
> 2. Developing location specific technologies for these states

h. Public funding in agriculture

Fan *et al*, (1999) found that investment in agricultural research provides a high marginal return relative to other investments in terms of both growth and poverty reduction, and this return may now be higher in rainfed areas. Careful targeting of public investment incorporating subsectoral and regional priorities and efficient use of existing infrastructure, particularly irrigation is essential for achieving the 4 percent growth per annum contemplated in the current national agricultural policy. However, high levels of subsidies compete with funds available for needed public investment, including investment in agricultural research.

How to increase Private investment in agricultural R&D ?

In OECD countries, private-sector research and development (R&D) is a major source of innovation and productivity growth as private companies now conduct half of all agricultural R&D (Pardey, Beintema, and Dehmer, 2006) and account for much of the increase in crop and livestock productivity in the United States (Huffman and Evenson, 2006) and elsewhere. Studies in India have shown that the private sector in developing countries can also play a key role in agricultural innovation and productivity growth, even though private research in developing countries is currently limited (Evenson, Pray, and Rosegrant, 1999; Ramaswami, Pray, and Kelly, 1979).

In China, since the mid-1990s, Chinese leaders have encouraged and supported private R&D investment by implementing three types of policies. The first provided incentives to public research institutes to increase basic research and privatized some public research institutes that conducted applied research. This shift in public research focus to basic research aimed at stimulating private-sector innovation. The second liberalized input markets and enacted specific laws allowing the private sector to conduct research. The third strengthened IPRs and provided specific subsidies and tax incentives for private companies conducting R&D.

Generally, private firms' agricultural R&D are modeled as investments they make to increase profits. Expected returns to research investment will improve in the presence of sizeable expected demand for research products, the strength of exclusion mechanisms such as patents which allow the firm to appropriate part of the benefits from the new product or process, and a favorable business environment that permits profitable innovations. The profitability of private research also depends on technological opportunities and research costs (David, Hall, and Toole, 2000).

The transformation of the Chinese system to a market economy has provided larger markets for private innovations as the government has withdrawn from agricultural input markets. Markets for agricultural inputs and food products have grown with increased demand for food products. Appropriation has improved with the development and enforcement of intellectual property rights legislation. Technological opportunities have grown as government research in more basic research has grown.

To encourage the private sector involvement in agricultural technology development, India has strengthened its IPR regimes in harmonization with international agreements. IPR guidelines by ICAR are geared to stimulate innovation by sharing research benefits with innovations. It was fostering the partnerships with the private sector for the scaling up and commercialization of technologies developed in the private sector.

Further we need to follow China by changing our research priorities and making certain policy changes:

1. Public R & D should be geared towards basic research and the institutes that are engaged in applied research can be privatized. This will help in reducing number of research institutes under public domain and thereby ensures higher level of fund availability for each institute.
2. Agricultural input industry should be totally privatized so that the private organizations would come forward to invest in innovative R & D for product .opmen
3. Tax exemption for the income generated on technology generated / transferred to farmers

2. Input management

a. Timely and adequate availability of inputs for better adoption of modern technology

In China, all the agricultural input supplies are privatized and because of that there is timely supply of inputs and there is no subsidy burden on the government resulting in no imbalanced application of fertilizers. This also helped in innovative research by private organizations for better product development with minimal investment.

b. Groundwater exhausted due to subsidized or free electricity

Free supply of electricity for irrigation purpose has resulted in over exploitation of ground water in Indo Gangetic plains especially in Punjab, Haryana and Western UP. Farmers of these states must understand that the early regular supply (in the month of June) of subsidized electric power to tubewells is a sweet poison because it is the main reason behind the rapid fall of water table and the indebtedness of farmers. Agriculture all over the world is subsidized. The shifting of subsidy from input (subsidized power to tubewells) to output (increase in procurement price or bonus on marketable agricultural produce) should encourage farmers to make efficient use (Hira, 2009).

c. Development of minor irrigation for improving irrigation use efficiency

The area under irrigation increased substantially with the construction of major, medium and minor irrigation projects during the last 60 years. The underground water is made available for irrigation free of cost which resulted in over exploitation especially with the availability of free electricity for its pumping. In India flood irrigation was the only method being used till 1985. The irrigation efficiency is only 35 to 55% in flood irrigation. The drip irrigation/micro irrigation was introduced in Israel, USA and Australia in early 70s itself. The minor/micro irrigation can provide controlled water supply that too timely irrigation which helps in covering more area and thereby enhancing the productivity. There are many benefits of this minor irrigation such as the area under irrigation can be doubled, enhanced irrigation efficiency, efficient use of fertilizers and enhanced productivity. The only drawback of this system is huge initial investment. This can be overcome by the subsidies provided by state governments. The National Mission on Micro Irrigation (NMMI) launched in 2010 is performing well in integration with other schemes to enhance sustainable production.

At present 91% of wheat and 59% of rice area are under irrigation in India. By adopting micro irrigation in other crops like horticulture crops, cotton and sugarcane it is possible to grow rice and wheat entirely under irrigation which can enhance their productivity and thereby food security. The information on area under irrigation of various agriculture crops in India is depicted in Figure 12.

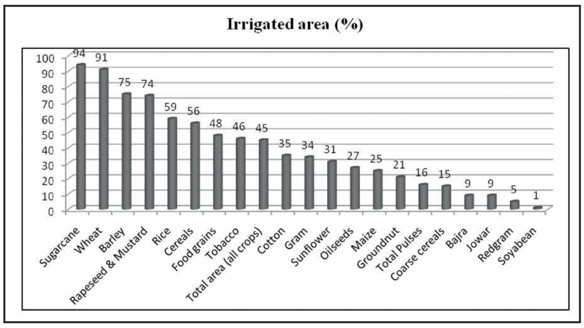

Figure 12: Area under irrigation of various agricultural crops

Source: SIA, 2012

International Rice Research Institute signed an MOU with Jain Irrigation Systems in February 2010 to conduct research on making use of micro irrigation for rice cultivation. Once the research findings are found encouraging, then it would save on lot of water under irrigation.

d. Water saving techniques in rice cultivation

A) Suitable time for crop growing: Nielsen (2004) described selection criteria for suitable period of rice cultivation and suggested that

i) Cultivate in rainy season and harvest at the end of season,
ii) For non photoperiod sensitive varieties (110 to 120 days) the harvesting date should be planned at the end or rainy season in order to set the growing date,
iii) Cropping calendar should be planned suitable to wet and dry season.

B) Developing varieties with high water productivity : The modern "IRRI varieties" have about 3-fold increase in water productivity compared with the traditional varieties (Tuong, 1999). The photosynthesis to transpiration ratio was 25 to 30% higher for the tropical japonica than for the indica type (Tuong and Bouman, 2003)

C) Laser levelling: Laser land levelling is the most effective innovation in the field of agriculture especially for less and equitable usage of inputs for maximum production. It reduces the unevenness of the field to about ±2 cm, resulting in better water application and distribution efficiency, improved water productivity, increased fertilizer efficiency and reduced weed pressure. Savings of up to 50% in wheat and 68% in rice have been reported by Jat *et al*. (2006).

D) Direct seeding: Direct seeding of rice compared with transplanting saves labor and fuel. Seeding into dry soil save water as there is no puddling and the total growing period from seed to seed is reduced at about 10 days.

2. Support for marketing infrastructure:.

An efficient agricultural marketing structure is essential for the development of the agricultural sector. To benefit the farming community agriculture and agricultural marketing system needs to be integrated and strengthened. Government of India has initiated agricultural marketing reforms and has taken many steps for creation of marketing infrastructure. In India about 30% of post harvest losses are recorded in agricultural produce. It can be avoided through development of proper transportation facilities including roads and refrigerated containers for perishable products and making good storage facilities available.

> Periodical over-production of coarse cereals during favourable rainfall year always led to crashing of market prices. Pearl millet (bajra) is the dual purpose, drought tolerant main coarse cereal crop, most important fodder for animals, witnessed highest productivity growth among all cereals (Table 9) and its prices crashed during high rainfall years of 2003 and 2010 due to market failures.

In this context, the effort by National Spot Exchange in laying down the foundation for Farmer Aggregator Model in the form of 'Western Ghats Growers Association' is a welcome initiative. This will attract farmers' participation into futures and electronic spot markets. This will function as an aggregator for all its farmer members and use futures exchanges to hedge their price risks in related commodities. I hope the small and marginal farmers of Kerala will be able to get the advantages of both spot exchange and futures exchange through Western Ghats Growers Association.

a. Post harvest losses

Yield losses can be caused during pre- and postproduction. Post-production losses range from 10% to 30% of the harvestable yield. Losses are more serious in the wet-season harvests due to the lack of drying facilities. Resource-poor farmers tend to deploy labor-intensive practices in hand harvesting, sun drying, manual threshing, wind winnowing, and inappropriate storage, thus contributing greatly to grain losses. Training of farmers and access to credit to introduce more efficient technologies to handle threshing, drying, storage, and milling at the village level are important for reducing postproduction losses.

b. Establishment of collection centers

A large majority of the farmers are marginal and small and cannot influence the market individually and operate in a very disadvantageous buyer's market. They have usually little marketable surplus and also do not have enough storage facilities with them. The farmers are very often compelled to go in for distress sale because they have to pay back the credit availed, or to meet their obligations. This situation is often exploited by traders and with the result farmers do not get the right price for their produce.

Under such a situation, the farmers can benefit from futures trading. The Futures markets provide platform for price discovery and price risk management. Farmers and growers benefit through the price signals emitted by the futures markets even if they may not directly participate in the futures market. Price discovered on futures exchange provides a benchmark and is extremely helpful in the decision making process by farmers regarding the crops to sow what prices to expect etc.

c. Value addition

Traditionally, the role of farmers in the agriculture value chain has been confined to cultivation of crops and to sell the same to local traders in bulk immediately after harvesting. In general, price realization for any commodity is higher after sorting, grading, processing, packaging or value addition in any other form. Since the farmers sell their produce in bulk without any value addition, they are not able to take home such incremental price advantage. As a result, a farmer who invests his hard earned money in buying agricultural inputs, who spends his day and night in caring for his crop and suffers from all sorts of natural calamities such as unfavourable weather, un predictable monsoon and uncertain price behaviour of his produce, gets significantly lower profit for his entire venture. On the other hand, a trader or exporter, who buys the crop produced by a farmer, does some value addition in the form of sorting, grading, packaging, branding, etc. Thereafter, he sells such graded crop to up country buyers or overseas importers. In the process, he gets relatively higher profit margin in the agriculture supply chain compared to a farmer growing the same. This is the crux of the issue impeding agricultural growth in India. This is why farmers are still not better off, even though prices are going up and even though production is also going up in quantitative terms. Unless we turn the table and make agriculture more remunerative for the farmers, it would be difficult to get significant momentum in agricultural growth in our country.

In rice, the total estimated losses in post harvest process are around 10-37% and if these losses can be brought down, it would definitely be an addition to food security. During secondary processing, some useful by-products such as broken rice, bran and husk are obtained. From these byproducts, it is possible to make some value added products like rice floor from broken rice, edible oil/cake from rice bran and the husk. In tertiary processing, conversion of milled rice to ready to eat food products likes flaked rice, puffed rice, quick cooking rice, fortified rice, rice cake etc takes place.

> Brown rice is rich in vitamin B1, B2, B3, B6 and iron as compared to polished white rice. Brown rice can be stored well in hermetic storage or freezing condition.

The broken rice, a low value material, can be converted into several value added products like rice noodles, vermicelli, rice starch, rice flour and rice ethanol. Rice flour can also be used for production of rice analog (whole grain shaped pasta product) in conjunction with protein materials (wheat gluten, black gram flour, and gelatin) as functional supplements.

For this value addition, support is required from government to establish these units by encouraging farmers or traders by providing them tax holidays or low interest loans initially so that there will be substantial reduction in post harvest losses.

d. Arrangement between state governments for deploying excess production to deficient states

There is policy very much needed to channelize the surplus food to regions of deficit without inflation in the food prices. A food distribution management act is necessary to ensure an uplift in the socio-economic nutritive status of the people of India. In order to reduce storage and transit losses (during transportation) of food grains at farm and godown level, the Indian Government has implemented a national policy on handling, storage and transportation in June 2000, under which integrated bulk grain handling, storage and transportation facilities of about 5.5 lakh million tons has been created through private sector participation (e.g. PEG-2008) on Build-Own-Operate (BOO), Build-Own-Operate-Transfer (BOOT), Build-Own-Lease-Transfer (BOLT) basis, etc. Due to record levels of procurement in the last 4 years (2007-12), several States have been facing a problem of covered storage capacity for storing the food grains.

In some states like Punjab, Haryana and Andhra Pradesh there would be excess production of rice in most of the years. At the same time there are states in which rice production is too low but demand is high. If some agreement can be made between state governments of excess production to low production it would be easier to have optimal availability of food grains in all the states. Otherwise the middle men are taking advantage of this situation by procuring the food grains from excess production states and selling them in low production states at exorbitant rates. This benefits only the traders and the middlemen but both producers as well as consumers are disadvantage. This can be avoided by making some policy to divert the excess production to the states where there is higher demand.

Food Grid: We can form a National Food Grid Network to transfer the excess quantity of agricultural production to deficient areas, to ensure availability of food throughout the country and to restrict the over exploitation by middlemen.

e. Buffer stock policy

The availability of food is characterized by sharp fluctuations in production and becomes an important element to be taken care of in India's food policy. It is, therefore, necessary to use a part of the bumper production of good years in the subsequent year(s) of lower production by creating buffer stocks during favourable years and using such stocks in the lean years. Buffer stocks also stabilize the intra-year availability, taking care of the lean months. There are some critics of buffer stocking policy of the Government of India, who argue that these involve huge costs, as also some inevitable damage to stored grains and, therefore, suggest imports, as and when required, as an alternative. Practical experience has, however, shown that imports can never provide that sort of the national food security for a big and populous country like India, which buffer stocks can. Most importantly, imports cannot be on the tap, as if imports of all the required quantities will materialize as and when one wishes. There is not only a lead time but in the absence of buffer stocks from which quantities can be immediately released in the market, speculative tendencies will not only have a field day in the domestic market but the country's bargaining power in the international market would be seriously eroded with the result that purchases may have to be made at high prices and on the sellers terms. The money required will be in foreign exchange whereas cost of buffer is at least in the domestic currency. Above all, why is it that a natural calamity like drought, flood a cyclone can still impair food security of the affected people very grievously in the developing countries but as observed by Jon Bennett "No one in USA starves when drought hits the mid West plains, for the country has mountains of stored grains. And why does Japan still wants to produce its own rice at great cost when it can buy any amount of rice any time. The moral is try and have your own food buffer. Finally, in the absence of buffer stocks, the nation is prone to be pressured economically as well as politically- the autonomy of the country may itself be in the danger of being impaired. (Jon Bennet, 1987) Buffer stocks provide food security to nation and also give it the required strength and pride at the global level. It has also been experienced that when India enters the international market for imports, which necessarily have to be substantial, the prices tend to harden. Further, the food grains especially rice, in this part of the world also suffers a decline and even the availability goes down. During 1992, when India had to import, Australia, which is the cheapest and ideal source, indicated their inability to spare any quantities out of their 1991 harvest, which had also gone down by 20 to 25 percent due to poor rains.

A minimum 16 million tonnes would be required to buffer frequently occurring fluctuations in production due to increasing frequency and intensity of extreme weather/ disastrous events of global warming. Rice and wheat have been major commodities of procurement and public distribution of food. Rice, wheat and other grains procurement capacities of States other than Punjab, Haryana, UP, Andhra Pradesh, etc. are grossly inadequate. Food Corporation of India is having 30.6 million tonnes of storage capacity consisting of 90% in godowns and 10% Covered Area Plinth (CAP). About 51% of storage capacity is in public sector and 49% is rented from private sector. About 71-73% of the capacity has actually been utilized in the past. By all means the current safe storage capacity and its quality falls short of the food security requirements of 52 to 74 million tonnes. Lack of extended safe storage into modern silos with controlled conditions is a great infrastructural and managerial challenge.

For avoiding post harvest losses and to get the farmers premier price for their produce depending upon the quality, the government should enhance the storage capacity by constructing godowns either on its own or by encouraging private investment in this sector.

f. Encouraging Private partnership in construction of godowns or warehouses

Warehousing is very important in agricultural marketing as it can manage both glut and scarce situations. Private entrepreneurs are not showing much interest because it requires huge investments and also large area of land for construction.

Table 39: Storage capacity of government and private warehouses

S.No.	Name of the Organization /Sector	Storage Capacity in Million MTs
1.	Food Corporation of India (FCI)	32.05
2.	Central Warehousing Corporation (CWC)	10.07
3.	State Warehousing Corporations (SWCs)	21.29
4.	State Civil Supplies	11.30
5.	Cooperative Sector	15.07
6.	Private Sector	18.97
Total		**108.75**

(Source: Planning Commission, GOI, 2011)

The storage space available is not enough to stock the procured food items and because of this, large quantities of food grains are being stored under CAP. Construction of ware houses need larger area and investment, many private companies are not coming forward. The storage capacity of private and public warehouse is given in Table 39.

Punjab had been urging the central government to allow the setting up of more warehouses and silos for storing food grain since the existing infrastructure was overflowing with stocks of previous years and thousands of tonnes of food grain was rotting every year, leading to wastage. The Centre allocated about 50 lakh tonnes of new storage capacities for Punjab to prevent wastage of wheat and rice in the wake of inadequate storage capacities in the State. Punjab suffers from a severe shortage of storage space. Punjab still faces shortage of 40-45 lakh tonnes of food grain against the present capacity of 100.6 lakh tonnes of covered space and 105 lakh tonnes of Covered Area Plinth (CAP).

Kairon said that Punjab, the food granary of the country, purchases 24 million tonnes of grain annually. "This is even higher than the largest global food grain export countries of

Canada and Russia that export 21 million tonnes and 20 million tonnes respectively per year," he said. Punjab, known for producing wheat and paddy (rice) and contributing nearly 70 percent food grain to the national kitty, makes an annual payment of Rs.35,000 crore to farmers during the procurement season.

4. Efforts for effective transfer of technology

The country, both in public and private sectors, has spent considerable resources in developing new technologies. If deployment of such technologies is not effective, it would amount to a colossal waste of national resources. In addition, there is some indigenous technical knowledge available from our ancestors who practiced farming for so many years. Some farmers being innovative are capable of thinking differently and developing some innovative technologies like identification of certain varieties through selection, some innovative irrigation methods and some plant protection procedures etc. Such farmers need to be given encouragement to make those innovations recognized and be useful for other farmers.

Special support system for Innovative farmers: Innovative farmers who developed some useful and innovative technologies need to be provided with some sort of support from government like interest free or lowest rate of interest loans for encouraging innovations in agriculture

5. Seed sector needs to be strengthened

For strengthening the seed sector, improving policies and legislation for variety development and release as well as seed supply; strengthening capacity by creating a new generation of skilled practitioners to support enhanced breeding; working with farmers to explore the ways in which crops and varieties contribute to successful intensification

Seed Village concept to produce their own seeds by farmers: This is an age old practice in several parts of country side which can be revived and modernized

6. Making use of urban biodegradable waste into useful agricultural input

The ministry of urban development has released data that states that Indians generate 115,000 million tons of municipal solid waste every day. Unfortunately, metro cities including Bengaluru, Thiruvananthapuram, Mumbai, Delhi and Pune are no longer able to cope with these mountains of trash. Mumbai alone generates over 5,500 tons of garbage every day while smaller cities are touching the 1,000 tons per day mark. The problem is equally acute across states. Lack of garbage management has driven high-end tourists away from Goa, according to the data.

BARC's Nisarguna biogas technology can produce 25-30 kg of methane and 50-60 kg of organic manure from one tonne of biowaste. A staggering amount of waste is generated every day in every town and city, and the local bodies are grappling with logistics for its disposal. The problem arises as the government and individuals fail to see waste as a potential source of energy and agricultural input in the form of manure. The Bangalore Corporation, which recently made waste segregation mandatory at the household level, is showing the way for the rest of India. It is setting up 12 Nisargruna biogas plants across the city to convert biodegradable waste into methane and organic manure. Even it can be used to produce electricity. Kerala government is providing subsidy for establishing compost management units and biogas plants for urban waste management.

A systematic and scientific approach to solid waste management, as explained above and proper implementation of legislative tools will go a long way in effective handling of solid wastes. As in several other sectors, MSW sector should also be identified for providing fiscal and other tax incentives including appreciation by the authorities. This decision shall bring private sector participation and waste of present day shall be a resource for generating energy and large number of direct employment in the country. TERI (1999) reports that nearly 1000 MW electric energy can be generated from urban and municipal waste and about 700 MW from industrial wastes by applying waste management technologies in India. The National Bioenergy Board is evolving policy guidance and direction and Ministry of Non-conventional Energy Sources have initiated many programmes including biomethanation and other projects like pelletization, gasification, pyrolysis, incineration, and sanitary landfills in many states. It is opined that more demonstration projects and private sector participation with financial and fiscal incentives for waste disposal and management may encourage more investment which finally shall generate more employment, revenue and energy.

7. Enforcement of pesticide regulations will help improve adoption of IPM

Although many of the pesticides are banned in some of the states they are available in neighbouring states, allowing the farmers to use them non judiciously leading to development of residue problems as well as resistance to pests and diseases. Strict enforcement of the regulations governing production, use, distribution and quality of pesticides would help to weed out spurious elements from the industry and would benefit the farmers.

8. Minimizing the transaction cost

The transaction cost towards credit facility in banks is very high at present. This needs to be minimized in order to encourage poor farmers to avail the credit facilities from the banks. Besides this, there are no proper land records available with many of the small and marginal farmers. This makes them devoid of availing bank credit.

Summary

The rice production can be improved in eastern belt as the performance of these states had been low besides good resource availability by providing enough input and output marketing support. Hybrid seed production in rice is picking up especially under private sector which can be promoted through some policy intervention.

The subsidies provided in different inputs in the backdrop of green revolution have outlived their significance and need to be phased out because, they have become a big burden to the national exchequer and are restricting the investments in other important areas like infrastructure, R & D etc. NBS is an important move in this direction.

To encourage private sector partnership, steps may need to be taken to safeguard the IPRs. Passing the long pending Seed Bill 2004 can also ease some of the restrictions on private sector to invest on research, extension and marketing aspects.

The legalized water management regulatory frame work would help in defining water usage problems. Subsidized/free electricity has resulted in over exploitation of ground water and pushed water levels to unrecoverable levels. The old system of canal irrigation needs to be re emphasized by giving importance to micro irrigation.

References:

Beintema, N.M. and Stads, G.J. (2008) Measuring Agricultural Research Investment: A Revised Global Picture. ASTI background note. International Food Policy Research Institute, Washington, DC, USA.

Bennett, Jon. (1987). The Hunger Machine: The Politics of Food. (New York: Polity Press)

David, P. A., B. H. Hall, and A. A. Toole. "Is Public R&D a Complement or Substitute for Private R&D? A Review of the Econometric Evidence." Research Policy 29(2000):497–529.

Fan Shenggen, P. Hazel, S. Thorat, (1999), Linkages between Government Spending, Growth, and Poverty in Rural India, Research Report 110, International Food Policy Research Institute, Washington DC.

Hira G S 2009. Water Management in Northern States and the Food Security of India. Journal of Crop Improvement 23(2) pp ; 136-157

Huffman, W. E. and R. E. Evenson. 2006a. Science for Agriculture: A Long-Term Perspective. 2nd ed. Blackwell Publishing, Ames, Iowa.

Jat ML, Chandna P, Gupta R, Sharma SK, Gill MA (2006). Laser land leveling: a precursor technology for resource conservation. Rice-wheat consortium Technical Bullletin series No.7. New Delhi, India, Rice-Wheat consortium for the indo-gangetic plains, p. 48.

Mruthyunjaya and Kumar, Praduman (2010) GCARD Regional Review for Asia Pacific: South Asia Report, presented at Global Conference on Agricultural Research for Development, held in March 2010.

Nielsen TK (2004). Lecture Note on Paddy Cultivation.

Pardey, Philip G, Beintema, Nienke M. & Dehmer, Steven & Wood, Stanley, 2006. "Agricultural research: a growing global divide?" Food policy reports 17, International Food Policy Research Institute.

Praduman Kumar and Surabhi Mittal (2006) Agricultural Productivity Trends in India:Sustainability Issues. *Agricultural Economics Research Review* Vol. 19 (Conference No.) 2006 pp 71-88.

Ramaswami, B., C. E. Pray, and T. Kelly. "Dissemination of Private Hybrids and Crop Yields in the Semi-arid Tropics of India." Indian Journal of Agricultural Economics 57(1979):39–51.

Ramesh Chand, Praduman Kumar and Sant Kumar 2012. Total Factor Productivity and Returns to Public Investment on Agricultural Research in India *Agricultural Economics Research Review* Vol. 25(No.2) July-December 2012 pp 181-194

Ranjitha, P. 1996. An analysis of investment in agricultural research and extension in India. Ph.D. thesis, Indian Agricultural Research Institute, New Delhi, India.

Robert E. Evenson, Carl E. Pray, Mark W. Rosegrant (1999). Agricultural Research and Productivity Growth in India. International Food Policy Research Institute.

Saikia Dilip, 2009. Total Factor Productivity in Indian Agriculture: Some Conceptual and Methodological Issues. Online at http://mpra.ub.uni-muenchen.de/28578/ MPRA Paper No. 28578, posted 03. February 2011 / 19:30

Shilpa Chaudhary 2012. Trends in Total Factor Productivity in Indian Agriculture: State-level evidence using non-parametric sequential malmquist index. Working Paper No. 215 Centre for Development Economics.Department of Economics, Delhi School of Economics

Suresh pal, Michael Rahija and Nienke M.Beintema, (June, 2012), Recent Development in Agricultural Research in India report, ASTI- country Report, http://asti.cgiar.org/india/.

Tuong TP, Bouman BAM (2003). Rice Production in Water-Scarce Environments, International Rice Research Institute Metro Manila, Philippines.

Key Suggestions

New innovations are required to enhance the agricultural production in general and food grain production in particular. Rice and Wheat are the two major cereals which command the food grain situation in our country. This project provides information on innovations that took place in research, policy frame work and institutional environment especially in rice and wheat crops that shaped agricultural production in India. After analysing the data sets available from different sources and through field visits to six different districts (both from Green Revolution states and others), we could analyse the actual situation. With this background, we suggest some recommendations for research, policy and also in institutional frame work for maintaining better food security condition in the country.

1. Deceleration in Food grain Production

A major change in food grain production scenario was witnessed due to green revolution technologies and after that no major breakthrough could be achieved. Yield gain in rice and wheat during last forty years is mainly because of improvement in the yield. Green revolution was highly successful in Punjab, Haryana and Western UP due to combined effects of technology, policy support and farmers' acceptance. The side effects of green revolution and other policy implications are being experienced in GR states in the form of over exploited soils and water regimes. This has led to plateauing in yields of major food grains. In rice production, West Bengal occupies number one position in area and total production whereas the average yield is high in Punjab. With respect to wheat, UP occupies first position in area and production (with >30% area and Production) and Punjab records the highest average yield (4462 kg/ha).

There could be some other reasons also for this downward growth. There is lower rate of adoption of modern technologies in many parts of the country, climate change and dependence on vagaries of weather and rainfall, small size of land holdings, opening up of economy, lack of timely availability of credit loop holes in subsidy policy and also in some welfare schemes etc.

2. Production can be enhanced through innovative research techniques

With the available varieties and technology no major shift can be expected in food grain production and hence we need to have some innovative techniques which can improve the yields by breaking the yield barriers.

Innovations in rice research

Development of C4 Rice for enhanced photosynthetic efficiency, use of MAGIC for multiple stress resistance, developing varieties suitable for aerobic conditions and developing P efficient rice varieties through the use of PISTOL1 gene can enhance the rice productivity by breaking the yield plateau. Hybrids in rice are highly productive in China unlike India, where the yield levels are not so high and the cooking quality is also not up to the mark. Hence, further improvement in yield and quality can make them acceptable to the farmers.

Innovations in wheat research

Developing hybrids by utilizing heterosis, broadening of the genetic base, resource conservation technologies and developing suitable technologies for enhancing productivity of low production states viz., UP, MP, Bihar, Gujarat, Rajasthan and eastern parts.

3. Policy environment should undergo some changes for attaining sustainable food security

There were many important policies for enhancing food grain production viz., IADP, IAAP and ACRP, region specific programmes like ICDP, TMM, Minikit demonstration, ISOPOM, NFSM and RKVY etc. Apart from them, establishment of institutions like NSC, APC, FCI, Ware housing corporation, ICAR, AICRP etc also contributed enormously for the development of agricultural production in the country. However, emphasis on usage of inputs through provision of subsidies has led to unsustainable production and over exploitation of soil and water resources especially in GR states viz., Punjab, Haryana and Western UP, which are the main sources of food procurement in the country. The water resources are over exploited in these states. Now, policies are required to bring these areas to normalcy by developing strategies for diversification and emphasizing on other food items such as horticulture, dairying, poultry farming and integrated system of farming. In 2013-14 budget, Union government has allotted Rs.500 crores for diversification of farming in these states. This is a welcome step and such diversification needs to be done in other parts of the country as it is likely that many parts of the country are also undergoing similar transition, which might be taking longer time.

Input Policies need some radical changes to revolutionize Indian agriculture

India needs a strict water policy for avoiding further exploitation of ground water especially in over exploited areas and also by shifting the rice cultivation from North – western states to Eastern states by modifying the food grain procurement policy to these states. Emphasis should also be given on water use regulations and conjunctive use of water. The subsidies on irrigation in the form of electricity and credit needs to be revisited and modified in the interest of restricting ground water over exploitation. Policies needs to be strengthened to supply enough quantities of quality seed for maintaining recommended seed replacement ratio which is below normal.

Fertilizer subsidies through NBS (Nutrient Based Subsidy) are expected to give good results in harmonising the ill effects of GR technologies and earlier policies on fertilizer subsidies. However, this need to be extended to Urea also and the policies are to be made for its strict implementation as it greatly influences food security condition of future generations.

In farm mechanization, the problems need to be tackled by supplying farm machinery evenly in all the regions and by making it available to small and marginal farmers through various supportive measures like custom hiring and providing concessional loans for their purchase. Research also needs to be strengthened to develop machinery suitable for use in small holdings and affordable to small farmers.

Output Policies need to be strengthened for creating favourable market environment

Minimum Support Price policy is really a boon to farming community. During the last two years, fertilizer prices especially DAP and complexes have increased unprecedentedly. However, the improvement in MSP seems to not be in line with that of input prices. Even during our survey, many of the rice and wheat farmers expressed dissatisfaction over this. Moreover, the time line for the announcement of MSP is another important problem expressed by the farmers. Hence steps to formulate the policies which will announce the MSP well in advance and the enhancement of input prices may be considered for calculating MSP need to be taken.

The procurement policy on food grains needs little modification by focusing rice procurement from eastern states and encouraging crops other than rice and wheat in north western states. Recently, Government announced a policy on cash transfer for input subsidy and also for the purchase of food grains, which is going to affect the procurement scenario and thereby farmers' interests. A serious thinking may be required to continue the same after evaluating the benefits and detriments of this scheme.

A large majority of the farmers are marginal and small and cannot influence the market individually and operate in a very disadvantageous buyer's market. They would be having little marketable surplus and do not have enough storage facilities. The farmers are often compelled to go in for distress sale because they have to pay back the credit availed, or to meet their obligations. This situation is often exploited by traders and with the result farmers do not get the right price for their produce.

Under such a situation, the farmers can benefit from futures trading. The Futures markets provide platform for price discovery and price risk management. Farmers and growers benefit through the price signals emitted by the futures markets even if they may not directly participate in the futures market. Price discovered on futures exchange provides a benchmark and is extremely helpful in the decision making process by farmers regarding which crops to sow and what prices to expect etc. Enhancement of storage capacity by construction of godowns either by government or through private agencies is an important requirement.

Seed Bill 2004 need to be passed which can ease some of the restrictions on private sector to invest on research, extension and marketing aspects. Steps may need to be taken to safeguard the IPRs for encouraging private sector partnership.

4. Better credit support and extension services need to be provided through institutional dynamism

Credit support is very essential for farmers to take up farming operations. Our government has tried to give possible support through various institutions like commercial banks, Regional Rural Banks, Cooperatives and NABARD etc. Even then, the credit support is yet to reach a sizeable population of farmers especially small and marginal. For making credit available to all the farmers, lot more needs to be done in an innovative way.

This objective can be met out by modernizing the credit institutions through latest technological advancements in telecommunications, information technology tools etc. But this needs a network of players who can provide banking facilities in combination with farming technology, market information and guidance. So, for this the traditional banking institutions would not be enough and they need to work with other players which include technology providers (IT companies), insurance companies, retailers in the village, extension specialists etc. in coordination. This may result in increased efficiency of credit support initiatives and larger portion of needy farmers would get benefit from such a network. Enough investment on extension activities is required to provide knowledge on latest developments like new varieties developed, new techniques in planting patterns, fertilization and weed management, irrigation management, pest and disease management, market information, new machinery etc.

5. Research investment needs to be enhanced for achieving desired effect

To attain 4 per cent growth in agriculture, as targeted by the Planning Commission, we need to enhance investment on research. Because, at least one-third of this targeted growth must come through technological innovations and remaining two-thirds has to be achieved through additional use of agricultural inputs. To meet these targets, investments on agricultural research need to be doubled by 2015 and tripled by 2020 in relation to the investment level of 2002. An aggressive R & D investment strategy is absolutely essential for meeting the demands of present competitive world to have a reasonably good growth in agriculture as well as food security situation. This requires an adequate and continuous investment in agricultural R & D for sustained growth. At present, India spends only 0.6% of agricultural GDP on research. This needs to be enhanced up to 1 % at least in comparison to 2% in developed countries.

6. Integrated Farming System approach is a way for risk aversion and better soil health

The farming system approach need to convert every family farm into eco cum bio-fortified farm. It is essential to follow eco-friendly farming and subsidiary farm enterprises for risk aversion in increasing soil fertility. In this connections, we need to encourage Subsidiary farm enterprises.

Practicing only farming is highly risk prone and hence it needs to be diversified with the inclusion of allied enterprises like dairying, sheep and goat rearing etc. which can help not only in enhancing net returns but also in maintaining soil quality for future generations.

Goats contribute to a family's food security by providing food (milk), meat and generating employment and income that help assure access to other foods. Families of goat-keepers had access to 0.41- 4.0 liters of goat milk per day per family from 60 to 150 days a year. Goats are considered living banks to be used to acquire food and fulfill other needs. Diseases in goats had a direct bearing on the food security of goat-keeping families as a result of reduced milk supply and lower income from family labor.

7. Development of climate resilient varieties and technologies

During the last 16 years, area under food grain cultivation has fluctuated around a constant value of 121 million ha whereas total production has increased due to gradually improving productivity. After 1996-97 additional production came mostly from three commodities - rice, wheat and maize only at very narrow base. Growth rate in sown area and production is bumpy over the years with sufficient negative values. It is due to uncertainties in the behaviour of weather especially rainfall, its onset, long dry spells in between, withdrawal and distribution, floods, hot/cold waves, cyclones etc. Intensity and frequency of occurrences of extreme weather events or risks have gone high during the past 10-15 years as manifestations of global warming and climatic changes. It requires mitigation measures, innovative alternative land uses for reducing vulnerability and improvements in the safety nets especially in rainfed area to assure the farmers to go for the modern technologies. Market interventions and infrastructural investments into silos to regulate volatility of prices, farmers/consumers distress, procurement, prompt payments, extended safe storages and flawless distribution networks need very high priority.

Climate change is expected to gravely affect rice cultivation and thereby food security situation in India. Conditions for rice production will deteriorate in many parts of India through water shortages, low water quality, thermal stress, floods and intense tropical cyclones. A 15% decrease in irrigated rice yields in developing countries and a 12% increase in rice price is anticipated as a result of climate change by 2050.

8. Soil quality can be maintained through amelioration of polluted soils

Stress-prone rice area in the country accounts for as much as 24 million ha, out of the 44 million ha, posing a huge challenge for stabilising rice production. Development of rainfed agriculture with emphasis on development of eastern India needs to be achieved. Special programmes like BGREI (Bringing Green Revolution to Eastern India) need to be strengthened.

Rainfed agriculture being practised on 60% of cultivated land, supporting 40% of population, 60% of livestock and 40% of food, is having significantly low productivity as compared to assured irrigated farming and has some unexploited potentials.

9. Corporatization of agriculture by making farmers as shareholders Encouraging and retaining youth in farming

Now-a-days, the youth in villages are not interested in farming and most of them want to discontinue agriculture if some alternative means of livelihood is available. This is mainly because agriculture is not lucrative in terms of net income and it has become very difficult to do farming because of labour problem, increased cost of inputs, vagaries of weather, increased risk of pests and diseases etc. Even after toiling for so many days the farmers will end up with distress as either they do not get enough income to run the family or they incur into losses if the climatic condition do not co-operate. That is why none of the farmers want their children to continue in farming.

For retaining the youth in farming, the government should provide some alternate means of livelihood as dependence on farming alone is highly risk prone. This is possible by establishing some agro processing industries in the villages and allowing the farmers to work in rotation according to their convenience without clashing with the farming operations. Farmers can be made as share holders in this type of enterprises and the profit can be distributed among the shareholders as per their contribution.

This is possible by forming farmers' associations in the similar lines to that of Maharashtra where they have crop/commodity associations and they are running even agribusiness centres. This needs initiatives from farmers themselves and the local government should also help them to forge ahead by providing some initial help.

10 Self reliance and self respect to farming community

The farming community which provides us our daily bread, lack self reliance and they do not command respect in the society which they deserve. This is because, in general most of the farmers are illiterate and unaware of the modern technologies in different fields like IT, space research etc. Moreover, the income from their small land holding is no where comparable with any salaried person. Sometimes they even incur into losses, unable to meet the daily needs of the family. All these factors make them weak, financially vulnerable to lose self respect in the society. But if their economic condition is improved by providing some complimentary employment along with their farming, they can command respect and they can also maintain a good life style. Further, if they are provided with some free education that will also help them in understanding the problems of their community and they will try to find out some solutions at their own level.

11. Farmers need to have easy access to information

Although there are many different approaches of extension to make the farmers acquire information on agriculture, most of the farmers still do not have access to any source of information. The public extension system mostly concentrates on on-farm activities and no emphasis is given on marketing aspects whereas, the ATMA (Agricultural Technology Management Agency) model focuses on crop diversification. The ITC (Indian Tobacco Company) initiative of e-Choupal to supply farmers with all information including market prices is an improvement but it can work out well where there are incentives for crop failure and where the farmers are ready to pay.

In the context of innovation systems, operationalized by integrated agricultural research for development, an innovation can emerge from many sources and through complex interactions and knowledge flows, with the farmer being at the center of the process. Therefore, knowledge sharing should go beyond the formal public-sector extension system and utilize the various agents and intermediaries who interact with farmers and other stakeholders in the innovation system so that the knowledge and information required by farmers to innovate can be provided and linkages developed. In this respect, the organizational innovation presented by agriclinics in integrating the provision of several services to farmers, including advisory services, is worthy of study.

General Suggestions

1. Input Efficient Technologies rather than Input Intensive Technologies

The green revolution technologies and the other modern day technologies are input intensive as the need of the hour at that time was only increasing the total production. But under present day conditions, maintaining the soil quality and conserving natural resources for future generations is the priority issue. This needs technologies which are natural resource friendly and should not allow any further deterioration of soils.

> Randhawa (1984) quoted Noble laureate Dr.Borlaug's observation on Green Revolution and stated that "Never before in the history of agriculture has a transplantation of high-yielding varieties coupled with an entirely new technology and strategy have been achieved on such a massive scale, in so short a period of time and with success". Approximately 27 – 40% of growth in Indian agriculture is attributed to Green Revolution

The Green Revolution has changed the cropping pattern in favour of rice, wheat and maize at the cost of pulses and coarse cereals. Due to the introduction of high yielding varieties with fertilizer and water responsiveness, the water and nutrient intensive crops were grown in place of traditional crops which require less water and fertilization. No doubt that this transformation has brought a radical change in food grain situation of India from begging bowl to self sufficient nation but at the same time that also paved way for some second generation effects in terms of regional imbalances, social in-equality and second generation problems of soil degradation.

Under these circumstances, maintaining the pace of increase in overall food grain production to meet the demand of growing population requires continuous innovation and careful planning to harness the potential of available natural resources keeping in view the path of sustainable growth rate.

> So research priority should be directed towards development of input efficient, pest and disease resistant varieties with more tolerance to drought or water stress conditions. Though these may be low yielders, the farmer would be at an advantage as he could save on input use as well as protect his invaluable soil resource against deterioration.

2. Development of climate resilient varieties and technologies

Impact of climate change on crop production especially food grains

During the last 16 years, area under food grain cultivation has fluctuated around a constant value of 121 million ha whereas total production has increased due to gradually improving productivity. After 1996-97 additional production came mostly from three commodities-rice, wheat and maize but on a very narrow basis. Growth rate in sown area and production is bumpy over the years with sufficient negative values. It is due to uncertainties in the behaviour of weather especially rainfall, its onset, long dry spells in between, withdrawal and distribution, floods, hot/cold waves, cyclones etc. Intensity and frequency of occurrences of extreme weather events or risks have gone high during the past 10-15 years as manifestations of global warming and climatic changes. It requires mitigation measures, innovative alternative land uses for reducing vulnerability and improvements in the safety nets especially in rainfed area to assure the farmers to go for the modern technologies. Market interventions and infrastructural investments into silos to regulate volatility of prices, farmers/ consumers distress, procurement, prompt payments, extended safe storages and flawless distribution networks need very high priority.

Climate change is expected to gravely affect rice cultivation and thereby food security situation in Inida. Conditions for rice production will deteriorate in many parts of India through water shortages, low water quality, thermal stress, floods and intense tropical cyclones. A 15% decrease in irrigated rice yields in developing countries and a 12% increase in rice price is anticipated as a result of climate change by 2050.

To combat the ill effects of climate on rice production, we need to

1. Develop varieties with heat tolerance and multiple stress tolerance like acidity, salinity etc.
2. Options to reduce GHG emissions and increase yield and CER are to be evolved.
3. Best suited cropping systems to withstand the vagaries of climatic change need to be designed.

Recent decades have seen an increase in the frequency and strength of harsh climatic events, including very high precipitations as well as extended drought periods and extreme temperatures (Met Office, 2005). Agricultural production systems are highly vulnerable to these changes (Friedrich and Gustafson, 2007). Crop water requirement can assist in the adaptation to climate change, by improving the resilience of agricultural cropping systems and making them less vulnerable to abnormal climatic situations. Better soil structure and higher water infiltration rates reduce the danger of flooding and erosion following high intensity rainstorms (Saturnino and Landers, 2002). Increased soil organic matter levels improve the water-holding capacity and hence the ability to cope with extended drought periods. Yield variations under conservation agriculture in extreme years (dry or wet) are less pronounced than under conventional agriculture (Shaxon and Barber, 2003; Bot and Benites, 2005).

Rice and wheat productivity of India can be increased from their current productivity of 3.26 and 2.73 Mt ha^{-1} to 5.66 and 6.15 Mt ha^{-1}, respectively with increased irrigation and N use. But this would increase the GWP by 27 and 40%, respectively.

Bhatia *et al* (2009)

In spite of the increased GWP the carbon efficiency ratio (CER) would increase from the current values of 0.67 and 0.85 to 1.06 and 1.75 in rice and wheat, respectively. Thus there is a 'win-win' situation in terms of increased CER for increasing productivity.

The simulation study evaluated the yield response and GWP of rice and wheat due to increased N and water use in current and future climatic scenarios. The current yields of rice and wheat were limited by water and N availability. The productivity can be increased substantially with increased use and better management of N and water. However, this would lead to

Trade-off between productivity, global warming potential (GWP) and carbon efficiency ratio (CER) of rice and wheat in the various regions of India

Region	Current				Potential			
	N level (kg ha^{-1})	Yield (kg ha^{-1})	GWP (kg CO_2 equiv. ha^{-1})	CER	N level (kg ha^{-1})	Yield (kg ha^{-1})	GWP (kg CO_2 equiv. ha^{-1})	CER
Rice								
North	90	3,291	2,460	0.65	240	7,500	2,910	1.26
East	30	2,457	2,235	0.54	120	5,200	2,580	0.98
South	60	3,785	1,865	0.99	150	6,000	2,590	1.13
Central	30	1,785	1,950	0.45	120	3,600	2,405	0.73
West	30	2,451	1,680	0.71	150	6,000	2,470	1.18
Wheat								
North	90	2,881	1,400	1.00	270	8,000	2,010	1.94
East	40	1,788	1,070	0.81	240	5,800	1,705	1.66
Central	50	1,823	1,285	0.69	180	5,600	1,628	1.68
West	30	2,008	1,110	0.88	180	5,200	1,472	1.72

an increased GWP. Supplementing organic manure with inorganic N is beneficial for soil health, but its use would enhance GWP without much increase in yield. Moreover, with the 2050 climatic scenario, rice and wheat yields in India may be impacted and could lead to a positive feedback on global warming. Therefore, gain in one area (increased yield) would cause loss in the other (increased GWP). But in some cases a 'win-win' outcome (increased CER) can be achieved. Options that reduce GHG emissions and increase yield and CER are clearly the most desirable. There is a greater need today for more rational management practices including efficient use of inputs particularly irrigation and N.

3. Natural Resource management

Amelioration of polluted soils for maintaining soil quality

Stress-prone rice area in the country accounts for as much as 24 million ha, of the 44 million ha, posing a huge challenge for stabilising rice production. Development of rainfed agriculture and emphasis on development. of eastern India : Special programmes like BGREI need to be strengthened.

Rainfed agriculture being practised on 60% of cultivated land, supporting 40% of population, 60% of livestock and 40% of food is having significantly low productivity as compared to assured irrigated farming and has some unexploited potentials.

> Rainfed regions are complex, diverse, risky and 13-15 times under invested compared to irrigated command development. Innovative safety nets against risks would be required to convince farmers for adopting improved rainfed technologies and intensive inputs (Vision 2030).

4. Involvement of farmers in research project planning process

Generally research programmes are planned by the scientists by identifying the local problems either through survey or through literature search. But the farmers who are the real toilers in the field are the best judges in identification of field problems and only they know what type of solutions are required to deal with such problems. However, nowhere there is evidence of involvement of farmers either in planning of research programmes, their evaluation or refinement to produce real practical solutions to the problems. Hence, it is recommended to involve farmers both in planning, evaluation and refinement of new technologies

5. More emphasis on location specific technologies

Large parts of the rice-wheat system in Indo-Gangetic plains are showing clear signs of nonsustainability. It was estimated that about 62% of the rice area and 53% of the wheat area are nonsustainable for rice-wheat production. The nonsustainable subregions are contributing about 55% of both rice and wheat production in the Indo-Gangetic Plains. Increase in production is constrained by the plateauing of rice and wheat yields and the limited scope to expand area. In high productive regions such as Punjab, Haryana and western Uttar Pradesh, overexploitation of groundwater and declining biodiversity are responsible for nonsustainability. Nonetheless, there is great potential to raise yield levels in low-productive regions, where farmers have not fully exploited the technological potential due to inadequate infrastructure investment in irrigation and marketing as well as socioeconomic constraints. Though both regions offer opportunities to increase production and supply, each requires a different technological solution and research strategies to provide the relevant agro-technology (Reddy and Mahipal, 2005).

In a study conducted by Shilpa Chaudhary (2012) using state domestic product from agriculture as criterion, a decline in efficiency is observed in thirteen out of fifteen states during the period of 1975 to 2005. Those states are Bihar, Karnataka, Madhya Pradesh, Maharashtra, Andhra Pradesh, Gujarat, Rajasthan, Uttar Pradesh, West Bengal, Assam, Haryana, Orissa and Punjab. The worst performance is reported by Orissa and Madhya Pradesh with 'small' decline in efficiency over different time periods. A smaller subset of these states- Madhya Pradesh, Orissa, Bihar, Karnataka, Maharashtra and Rajasthan- report productivity decline, while the others report technological progress sufficient to nullify the effect of efficiency regress.

Except Punjab, Haryana, Tamil Nadu, Uttar Pradesh and West Bengal, all remaining states have less than fifty percent of gross cropped area as irrigated area. Lack of assured water supply constraints the farmers to use better varieties of seeds and other complementary inputs. These are also the states that are well-known for dismal performance in several interrelated fields- literacy, health and infrastructure. This highlights the need for a 'package' policy focusing on several areas simultaneously- improving education and health of rural population, increasing connectivity of rural areas, easy availability of quality inputs, institutional credit and warehousing/ marketing facilities and concessions for the needy farmers. There is also a need to increase the land under high yielding varieties of seeds, expand the network of irrigation system and rationalize the use of fertilizers and pesticides (Shilpa Chaudhary, 2012).

Moreover, rice crop is grown under different ecologies in different parts of the country. The biotic and abiotic problems of each ecosystem are entirely different from that of others. A generalized recommendation cannot be adopted in all these ecosystems. Hence, location specific technologies need to be developed for each location depending upon its problems.

6. Science needs to be properly propagated among stake holders

The stake holders involved in development and implementation of modern technologies that include scientists, bureaucrats, policy makers, farmers, traders etc. need to understand the process and its impact both in short as well as long term time frame for its proper implementation and for reaping the benefits. As the popular saying says "Half the knowledge is highly dangerous", people with half knowledge create problems in adoption of new technologies and implementation of government policies. For example: GM crops. Enormous safety data on *Bt* crops have already been generated in more than 25 countries, including India, and various *Bt* crops have been under commercial cultivation for the last 16 years (*Bt*-cotton in India since 2002) with significant social, economic and environmental benefits. There has been no scientifically proven adverse affects of these as well as other GM crops on humans, animals, plants or the environment. Due to lack of enough knowledge the allegations on their safety are being spread without any scientific basis. This needs to be understood by all the stake holders and should be a welcome change for the development of the society.

7. Integrated Farming System approach

As suggested by Prof. Swaminathan, the aim of farming system approach should be to convert every family farm into eco cum bio-fortified farm by main streaming the principles of ecology and nutritional farming system.

Encouraging organic farming: In 1960s farmers were approached by agricultural scientists for encouraging the use of chemical fertilizers under Green Revolution. Now we need to go back to organic agriculture for maintaining soil quality.

Subsidiary farm enterprises: Practicing only farming is highly risk prone and hence it needs to be diversified with the inclusion of other enterprises like dairying, sheep and goat rearing etc. which can help not only in enhancing net returns but also in maintaining soil quality for future generations.

Goats contribute to a family's food security by providing food (milk), and generating employment and income that help assure access to other foods. Families of goat-keepers had access to 0.41- 4.0 liters of goat milk day-1 per family from 60 to 150 days a year. Goats are considered living banks to be used to acquire food and fulfill other needs. Diseases in goats had a direct bearing on the food security of goat-keeping families as a result of reduced milk supply and lower income from family labor.

8. Managing Labour problem

a. Rice

Scarcity of labour and increasing wages make the manual weeding less efficient and uneconomical. Several herbicides like butachlor, oxadiazon, anilophos and oxyflurofen were found effective in controlling common weeds in lowland rice. Recent research has shown that use of herbicide combinations like butachlor + 2, 4-D Na, anilophos + 2, 4-D EE, pretilachlor + 2, 4-D EE, bensulfuron- methyl + butachlor etc. control wide spectrum weed flora and were cost effective in transplanted rice. Butachlor + safener, Pretilachlor + safener or Pyrazo sulfuron ethyl gave best control of weeds in direct-sown rice under puddle conditions.

Among the several labour saving methods of cultivation being developed and adopted are direct seeding through broad casting or through the use of drum seeder and mechanical transplanting which are becoming popular. Combine harvesters are also being used increasingly that saves time and labour cost of harvesting.

Rice crop established by broadcasting of seeds under puddled conditions generally suffers from uneven growth and gives lower yields than a transplanted rice crop. Line sowing of sprouted seeds at 20 cm spacing with a row seeder produced excellent crop stand and similar yields to that of transplanted crop. Varieties like 'Vikas', 'IET 9994', 'IET 10402' and 'Jalapriya' performed well.

In addition to these, we can also try mutual sharing of labour in villages from different households and also deployment of labour from states having adequate labour resources to the states with scarce resources of labour.

b. Farm Mechanization

Labour problem can also be solved to a great extent with farm friendly mechanization. Here the major constraint is that the machinery developed for different operations are not affordable for small and marginal problems. This can be solved by custom hiring and providing low interest loans for the purchase of small size machinery etc.

c. Mutual Sharing of family Labour

By mutually sharing the labour between farming families, labour problem can be solved to a great extent.

Dharmasthala Model : The 'Pragathibandhu' SHG model in Dharmasthala comprises 7 to 8 members of small and marginal farmers who share labour among themselves in a compulsory manner is highly efficient in solving labour problem as they get five to six free labour days in two months.

9. Genetically Modified crops

Genetically modified/engineered transgenic and other foods have tremendous potentials but their environmental, phyto- and bio-safety for human consumption and public acceptability is a major bottleneck of utilizing R&D products.GM technology in agriculture (i.e., crop biotechnology) has a great potential to address some of the major biotic and abiotic as well as other challenges mentioned above. This technology is to be treated as an extension of conventional breeding for expeditious and precise applications. Similarly, molecular breeding is another promising technology. Our country which was one of the first to establish an independent Department of Biotechnology way back in 1986, needs to adopt policies that would enable bringing out more biotech products without undue delay, of course without compromising on the quality of research and safety. There can be case by case studies of each crop and then be made available with all safety guidelines and protocols in place as it can save lots of natural resources without deterioration.

10. Gender mainstreaming

Reducing the gender gap between male and female farmers could raise yields on farms operated by women by 20 to 30 percent. As a consequence, there would be significant gains in agricultural production at national levels, and it is estimated that this would result in a reduction of undernourished people in the world by 12 to17 percent, which translates into 100 to 150 million fewer people living in hunger (FAO, 2010-11).

11. Information and Communication Technologies (ICTs) in agriculture help farmers in rational decision making

In today's world, ICT can provide access to new information on market, trade, technology, investment and services related to education, health, nutrition and help farmers in taking rational decisions. Innovations in the use of ICT in rural areas for technology dissemination, for market knowledge and information would help in bringing awareness among the farming community. Focus also need to be directed towards developing climate smart villages by utilizing the modern information technology tools.

12. Protecting Natural resources

Under dwindling natural resources and increasing human and animal population, we need to produce more from available resources. The aim needs to be not only to produce more but also to have safe food by protecting natural resources

References:

Bhatia, A.H. Pathak, P. K. Aggarwal and N. Jain. 2009. Trade-off between productivity enhancement and global warming potential of rice and wheat in India. Nutrient Cycling in Agroecosystems © Springer Science+Business Media B.V. 2009 10.1007/s10705-009-9304-5

Bot A, Benites J (2005). The importance of soil organic matter, key to droughtresistance soil and sustained food production; FAO soil bulletin 80, FAO Rome.

Friedrich T, Gustafson D (2007). Conservation agriculture: synergies of resource-conserving technologies in rice-based systems, Articulos Generals.

Met Office (2005). Climate change, Rivers and Rainfall, recent research on climate change science from the Hadely centre, Exeter/UK. Nielsen TK (2004). Lecture Note on Paddy Cultivation.

Randhawa M.S. (1984). Break through in Wheat. The Sunday Tribune, May 27. [The article describes the break through in wheat breeding and the introduction of short duration input responsive high yielding varieties, which heralded the green revolution in India.]

Reddy Y VR and Mahipal, An Economic Evaluation of Watershed Programs, Impact of Agricultural Research Post-Green Revolution Evidence from India Eds P K Joshi, Suresh Pal, P S Birthal and M C S Bantilan, 2005 pp: 325

Saturnino HM, Landers JN (2002). The environment and zero tillage. Brasilia Brasilia, Brazil, APDC-FAO, 144 pp.

Shaxon TF, Barber RG (2003). Optimizing soil moisture for plant production – the significance of soil porosity. Rome, FAO. FAO Soils Bull., p. 79.

Shilpa Chaudhary 2012. Trends in Total Factor Productivity in Indian Agriculture: State-level evidence using non-parametric sequential malmquist index. Working Paper No. 215 Centre for Development Economics Department of Economics, Delhi School of Economics.

The State of Food Insecurity in the World(2010). Food and Agriculture Organisation, Rome.

Appendix-I

Seminar, Workshop and International Conference

As a part of our project, the project team has organized one day national workshop on "The Present Situation and Prospects of Rice Production in India" on August 3rd , 2012, at NIAS, Bangalore. In addition to this, a National Workshop on "Innovations in Agricultural Policies/ Schemes/ Programmes in India" was organized on August 10th , 2012. Further an International Conference on "Increasing Agricultural Productivity and Sustainability in India" – The Future we Want" was organized on 8th and 9th of January, 2012.

1. The Present Situation and Prospects of Rice Production in India

As we all know, Agriculture is an integral part of India's economy and society, accommodating 60% of total workforce in the country. India has about 120 million farming families, 80 per cent of which are small and marginal. Majority of Indian farmers practice subsistence agriculture and is a source of livelihood. The green revolution which occurred in late 1960s was a turning point in Indian agriculture. However during 1990-2010 the average growth rate of food grains production slashed down to1.6 per cent, while the average population growth was at 1.9 per cent. Fortunately, we have achieved a food surplus during last two years. But in the long run, concern of food security is likely to become more intense with increasing population and decreasing land availability. Currently in India, there is a steady annual population growth rate of 1.7%, where as annual growth of food grain production is only 1.3%. By 2020, to meet the food demand of 1.3 billion population, India needs to produce 281MT of food grains with an annual growth target of 2%.

Currently, the rice production in our country is passing through serious constraints like low yield, water scarcity, increasing use of agro inputs, delay in monsoon, flash floods, water logging, labor availability, inadequate storage facilities and lack of policy innovations. Unfortunately, this year is going to be a bad year for rice production in the country as many parts of the country is facing severe drought, particularly, Karnataka, facing the worst drought in the last four decades turning 123 taluks in 25 districts severe drought affected. One of the main issues which need to be addressed is enhancing the agricultural productivity in India, which remains an unanswered question. Balanced use of nutrients, replacement of low yield varieties by new high yielding varieties, improved post harvest technologies, developing water scarce irrigation technologies are the possible remedies in bridging this yield gap.

Further, the widening regional disparity in rice yield is an area which needs special attention. The eastern states which account for 34% of total rice producing area in the country shows the lowest yield of 1.6 tons/hectare compared to the national average of 3.1 tons/ hectare. Government initiatives like bringing Green Revolution to Eastern India, National food Security Mission for Rice will help in developing sustainable rice cultivation and improving the livelihood of farmers. The nationwide spreading of such initiatives in rice production through proper institutional dynamics need to be carried out. Rice being an important crop in India, there is a lot to focus on enhancing rice production & productivity in the country. This seminar is organized to review the past, present and future of rice production and productivity in India with reference to the research, policy and institutional dynamics.

The key recommendations from the seminar are

1. The investment in R&D in agriculture in general and rice in particular needs to be enhanced as rice contributes lot to the GDP and foreign exchange. ICAR is spending only 5% on rice research and SAU's about 13 % of total research fund. So there is scope for increasing private investment in R&D. Additional agricultural research & development is necessary to address future challenge in rice research like weather variability, research sustainability and market variability.
2. China's annual CGR of rice production is almost stagnated in last 5 years but India has further scope for increasing the productivity by new high yielding varieties & hybrids by reducing the yield gap through yield boosting technologies. Only research on HYVs of rice has contributed to total factor productivity and no other inputs used on irrigation, roads, market have contributed.
3. From the food security point of view, we need to grow more rice. But at the same time, we should also make judicious use of water by diversifying with crops like vegetables, millets, pulses etc, as it is a scarce resource. The places or regions for growing rice need to be identified and our efforts should be directed towards vertical growth to enhance the productivity. The technologies should aim at saving the inputs including water.
4. Government should fix and extend MSP on scientific basis to the rice farmers and it is needed to announce well in advance before beginning of the season.
5. Extension system should be made professional, purposeful and farmer friendly through group approaches, market-led extension, use of ICT tools & Farmer Field School. There should be a strong, effective functional linkage between ICAR institutes, SAUs, NGOs, KVKs, line departments and all stakeholders and the Public Private Partnership approach is to be encouraged in rice production. Appropriate technological interventions are to be popularized in the eastern & north India through important extension approaches.
6. Multiple cropping systems for various agro-climatic situations are to be given much importance. Farmer to farmer approach may be encouraged across the country as in the case of paddy variety "Swarna Mahsuri".
7. Potential for high area low productivity states in eastern region of the country can be utilized by reducing yield gap with existing yield boosting technologies.

2. Innovations in Agricultural Policies/ Schemes/Programmes in India

Agriculture is a way of life, a tradition, which, for centuries, has shaped the thought, the outlook, the culture and the economic life of the people of India. Agriculture, therefore, is and will continue to be central focus to all strategies for planned socio-economic development of the country. Rapid growth of agriculture is essential not only to achieve self-reliance at national level but also for household food security and to bring about equity in distribution of income and wealth resulting in rapid reduction in poverty levels.

Over 200 million Indian farmers and farm workers have been the backbone of India's agriculture. Though the farming community has significantly contributed to the national food security, the well being of this community continues to be a matter of grave concern for planners and policy makers.

One of the key issues before the policy makers is that in recent decades, the share of agriculture and allied activities in India's GDP has drastically fallen; from 28.4 per cent during the decade ended 1999-2000 to 19.4 per cent during the decade ended 2009-10; furthermore, the GDP share declined to 13.8 per cent in 2011-12. As 70 per cent of the population lives in rural areas, it is a matter of concern that the share of agriculture and allied activities is only 14.4 per cent of GDP. The present sectoral distribution of income triggers migration from rural to urban areas, particularly to metropolitan cities.

India continues to add 16-18 million to its population every year. Planners hope that 4 per cent per annum growth of GDP from agriculture & allied sector is necessary to support overall GDP growth target of 9 per cent. This calls for a viable & innovative agricultural policy in order to make growth sustainable.

Innovation in agricultural policies and programmes are essential for enhancing the agricultural production and productivity in the country. Innovations in agriculture policy must accelerate all-round development and economic viability of agriculture in comprehensive terms. This needs to look in to the vast untapped growth potential of Indian agriculture, need to strengthen rural infrastructure to support faster agricultural development, promote value addition, accelerate the growth of agro business, create employment in rural areas, further secure a fair standard of living for the farmers and agricultural workers and their families, discourage migration to urban areas and face the challenges arising out of economic liberalization and globalization.

India needs to look at certain policies which need immediate attention and action like Land Reform policy, setting a goal for agriculture, price market etc. The minimum support price (MSP) policy has no meaning in most of the states as they are not coupled with procurement policy. Most of the policies on paper are excellent but implementation is not effective. In case of labour policy, we need second generation reforms. Future policy should concentrate on market price of crops and the MSP should be not just only for 24 forecast crops but for other crops as well. Stable policy for pricing and procurement needs a self triggering system. Further we are also in need of the agricultural insurance policy for major crops. Farm mechanization and practices suitable to small and medium farmers for majority of the crops must be evolved and available to increase the productivity. MSP must be based on the cost of production of crops at farmers' field level. Corporate and co-operative farmers farming can play a major role to increase the productivity under the situation of climate change as well as rapid farm mechanization.

Recommendations

- Strengthening of rural infrastructure to support faster agricultural development
- Establishing Agro Economic Zone (AEZ) in lines of SEZs to boost agro processing industry to reduce the agrarian distress
- Innovations in policies for promotion of judicious mix of yield enhancing and input responsive technologies
- Policies for easy credit availability, remunerative pricing for agriculture products, supply of drought resistant and short duration high yielding varieties
- Emphasis on individual farmer insurance policy

- Innovations for food storage
- Future policies may be directed to have a judicious mix of food crops and cash crops for the food security of nation
- Minimum Support Price for all the crops is suggested with a scientific basis to arrive its value.
- Interventions in rainfed horticulture, disease diagnostics, seed and planting material, mechanisation, labour shortage, climate resilient technologies and strengthening of market linkages are required
- New initiatives by TNAU, UAS, MSSRF like interacting with farmers through video conferencing, SMS, Kissan scheme, community radio station, DVDs on various technologies are to be adopted and widespread throughout the country
- Transaction cost in many of the government programmes need to be brought down

3. Increasing Agricultural Productivity and Sustainability – The Future We Want

Indian agriculture has undergone transformation from an era of chronic food shortage during the period of independence to food self-sufficiency and even surplus in some sectors due to various factors. The increase in the farm productivity and production have placed India among the leading producers of wheat, rice, pulses, sugarcane, milk, eggs, fruits, vegetables and fish. Agriculture engages 52% of the workforce, contributes nearly 14% of the national GDP and accounts for about 10% of the exports. Agriculture will therefore, remain central to India's economic security. Hence, it is critical to visualize interventions to facilitate growth in agriculture and allied sectors to enable its GDP contribution commensurate with the involved workforce. A blend of scientific skill, political will and farmers toil will be able to increase the productivity. The challenge now is to produce more from less in the sense increasing the productivity with declining and deteriorating production environment. The need is not only for more food production, but also access to safe food and address nutritional security. Some of the frontier areas of research like nanotechnology, climate smart villages and bioengineering, organic farming and on the whole integrated farming system would be the way forward. The future we want is remunerative agriculture, self sufficiency in pulses, precisions farming, farm efficiency, equity & empowerment, comprehensive agriculture biosecurity system, quality HRD (Men and Mentoring) and integration, innovation and investment. Sustainable and growth oriented productivity should be the 'mantra' for the future and productivity in the past was only partial and incremental and in the future it should be total factor productivity (TFP) which may be equivalent to Ever-Green Revolution proposed by Prof. M S Swaminathan.

Research, Policy & Institutional Dynamics

- High investment in research.
- Effective quarantine against pest and diseases.
- Addressing issues on patent regime hindering gene flow.
- Improve the storage facilities in rural areas.
- Development of machineries for small holders and policy focus on mechanization.
- Fixation of Minimum Support Price based on scientific rationale.
- Bridging yield gap through effective Transfer of Technology.
- Rural infrastructure, connectivity and proper supply of electricity
- Rational policy on export.
- Develop varieties to withstand the biotic and abiotic stress
- Development of fortified rice and breeding varieties for no till agriculture.
- Redefining the roles of KVKS, ATMA schemes etc.

- Identifying varieties and packages suitable for local areas
- Promoting knowledge based agriculture and its dissemination.
- Identifying NGO's and priority farmers groups and encouraging community participation.
- Technology for enhancement of bioprecipitation during drought years
- Promoting local knowledge and its integration with modern sciences
- There is need for second green revolution making use of "Genetic Engineering Technology" and focus on pulses and oilseeds.
- Inclusive growth by ensuring ecological sustainability, natural resources sustainability and sustainability of small farmers.
- Effective steps to prevent food wastage are needed to ensure food and nutritional security to the deprived.
- Farming System approach by conservation farming etc to save energy and resources.
- Inefficient subsidies need to be removed.
- Appropriate Water Management strategies by micro-irrigation, conservation farming and dryland agriculture
- Plant protection by promotion of pest resistant varieties, natural predator's conservation, optimum nutrient management and farmers skills and knowledge updation.
- Agriculture policy should be focused on small farmers, increasing public delivery system efficiency, reducing transaction time and cost, and rebuilding research and technology transfer
- Empowering the youth, who are an important workforce in India.
- Rural urban connectivity and migration control measures are need of the hour.
- Ban of pesticides abuse and unscientific use and human errors.
- Maintenance of agriculture/horticulture based forestry system for livelihood, agroforestry for energy security, agroforestry for bio energy, agroforestry for carbon segmentation and agroforestry based industries.
- Combining livestock farming with main agriculture should be the priority of the farming sector of India in order to provide better socio- economic conditions and to use the rural youth effectively to prevent their migration to urban areas,.
- GAP (Good Agricultural Practices) can be a big step in pest management which guidelines for safety standards in crop production with minimum use of pesticides.
- Promoting processing of various produce at the field level, on cooperative basis, which can help a large number of farmers to reduce the PHL in their farm.
- Growing more of horticultural products through horticultural diversification and aiming for maximization of export earnings Effective and economical methods of handling, storage, packaging and processing and marketing of semi-perishable and highly perishable products like fruits and vegetables for enhancing the total farm income.
- Horticultural seed production needs stringent government monitoring.
- Pesticide usage and residue need to be tackled properly by strict law
- Infrastructure need to be strengthened for cold storage facilities and power supply to avoid wastage of vegetables and fruits.
- Strategies to increase pulse production are short duration and high yielding and drought tolerant varieties, improved seed delivery system, concentration on mechanization are need of the hour.
- Use and adoption of PRA techniques / tools in all crops and enterprises for future research

- Holistic- Consortium approach – by considering capacity building, group formation, knowledge empowerment and also information sharing are really human centered effort.
- Transformational Governance and developing the local leaders in agriculture is very important
- Considering Lab to Land – Land to Lab approach is two way development focus in agricultural strategy
- Integrated Farming System approaches, learning to work together on co-operative basis is very important
- Climate smart agricultural practices, site specific integrated participating programme
- Capacity building programmes to be undertaken using both conventional methods of extension as well as modern tools and techniques, including use of ICT's, in promotion of various technologies in agriculture.
- Integrated farming approach and practice like Bio-Resource complex programme need to be promoted on large scale, which includes production, PHM and processing, marketing and value addition etc. of both agriculture produce, including products from allied enterprises like horticulture and livestock rearing for income generation and for livelihood security of the farmers.

References

Aulakh KS (2005). Punjab Agricultural University, accomplishments and challenges. Ludhiana, p. 23.

Barker, JHA, Matthes M, Arnold GM, Edwards KJ, Ahman I, Larsson S, Karp A (1999). AFLP analysis sheds light on the distribution of two Salix species and their hybrid along a natural gradient. Mol. Ecol., 6: 989-993.

Bayer D, Hill J (1993). Weeds. In M. Flint, ed. Integrated pest management for rice. University of California and Division of Agricultural and Natural Resources, 3280: 32-55

Cabangon R, Lu G, Tuong TP, Bouman BAM, Feng Y, Zhang ZC (2003). Irrigation Management Effects on Yield and Water Productivity of Inbred and Aerobic Rice Varieties in Kaifeng. Proceedings of the first International Yellow River Forum on River Basin Management, 2: 65-75.

Colombo, Sri Lanka: International Irrigation Management Institute. Geneva: World Health Organization.

Dhaliwal, G.S. and R. Arora. 1996. Principles of insect management. Commonwealth Publishers, New Delhi. http://www.hindu.com/seta/2011/04/14/stories/2011041450181500.htm retrieved on 7.3.13 (Dharmasthala model)

FAO (2000a). Agriculture towards 2015/2030, FAO, Rome.

FAO (2000b). Global Assessment of Soil degradation GLASOD.

FAO (2006). The State of Food insecurities in the world.

FAO (2002). Agriculture: towards 2015/2030. Rome, p. 420.

FCI (2012), "*Annual Report 2010-11 and earlier Issues*", Food Corporation of India, New Delhi.

FCI (2012a), "*Progressive Procurement of Rice during Kharif Marketing Season and Wheat during Rabi marketing Season 2012-13 (as on 12/07/2012)*", Food Corporation of India, New Delhi.

Ferrero A, Vidotto F (2007). Weed Management in European Rice Fields, Articulos Generals.

Ferrero A, Tabacchi M, Vidotto F (2002). Italian rice field weeds and their control. In J.E. Hill and B. Hardy, eds. Proc. Second Temperature Rice Conference, Sacramento, CA, 13-17 June 1999. Los Banos, Philippines, IRRI, pp. 535-544.

Gleick PH (1993). Water crisis: A guide to the world's fresh water resources. Pacific Institute of Studies in Development, Environment and Security. Stockhlom Environment Institute. Oxford University Press. New York.

GoI (2012a), "*Foodgrains Bulletin May 2012 and earlier Issues*" Department of Food & Public Distribution, Ministry of Consumer Affairs, Food and Public Distribution, Govt. of India, May 2012

Government of India. 2010. *Seed Statistics. SeednetIndia Portal*. New Delhi: Government of India.

Government of Maharashtra. 2010. National Food Security Mission in Maharashtra. http://nsfm.gov.in.

Government of Uttar Pradesh. 2010. National Food Security Mission in Uttar Pradesh. http://nfsm.gov.in.

Government of Bihar. 2010. Implementation Status of National Food Security Mission in Bihar. Accessed March 4 2010. http://nfsm.gov.in/.

Government of India. 2002. Master Plan for Artificial Recharge to Groundwater in India. Central Ground Water Board, Government of India. http://cgwb.gov.in/documents/MASTER PLAN Final-2002.pdf.

Guerra LC, Bhuiyan SI, Tuong TP, Barker R (1998). Producing more rice with less water from irrigated systems. SWIM Paper 5. Sri Lanka,Colombo: International Water Management Institute.

Hobbs PR (2001). Tillage and crop establishment in south Asians rice-wheat systems: Present practices and future options. J. Crop Prod., 4: 1-22. http://www.ibtimes.com/articles/240723/20111031/world-population-rea ches-7-billion-impact-megacities.htm accessed on 25.1.2013

IRRI (1998). Sustaining food security beyond the year 2000: a global partnership for rice research, IRRI Rolling Medium-Term Plan 1999-2001. International Rice Research Institute, Los Banos (Philippines).

ICRISAT http://www.sri-india.net/html/wwf project.html

Kalirajan, K.P. and Shand, R.T. (1997) Sources of output growth in Indian agriculture. *Indian Journal of Agricultural Economics*, **47** (3):451-458.

Klemm (1999). Water saving in irce cultivation. In "Assessment and orientation towards the 21st century", Proceedings of 19th session of the International Rice Commission, Cairo, Egypt, 7-9 September 1998. FAO, pp. 110-117.

Kumar, P., C.C. Maji and R.K. Patel, 1977. "Returns on Investment in Research and Extension: A study on Indo-Swiss Cattle Improvement Project, Kerala", Indian J Agric. Econ. 32 (3): 207-216

Kumar P and D Jha, 2005 Measurement of Total Factor Productivity Growth of 25 Rice in India: Implications for Food Security and Trade 99: 25-36. Impact of Agricultural Research: Post-Green Revolution Evidence from India, *Edited by* P K Joshi, Suresh Pal, P S Birthal and M C S Bantilan

Mao Z (1993). Study on evaluation of irrigation performance in China, Maintenance and operation of irrigation/drainage scheme and improved performance. Proceedings of Asian Regional Symposium, Beijing, China, pp. 6-35.

Mao Z (1996). Environmental Impact of Water-saving Irrigation for Rice, Department of Irrigation and Drainage Engineering, Wuhan University of Hydraulic and Electric Engineering, Wuhan, China.

Ministry of Agriculture. 2010a. *Agricultural Statistics at a Glance 2009*. New Delhi: Government of India

PDCSR (2005). Project directorate for cropping systems research. Annual Report 2004-05, India, Modipuram-Meerut, p. 143.

Peng S, Laza RC, Khush GS, Sanico AL, Visperas RM, Garcia FV (1998). Transpiration efficiencies of indica and improved tropical

japonica rice grown under irrigated conditions. Euphytica, 103: 103-108.

Ruifa Hu, Qin Liang, Carl Pray, Jikun Huang, and Yanhong Jin 2011. Privatization, Public R&D Policy, and Private R&D Investment in China's Agriculture. Journal of Agricultural and Resource Economics 36(2):416–432

RWC-CIMMYT (2003). Addresssing resource conservation issues in rice-wheat systems of south asia: a resource book. New Delhi, India, Rice-Wheat consortium for the indo-gangetic plains-International Maize and Wheat Improvement Centre, 305 pp.

Sharma V. P.. India's Agricultural Development under the New Economic Regime: Policy Perspective and Strategy for the 12th Five year plan. *Working paper/ Indian Institute of Management Ahmedabad* (2011).

Singh R, Van Dam JC, Feddes RA (2006). Water productivity analysis of irrigated crops in Sirsa district, India. Agric. Water Manage., 82: 253-278.

Singh, J. 2005. Scope, Progress and Constraints of Farm Mechanization in India. In *Status of Farm Mechanization in India*, edited by K. Tyagi, H. Bathla, and S. Sharma. New Delhi: Indian Agricultural Statistics Research Institute.

Tuong TP, Pablico PP, Yamauchi M, Confesor R, Moody K (1998). Increasing water productivity and weed suppression of wet seeded rice: effect of water management and rice genotypes. Exp. Agric. (Submitted)

Tuong TP (1999). Productive water use in rice production: Opportunities and limitations. J. Crop Prod., 2: 241-264.

Van der Hoek W, Konradsen F, Ensink JHJ, Mudasser M, Jensen PK (2001). Irrigation water as a source of drinking water: Is safe use possible? Trop. Med. Int. Health, 6: 46-55.

Waqar A, Jehangir H, Turral IM (2004). Water productivity of rice crop in irrigated areas, Proceedings of the 4th International Crop Science Congress, Brisbane, Australia.

Waqar A, Jehangir IM, Shehzad A, Mustaq AG, Maqsood A, Riaz AM, Muhammad RC, Asad SQ, Hugh T (2007). Sustaining Crop Water Productivity in Rice-Wheat Systems of South Asia: A Case Study from the Punjab, Pakistan, International Water Management Institute, IWMI.

WASSAN (2006). Realize full potential of Paddy Plant, SRI (System of Rice Intensification) Method of Paddy Cultivation. Publ. Watershed Support Services and Activities Network Tarnaka, Secunderabad India.